BAAN/W2/2

TOWN AND COUNTRY PLANNING ACT 1990

Appeal by Bristol Airport Limited concerning land at North Side Road, Felton, Bristol, BS48 3DY

DEVELOPMENT OF BRISTOL AIRPORT TO ACCOMMODATE 12 MILLION PASSENGERS PER ANNUM

Appeal Reference APP/D0121/W/20/3259234

APPENDIX TO

PROOF OF EVIDENCE

of

Finlay Asher (MEng)

Founder at Green Sky Thinking

15 June 2021

INDEX

APPENDIX 1

PRESS RELEASE

AIRBUS

BOEING

DASSAULT AVIATION

GE Aviation

ROLLS ROYCE

SAFRAN

United Technologies

Joint Statement from Industry CTOs

Paris Airshow, Le Bourget, Tuesday, June 18 2019

CTOs cooperate to drive the sustainability of aviation.

The aviation industry has committed to ambitious targets to reduce CO2 emissions.

The Chief Technology Officers of seven of the world's leading aerospace manufacturers released today a joint statement to demonstrate how they are collaborating and sharing approaches to drive the sustainability of aviation and reach the industry-wide ATAG targets.

Joint statement

A Statement by the Chief Technology Officers of seven of the world's major aviation manufacturers.

A Unified Commitment
Aviation connects our world by efficiently and rapidly moving people, opening new economic opportunities and transporting food and goods all over our planet. Aviation promotes global understanding, generating rich cultural exchanges and thereby contributing to peaceful co-existence.

At the same time, climate change has become a clear concern for our society. Humanity's impact on the climate requires action on many fronts. The aviation industry is already taking significant action to protect the planet and will continue to do so.

Aviation contributes to two percent of human-made carbon dioxide emissions. The industry has challenged itself to reduce net CO_2 emissions even while demand for air travel and transport grows significantly. Through the Air Transport Action Group (ATAG), the aviation industry became the world's first industrial sector to set an ambitious target: reduce CO_2 emissions to half of year 2005 levels by 2050, and to limit the growth of net CO_2 emissions by 2020. We are on track to meet those near-term commitments, including the 2019 implementation of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) program as agreed upon by the nations of the International Civil Aviation Organization (ICAO).

The Chief Technology Officers of seven of the world's leading aviation manufacturers are now each working at an unprecedented level to ensure the industry meets these aggressive and necessary commitments.

The Strategy
There are three major technological elements to sustainable aviation:

1. Continuing to develop **aircraft and engine design and technology** in a relentless pursuit of improvements in fuel efficiency and reduced CO_2 emissions.
2. Supporting the commercialization **of sustainable, alternate aviation fuels**. Around 185,000 commercial flights have already proven that today's aircraft are ready to use them.
3. Developing radically new aircraft and propulsion technology and accelerating technologies that will enable the **'third generation'** of aviation.

Other factors, such as efficient air traffic management and aircraft routing that minimizes fuel consumption also have a vital part to play. Our industry has demonstrated significant progress on reducing noise and other environmental impacts and will continue to do so.

Aircraft and Engine Design and Technology
For the last 40 years, aircraft and engine technology has reduced CO_2 emissions by a yearly average of over one percent per passenger mile. This has been the result of significant R&D investments in materials, aerodynamic efficiency, digital design and manufacturing methods, turbomachinery developments and aircraft systems optimization.

For many years, through a variety of industry organizations and international bodies, the aviation community has voluntarily committed to meet a set of aggressive targets for enhanced airplane environmental performance. Targets set by the Advisory Council for Aeronautics Research in Europe call for a 75 percent reduction in CO_2, a 90 percent drop in NO_X and a 65 percent decrease in noise by 2050, compared with year 2000 levels.

To help achieve these aggressive goals, global agreements reached through ICAO call for a fuel-efficiency performance standard to be part of the certification process applied to every airplane.

We remain committed to improving existing aircraft and engine designs to continue the trajectory of improving efficiency as much as possible. Concurrently, we note the tremendous technological challenges ahead of us and the likely need to include more radical 'third generation' approaches.

Fostering the Energy Transition: Sustainable Aviation Fuels

Aviation will continue to rely on liquid fuels as the fundamental energy source for larger and longer-range aircraft for the foreseeable future. Even under the most optimistic forecasts for electric-powered flight, regional and single-aisle commercial airplanes will remain operating in the global fleet with jet fuel for decades to come. Therefore, the development of Sustainable Aviation Fuels (SAFs) which use recycled rather than fossil-based carbon and meet strong, credible sustainability standards is an essential component of a sustainable future. Five pathways for production of SAFs have already been approved for use, with commercial scale production of one of these pathways already in place. We believe that accelerating production scale-up of all commercially viable pathways, while simultaneously developing additional lower cost pathways, is the key to success. This work is already underway at research institutions and within companies in various industrial sectors. What is needed is an expansion of government support for technology development, production facility investment, and fuel production incentives around the world.

We are fully supportive of any fuel, which is sustainable, scalable, and compatible with existing fuels. We will work closely with fuel producers, operators, airports, environmental organizations and government agencies to bring these fuels into widespread aviation use well ahead of 2050.

The Third Era of Aviation

Aviation is at the dawn of its third major era, building on the foundation laid by the Wright brothers and the innovators of the Jet Age in the 1950s. Aviation's third era is enabled by advances in new architectures, advanced engine thermodynamic efficiencies, electric and hybrid-electric propulsion, digitization, artificial intelligence, materials and manufacturing. Larger aircraft will begin to benefit from novel designs that will further improve efficiency through management of aircraft drag and distributing propulsion in new ways. New materials will enable lighter aircraft, further improving efficiency.

We are excited by this third generation of aviation and, even though all of the represented companies have different approaches, we are all driven by the certainty of its contribution to the role of aviation in a sustainable future. We believe aviation is entering its most exciting era since the dawn of the Jet Age. This third era promises a transformative positive impact on lives around the globe — and we stand ready to make it a reality.

Call to Action: Let's Make This Future Together

The future of aviation is bright. Yet, in addition to the significant efforts our sector is undertaking, we also depend on the coordinated support from policymakers, regulators and governments working together to achieve these goals.

There must be additional public and private commitment to establish a sound regulatory foundation to address the novel issues associated with emerging aviation technologies and to provide the necessary economic support for widespread SAFs commercialization. We envision broader, deeper and ongoing coordination through ICAO to facilitate unified approaches to regulation with established national and global regulatory and standards-setting bodies. These include the U.S. Federal Aviation Administration, the European Aviation Safety Agency, and the Civil Aviation Administration of China, Transport Canada, ANAC of Brazil and others.

As industry CTOs we are committed to driving the sustainability of aviation. We believe in this industry and its role in making our world a brighter and safer place. We also strongly believe we have an approach to make aviation sustainable and play an even bigger role in our global community.

Grazia Vittadini
Chief Technology Officer
Airbus

Greg Hyslop
Chief Technology Officer
The Boeing Company

Bruno Stoufflet
Chief Technology Officer
Dassault Aviation

Eric Ducharme
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Paul Stein
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Reducing emissions from aviation

Aviation is one of the fastest-growing sources of greenhouse gas emissions. The EU is taking action to reduce aviation emissions in Europe and working with the international community to develop measures with global reach.

Revision of the EU ETS Directive concerning aviation

The revision of the EU ETS Directive concerning aviation will serve to implement the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) by the EU in a way that is consistent with the EU's 2030 climate objectives. The initiative will also propose to increase the number of allowances being auctioned under the system as far as aircraft operators are concerned.

The proposal, planned for the second quarter of 2021, will be part of the broader European Green Deal [https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en] .

Roadmap

The Inception Impact Assessment (Roadmap) [https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12494-Revision-of-the-EU-Emission-Trading-System-Directive-concerning-aviation-] on the legislative initiative was open for feedback until 28 August 2020.

Public consultation

The open public consultation on the legislative initiative is open until 14 January 2021.

Aviation emissions

Policy actions and the efforts of industry have led to improvements in fuel efficiency over recent years. For instance, the amount of fuel burned per passenger dropped by 24% between 2005 and 2017. However, these environmental benefits have been outpaced by a sustained growth in air traffic, with passengers in 2017 flying on average 60% further than in 2005.
In the EU in 2017, direct emissions from aviation accounted for **3.8% of total CO_2 emissions**. The aviation sector creates 13.9% of the emissions from transport, making it the second biggest source of transport GHG emissions after road transport.

- If global aviation were a country, it would rank in the top 10 emitters.
- Someone flying from Lisbon to New York and back generates roughly the same level of emissions as the average person in the EU does by heating their home for a whole year.

Before the COVID-19 crisis, the International Civil Aviation Organization (ICAO) forecasted [https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx] that by 2050 international aviation **emissions could triple** compared with 2015.

Aviation also has an impact on the climate through the release of nitrogen oxides, water vapour, and sulphate and soot particles at high altitudes, which could have a significant climate effect. A November 2020 study conducted by the European Aviation Safety Agency (EASA) looks into the non-CO_2 effects of aviation on climate change, and fulfils the requirement of the EU Emissions Trading System Directive (Art. 30.4). Overall, the significance of combined non-CO_2 climate impacts from aviation activities, previously estimated to be at least as important as those of CO_2 alone, is now fully confirmed by the report [https://ec.europa.eu/clima/news/updated-analysis-non-co2-effects-aviation_en] .

To achieve climate neutrality, the European Green Deal sets out the need to reduce transport emissions by 90% by 2050 (compared to 1990-levels). The aviation sector will have to contribute to the reduction.

Aviation in EU Emissions Trading System

CO_2 emissions from aviation have been **included in the** EU emissions trading system [http://ec.europa.eu/clima/policies/ets_en] (EU ETS) since 2012. Under the EU ETS, all airlines operating in Europe, European and non-European alike, are required to monitor, report and verify [http://ec.europa.eu/clima/policies/ets/monitoring_en] their emissions, and to surrender allowances against those emissions. They receive tradeable allowances [http://wcmcom-ec-europa-eu-wip.wcm3vue.cec.eu.int:8080/clima/policies/ets/allowances/aviation/index_en.htm] covering a certain level of emissions from their flights per year.

The system has so far contributed to reducing the carbon footprint of the aviation sector by more than 17 million tonnes per year, with compliance covering over 99.5% of emissions.

In addition to market-based measures like the ETS, **operational measures** – such as modernising and improving air traffic management technologies, procedures and systems – also contribute to reducing aviation emissions.

The legislation [http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0101] , adopted in 2008, was designed to apply to emissions from flights from, to and within the European Economic Area (EEA) – the EU Member States, plus Iceland, Liechtenstein and Norway. The European Court of Justice has confirmed that this approach is compatible with international law.

The EU, however, decided to **limit** the scope of the EU ETS to **flights within the EEA until 2016** to support the development of a global measure by the International Civil Aviation Organization (ICAO).

In light of the adoption of a Resolution by the 2016 ICAO Assembly on the global measure (see below), the EU has decided to maintain the geographic scope of the EU ETS limited to intra-EEA flights from 2017 onwards. The EU ETS for aviation will be subject to a new review in the light of the international developments related to the operationalisation of CORSIA. The next review should consider how to implement the global measure in Union law through a revision of the EU ETS legislation. In the absence of a new amendment, the EU ETS would revert back to its original full scope from 2024.

Aviation activities are also included in the Linking Agreement with Switzerland [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02017A1207(01)-20200101] . The aviation activities in the ETS of Switzerland reflect the same principles as those of the EU ETS. Following the entry into force [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:22019X1220(01)] of the Linking Agreement, a Commission Delegated Decision [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020D1071] adapted the text of the EU ETS Directive to reflect the scope of aviation activities covered by the Linking Agreement. A Commission Decision [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:C:2021:047I:TOC] ensures the corresponding changes of the free allocation to aviation operators.

Results of public consultation

In 2016, the European Commission held a **public consultation on market-based measures** to reduce the climate change impact from international aviation. The consultation sought input on both global and EU policy options.

In total, 85 citizens and organisations responded.

View the contributions [https://ec.europa.eu/clima/consultations/articles/0029_en]

Global scheme to offset emissions

In October 2016, the International Civil Aviation Organization (ICAO) agreed on a Resolution for a **global market-based measure** to address CO_2 emissions from international aviation **as of 2021**. The agreed Resolution sets out the objective and key design elements of the global scheme, as well as a roadmap for the completion of the work on implementing modalities.

The **Carbon Offsetting and Reduction Scheme for International Aviation, or CORSIA**, aims to **stabilise CO_2 emissions at 2020 levels** by requiring airlines to offset the growth of their emissions after 2020.

Airlines will be required to

- **monitor** emissions on **all international routes;**
- **offset** emissions from **routes included** in the scheme by purchasing eligible emission units generated by projects that reduce emissions in other sectors (e.g. renewable energy).

During the period 2021-2035, and based on expected participation, the scheme is estimated to offset around **80% of the emissions above 2020 levels**. This is because participation in the first phases is voluntary for states, and there are exemptions for those with low aviation activity. **All EU countries** will join the scheme from the start.

A **regular review** of the scheme is required under the terms of the agreement. This should allow for continuous improvement, including in how the scheme contributes to the goals of the Paris Agreement.

Work is ongoing at ICAO to develop the necessary **implementation rules and tools** to make the scheme operational. Effective and concrete implementation and operationalisation of CORSIA will ultimately depend on national measures to be developed and enforced at domestic level.

https://www.rolls-royce.com/media/our-stories/insights/2020/aviation-must-go-low-carbon.aspx

APPENDIX 3

The aviation industry must – and can – go low carbon

Prince Charles last week asked if those in power "want to go down in history as the people who did nothing to bring the world back from the brink of a climate crisis?". He called for 2020 to be "the year that we put ourselves on the right track".

The aviation challenge

One sector that people fear could drag the world off-track is aviation.

For thousands of years, the exchange of culture, ideas, goods and services has been the powerhouse of human progress. Aviation has accelerated that exchange across continents, making a huge contribution to humanity and the global economy. International trade is responsible for much of the development and prosperity of the modern world.

But today the industry faces a real challenge. If demand for air travel grows in line with current projections, and other sectors are able to decarbonise more quickly, emissions from the aviation industry will grow significantly as a proportion of the total. Under some scenarios, this could approach 25% in a couple of decades - and even sooner if the world moves faster and we do not.

We urgently need to pioneer flight without adding more CO2 to the atmosphere. There is no one single solution that will get us there. It will take genuine collaboration across industries and borders to make progress.

Unlike the world of automotive where different alternatives can evolve in different regions, in the world of aviation it is a global challenge and will ultimately require a global solution. The UK, with its rich history of innovation, has an opportunity to help lead the way, supported by a Government committed to tackling global climate change.

Industrial leader

"I firmly believe that few companies on the planet are better placed than Rolls-Royce to help solve this problem. Last month, I committed us to a pathway that gets Rolls-Royce to net zero carbon by 2050. As an industrial technology leader, we want to use our capabilities to enable others to do the same. We will get our own factories and facilities there sooner, in 2030, but it is reducing the impact of our products – and particularly those that serve aviation – where the greatest challenge lies."

Waren East
CEO, Rolls-Royce

Inevitably, the sheer complexity of the challenge and the early stage of some technologies needed to decarbonise aviation, means that there will be differences in opinion about the exact pathway for the whole industry. At the outset of a 30 year journey, that is to be expected. The important thing is that there is now no question about where aviation needs to get to – net zero – and a shared recognition of the urgent need to get there as fast as possible.

In my view that means we, at Rolls-Royce, need to pioneer on three fronts. First, we need to redouble efforts to improve the fuel efficiency of engines and develop new technologies and capabilities for future low emission products. We have been improving airframe engine combinations around 1% every year for the past 20 years and our large engine UltraFan concept is another significant step forward.

Second, we need to work with the fuels industry to significantly ramp up the availability of environmentally friendly sustainable aviation fuels (SAFs) that are scalable and compatible. A new form of collaboration is needed across the industry – from airlines, airport operators and aircraft manufacturers to energy companies, financial institutions, government, civil society groups and customers.

Third, we need to accelerate development of disruptive technologies, such as hybrid-electric and all-electric power and explore the use of new fuels such as hydrogen. Rolls-Royce is already deploying hybrid electric systems today in the rail and marine markets and supplying microgrids for power generation. Electrification is not a panacea on its own, but may help some areas of aviation, such as commuter and regional routes, to move swiftly.

In 20 years – the life of one commercial aircraft – the planet will be supporting four times more people than it did a hundred years earlier. This is a massive strain on our natural ecosystem. We absolutely must do as much as sustainably possible to bring the world back from the brink. There has never, ever, been a greater challenge to human kind. But, for us, there has never been a more exciting time to strive to be part of the solution.

January 2020

APPENDIX 4

FAQ

Title : 1. Why does ICAO not take account of non-CO2 effects in the methodology? (1)

The ICAO Carbon Emissions Calculator is limited to the calculation of the CO2 amounts released into the atmosphere by the aircraft engines during a flight. Consequently, the ICAO Emissions Calculator does not quantify the climate change impact of aircraft emissions using the Radiative Forcing Index (RFI) or other such multipliers. The scientific community has not yet reached consensus on the use of the RFI or other such multipliers and therefore ICAO will only adopt a multiplier if and when the scientific community reaches a general agreement on this issue. ICAO is working in collaboration with IPCC on this subject and will adapt a multiplier methodology in due course accordingly.

Title : 2. What is offsetting? (1)

In general terms, an offset is a "compensating equivalent". As an activity, it can mean to "cancel out" or "neutralise" emissions from a sector like aviation by financing or creating equivalent emissions reductions in a different activity or location.

Title : 3. Why doesn't ICAO provide an offsetting scheme on its website? (1)

ICAO notes the positive contribution that offsetting makes to the mitigation of greenhouse gas emissions through carbon markets, and its role in consumer education. The voluntary offset market has undergone rapid growth in the last few years, producing a wide variance in the quality of offset credits and some public confusion about their role. As a member of the United Nations, ICAO cannot recommend specific services offered by commercial entities. However, the answers to the questions below may help individual travelers to select the best means to offset their air travel CO2 emissions.

Title : 4. What should I look for in an offset scheme? (1)

While ICAO cannot recommend a specific offset provider, there are factors that you should consider in making your own selection, including:

- How is my carbon offset credit generated?
- Does it conform to recognised standards (and/or any guidance from governments)?
- Has it been audited and verified?
- Is it transparent?

Title : 5. How is my carbon offset credit generated? What different qualities do they possess? (1)

Most credits are generated through investment in specific emission reduction projects. Although not an exhaustive list, the most common projects to invest in are bio energy and clean non-emitting electricity generation (for example, harnessing wind, solar, and hydro power). These projects not only generate credits but provide investment in renewable sources that reduce our long-term reliance on fossil fuels. As well as new technologies, maintaining the planet's ability to absorb CO2 through nature is also important. For this reason forest-based carbon sequestration projects are also common and play an important role in tackling climate change, although some have doubts about the permanent carbon storage of such projects. Where a sequestration project is offered, look for information on how the forest is managed and risks are addressed. As a general rule, look for projects that provide evidence on how they contribute to sustainable development and whether they provide a genuine "additional" benefit (in other words, they finance projects that would otherwise have not taken place). This task is usually carried out for you where a project complies with a recognised standard. Also, you can also check to see whether any advice or information is provided by from local/national government.
Some companies and sectors have their emissions regulated and can be subject to a cap. Each regulated entity has a carbon allowance equivalent to the cap. Some offset providers offer the consumer the ability to purchase and cancel these allowances, forcing the regulated entity to make additional emission reductions to meet their cap.

Title : 6. Does it comply with a recognised standard? Has it been audited and verified? (1)

Carbon credits can be generated through the Kyoto Protocol's Clean Development Mechanism (CDM) and Joint Implementation (JI) [Ref. 1] as Certified Emission Reductions (CERs). All CER projects satisfy rigorous quantification requirements to determine how many tonnes of GHG the project has reduced. The projects must also successfully complete an additionality assessment, contribute to sustainable development, and undergo third-party validation and verification of emission reductions before they are approved. The quality of Voluntary Emissions Reductions (VERs) is highly variable so they should be approached with appropriate caution. One indicator is compliance with ISO 14064 (Part 2, 2006) [Ref. 2] . ICAO does not offer any advice on national standards or other voluntary standards, although many provide a robust test.

[Ref. 1] Clean Development Mechanism allows emission-reduction (or emission removal) projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol.
The mechanism stimulates sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets. The projects must qualify through a rigorous and public registration and issuance process designed to ensure real, measurable and verifiable emission reductions that are additional to what would have occurred without the project. The mechanism is overseen by the CDM Executive Board, answerable ultimately to the countries that have ratified the Kyoto Protocol. UNFCCC website http://cdm.unfccc.int/about/index.html
Joint Implementation allows a country with an emission reduction or limitation commitment under the Kyoto Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one tonne of CO2, which can be counted towards meeting its Kyoto target.
Joint implementation offers Parties a flexible and cost-efficient means of fulfilling a part of their Kyoto commitments, while the host Party benefits from foreign investment and technology transfer. UNFCCC website
http://unfccc.int/kyoto_protocol/mechanisms/joint_implementation/items/1674.php

[Ref. 2] Greenhouse gases -- Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements.

Title : 7. Is it transparent? (1)

The degree of transparency about the offsetting program varies significantly between programs. Using schemes that are well documented make an informed choice possible. As a minimum, you should have sufficient information about the project to answer all of the above questions.

Title : 8. Can I calculate the monetary cost of my carbon emissions? (1)

In general, the price of an offset credit is no guarantee of its quality. The price of a project credit is determined by the investment required to generate a carbon saving, and the administration cost. Project investment will vary by location and the nature of the project, even if the quality is the same. Administration costs also vary. Some projects claim to invest 100% of your money directly in projects, but somewhere between 80-90% is typical. In practice, there may be little difference as some schemes attribute overheads and verification costs directly to the project.
Like the carbon markets generally, prices can and do fluctuate. This makes it difficult to provide accurate information on the average price of carbon offset credits at any moment in time. Some indicative information can be found by looking at the trends in the carbon markets. Various carbon markets are in operation, some are mandatory like the European Union (EU) emissions trading scheme and others are on a voluntary basis.

APPENDIX 5

Interview: Alan Newby, director of aerospace technology and future programmes, Rolls-Royce

13th November 2019 9:30 am

Air of positivity: Rolls-Royce's Alan Newby believes that the aviation industry needs to be bolder in stressing its positive contribution to the modern world. Stuart Nathan reports

The aerospace industry isn't having the easiest of rides in the public eye at the moment. It's widely seen as an environmental malefactor, responsible for carbon emissions, noise and other pollution misdemeanours, and a movement started in Sweden known as *flygskam* (or 'flight shaming') aims to convince people to give up air travel whenever possible in favour of trains or boats.

Against this background, Alan Newby, director of aerospace technology and future programmes at Rolls-Royce, would appear to have an uphill struggle. Engineering industry insiders are well aware of the progress that Rolls-Royce and other aerospace companies have made in improving the environmental performance of their product since the advent of jet-powered air travel in the 1950s, but Newby believes that this message – and the advantages that air travel has brought to society – are still largely lost to the public in general and, to an extent, to policymakers.

"I think it's important that we stress the importance of aviation itself as an industry, both as a means of connecting people, but also from a trade point of view," he told *The Engineer*. "It's a matter of stimulating business, allowing people to understand different cultures, and, particularly with the defence business, of delivering humanitarian aid." Newby believes that communicating the benefits of air travel is a task for the entire aerospace industry, although Rolls-Royce should play a part in that effort, he concedes.

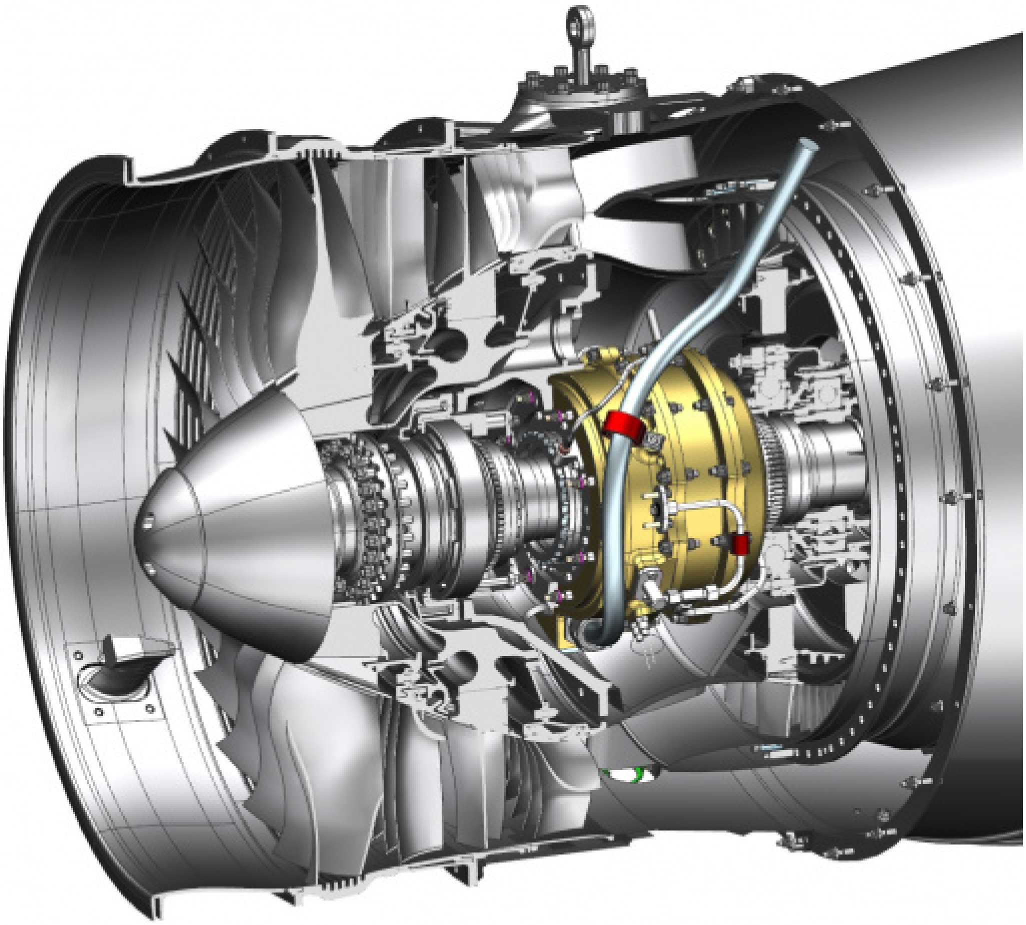
The benefits are also economic, he added. "A significant part of world trade is transported by air, the sector is a huge employer and supports many jobs in other industries as well, and if you were to rank aviation in terms of its size, compared with the GDP of the world's countries, it would rank 20th, so that is a pretty massive contribution to economic well-being around the world."

"New technology ideas and sustainable fuels are going to be the final piece in the puzzle and they will bring us down to our 2050 performance and emission targets"

Since the advent of jet technology, carbon-dioxide emissions from aviation have reduced by 80 per cent, Newby said, and engines are 75 per cent quieter. This is all a ma er of making engines more efficient, he stressed: an efficient engine produces more thrust with less fuel, and therefore emits less carbon. Noise is also an artefact of low efficiency and improving the efficiency of the airflow through the engine ensures that less energy is lost as sound and more is channelled into propelling the aircraft forwards.

The advent of Rolls-Royce's Trent gas turbine engines roughly coincided with the rise of environmental matters in public consciousness, and as the Trents are still the company's major product range, with the Trent 7000 and Trent XWB the latest to enter service, the progress of emissions and noise reduction in these engines provides a useful guide to how the company has performed since air travel came under its current level of scrutiny. Trents have now come full circle, Newby added, with the 7000 model replacing the first Trents on the wings of Airbus A330s. "We've been working on the Trents since the back end of the 1980s, and the first of these engines entered service around 1995," Newby said. Since the introduction of the Trents, CO_2 emissions have declined by around 15 per cent, NO_x emissions by around 30 per cent and noise by around 10 per cent.

Rolls-Royce is fully signed up to – and played a part in setting – the industry goals set under the ATAG and ACARE programmes, which respectively commit the aerospace sector to 1.5 per cent fuel efficiency improvement from 2009 to 2020 and to subsequent carbon-neutral growth, halving net emissions by 2050 relative to 2005; and 75 per cent reduction in CO_2, 90 per cent reduction in NO_x and 65 per cent improvement in perceived noise, all by 2050 and



Gearboxes and electric starter-generators (in gold) are among innovations in new gas turbine engines *(courtesy Rolls-Royce)*

relative to a new aircraft in 2000. "Some of this will be through commercial mechanisms such as offsetting and emissions trading schemes, especially in the near term, because it won't necessarily all be available through technology, but new technology ideas and sustainable fuels are going to be the final piece in the puzzle and they will bring us down to our 2050 targets."

Rolls-Royce is looking at two parallel strands of R&D to meet these targets. For shorter range flight – which it defines as anything less than about 4,000 nautical miles – it is increasingly looking towards electrical solutions, either with electric motors providing propulsion, or hybrid systems (which Newby refers to as "more electric"). But above that 4,000 nautical mile limit, the company still sees gas turbines as being the primary source of propulsion, and so it is looking at ways to improve the performance of its large gas turbine engines, with programmes called Advance3 and UltraFan. Both programmes are now in test phases, although no decision has yet been taken as to whether the resulting engines will be branded as a continuation of the Trents or given a new name when they come into service next decade.

As part of these two programmes, Rolls-Royce is developing a new engine core with efficient combustion systems to reduce both NO_x and CO_2, and fan systems based on lightweight carbon-titanium composites (comprising both the fan blades themselves and the surrounding fan case) to produce more efficient thrust by moving large amounts of air more slowly, which, as Newby explains, is the best way to reduce noise. To accommodate the new, fast-rotating core and the slower-moving fan, the company is developing a gearbox system capable of handling up to 100,000hp, currently under test in Germany. The new engine core also represents an advance in technology, with the use of silicon carbide composite turbine blades that can operate at higher temperatures than single-crystal nickel superalloy blades; this is also currently under test. New testbeds, such as one under construction currently in Derby, will be needed to test this new generation of engines, which have a 140in (3.56m) fan case diameter making them too big for existing facilities to handle. Integration of these 'demo blocks' of composite fan, gearbox and engine core will take place over the next few years, leading to the eventual introduction of this new evolution in gas turbine power.

Flight-testing blue composite fan-blades, on right of image *(courtesy Rolls-Royce)*

But while liquid-fuelled gas turbine engines remain a major part of Rolls-Royce's future plans, the future is increasingly electric, and with the company's acquisition of Siemen's eAircraft business in June, the company now has a larger number of electrical engineers specialising in aerospace applications (although Newby points out that it already had considerable expertise in electrical systems, mainly from its businesses in the rail and marine sectors).

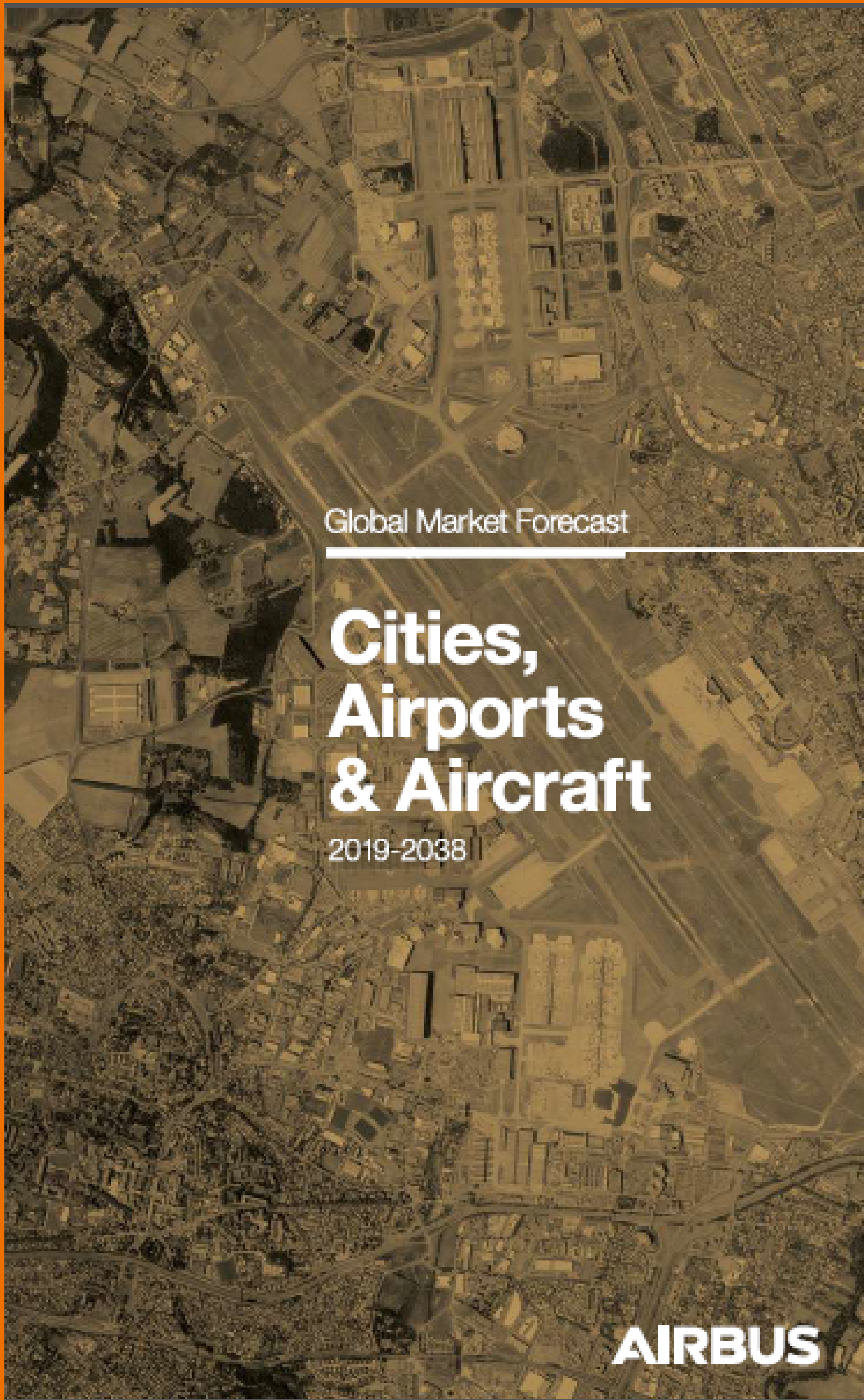
The electric propulsion flight paradigm will be seen in a number of aircraft designed to tackle different ranges: from personal air mobility (such as flying taxis) for flights up to 200 nautical miles, which would use entirely electric propulsion; to small and large regional aircraft, for flights up to 850 nautical miles and even narrow-body and small-to-medium business jets, which would use hybrid-electric systems.

Newby highlights electrical projects such

as an attempt to break the world electric flight speed record, which, he points out, "is a fantastic learning experience for the management and integration of aviation battery systems and is a massive STEM project in terms of getting young people interested in aviation. This is a zero-carbon propulsion system, which is going to do something quite interesting in breaking records." Rolls-Royce has also recently developed an electrical starter generator integrated with a gas turbine engine, which will generate electricity for onboard systems and has synergies with the engine it is developing for the new British Tempest fighter aircraft, which will also generate power for ranged laser weapon systems.

Latest Articles

APPENDIX 6



Cities, Airports & Aircraft

Introduction

“What is the city but the people?”

William Shakespeare

Cities, airports & aircraft

Welcome to the 2019 edition of Airbus' Global Market Forecast (GMF). This year we explore the relationship between the World's cities, their airports and the types of aircraft, in terms of size and range, which are supporting them.

In the past we have explored the importance of Aviation Mega-Cites (AMCs), particularly for larger aircraft, but this is just a part of the story. In 2018, there were 66 cities that we classify as AMCs, they account for 40% of all passengers, up from 29% in 2002, but well over 70% of long-haul passengers and 35% of the short-haul. Many of these cities have developed a need for more than one airport, some with as many as three or four today. More than 600 airlines or nearly 80% of the world's airlines operate to AMC airports. A growing share of passengers are also flying with LCCs from or to these airports, nearly a quarter of AMC passengers today, from just 8% in 2002. Over this time average aircraft size has grown from ~155 seats in 2002, to ~175 today, as passenger numbers and for some, operational constraints increase.

But as Shakespeare wrote “What is the city but the people?” About a quarter of the World's urban population live in AMCs, and are a focus for more than a quarter of global GDP. Given both are important drivers for aviation growth it is unsurprising that these cities are key points in the global aviation network. By the end of our forecast period in 2038, we expect there to be some 95 aviation mega-cities, with cities like Lagos, Muscat, Rio de Janeiro and Philadelphia being added to the growing list of AMCs.

Air transport will continue to play a key role in connecting cities and their people particularly in emerging markets or where cost or simply geography make alternatives impossible. In doing this commercial aviation contributes 3.6% of global GDP and supports more than 65 million jobs. However, we recognise that aviation also contributes 2% to 3% of the world's manmade emissions of carbon dioxide (CO_2), with transportation as a whole (cars, trains, shipping etc.) producing ~24% according to the United Nations Intergovernmental Panel on Climate Change (IPCC). So our industry has worked diligently to limit its impact on the environment. For example aircraft today, are 75% quieter and 80% more fuel efficient per seat than they were when jets were becoming a more common sight in cities around the world. But this is by no means the end of these efforts.

Airbus is conscious of climate change and its responsibility to society as well as future generations. We have the ambition to continue serving society's demand for air travel and transport and to continue delivering significant social benefits whilst ensuring a sustainable future of air travel.

We hope that you find the 2019 Global Market Forecast informative and useful. We seek to improve our analyses continually, and your questions, challenges and suggestions help us advance towards this goal. Don't forget you can access tailored GMF2019 content on your phone or computer, including interactive material, and the forecast results in Excel format using this link: http://gmf.airbus.com/ or simply scan the QR code on the back cover.

EXECUTIVE SUMMARY

01 Executive summary

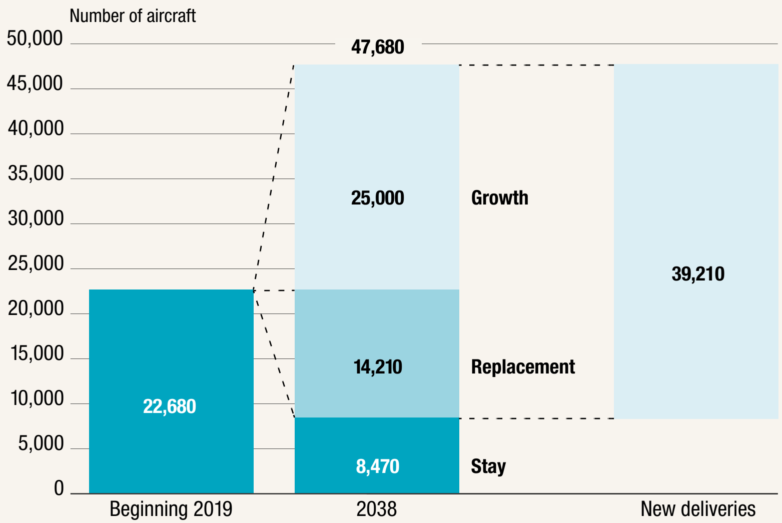
LONG TERM GROWTH POTENTIAL FOR OUR INDUSTRY IS CONFIRMED

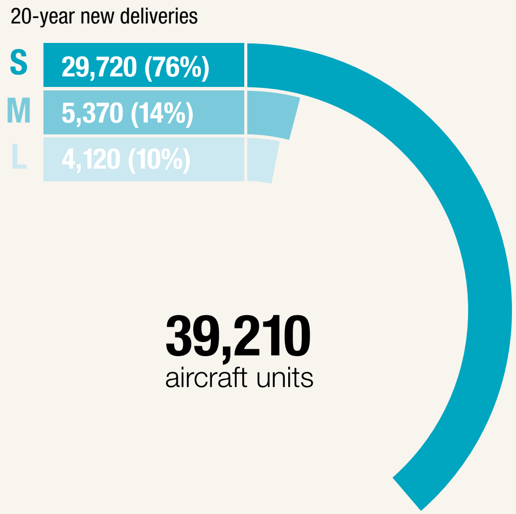
- The commercial aviation Industry has been resilient to external shocks, traffic has grown **x2.4** since 2000.
- Traffic forecast **to double** in the next 15 years.
- Our forecast confirms a **4.3%** average traffic growth p.a. over the next 20 years.
- Demand for **39,210** passenger and freight aircraft over the next 20 years.
- **36%** for aircraft replacement, and **64%** for growth.
- More than **14,200** aircraft will be replaced with **~38,360** passenger aircraft and **850** new build freighters.
- The S segment will represent **76%** of deliveries.
- The M and L segments will represent **24%** of demand in units.
- Asia-Pacific will account for **42%** of deliveries, with airlines in North America and Europe together **36%** of the passenger and freight aircraft deliveries.
- The services market is forecast to deliver a cumulative **US$4.9 trillion** over the next 20 years; see the services chapter for more details.

FLEET IN SERVICE EXPECTED TO MORE THAN DOUBLE OVER THE NEXT 20 YEARS

Source: Airbus 2019

Notes: Passenger aircraft (≥100seats), Jet Freight Aircraft (>10 tonnes) | Rounded figures to nearest 10

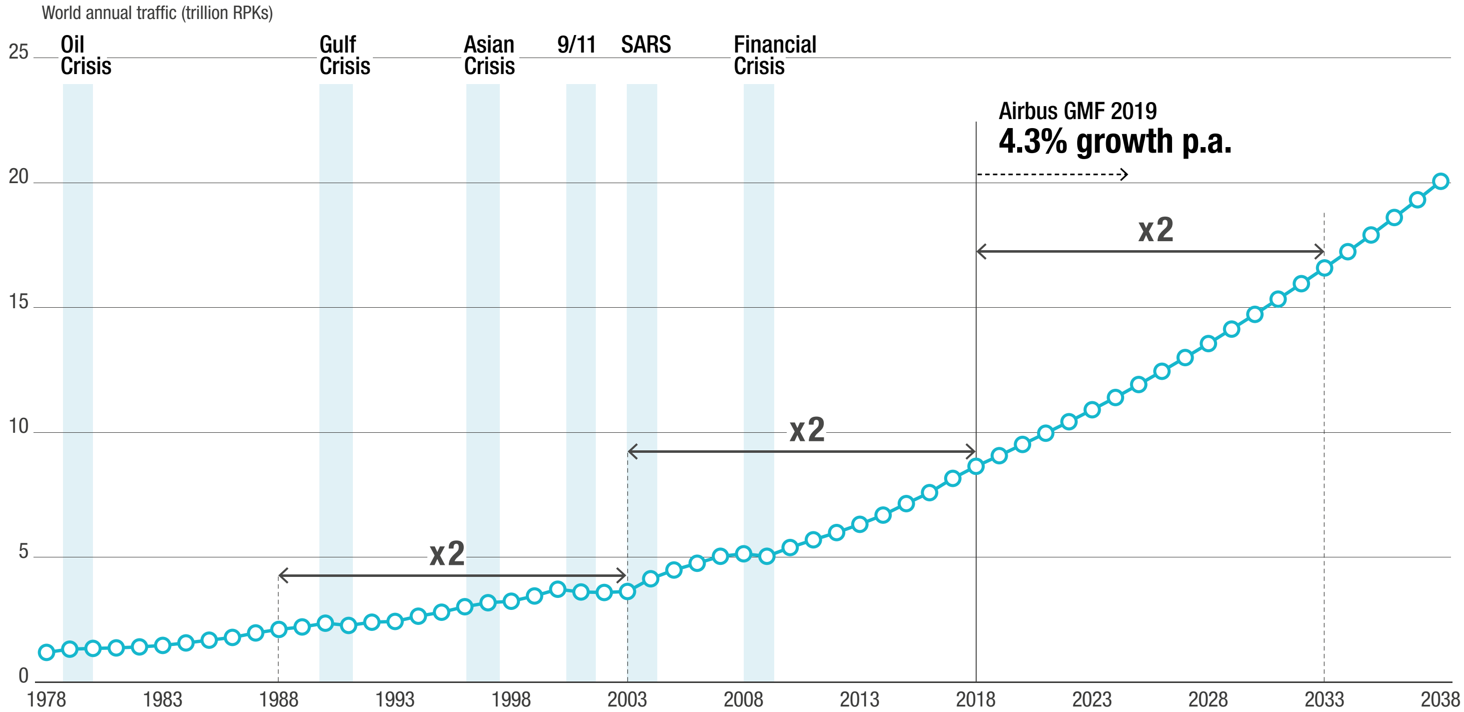




DEMAND FOR 39,210 NEW AIRCRAFT

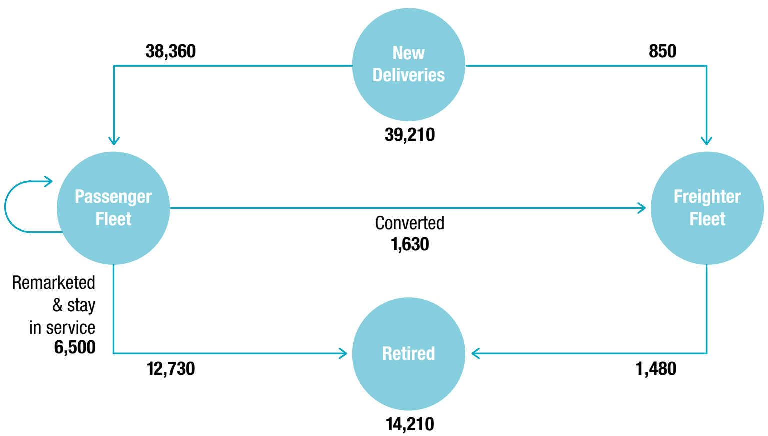
Source: Airbus 2019

Notes: Passenger aircraft (≥100 seats), Jet Freight Aircraft (>10 tonnes) | Rounded figures to nearest 10



TRAFFIC HAS PROVEN TO BE RESILIENT TO EXTERNAL SHOCKS AND DOUBLES EVERY 15 YEARS

Source: ICAO, Airbus GMF 2019
* RPK: Revenue Passenger Kilometer



	2019-2028	2028-2038	2019-2038	SHARE OF 2019-2038 NEW DELIVERIES
AFRICA	520	750	1,270	3%
ASIA-PACIFIC	6,500	10,040	16,540	42%
CIS	700	840	1,540	4%
EUROPE	3,790	3,750	7,540	19%
LATIN AMERICA	1,330	1,370	2,700	7%
MIDDLE EAST	1,410	1,830	3,240	8%
NORTH AMERICA	3,330	3,050	6,380	17%
WORLD TOTAL	**17,580**	**21,630**	**39,210**	**100%**

02

Demand for air travel

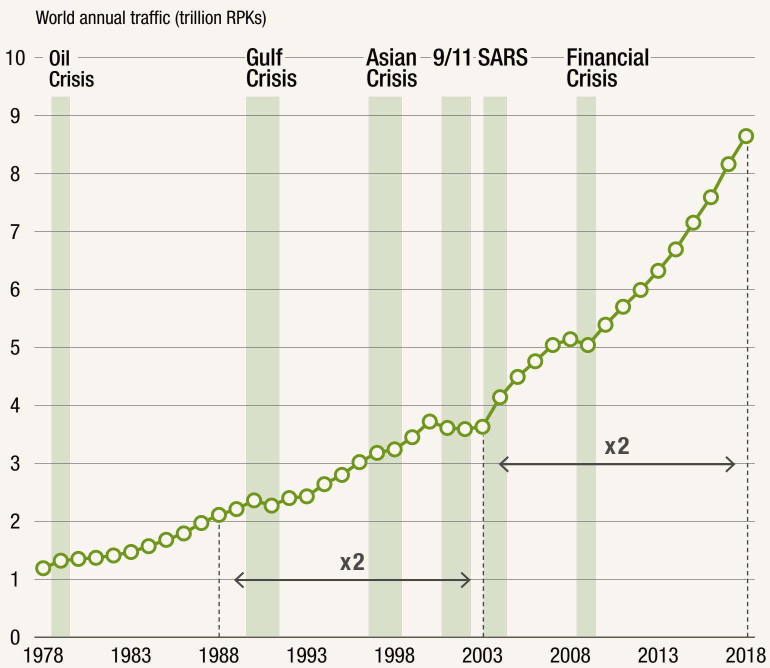
DEMAND FOR AIR TRAVEL

THE CYCLE
& THE SHORT TERM

When the air transportation market is discussed, cyclicality is often a word that comes up early in the conversation. This is primarily due to the impact a number of cycles have had on the industry since the 1990s. These past cycles are typified with their roots in a general economic slowdown and then exacerbated with an adjacent so called "exogenous" shock. The decade from the beginning of the new millennium provide to be the most significant for such events with two global (the events of 2001 and the financial crisis in 2008/2009) and one more regional, but no less difficult, focused in Asia (the SARS outbreak). What made these more challenging was the fact they followed, more or less, one after the other. This said, each was followed by a rebound, with traffic able to eventually return to its long term trend. From 2010, the industry has been free from such perturbations and has been able to meet the needs of passengers who have been unimpeded by the impact of these cycles, and whilst margins are still thin, airlines have been able to make a profit at the same time. In fact, airlines' have made almost as much profit since 2015, as they had between 1970 and 2014.

THE LAST 10 YEARS MORE STABLE FOR THE INDUSTRY THAN THE 10 YEARS PRECEDING

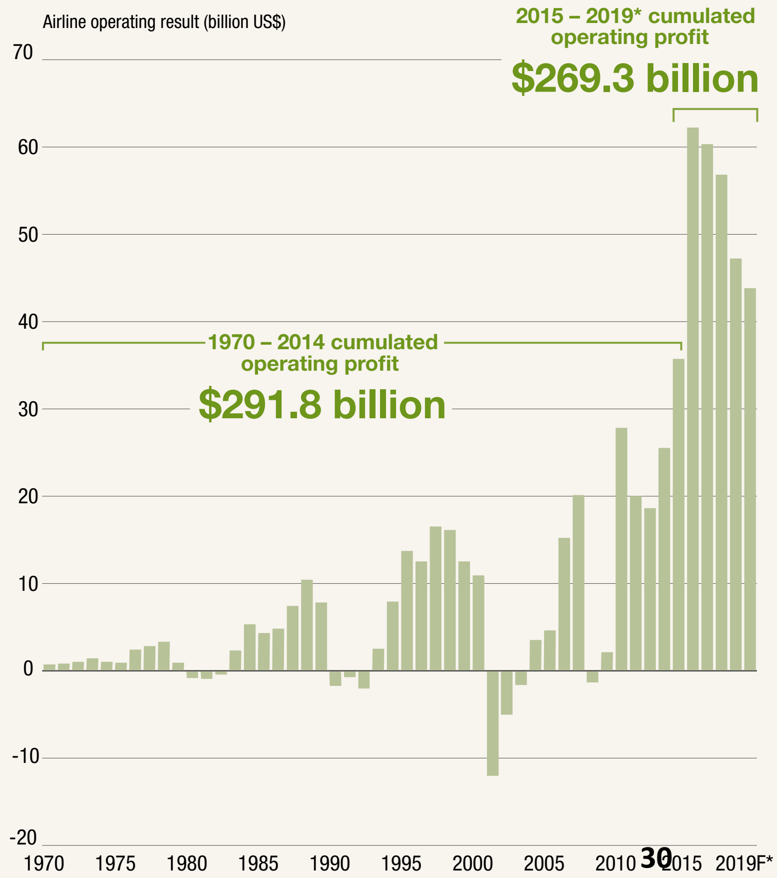
RPK: Revenue Passenger Kilometer
Source: ICAO, Airbus GMF 2019



Drivers during this period included the number of passengers able to grow driven by evolving business models, emerging markets, and deregulation and importantly unimpeded by the effects of an aviation cycle(s).

AIRLINES CUMULATED OPERATING PROFITS FROM 2015 TO 2019* EQUIVALENT TO CUMULATED OPERATING PROFITS FROM 1970 TO 2014: A NEW ERA FOR THE INDUSTRY?

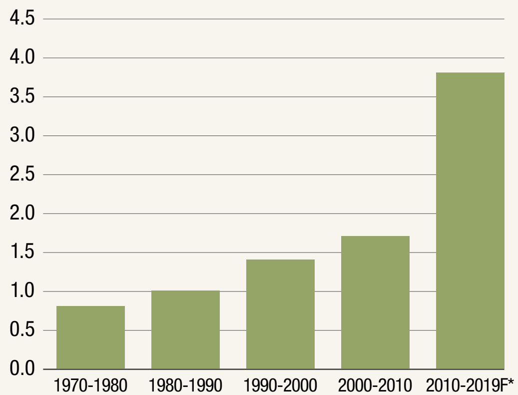
Source: ICAO, IATA, Airbus
*forecast



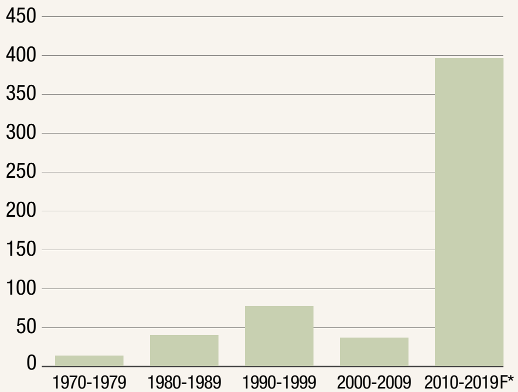
AIRLINE ADDED PASSENGER TRAFFIC AND CUMULATED OPERATING PROFITS

*forecast

Airline added passenger traffic (trillion RPKs)



Airline cumulated operating profits (billion US$)



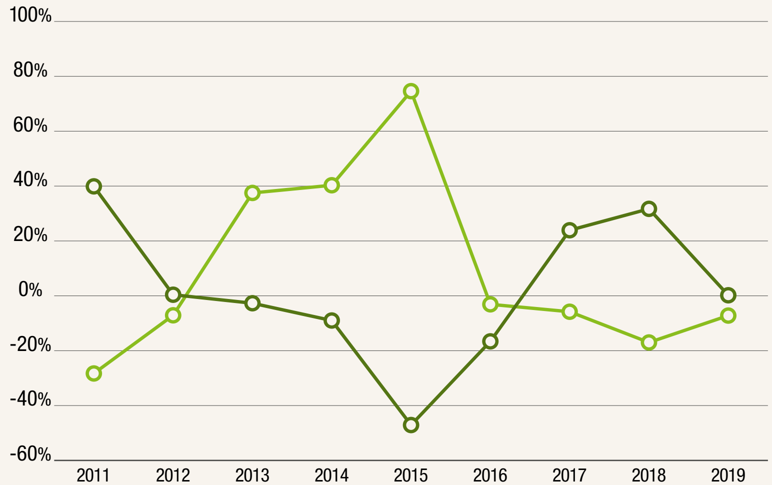
Another contributing factor was the price of oil, which has a negative correlation to airline profitability. From 2010, airlines enjoyed a period of lower or more stable fuel prices which due to the fact that fuel cost can be over 30% of airline costs, had a significant contribution to profits over this period.

STRONG NEGATIVE CORRELATION BETWEEN OIL PRICES AND AIRLINE PROFITABILITY

Source: ICAO, IATA, Airbus

Airline profitabilty year-over-year evolution

Oil prices year-over-year evolution



One question on the minds of most in the industry is when is the next cycle due? Given their potential effects it is unsurprising, with the forecasting team at Airbus monitoring leading indicators for some insight into the possibility and timing of at least an economically driven cycle. The traffic light chart shown here is one of the tools we employ. It summarises some of the indicators we monitor and their condition at the time of writing in the middle of 2019. As you will see many remain green, although geo-politics, particularly in the area of trade, remains a risk to the broader economic picture. However, productivity remains positive and stable, aircraft storage is at historically low levels, and load factors at historically high levels, indicating a continuing balance between supply and demand. So far in 2019, so good…

THE AIR TRANSPORT SHORT TERM OUTLOOK REMAINS POSITIVE

INDICATOR	STATUS	TREND	COMMENT
Geopolitics	Concerns	unchanged	• Increased protectionism and other geo-political risks remain a concern
Economy	Positive	moderating	• World real GDP growth is projected to gradually slow from +3.3% in 2017 and +3.2% in 2018, to +2.8% this year and +2.7% in 2020 (for reference, average World real GDP growth 2011-2016 was +2.5%). This as a result of slowing trade and industrial sectors growth
Passenger traffic	Positive	moderating	• Sustained passenger traffic growth in the first half of 2019 (+4.6% year-over-year growth in terms of RPKs), especially for airlines from Emerging Markets • Passenger load factor at record level in the first half of 2019
Freight traffic	Concerns	unchanged	• Weak air freight market in the first half of 2019 (-3.3% year-over-year in terms of FTKs) when compared with a strong first half 2018
Finance	Positive	unchanged	• Some volatility in finance and stock markets • Generally, interest rates at historical low levels, although baseline forecasts suggest US rates may continue to grow marginally
Aircraft	Positive	unchanged	• Stored aircraft remaining at historical low levels • Passenger aircraft productivity continues to improve
Airlines	Positive	unchanged	• Airline profitability expected to remain solid in 2019, although it may marginally decrease as a consequence of increased jet fuel / labour costs and currency volatility

Traffic light code:
- ● : Positive
- ● : Concerns
- ● : Negative

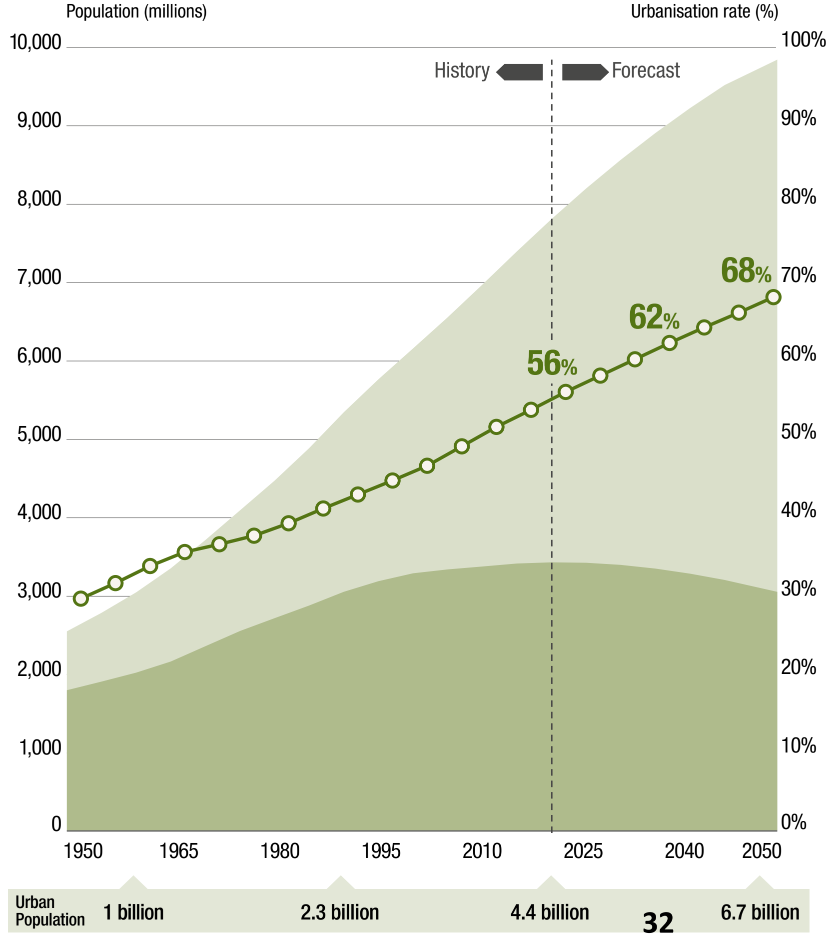
Trend indication:
- → : unchanged
- ↗ : improving
- ↘ : moderating

This year the theme of our forecast material is the importance of cities in the global aviation network and how airports and then aircraft evolve and support demand. As Shakespeare said "What is the city but the people" an insight as important today as it was in the fifteen hundreds. As the World's population has grown so too has the trend to greater urbanisation. At the start of the jet age in the 1950's about a third of the World's population was urbanised, today, it's over 50% and four billion people. Forecasts suggest this trend will continue reaching nearly seven billion people and 70% living in an urban environment by 2050. With greater urbanisation greater wealth is forecast with the number of people who can be classified as middle class expected to grow 50% over the next 20 years to 5.9 billion people from 3.9 billion today. There is little doubt that this demographic trend will also continue to shape the aviation network in the future as it has in the past.

In previous years, we have talked about the propensity to fly linked to countries and their wealth per capita, with this year's theme we have shown this but at a city level. Again there is a correlation to wealth, but at a city level some cities, particularly in Asia-Pacific, have achieved similar levels of flying to others with higher levels of GDP per Capita. This indicates the importance that aviation has on the daily lives of cities and their people. In fact from the cities studied 514 had at least one airport, with 50 cities having two or more.

WORLD URBAN POPULATION EXPECTED TO RISE FROM 4.4 BILLION PEOPLE TODAY UP TO 5.6 BILLION BY 2035 AND 6.7 BILLION BY 2050

Source: United Nations, Airbus



APPENDIX 7

Climate change and flying: what share of global CO2 emissions come from aviation?

by Hannah Ritchie
October 22, 2020

Our World in Data presents the data and research to make progress against the world's largest problems.
This blog post draws on data and research discussed in our entries on ***CO_2 and Greenhouse Gas Emissions*** *and* ***Energy****.*

Flying is a highly controversial topic in climate debates. There are a few reasons for this.

The first is the disconnect between its role in our personal and collective carbon emissions. Air travel dominates a frequent traveller's individual contribution to climate change. Yet aviation overall accounts for only 2.5% of global carbon dioxide (CO_2) emissions. This is because there are large inequalities in how much people fly – many do not, or cannot afford to, fly at all [best estimates put this figure at around 80% of the world population – we will look at this in more detail in an upcoming article].

The second is how aviation emissions are attributed to countries. CO_2 emissions from domestic flights *are* counted in a country's emission accounts. International flights are not – instead they are counted as their own category: 'bunker fuels'. The fact that they don't count towards the emissions of any country means there are few incentives for countries to reduce them.

It's also important to note that unlike the most common greenhouse gases – carbon dioxide, methane or nitrous oxide – non-CO_2 forcings from aviation *are not included* in the Paris Agreement. This means they could be easily overlooked – especially since international aviation is not counted within any country's emissions inventories or targets.

How much of a role does aviation play in global emissions and climate change? In this article we take a look at the key numbers that are useful to know.

Global aviation (including domestic and international; passenger and freight) accounts for:

- **1.9%** of greenhouse gas emissions (which includes all greenhouse gases, not only CO_2)
- **2.5%** of CO_2 emissions
- **3.5%** of ' effective radiative forcing ' – a closer measure of its impact on warming.

The latter two numbers refer to 2018, and the first to 2016, the latest year for which such data are available.

Aviation accounts for 2.5% of global CO_2 emissions

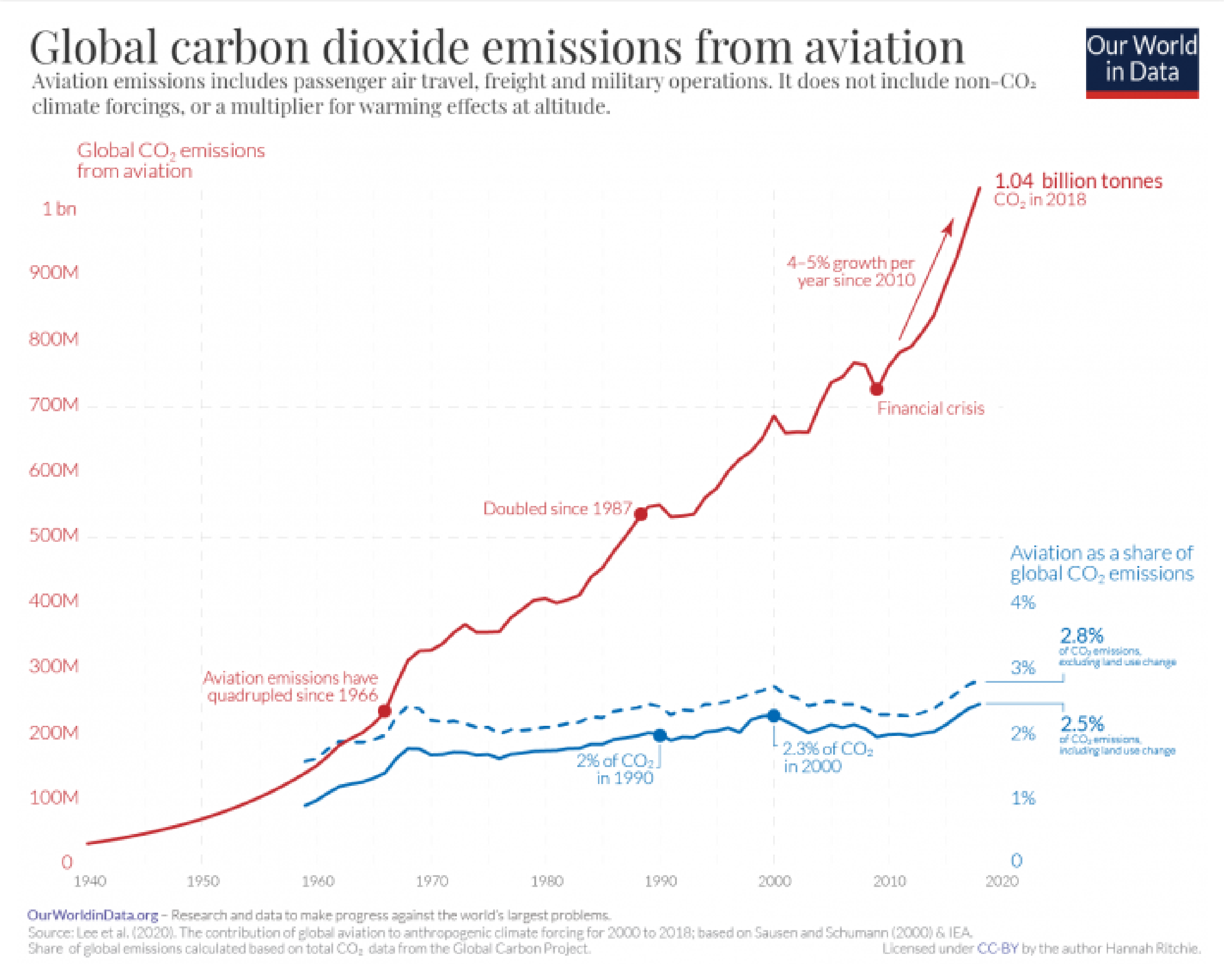
As we will see later in this article, there are a number of processes by which aviation contributes to climate change. But the one that gets the most attention is its contribution via CO_2 emissions. Most flights are powered by jet gasoline – although some partially run on biofuels – which is converted to CO_2 when burned.

In a recent paper, researchers – David Lee and colleagues – reconstructed annual CO_2 emissions from global aviation dating back to 1940.[1] This was calculated based on fuel consumption data from the International Energy Agency (IEA), and earlier estimates from Robert Sausen and Ulrich Schumann (2000).[2]

The time series of global emissions from aviation since 1940 is shown in the accompanying chart. In 2018, it's estimated that global aviation – which includes both passenger and freight – emitted 1.04 billion tonnes of CO_2.

This represented 2.5% of total CO_2 emissions in 2018.[3,4]

Aviation emissions have doubled since the mid-1980s. But, they've been growing at a similar rate as total CO_2 emissions – this means its share of global emissions has been relatively stable: in the range of 2% to 2.5%.[5]



Non-CO_2 climate impacts mean aviation accounts for 3.5% of global warming

Aviation accounts for around 2.5% of global CO_2 emissions, but it's overall contribution to climate change is higher. This is because air travel does not only emit CO_2: it affects the climate in a number of more complex ways.

As well as emitting CO_2 from burning fuel, planes affect the concentration of other gases and pollutants in the atmosphere. They result in a short-term increase, but long-term decrease in ozone (O_3); a decrease in methane (CH_4); emissions of water vapour; soot; sulfur aerosols; and water contrails. While some of these impacts result in warming, others induce a cooling effect. Overall, the warming effect is stronger.

David Lee et al. (2020) quantified the overall effect of aviation on global warming when all of these impacts were included.[6] To do this they calculated the so-called ' Radiative Forcing '. Radiative forcing measures the difference between incoming energy and the energy radiated back to space. If more energy is absorbed than radiated, the atmosphere becomes warmer.

In **this chart** we see their estimates for the radiative forcing of the different elements. When we combine them, aviation accounts for approximately 3.5% of effective radiative forcing: that is, 3.5% of warming.

Although CO_2 gets most of the attention, it accounts for less than half of this warming. Two-thirds (66%) comes from non-CO_2 forcings. Contrails – water vapor trails from aircraft exhausts – account for the largest share.

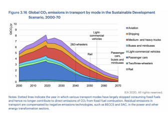
We don't yet have the technologies to decarbonize air travel

Aviation's contribution to climate change – 3.5% of warming, or 2.5% of CO_2 emissions – is often less than people think. It's currently a relatively small chunk of emissions compared to other sectors.

The key challenge is that it is particularly hard to decarbonize. We have solutions to reduce emissions for many of the largest emitters – such as power or road transport – and it's now a matter of scaling them. We can deploy renewable and nuclear energy technologies, and transition to electric cars. But we don't have proven solutions to tackle aviation yet.

There are some design concepts emerging – Airbus, for example, have announced plans to have the first zero-emission aircraft by 2035, using hydrogen fuel cells. Electric planes may be a viable concept, but are likely to be limited to very small aircraft due to the limitations of battery technologies and capacity.

Innovative solutions may be on the horizon, but they're likely to be far in the distance.



Towards zero-carbon transport: how can we expect the sector's CO_2 emissions to change in the future? →

Appendix: Efficiency improvements means air traffic has increased more rapidly than emissions

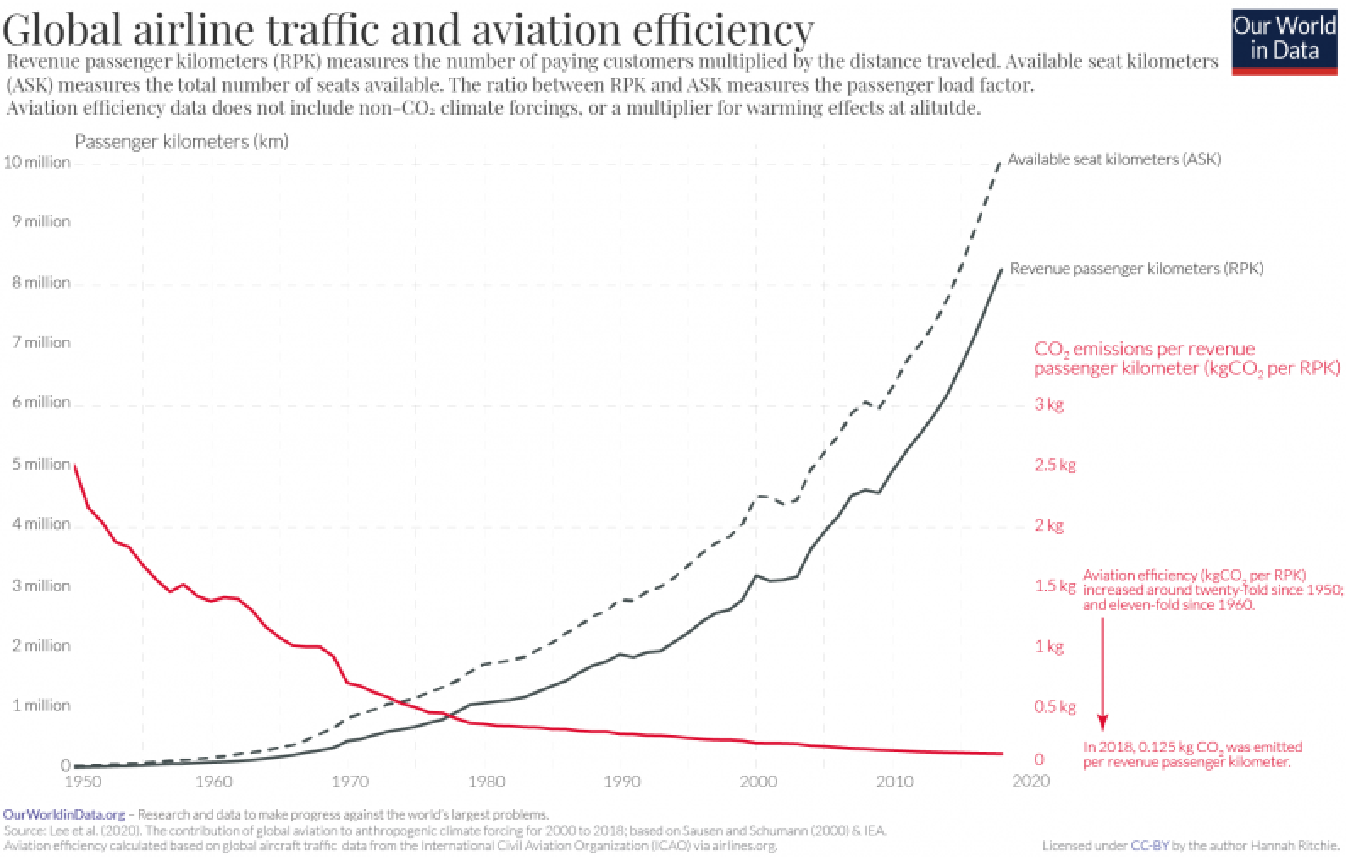
Global emissions from aviation have increased a lot over the past half-century. However, air travel volumes increased even more rapidly.

Since 1950, aviation emissions increased almost seven-fold; since 1960 they've tripled. Air traffic volume – here defined as revenue passenger kilometers (RPK) traveled – increased by orders of magnitude more: almost 300-fold since 1950; and 75-fold since 1960 [you find this data in our interactive chart here].[7]

The much slower growth in emissions means aviation efficiency has seen massive improvements. In the chart we show both the increase in global airline traffic since 1950, and aviation efficiency, measured as the quantity of CO_2 emitted per revenue passenger kilometer traveled. In 2018, approximately 125 grams of CO_2 were emitted per RPK. In 1960, this was eleven-fold higher; in 1950 it was twenty-fold higher. Aviation has seen massive efficiency improvements over the past 50 years.

These improvements have come from several sources: improvements in the design and technology of aircraft; larger aircraft sizes (allowing for more passengers per flight); and an increase in how 'full' passenger flights are. This last metric is termed the 'passenger load factor'. The passenger load factor measures the actual number of kilometers traveled by paying customers (RPK) as a percentage of the available seat kilometers (ASK) – the kilometers traveled if every plane was full. If every plane was full the passenger load factor would be 100%. If only three-quarters of the seats were filled, it would be 75%.

The global passenger load factor increased from 61% in 1950 to 82% in 2018 [you find this data in our interactive chart here].



Endnotes

1. Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., … & Gettelman, A. (2020). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment*, 117834.

2. Sausen, R., & Schumann, U. (2000). Estimates of the climate response to aircraft CO2 and NOx emissions scenarios. *Climatic Change*, *44*(1-2), 27-58.

3. The Global Carbon Budget estimated total CO_2 emissions from all fossil fuels, cement production and land-use change to be 42.1 billion tonnes in 2018. This means aviation accounted for [1 / 42.1 * 100] = 2.5% of total emissions.

4. Global Carbon Project. (2019). Supplemental data of Global Carbon Budget 2019 (Version 1.0) [Data set]. Global Carbon Project. https://doi.org/10.18160/gcp-2019.

   If we were to exclude land use change emissions, aviation accounted for 2.8% of fossil fuel emissions. The Global Carbon Budget estimated total CO_2 emissions from fossil fuels and cement production to be 36.6 billion tonnes in 2018. This means aviation accounted for [1 / 36.6 * 100] = 2.8% of total emissions.

5. 2.3% to 2.8% of emissions if land use is excluded.

6. Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., … & Gettelman, A. (2020). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment*, 117834.

7. Airline traffic data comes from the International Civil Aviation Organization (ICAO) via Airlines for America. Revenue passenger kilometers (RPK) measures the number of paying passengers multiplied by their distance traveled.

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Our World In Data is a project of the Global Change Data Lab, a registered charity in England and Wales (Charity Number 1186433).

APPENDIX 8

10. July 2019 • Innovation

Thermal engines vs. electric motors

How new propulsion technologies are influencing the next generation of air vehicles

The transition to electric propulsion is fully underway on a global scale, evidenced by the growing number of hybrid/electric cars and electric drones in the streets and in the skies. But how does electric propulsion – which uses electrical energy supplied by a battery pack or hydrogen fuel cell – compare to traditional, fossil fuel-powered thermal propulsion?

Depending on the machine, combustion engines can appear very different. In large planes and helicopters, the combustion engine takes the form of a turbine. In the turbine, fuel burns in an oxygen-rich environment, creating hot air and high pressure in a confined chamber, and employing that energy to power the aircraft.

CityAirbus – an urban air vehicle demonstrator designed to be fully-electric and emissions-free – is advancing electric vertical take-off and landing (eVTOL) flight

In electric-powered vehicles, the motor is composed of a rotor and a stator. With pulses of electricity from a power electronics device, the stator produces a magnetic field around the rotor which rotates and then turns a vehicle's drive train, rotor shaft, etc. The energy is supplied by a hydrogen fuel cell or a battery pack, which is generally powered by lithium-ion cells. These are similar to the batteries in a laptop, but multiplied by several thousand.

The limits of thermal-propulsion technology

Combustion engines are ideal for long-range travel because fossil fuels produce a lot of power and energy per kilogram of fuel (power and energy density, respectively). In other words, they enable long-range missions with a limited mass of fuel. And fossil fuel tanks are quite lightweight, considering the fuel mass they contain.

The main drawback is the emissions (NOx, CO2, particles, etc.) they produce. In addition, a lot of fuel is consumed (or wasted) in heat. In fact, three-quarters to two-thirds of fuel energy transforms into heat or is lost via the exhaust. Advances are being made to counter these negatives, like drawing off some of the lost energy from the hot exhaust (to warm up the air before combustion), but these improvements will eventually reach a plateau.

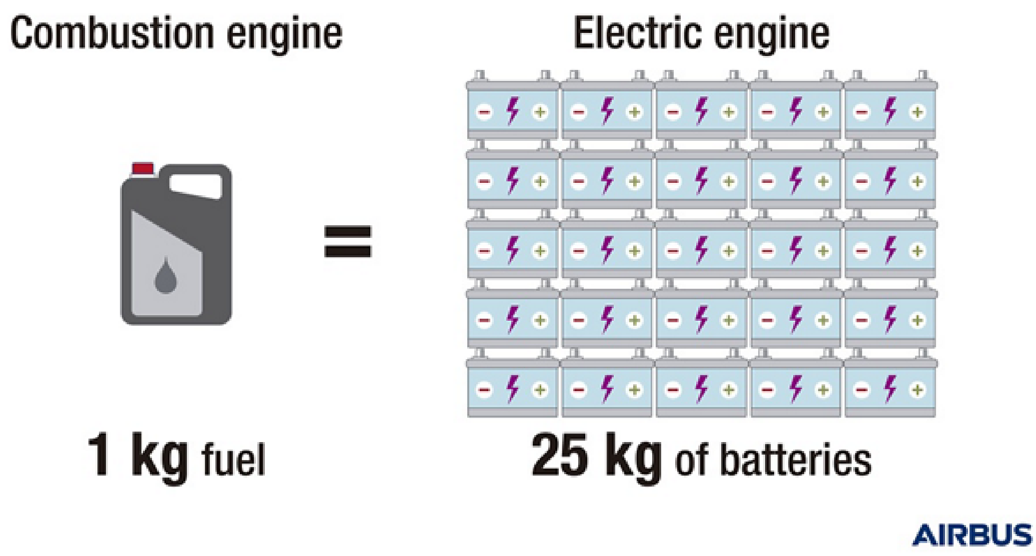
Is electric propulsion the answer? The performance of electric motors and power electronics has vastly improved: today, they achieve a better degree of power density than that of combustion engines. In addition to their light weight, electric motors have a greater range of speed than combustion engines, which reduces the need for gearboxes.

Electric energy presents challenges

The primary challenge of electric energy is that it cannot be stored efficiently (from the perspective of both mass and volume), at least not with today's technology. In the simplest terms, a large quantity of batteries is required to equal the performance of fuel. This means that the battery in an electric car can represent approximately a third of its empty weight.

Compared to ground vehicles, the mass and volume needed to store energy are more critical on aircraft and rotorcraft because they may directly impact payload and/or performance. And unlike a car's fuel tank, a battery does not become lighter during the trip – representing another disadvantage.

Mass and volume storage also are problematic for hydrogen fuel cells. This is because the chemical hydrogen must either be stored at high pressure, as in a gas state, or as saturated liquid hydrogen – which needs to be kept at around -253°C and requires large and heavily insulated tanks.

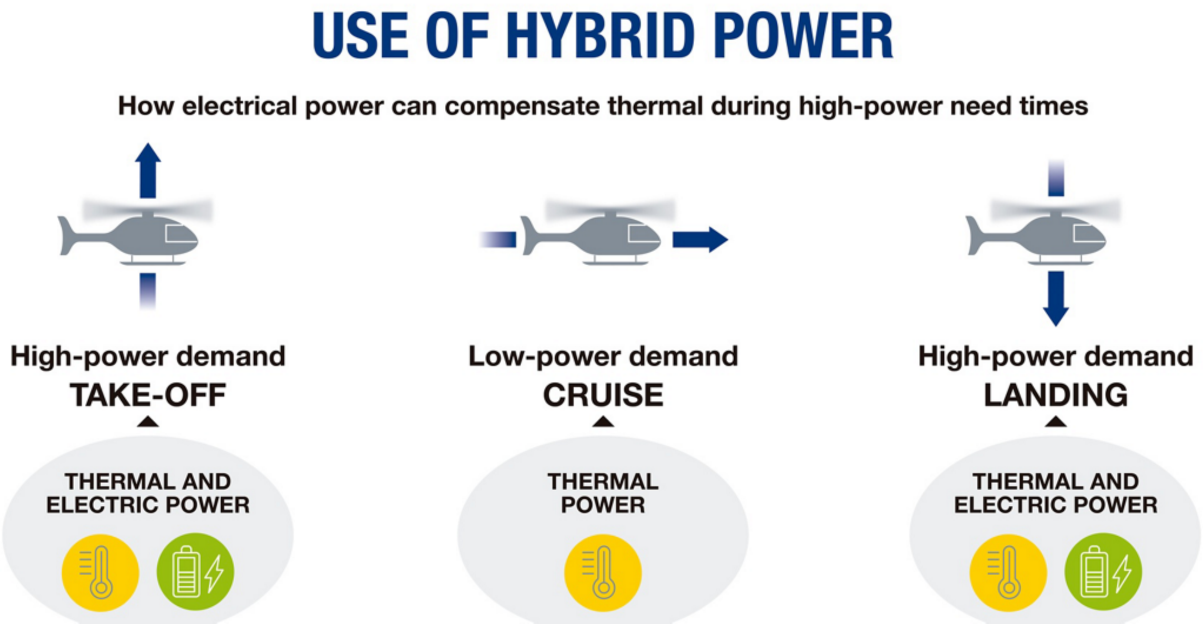


The current usable energy density of rechargeable batteries is approximately 120Wh/kg, compared to fossil fuel's 12,000Wh/kg*. In other words, the average efficiency of a motor and thermal engine can be equated to: 1 kg of fuel equals 25 to 30 kg of batteries

Finding middle ground: hybrid propulsion

Another option is to combine the best of both worlds. This is known as hybrid-electric propulsion, which uses a combination of conventional internal combustion engine with an electric-propulsion system.

“Hybridisation enables us to optimise,” said Luca Cossetti, Innovative Power Solutions at Airbus Helicopters, who is a part of a team developing a hybrid-propulsion solution for air vehicles. “You could use the thermal engine in certain phases of flight, thereby optimising its efficiency and consumption for that specific situation, and compensate with electrical power when the power demand is higher (such as during take-off and landing for a rotorcraft).”



The future is bright

So what might propulsion look like in future aircraft? For commercial airplanes and helicopters, combustion engines powered by cleaner, more sustainable fuels is already possible: Airbus has delivered wide-body A350 XWB aircraft that use a blend of sustainable jet fuel. In parallel, hybrid-electric propulsion systems are showing great potential for use in mid-sized airplanes and helicopters.

Consider Airbus’ E-Fan X. In this complex hybrid-electric aircraft demonstrator, one of the four jet engines will be replaced by an electric motor. This power is roughly the equivalent to that of 10 medium-sized cars. The electric propulsion unit is powered by a generator-fuelled battery and during descent, the engine blades work like small windmills to generate power and recharge the battery.

The promise of fully-electric propulsion

Such a scenario is already in development for urban transport, where the journey from an airport to a city centre is short, and the payload is comparable to the needs of a taxi. Today, more than 150 urban air mobility (UAM) vehicles – steered by start-ups, automotive manufacturers, established aerospace companies, and others – are in various stages of development worldwide.

These future urban air vehicles are designed to be fully-electric and zero-emission. Airbus is addressing this market by developing the Vahana and CityAirbus, both of which are advancing electric vertical take-off and landing (eVTOL) flight ideally suited for intra-city transport.

No matter the route taken, it is clear that the methods and materials to produce batteries, cells and hydrogen will be of paramount importance in the years to come.

Why the age of electric flight is finally upon us

By Tim Bowler
BBC News, Le Bourget, Paris

3 July 2019

Climate change

Eviation's nine-seater electric aircraft, Alice, was a hit at the Paris Airshow

EVIATION

Aerospace firms are joining forces to tackle their industry's growing contribution to greenhouse gas emissions, with electric engines seen as one solution. But will this be enough to offset the growing demand for air travel?

This week's Paris Airshow saw the launch of the world's first commercial all-electric passenger aircraft - albeit in prototype form.

Israeli firm Eviation says the craft - called Alice - will carry nine passengers for up to 650 miles (1,040km) at 10,000ft (3,000m) at 276mph (440km/h). It is expected to enter service in 2022.

Alice is an unconventional-looking craft: powered by three rear-facing pusher-propellers, one in the tail and two counter-rotating props at the wingtips to counter the effects of drag. It also has a flat lower fuselage to aid lift.

- **Firms team up on hybrid plane tech**
- **EasyJet backs plan for electric planes**
- **The Disruptors - Up, up and away**

"This plane looks like this not because we wanted to build a cool plane, but because it is electric," says Eviation's chief executive Omer Bar-Yohay.

"You build a craft around your propulsion system. Electric means we can have lightweight motors; it allows us to open up the design space."

Eviation has already received its first orders. US regional airline Cape Air, which operates a fleet of 90 aircraft, has agreed to buy a "double-digit" number of the aircraft.

The firm is using Siemens and magniX to provide the electric motors, and magniX chief executive Roei Ganzarski says that with two billion air tickets sold each year for flights of under 500 miles, the business potential for small electric passenger aircraft is clear.

Crucially, electricity is much cheaper than conventional fuel.

A small aircraft, like a turbo-prop Cessna Caravan, will use $400 on conventional fuel for a 100-mile flight, says Mr Ganzarski. But with electricity "it'll be between $8-$12, which means much lower costs per flight-hour".

"We're not an environmentalist company, the reason we're doing this is because it makes business sense."

MagniX is now working with seaplane operator, Vancouver-based Harbour Air, to start converting their existing fleet to electric.

The future also looks reasonably bright when it comes to medium-range flight - a range of up to about 1,500km.

Unlike Alice, aircraft targeting this range would use a mix of conventional and electric power, enabling them to cut CO_2 emissions significantly by switching on the electrical component of their propulsion at the key points in a flight - take-off and landing.

Several demonstration projects are now nearing fruition.

For example, Rolls-Royce, Airbus and Siemens are working on the E-Fan X programme, which will have a two megawatt (2MW) electric motor mounted on a BAE 146 jet. It is set to fly in 2021.

"There are huge amounts of energy involved here, the engineering is absolutely leading-edge - and our investment in electrification is ramping up rapidly," says Rolls-Royce's chief technology officer Paul Stein.

United Technologies, which includes engine-maker Pratt & Whitney in its portfolio, is working on its Project 804, a hybrid electric demonstrator designed to test a 1MW motor and the sub-systems and components required.

The firm says it should provide fuel savings of at least 30%. It should fly in 2022 and is forecast to be ready for regional airliners by the mid-2020s.

Is United Technologies' hybrid-electric demonstrator plane the shape of things to come?

UNITED TECHNOLOGIES

Zunum Aero, backed by Boeing, is using a engine turbine from France's Safran to power an electric motor for a hybrid craft. And low-cost airline EasyJet is working with Wright Electric, saying it will start using electric aircraft in its regular services by 2027. This is likely to be on short-haul flights, such as London to Amsterdam - Europe's second busiest route.

"Electric flying is becoming a reality and we can now foresee a future that is not exclusively dependent on jet fuel," says EasyJet chief executive Johan Lundgren.

It's a statement underscored by a report from investment bank UBS which predicts the aviation sector will quickly switch to hybrid and electric aircraft for regional travel, with an eventual demand for 550 hybrid airliners each year between 2028 and 2040.

But the prospects for electric long-haul flights are not so rosy.

While electrical motors, generators, power distribution and controls have advanced very rapidly, battery technology hasn't.

Even assuming huge advances in battery technology, with batteries that are 30 times more efficient and "energy-dense" than they are today, it would only be possible to fly an A320 airliner for a fifth of its range with just half of its payload, says Airbus's chief technology officer Grazia Vittadini.

"Unless there is some radical, yet-to-be invented paradigm shift in energy storage, we are going to rely on hydrocarbon fuels for the foreseeable future," says Paul Eremenko, United Technologies chief technology officer.

The big problem with this is that 80% of the aviation industry's emissions come from passenger flights longer than 1,500km - a distance no electric airliner could yet fly.

Yet the UK has become the first G7 country to accept the goal of net zero carbon emissions by 2050 - a huge challenge for the air travel business with 4.3 billion tickets sold this year and eight billion expected to be sold by 2037.

Regulators are also piling on the pressure.

In Europe, the European Aviation Safety Agency says it will start categorizing aircraft based on their CO_2 emissions, while Norway and Sweden are aiming to make short-haul flights in their airspace electric by 2040.

So logically, is the only answer is to ditch long-haul flights?

This obviously isn't an appealing prospect for the industry. Rolls-Royce's Paul Stein says starkly that the world would be in a "dark place" if we stopped travelling.

He argues that in a global economy "where peaceful co-existence comes about from travelling and understanding each other, if we move away from that I am very concerned it's not the direction mankind should be going in".

APPENDIX 10

Hyperdrive

Airbus Touts Sustainable Fuel After Hydrogen Evangelism

By Charlotte Ryan and Siddharth Vikram Philip
March 30, 2021, 3:53 PM GMT+1
Updated on March 30, 2021, 10:20 PM GMT+1

- Company aims for 100% adoption of SAFs on its planes, CEO says
- Manufacturer still targets hydrogen aircraft's debut by 2035

Airbus SE will buttress its moonshot plan to build a hydrogen aircraft by the middle of the next decade with an effort to power conventional jets with sustainable fuels.

Chief Executive Officer Guillaume Faury said Tuesday that he's confident the European planemaker can bring a hydrogen plane into service by 2035. In the meantime, Airbus will work to increase the amount of sustainable aviation fuel that can be used in its engines, with a goal of reaching 100% from the current 50%.

"I'd like to correct a misunderstanding," Faury said at an online event hosted by Eurocontrol, which manages the region's air traffic. "We're not saying it's hydrogen and its not sustainable fuels. It's both, and on the contrary, in the very short term, sustainable aviation fuels will definitely play a very important role."

Faury's comments bring Airbus closer to the stance of rival Boeing Co., whose CEO Dave Calhoun has dismissed the potential for hydrogen power to be used at scale in commercial aviation for decades. The U.S. manufacturer is targeting certifying its aircraft lineup to fly on 100% sustainable fuels by 2030.

Guillaume Faury *Photographer: Balint Porneczi/Bloomberg*

Chess Game

The debate plays into the high-stakes chess-game over which aircraft designs get greenlighted in coming years. Boeing has been weighing whether to go ahead with a new plane that can challenge the coming Airbus A321XLR. The Airbus model, which is set to debut in 2023, has proven popular with airlines because it combines the economics of a single-aisle jet with the ability to travel long distances.

Airbus has promised to bring an alternative-fueled aircraft to market next, and has been vocal about its hydrogen plans. Meanwhile, though, it has solicited engine ideas for a more conventional single-aisle jetliner in development, Bloomberg reported in December. At the time, analysts suggested the talks may be focused on a plane that could be capable of switching over to alternative propellants as the market developed.

With current usage below 1%, the aviation industry needs to accelerate its adoption of sustainable fuels, Faury said Tuesday. SAFs are much more expensive than kerosene, and airlines are reluctant to eat the extra cost of adoption or to pass it on to passengers.

Hydrogen Push

Airbus has said it's examining three potential designs for its hydrogen aircraft -- a turboprop, a blended-wing format and a more conventional jet configuration. All of them would use hydrogen in modified gas turbines to propel the engines, and in fuel cells to create electrical power.

Bloomberg reported in February that the propeller option is gaining favor for the mid-2030s debut. While easier to pull off, the turboprop would have a shorter range and carry fewer passengers than today's single-aisle planes, and therefore address a smaller potential market.

Faury said it will take time before the whole fleet can be decarbonized. Provided Airbus can get its technology matured by 2025, he's confident of meeting the mid-2030s target for a hydrogen plane.

Hydrogen and electric propulsion could ultimately converge, with batteries too heavy to power conventional jets but other solutions such as powering a fuel cell with hydrogen a possibility, Faury said.

He added that Airbus is still very interested in urban air mobility, or so-called flying taxis. The company sees an opportunity to test electric propulsion at a small scale on such crafts, before scaling the technology up for commercial aviation.

Airbus shares added 0.3% in Paris on Tuesday. They are up 8.8% this year, while Boeing has risen 18%.

(Updates with Airbus share prices in final paragraph. An earlier version of this story corrected the date of Boeing SAF target.)

Carbon-negative crops may mean water shortages for 4.5 billion people

APPENDIX 11

ENVIRONMENT 8 March 2021

By Adam Vaughan

Irrigation systems, such as this one for potatoes, will be needed to grow energy crops
Dave Reede/All Canada Photos/Alamy

Billions more people could have difficulty accessing water if the world opts for a massive expansion in growing energy crops to fight climate change, research has found.

The idea of growing crops and trees to absorb CO2 and capturing the carbon released when they are burned for energy is a central plank to most of the Intergovernmental Panel on Climate Change's scenarios for the negative emissions approaches needed to avoid the catastrophic impacts of more than 1.5°C of global warming.

But the technology, known as bioenergy with carbon capture and storage (BECCS), could prove a cure worse than the disease, at least when it comes to water stress.

Fabian Stenzel at the Potsdam Institute for Climate Impact Research in Germany and his colleagues project that the water needed to irrigate enough energy crops to stay under the 1.5°C limit would leave 4.58 billion people experiencing high water stress by 2100 – up from 2.28 billion today. That is 300 million more people than a scenario in which BECCS isn't used at scale and warming spirals to a devastating 3°C.

"I was a little bit shocked. The takeaway message is, so far, we haven't looked at side effects enough. To limit all the trade-offs that we might face in terms of climate change and climate change mitigation, it's really important to look at the holistic Earth system," says Stenzel.

Widespread use of bioenergy with carbon capture and storage could lead to huge increases in high water stress

Percentage increase from 2010 (2006–2015) to 2095 (2090–2099)

Widespread BECCS, 1.5°C climate change Widespread BECCS with sustainable water use, 1.5°C climate change Little BECCS, 3°C of climate change

Area of high water stress

88
20
54

Number of people in high water stress

101
60
82

The analysis found high water stress, which is when the ratio of water demand to supply is more than 40 per cent, would expand to previously unstressed parts of the world due to the need for new BECCS crop plantations. South America and southern Africa would both be hit hard.

The upper-end projection of 4.58 billion affected people assumes a total of 6 million square kilometres of crops grown for BECCS, limited use of sustainable water and a global population reaching 9 billion by 2100.

Previous studies have warned that BECCS's potential to mop up emissions may be limited because the enormous land it requires would affect food production and biodiversity.

Stenzel and his colleagues' research doesn't mean we should allow unchecked climate change, but suggests BECCS has to play a smaller role in how we remove emissions from the atmosphere than the central one envisaged by some. Stenzel still expects BECCS will be needed, but as just one of a suite of approaches, such as burning biomass to put charcoal in soil, reforestation, direct air capture and more. "We will need some sort of negative emissions because, as humanity, we are stupid and slow," he says.

Peter Smith at the University of Aberdeen, UK, says: "This is another warning that we cannot rely on BECCS at the scale of hundreds of millions of hectares, as this has adverse consequences for water. The more we reduce emissions now, the less we will need to rely on negative-emission technologies like BECCS in the future."

Wil Burns at American University in Washington DC says the research doesn't fully account for ways that BECCS's hunger for water can be curbed, such as by picking the right trees to plant in high latitudes with few people.

Journal reference: *Nature Communications*, DOI: 10.1038/s41467-021-21640-3

More on these topics: CLIMATE CHANGE BECCS NEGATIVE EMISSIONS WATER STRESS

APPENDIX 12

7 facts about palm oil biodiesel

And why EU policy support must end

May 2018

Summary

The Renewable Energy Directive regulates the use of biofuels and renewable transport fuels in the EU. It is currently under review for the period 2020 to 2030 ("REDII").

Both the European Parliament and the Council of the EU have proposed their amendments to this EU law and their positions are quite different from each other. A key difference is the decision of the Parliament to end policy support for biodiesel made from palm oil in 2021, in an attempt to avoid the negative environmental, climate and social impacts linked to this biofuel feedstock.

The Parliament decision has sparked an international debate in which palm oil producing countries have spoken against the measure. Given the negative impacts linked to crop biodiesel – and especially palm oil – we consider the Parliament vote a step in the right direction, especially given these key facts:

1. The greenhouse gas emissions from palm oil biodiesel are three times worse than fossil diesel.

2. EU drivers are the biggest users of palm oil, more than the food and cosmetics industries together.

3. Current certification schemes can't guarantee sustainability of the biofuels used in the EU.

4. The Parliament's decision is not a ban on palm oil, it's an end to the policy support for palm oil biodiesel in the RED II.

5. There are other issues linked to mass-scale production of palm oil, such as labour and human rights violations.

6. Certified palm oil should be used to feed people, not cars.

7. Despite attempts, palm oil expansion leads to deforestation and peatland drainage.

Context and background

The EU renewable energy directive (RED), adopted in 2009, aimed to boost the use of renewables in Europe, including in the transport sector for which a target of 10% renewables was set for the year 2020. This target has driven a significant increase in the use of crop biofuels – particularly biodiesel. However, there are concerns about the negative impacts linked to these biofuels, such as greenhouse gas (GHG) emissions due to deforestation and biodiversity loss.

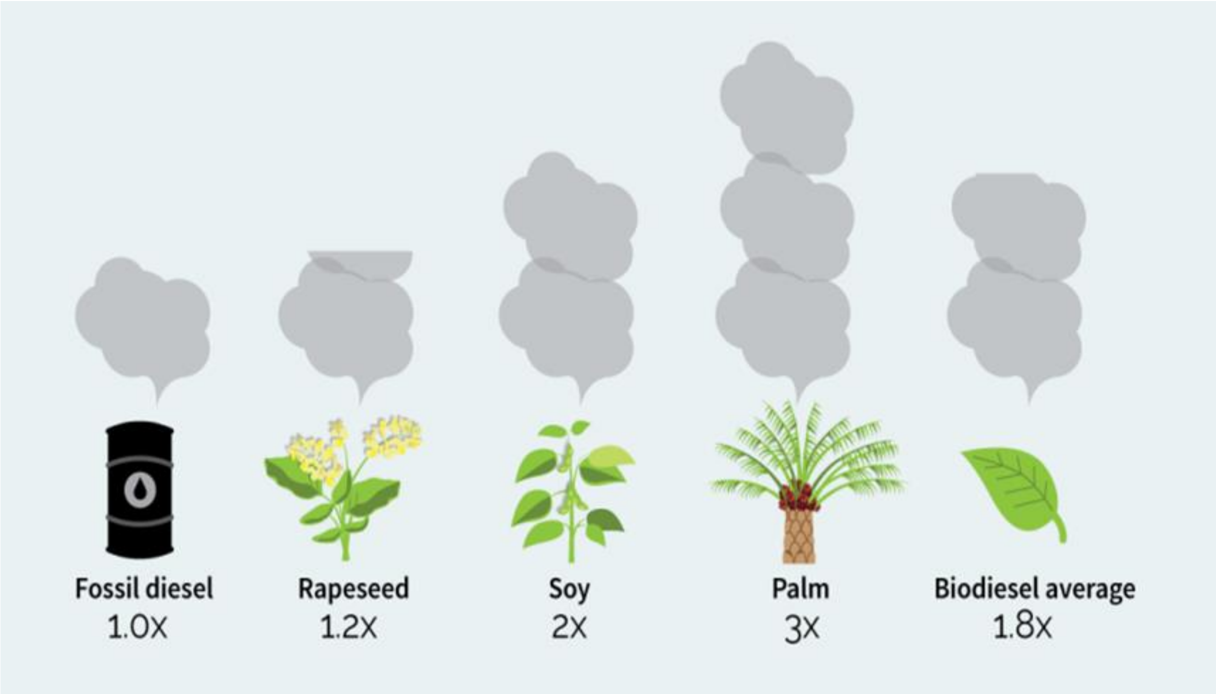
In 2015, in an attempt to address these concerns, the EU reformed the RED to establish a limit of 7% on the amount of crop biofuels that can count towards the 10% target. Now, in the middle of the RED review ('REDII'), the European Parliament has voted for a full phase-out of the policy support for palm oil biodiesel in Europe, by not allowing palm oil biodiesel to contribute to any EU renewables target. This decision has

triggered positive and negative reactions from various sectors, especially from palm oil producing countries. Discussions are still ongoing and this is one of the key topics.
The Parliament's decision on palm oil is a good step, although such a short-term measure should be broadened to tackle all high emitting biofuels.

7 reasons why ending support to palm oil biodiesel is a good idea

1. The GHG emissions from palm oil biodiesel are three times greater than fossil diesel.

Based on the latest available data – produced for the European Commission[1] [2] [3] – biofuels used in the EU cause (indirect) land-use change which eliminates most of their greenhouse gas emission benefits. In the case of crop biodiesel, the indirect emissions are exceptionally high (due to deforestation in high-carbon stock areas and peatland drainage) making crop biodiesel much worse than the fossil diesel it replaces. Burning palm oil biodiesel is three times worse than using fossil diesel from a climate perspective. However, these indirect emissions aren't accounted for in the RED, which makes it possible for all crop biofuels to pass the GHG emissions criteria established by the EU law.



The graphic above represents the amount of GHG emissions linked to each of the biodiesel feedstocks used in EU in comparison with the fossil diesel they replace. These figures are based on the Globiom model (see footnote 1). The studies on land-use impacts already take into account potential climate benefits linked to the production of co-products for animal feed, the productivity of different food crops and the agricultural yield responses to several factors (technological improvements, price fluctuations)[4].

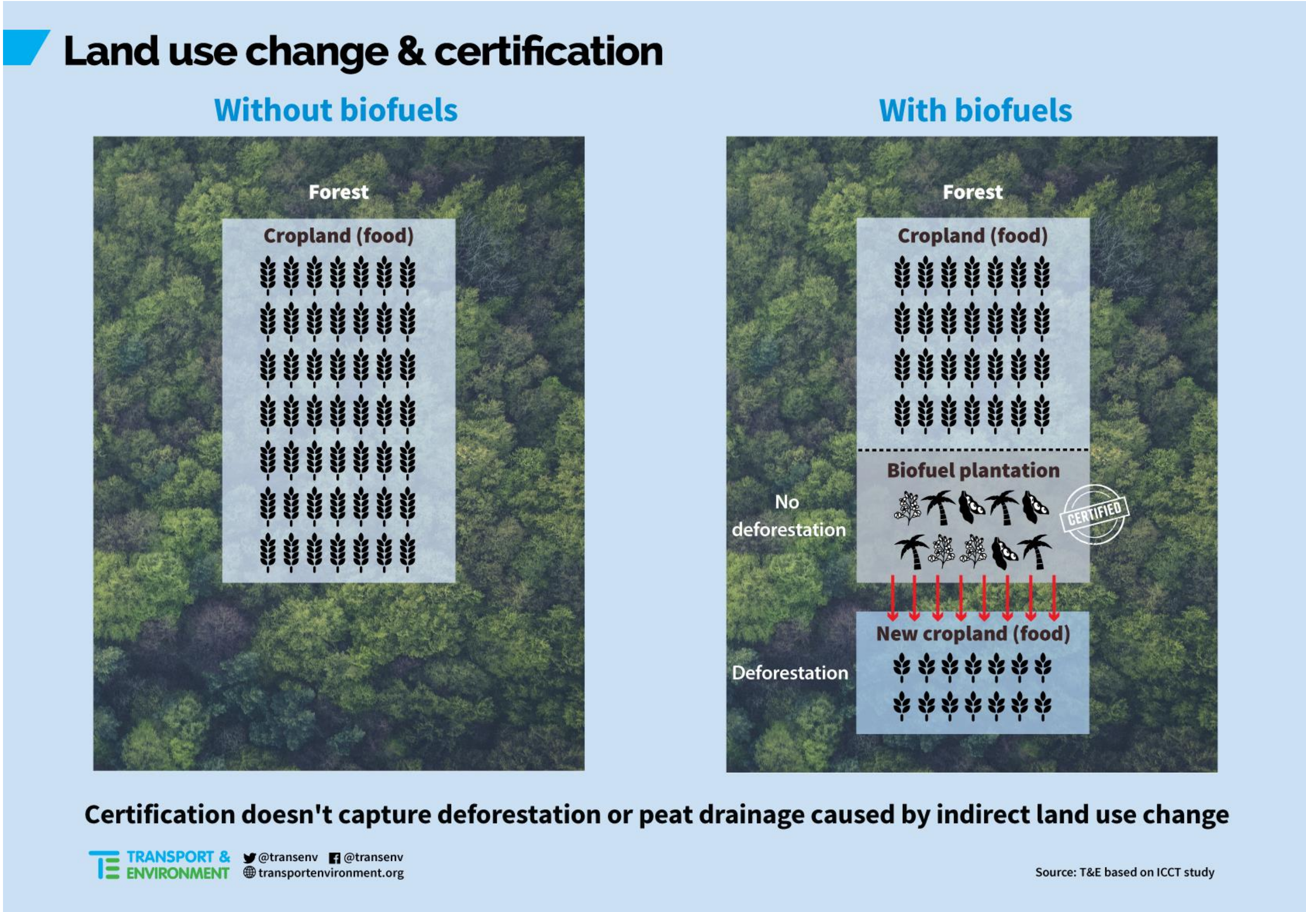
[1] The land use change impacts of biofuels consumed in the EU - Ecofys, IIASA and E4Tech for DG Energy, 2016
[2] Assessing the Land Use Change Consequences of European Biofuels Policy - David Laborde/IFPRI for DG Trade, 2011
[3] The land use change impacts of biofuels consumed in the EU. Complementary scenarios by 2030 – IIASA, 2016
[4] The land use change impacts of biofuels consumed in the EU- Pages XIV of executive summary; 6; 63, 210 (table 42).

2. EU drivers are the biggest users of palm oil, more than the food and cosmetics industries together.

The use of palm oil for biodiesel has greatly increased in the last decade. Since 2010 palm oil use for biofuel production has seen a huge increase: in 2010 – one year after the adoption of the RED – only 8% of all the palm oil imports were used for biodiesel; in 2016, 48% of all the imports were used in transport. This makes EU drivers the biggest users of palm oil in Europe[5]. The biggest producers of palm oil biodiesel in the EU are Spain and Italy, where 95% and 90% of the biodiesel production is based on palm oil, respectively[6].

3. Current certification schemes can't guarantee sustainability of the biofuels used in the EU.

All the biofuels used in the EU must be certified to be counted towards renewable targets. However, the current certification schemes do not consider indirect land-use effects, which is a big loophole as indirect impacts are very significant.



That's a key difference when comparing certification schemes for palm oil for food vs schemes for palm oil for fuel: in both cases, the schemes can certify the specific piece of land used to produce palm oil but, when certifying palm oil for biofuel use, the schemes can't certify the land that has been displaced elsewhere to grow food or feed and which has led to deforestation and/or peatland drainage (ILUC).
A report released by the EU Court of Auditors in 2016 reaches the same conclusion: certification schemes for biofuels used in the EU can't guarantee their sustainability[7]. The report highlights several loopholes in

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5 Reality check: 10 things you didn't know about EU biofuels policy - T&E, 2017
6 Europe keeps burning more palm oil in its diesel cars and trucks - T&E, 2016
7 Certifying biofuels: weaknesses in recognition and supervisions of the system - EU Court of Auditors, 2016

the EU biofuels certification schemes, such as lack of traceability of the supply chain or the fact that the schemes don't cover indirect land-use change impacts.

4. The European Parliament's decision is not a ban on palm oil, it's an end of the policy support for palm oil biodiesel in the RED II.

The Parliament voted[8] to end the policy support to palm oil biodiesel as of 2021. In practical terms this means that palm oil biodiesel can't count towards any targets (i.e. target for renewables in transport) under the REDII as of 2021. EU member states can still use palm oil biodiesel if they wish to do so, however they will have to use other fuels to meet their targets under REDII. This measure applies to the energy use of palm oil, and not to other markets like food, for instance.

5. There are other issues linked to mass-scale production of palm oil, such as labour and human rights violations.

In the recent years, several organisations have raised serious issues linked to palm oil plantations such as general welfare of palm plantation workers, including decent conditions and wage, child labour, forced labour, etc. NGOs and other organisations routinely highlight cases of human rights violations[9] but also corruption[10]. Unfortunately current biofuel sustainability schemes are unable to guarantee robust social and economic safeguards, because these are not required by EU law.

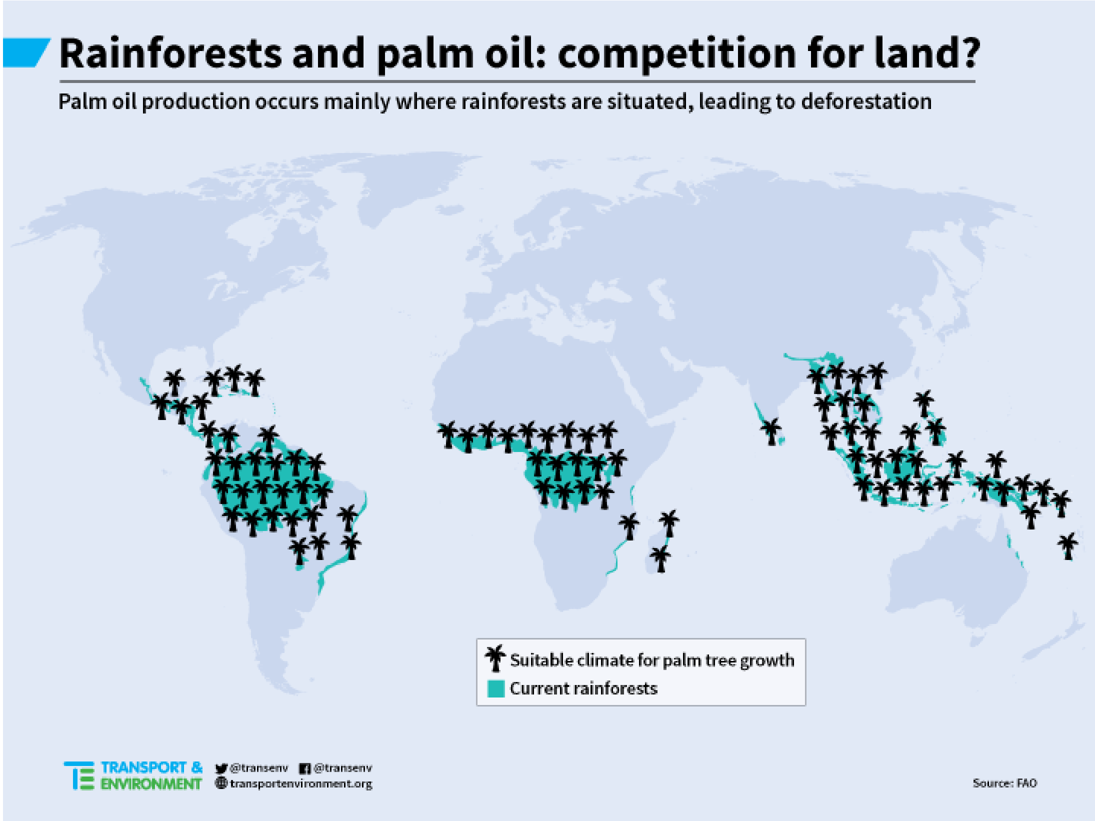
6. Certified palm oil should be used to feed people, not cars.

According to data from OECD and FAO[11], palm oil demand for food is expected to increase by about 40% between now and 2030. This means that there will still be significant new demand for palm oil, which needs to be met by sustainably sourced palm oil. However, palm oil certification must be improved: today, only 19% of the palm oil market is certified[12] and, despite the efforts to ensure welfare of workers and sustainability safeguards, enforcement and monitoring of the schemes must be tightened to ensure that the food industry is using truly sustainably sourced palm oil. Some NGOs – Greenpeace, notably – are working on improving these sustainability certification schemes, for instance by developing more credible verification systems[13].

7. Despite attempts, palm oil expansion leads to deforestation and peatland drainage.

There are moratoriums in place by the Government of Indonesia and private companies to prevent forest clearance for cultivation of palm oil and industry commitments not to produce on deforested land or peat. Despite these, deforestation continues in Malaysia and Indonesia. Over the last decade, palm oil plantations have been the main reason for deforestation and peatland drainage, which lead to a huge release of GHG emissions. Assuming that there is no fundamental change in forest governance or peat protection in Indonesia and Malaysia, deforestation and peatland drainage will continue: in Malaysia, 50% of new plantations will require deforestation, and 34% of new plantations will require peatland drainage. In the case of Indonesia, the scenario is similar: 50% of new plantations will require deforestation, and 32% of new plantations will require peatland drainage. As a comparison, the total deforested area will equal the size of The Netherlands (see footnote 10).

[8] Promotion of the use of energy from renewable sources - EU Parliament adopted text, January 2018.
[9] Palm Oil: Global brands profiting from child and forced labour - Amnesty international, 201
[10] Analysis: scandal-ridden Malaysian plantation firm is the cause of smallholders' problems, not the EU - IDM, 2018
[11] Driving deforestation. The impact of expanding palm oil demand through biofuel policy - Cerulogy, 2018
[12] Roundtable on Sustainable Palm Oil.
[13] POIG - Palm Oil Innovation Group.



Conclusions and recommendations

Crop-based biofuels have benefited from policy support in the EU since the adoption of the RED in 2009. However, the negative impacts on climate, environment and social circumstances described above explain why the EU should end policy support that encourages palm oil biofuels.

The decision of the European Parliament is a step in the right direction as it tackles the highest emitting type of crop biofuel (palm oil). It is important that such a measure is extended to other types of high emitting biofuels – such as soy and rapeseed.

The proposal of the Parliament is now being negotiated with EU member states and the European Commission. In order to achieve a good outcome and make the REDII fit for purpose, the EU should:

1. Not set a new target for crop biofuels but lower the limit on crop biofuels as much as possible.
2. Support the European Parliament's decision to phase out policy support under REDII for palm oil biodiesel by 2021.
3. Extend the measure to other high emitting crop biofuels such as soy oil biodiesel.

Further information

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APPENDIX 13

The Bioeconomy Consultants NNFCC

Implications of Imported Used Cooking Oil (UCO) as a Biodiesel Feedstock

May 2019

Release Date: May 2019

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Disclaimer

NNFCC is a leading international consultancy with expertise on the conversion of biomass to bioenergy, biofuels and biobased products.

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Contents

1 Executive Summary

Biodiesel is a class of transport fuel which includes Hydrogenated Vegetable Oil (HVO) and Fatty Acid Methyl Esters (FAME), produced from either vegetable oils or animal fats. Intended as a replacement for fossil-derived diesel, FAME biodiesel forms a significant component of the total renewable fuels supplied in the UK; between April 2017 and April 2018, nearly half of the 1,600 million litres of renewable fuel supplied in the UK was biodiesel.

The dominant biodiesel feedstock for biodiesel consumed in the UK is Used Cooking Oil (UCO), defined as the purified oils and fats of plant and animal origin that have been used to cook food. Since the BSE crisis European UCO is classified as a waste that is no longer fit for human or animal consumption, placing legal limitations on its collection and disposal; this resulted in it becoming a well-regulated feedstock for biodiesel sold on the market. Its utilisation as a biodiesel feedstock therefore increased significantly within the EU – between 2011 and 2016 there was a 360% increase in its use, rising from 0.68 million tonnes to 2.44 million tonnes in just 5 years driven by supporting renewable fuel policies, particularly in the UK, to incentivise its use.

Although European UCO from a quality perspective is relatively consistent, certain variables such as the characteristics of the base edible oil and the cooking conditions to which it has been subjected – including the number of times the oil has been used and how it has been stored – can directly influence the quality of the resulting waste product. Collation of UCO from different sources can therefore result in heterogenous feedstock streams., impacting the composition of the final product. Standardising the characteristics of UCO is therefore inherently difficult.

In addition to the heterogeneous nature of UCO, it is important that the energy associated with transporting and manufacturing UCO is minimised as much as possible in order to reduce GHG emissions. The GHG reduction delivered by UCO-derived renewable fuels are significant (typically of the order of 80-90% compared to fossil fuel). As the feedstock is classed as a waste in the EU, only the energy used in its transportation and the biofuel conversion process are used to calculate its GHG efficiency.

To meet the growing demand for UCO, sourcing and importing from outside the EU (predominantly Asia) are the only legitimate options for increasing its supply. However, as there are no current globally agreed standards for UCO, suppliers are only required to meet the operator's specifications, resulting in a wide variety of qualities and chemical compositions.

The net imports of UCO and UCO-based FAME biodiesel (UCOME) to the EU and UK have significantly increased since 2014, with a large proportion of this sourced from China, Indonesia and Malaysia. Consequently, in 2018 alone these 3 countries exported more than 500,000 tonnes of UCO into the EU, with around 15% of this delivered to the UK. This reliance is set to continue, with the imports of Chinese UCO into the EU increasing by 5.6% in Q1 of 2019 when compared to Q1 of the previous year.

Due to the reliance on palm within the Chinese, Indonesian and Malaysian food industries, their resulting UCO and UCOME is likely to fundamentally differ to that generated within the EU. Unlike European-grown oilseed rape, palm oil is high in saturated fatty acids – the resulting UCO will therefore have comparable fatty acid contents and chemical properties. This will impact the performance of the produced biofuel; palm oil has a high pour point meaning that, without the addition of cold flow improvers (CFIs), the biodiesel produced from palm UCO will likely gel in colder temperatures, causing engine failure.

Provenance of the UCO is therefore very important as it will make a huge difference to the properties it imparts to the resultant biofuel, especially in the colder winter months in the Northern Hemisphere. UCO sourced from the EU should not be assumed to be the same as that sourced from other parts of the world. For example, Chinese UCO contains a large volume of gutter oil – a crudely produced, 'illegal' cooking oil – which has high levels of rancidification, resulting in a poor-quality feedstock and biofuels that could have hidden problems.

Without a proper understanding of the current volumes of waste oil generated, it is almost impossible to confidently substantiate the GHG savings associated with the feedstock, or if additional wastes and/or unsustainable virgin materials are being produced and used as a result of the EU's policy support for imported UCO. This is further exacerbated by the possible inclusion of 'non-waste materials' within the UCO waste stream. High-grade waste vegetable oils that are deemed safe for consumption by animals outside of the EU (and are therefore not waste materials) are redirected from animal feed to biofuel production as the EU based fuel suppliers will pay more for a waste-derived biofuel than they would for virgin oil. Consequently, where used cooking oil was being used for animal feed it is now replaced by cheaper virgin oils such a palm, although their replacement within the supply chain – most likely goes unchecked. Indeed, although correlation does not necessarily equate to causation, the available evidence indicates that palm oil imports to China are increasing, in line with their increasing exports of UCO.

If these arguments are connected, then there would be potential for significant indirect land use change (ILUC) implications when imported UCO is used as a feedstock for biodiesel production. Furthermore, if imported UCO is to continue as a double counting feedstock, then confidence in its supply chain should be paramount; the certification process of UCO – specifically when sourced from outside the EU, where it is likely to be used as an animal feed – should be more robust, helping to ensure that the feedstock meets comparable levels of traceability and sustainability. This has recently gained publicity in the Netherlands, with alleged fraudulent activities relating directly to biodiesel production from UCO currently under investigation. Significant volumes of their supplied biodiesel in 2015 and 2016 were incorrectly designated as sustainable, with double-counting credits – that can be traded on the market – claimed as a result.

Undoubtedly, the use of legitimate UCO waste streams in biodiesel production offer an excellent pathway for reducing GHG emissions within the transport sector, however it's important to recognise that their use will not solve other issues like poor local air quality – especially in areas that have prominent issues with congestion.

Jet fuels and the road to future Jet fuels

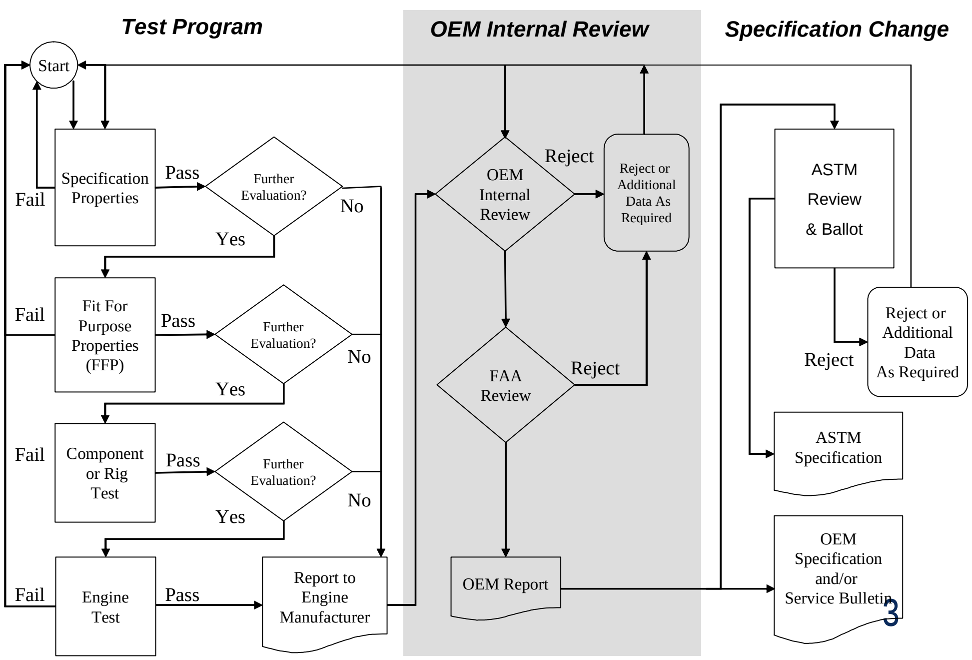
IATA Operations
Michel Baljet
Assistant Director, Fuel Services

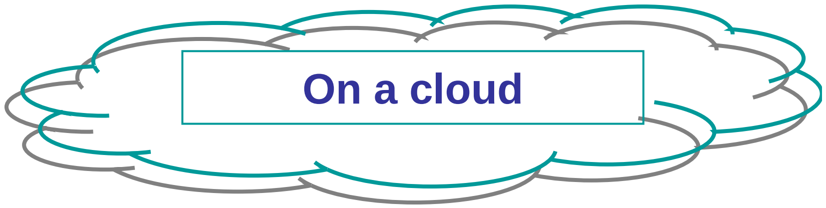
Jet fuels

- Aircraft need energy (MJ/kg)
  - More energy per unit mass means: less fuel to be carried
- But fuel needs to have certain properties:
  - Freezing Point (-40C Jet A / -47C Jet A-1)
  - Flash Point (+38C)
  - Thermal Stability (Improves efficiency)
  - Sulphur (lubricate fuel pump)
  - Viscosity (cold flow properties)
  - etc.

Certification process

- Harmonized process for main specifications Jet A & A-1)
- Approval process takes long testing and $$$





Planes rely on jet fuel from oil

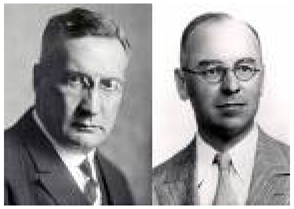
Or alternatives, like:

Fischer Tropsch (FT), synthetic fuel:

- Coal to Liquid
- Gas to Liquid
- Biomass to Liquid

JNB/SASOL (early 90's):

-since 1999 50% approved
-End 2009 100% approved



Mr. Fischer & Mr. Tropsch 1920

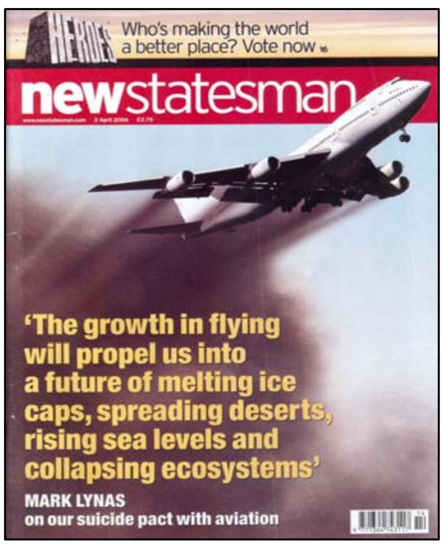
Four steps:

1. gasify into synthesis gas (CO, H_2, CO_2, H_2O, plus pollutants)
2. clean syngas to CO and H_2 (high energy !!)
3. syngas into FT reactor → wax
4. wax upgrade into end products by hydrotreating

5

2007: 70.5 billion US Gallons
Similar to 100,000 Olympic swimming pools!

Aviation growth….
Need more volume...
From all possible sources



+

Emissions trading

Our Vision

+ ↗ Is for carbon neutral growth
- ↗ Leading to a zero carbon emissions future

IATA alternative fuels position

- IATA recognizes that aircraft are long-lived assets and will be using kerosene and/or kerosene type fuels, from other sources then crude, for many years to come.
- IATA supports research, development & deployment of sustainable biofuels which
  - Offer net carbon reductions over their life cycle
  - Do not compete with fresh water requirements and food production

    (1st generation bio fuels)
  - And do not cause deforestation or other environmental impacts such as biodiversity loss
- While international fuel specifications for biofuels do not yet exist, IATA is working with industry partners towards agreed production standards and test requirements.

7

Biojet fuels from Sustainable biomass

- Main focus on drop-in fuels, 2nd & 3rd generation biojet fuels / sustainable biojet fuels
- 2nd generation biomass (H-C made from not-widely used sources)
  - Forest residues (e.g. sawdust)
  - Industry residues (e.g. black liquor paper industry)
  - Municipal waste
  - Agricultural residues (e.g. harvest remainings)
  - Sustainable Grown Biomass (e.g. jatropha)
- 3rd generation biomass (H-C made from additionally grown biomass)
  - Algae, switch grass, jatropha, babassu and halophytes

Algae: simple, photosynthetic plants, that can be grown with polluted or salt water and can produce up to 250 times more oil than 1st generation soybeans!!

Jatropha: reclaims wastelands, grows in poor soils

***Halophytes*: grows on salt grounds, where nothing else grows well**

Switchgrass: a hardy grass, needs very little water and produces a high output of biomass

Babassu: a native growing Brazillian tree with high oil yield nuts

Alternative fuels in practice

- **Airbus** flew a A380 in early 2008 with one engine powered by FT Gas to Liquid fuel
- **Virgin Atlantic** flew a Boeing 747-400 on 23 February 2008 with one engine operating on a 20% biofuel mix of babassu oil and coconut oil
- **Air New Zealand** flew a Boeing 747-400 with one engine on 50% jatropha derived biofuel and 50% kerosene on 30 December 2008
- **Continental Airlines** flew a Boeing 737-800 with one engine using 50% jet fuel and 50% algae and jatropha mix on 7 January 2009
- **Japan Airlines** trialed a 50% biofuel (camelina, jatropha and algae) and 50% kerosene mix on a Boeing 747-300 with P&W engines on 30 January 2009

Green fuels…not a simple task, but a MUST!!!

IATA ENVIRONMENTAL CAMPAIGN

Paul Steele-Director Environmental System Management

Operations	Infrastructure	Technology	Economics
• Green Teams • Fuel Book • Implementa-tion survey • Regulatory	• Routes &TMA Improvements • ATM Efficiency study.	• ***Alternative Fuel*** • Aircraft/Fleet Upgrade. • Roadmap	• Voluntary Offset Programme • Costing for Carbon Neutral Growth • Mckinsey study.

Communication

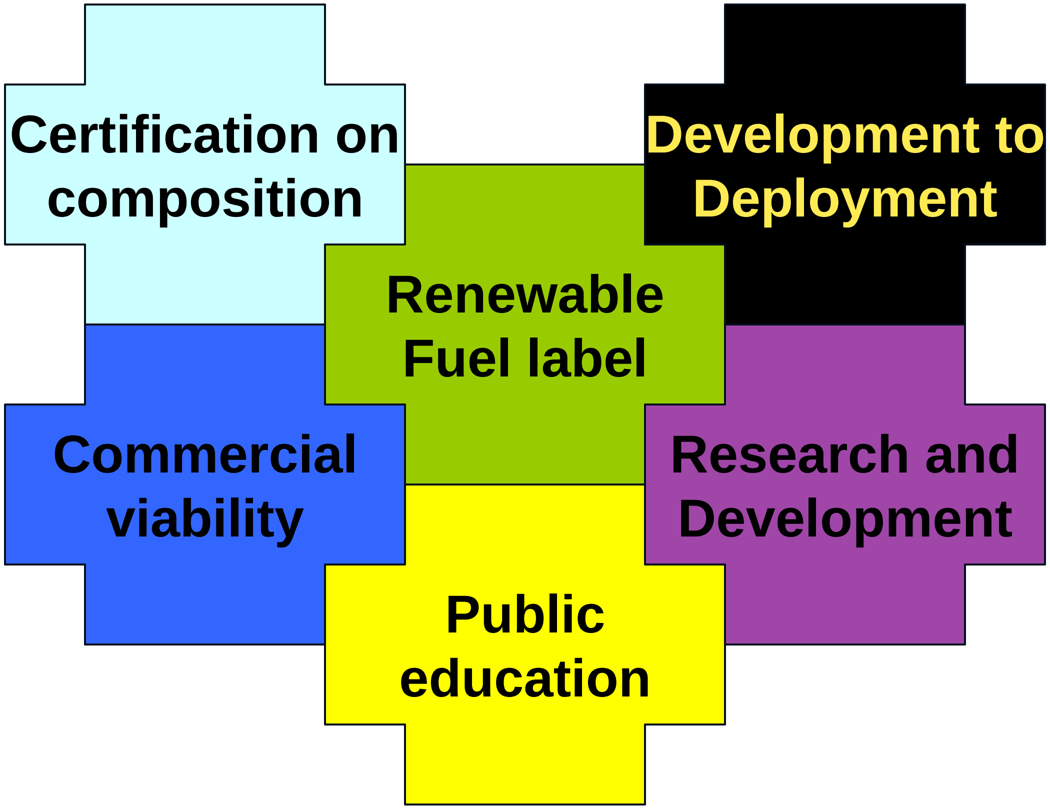
Work plan

- Proposed milestones accepted
- Evaluate milestones on yearly basis
- Evaluate actions each Fuel Forum

What do we want to achieve?

- Certification on fuel composition by 2012, optimistic 2010
- Sustainable renewable fuel label operational, January 2011
- Development to deployment, 2011 plant running
- Commercial viability 2014
- Research and development, 2010 overview of activities, than continuously updated
- Public educated, 2010
- 10% by 2017

6 step strategy / work plan



Actions

Departments:

- Aviation Environment
- Commercial Fuel Services
- Economic Department
- Government Relations
- Operations
- - -

16

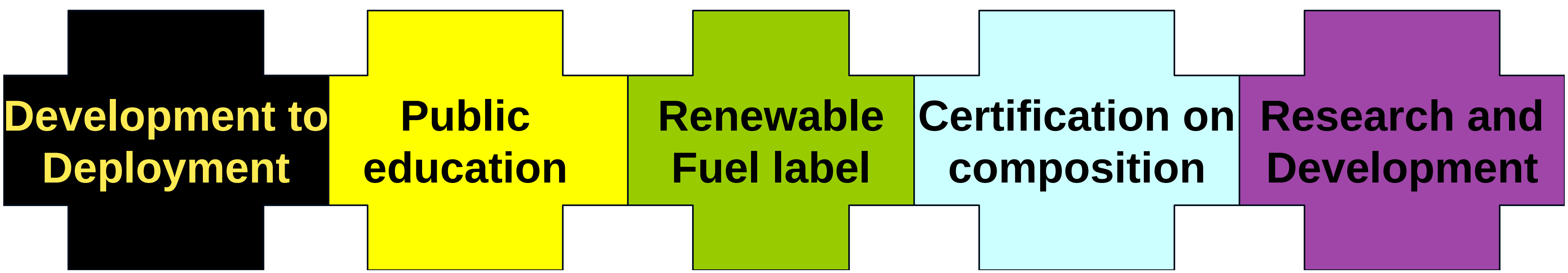
Key Areas – Alternative Fuel

- Technical & Operational
- Specification
- Testing
- Certification
- Production
- Procurement
- Distribution

- Political & Regulatory
- Public and policy maker acceptance
- Industry Acceptance
- Fiscal and legal framework
- Environmental certification

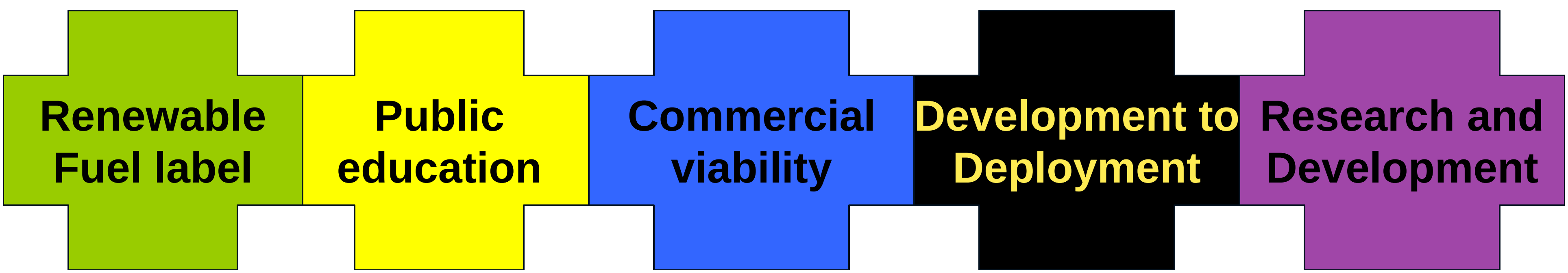
Milestones Operations 2009 (1)

- Ensure IATA is present at key 2009 events to promote ballot issue ASTM Dxxxx in 2009
- Information from OEM's about certification, testing and evaluation process and program
- Stimulate and support airline flight trials with bio fuel blends



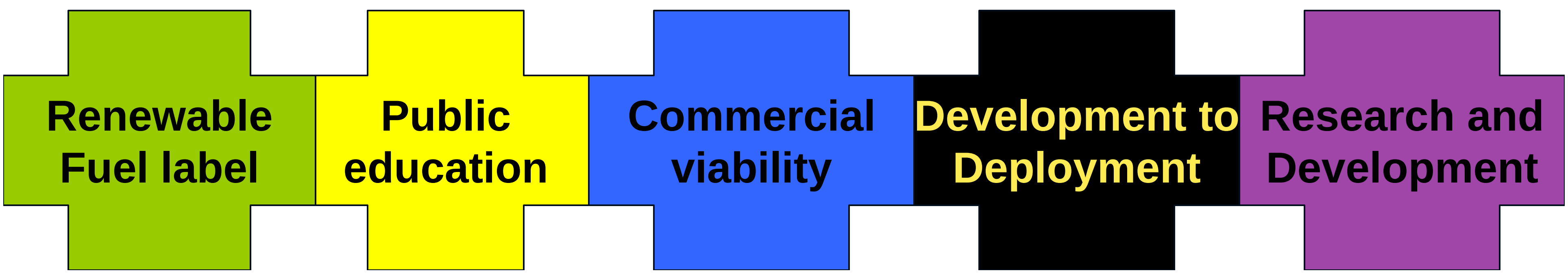
Milestones Operations 2009 (2)

- Follow-up studies required on:
  - Economic viability
  - Preferred production processes
- After those studies:
  - Start creation of database with potential suppliers
  - Workshop with Commercial Fuel Services on evaluation of way forward to establish the use of biojets by group of airlines



Milestones Operations 2009 (3)

- Intensify awareness:
  - Create IATA website events
  - Issue brochures/bulletins
  - Promote at key meetings of aviation industry
  - Issue 2009 Alternative Fuel report to BoG and OPC



Key Conclusions & Outlook

- Solid organisational fundament established
- Need industry involvement & participation
- Communication- & awareness plan

APPENDIX 15

Powering the future of flight

The six easy steps to growing a viable aviation biofuels industry

AIR TRANSPORT ACTION GROUP

April 2011, web version

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Welcome to the biofuel age of flight

We have given this publication a subtitle "the six easy steps to growing a viable aviation biofuels industry" but of course this is not an 'easy' task. What we set out to do, however, is illustrate the potential for sustainable aviation biofuels to be produced in countries all over the world and provide concrete examples of how some countries and the aviation industry have already made substantial progress.

BY **PAUL STEELE**, EXECUTIVE DIRECTOR OF THE AIR TRANSPORT ACTION GROUP

We certainly have come a long way in a short time.

It wasn't many years ago that the idea of using biofuels for flight was dismissed out of hand on technical and safety grounds. Today, we have tested a range of biofuels in flight, we have made our way through a very tough technical standards process to ensure flight safety and we have been working hard to establish the correct sustainability criteria for the fuels we use.

We are now getting ready to take the next steps in the journey of alternative aviation fuels: ramping up to get enough of this low-carbon energy into our fuel supply.

Essential

Globally, aviation produces around 2% of man-made carbon dioxide (CO_2), according to the Intergovernmental Panel on Climate Change. But with the forecast growth in demand for air services, these emissions will grow if we do not take action. In response, the aviation industry has developed a set of ambitious targets aimed at limiting its climate impact, while enabling it to continue to provide a key vehicle for economic growth. The targets include: improving fleet fuel efficiency by 1.5% per year until 2020; capping net aviation emissions from 2020; and most ambitiously, to halve aviation CO_2 emissions by 2050, compared to 2005.

These targets were set after careful analysis and follow the industry's track record of measured progress, while also being far-reaching. But they cannot be achieved by technology or operational improvements within the aviation industry alone. Governments will have to play their part in ensuring that we can operate in the most efficient skies – with the needed improvements in air traffic control infrastructure and management.

One of the biggest opportunities to meet the 2050 target lies in low-carbon, sustainable aviation fuels, particularly biofuels. They are an essential component in meeting our targets and a vital step to reducing aviation's climate impact. Aviation has no alternative to liquid fuel for the foreseeable future, unlike ground transportation or power generation which have had a choice of energy sources for many years, even if they have not grasped this opportunity as quickly as they could have. Therefore, aviation must look to replace fossil fuels with lower carbon alternatives – and second generation biofuels are a perfect fit.

Viable

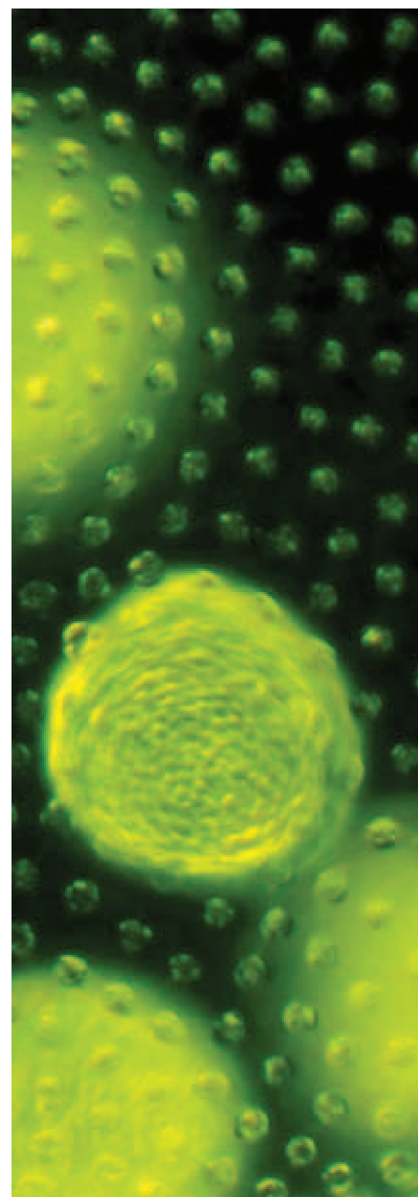
From a standing start just a few years ago, the aviation industry has embraced the concept of biofuels with enthusiasm and has already completed much of the technical work needed to start commercial flights. Rigorous testing, both on the ground and in the air, has shown that biofuels can deliver equal (and sometimes better) performance than the current fuel.

The biggest challenge now lies in ensuring a steady, reliable, cost-effective and sustainable supply of this new energy source. The fossil fuel industry has had a century to develop its fuel sources, supply chains and distribution networks. Not to mention its profit margins. The fledgling aviation biofuels industry will need to catch up and this will require capital from the investment community and start-up incentives from governments.

As a number of countries look to the green economy for growth in jobs and economic advantage, the fostering of a sustainable aviation biofuel industry will provide a double benefit – building green industry and making the vital tourist and business connections economically and environmentally viable.

Sustainable

There has rightly been a lot of unease about the impact that the first-generation of biofuels has had on both people and environments. Food price issues, land and water use and pollution have all been of great concern.
In beginning the process of looking at powering the future of flight through biofuels, the aviation industry has been extremely careful to try and avoid the mistakes made in the past.



→ COLLABORATION

Sustainable Way for Alternative Fuels and Energy for Aviation (SWAFEA)

This investigation of alternative aviation fuels feasibility and impacts from the European Commission's Directorate General for Transport and Energy is being conducted by an alliance of parties, representing all stakeholders from both biofuel and conventional fuel production up to aviation end-users.

"The steps may not be easy, but we can assure you the result will be worth it."

In many ways, we are fortunate that aviation is technically unable to use many of those first-generation fuels. Biodiesel freezes at the high altitudes at which we fly, for example, and ethanol doesn't carry the required energy density. So in aviation we have been looking at a wide range of non-food crops and sources of biofuel. We want to ensure that where crops are grown for aviation biofuels, that they are not taking the place of food crops. The industry has been working with organisations such as the Roundtable on Sustainable Biofuels to put in place the right sustainability criteria for aviation biofuels.

Cleaner

Without a doubt, aviation biofuels will have a big impact on the overall emissions of the aviation industry. Full lifecycle assessments of just some of the biofuel sources that have been explored so far show in excess of an 80% improvement on the fossil fuel currently used. While the industry is making some very significant steps in improving the efficiency of aircraft – since the first jets flew in the early 1960s, there has been a more than 70% improvement in fuel efficiency – technology can only take us so far. New fuels will help us achieve the targets we have set.

Practical

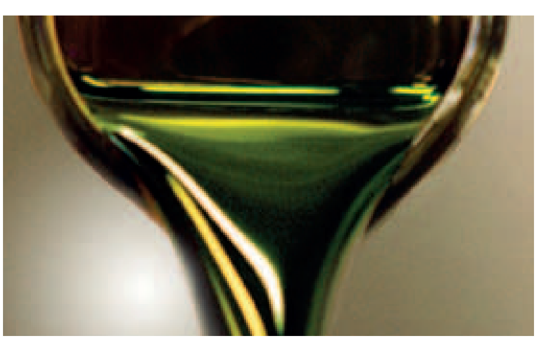
The second-generation biofuels that aviation is investigating are special – when refined, they are virtually identical to the Jet A-1 fuel we currently use. This means that we can simply drop them into the current fuel supply. No new engines, no new aircraft and no separate fuel delivery systems are needed at airports. It is the most practical solution. More biofuel can be added to the system as it comes on stream. We are striving to practically replace 6% of our fuel in 2020 with biofuel. We hope this figure can be higher.

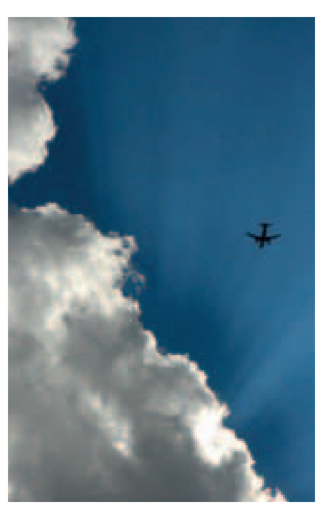
The supply of fuel to the commercial aviation industry is also on a relatively smaller scale and less complex than for other forms of transport. For example, there are over 160,000 retail gas stations in the United States alone. This compares to a relatively smaller number of airport fuel depots: 1,679 airports handle more than 95% of the world's passengers. For this reason, it is anticipated that it will be easier to fully implement the use of sustainable biofuels in aviation than in other transport systems.

It is also important to note that aviation is not looking at just one source of biofuel – we are investigating a range of alternatives as you will see from this publication. This will mean we can benefit from the most suitable feedstock in any given location and spread the sources for better security of supply.

It is clear that aviation is ready to become a major customer in the sustainable biofuel market. It is vital for our future and it is an important step in reducing carbon emissions. This publication, we hope, will provide some inspiration and ideas based on work already underway. It is not a comprehensive document – there are a great number of projects underway around the world to produce sustainable biofuels for aviation – but it does provide a few examples of different ways the challenge is being met. At the back, you will find some of the key steps we think need to be made in order to get the industry on the right flightpath to sustainable growth.

The steps may not be easy, but we can assure you the result will be worth it.





The economic case for biofuels

Biofuels for aviation have a number of benefits, the most important of which is the reduction in greenhouse gases emitted by aviation – an important conduit of world trade and economic development. But airlines will only be willing to move to sustainable fuels if there is a financial case. Currently, biofuels for aviation are rare and expensive. But as more and more supply comes on-stream, the costs will fall. The important milestone will be when the cost of biofuel reaches parity with the cost of using the current fossil fuel-based 'Jet A-1' for airlines.

BY **BRIAN PEARCE**, CHIEF ECONOMIST, INTERNATIONAL AIR TRANSPORT ASSOCIATION

Today it is not economical for airlines to use biofuels. Current estimates for the cost of producing biofuels suitable for air transport, suggest that airlines – and their passengers – would have to pay twice as much as they currently spend on jet kerosene. However, the economics of aviation biofuels and jet kerosene is likely to change.

There are three ways in which change will happen:

- First, government-imposed climate policies will add costs to users of fossil fuels.
- Second, the economics (and politics) of oil looks set to increase the price of jet kerosene.
- Third, the cost of producing and distributing aviation biofuel should fall.

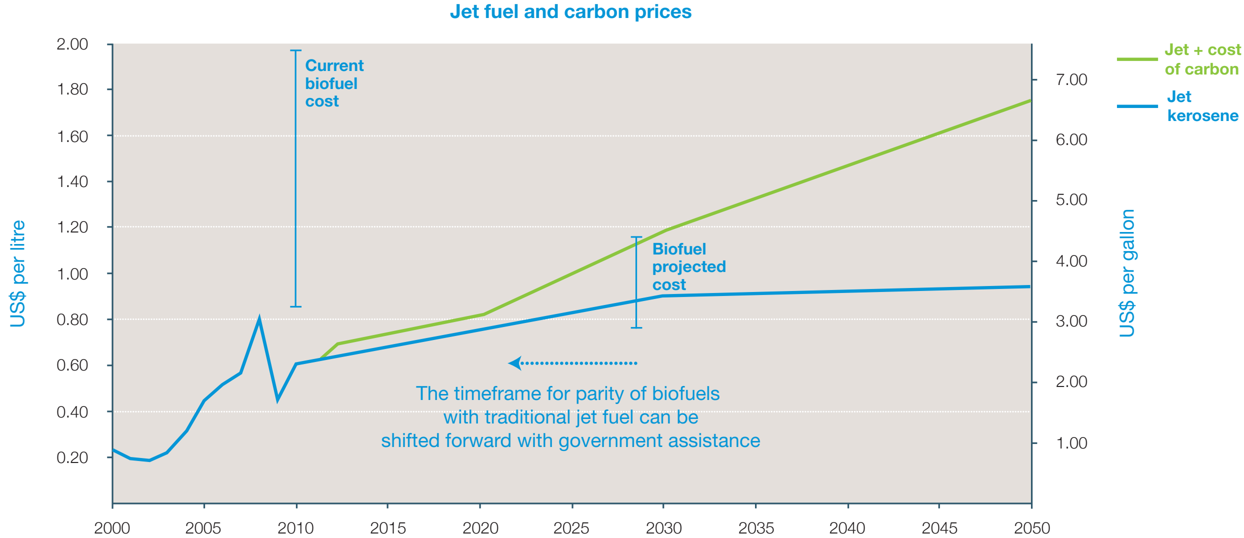
The speed and extent to which these three influences develop will determine how quickly biofuels become economic and how quickly they play a major role in reducing CO_2 emissions from air transport.

Cost of carbon

Climate change policy will likely change the economics of using jet kerosene. From 2012, as a result of the extension of the European Union emissions cap and trading scheme (ETS) to air transport, airlines flying to and from European airports will have to add the cost of carbon dioxide emission allowances to the cost of buying jet kerosene, unless overturned by pending legal challenges. The current price of €16 for an allowance to emit one tonne of CO_2 would add 2-3% to jet kerosene prices, closing the gap with biofuel costs only marginally. But allowance prices depend on the availability of cheap emission reduction options in certain sectors. Over time this low-hanging fruit will disappear and, by 2050, the cost of carbon is expected to double fossil fuel prices.

Climate policy costs for airlines may not have more than a marginal impact on the economics of aviation biofuels. From an aviation economics perspective, a more effective approach is to use positive economic measures at an early stage in the development of an aviation biofuel industry than waiting to rely on increasing costs of using fuels, which may come too late for aviation to be a user of biofuels.

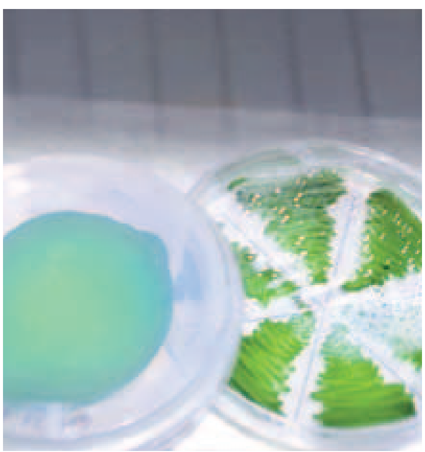
Jet fuel and carbon prices



Source: Jet kerosene price based on 25% markup over IEA's crude oil forecast in Energy Technology perspectives 2010. Carbon price taken from UK DECC 2010 central case forecast for traded carbon price. All are in constant (inflation adjusted) US dollars. IATA Economics. Schematic, indicative diagram.

→ COLLABORATION

Sustainable Aviation Fuel Users Group (SAFUG) *representing airlines that account for more than 20% of global commercial aviation fuel, has committed to drive development of commercial supply chains as well as support implementation of harmonised sustainability standards via the Roundtable on Sustainable Biofuels global multistakeholder processes.*



Black gold, or black platinum?

The economics of jet kerosene have already had a more significant impact than climate policies in making biofuels more economically viable. The rise in oil prices during 2008 was equivalent to a per tonne CO_2 allowance price of €100, compared to the current European ETS allowance price of €16. Early in 2011 the oil price once more surged through $100 a barrel showing its sensitivity both to demand from rapidly expanding emerging economies and to political turmoil in the Middle East. Oil and jet kerosene prices are currently four times higher than the average of the 1990s and early 2000s.

Peak oil proponents suggest the world is close to running out of this finite energy resource – in which case oil prices should continue to rise. But even if there are plentiful reserves of oil, it is still the case that new production oil is much more costly to extract. New fields being exploited are in deep or otherwise complex locations. Higher extraction costs will continue to exert upward pressures on oil prices, even without an impending shortage.

The view of many experts, including the International Energy Agency, is that these pressures will cause oil and jet kerosene prices to trend higher from now on. Adding the cost of buying CO_2 allowances it seems reasonable to forecast that by 2020 using jet kerosene will be at least as costly as the peak of the 2008 oil price spike. This will significantly close the cost gap between aviation biofuels and using jet kerosene. But even by 2020 rising fossil fuel and carbon costs may not be sufficient on their own to make aviation biofuels economic.

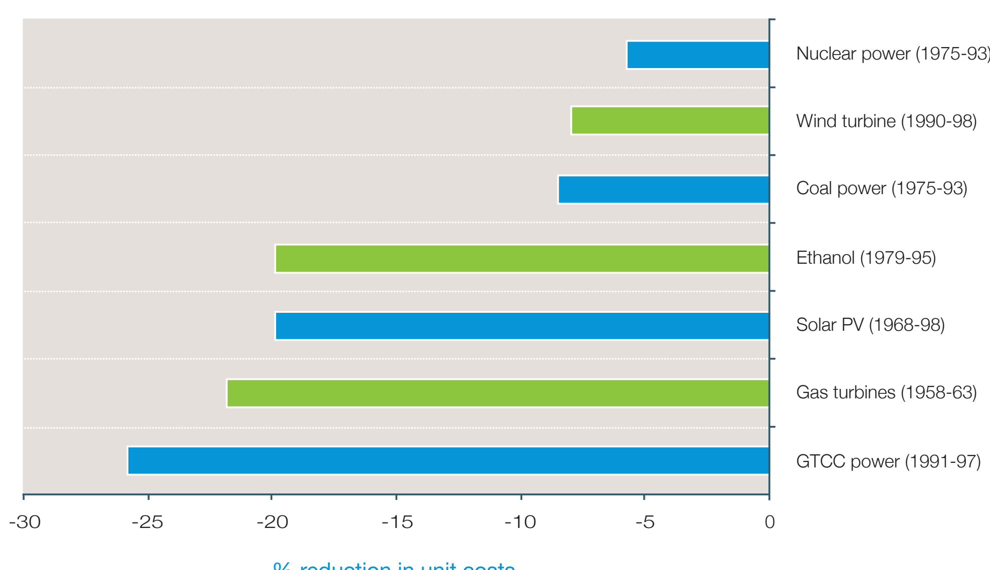
Production costs will fall

The key to improving the economics of using biofuels for air transport will be to significantly reduce unit production costs. This does look possible but it is a complex issue, not least because many of the biofuel technologies are in a very early stage of development.

Feedstock costs are a large proportion of costs in many of the newer biofuel technologies reliant on biological or chemical processes to convert biomass into fuel. Rising food prices today are indicative of the competition for arable land. Surface transport and power generation are also a source of increasing demand for energy crops. Put these competing demands together with a limited stock of land and the result is likely to be rising feedstock costs for aviation biofuels.

So reducing the unit production costs of aviation biofuels is likely to be dependent on big improvements in the productivity of feedstock, the extraction of oil or sugars from those crops, and the conversion into fuel. This means improved technology and innovation. Much has already been achieved. Venture capital and government funding is

Reduction in production costs with every doubling in capacity



Source: International Energy Agency

being sunk into a number of ventures. However, there are numerous different biofuel technologies being developed but few have yet been tested at commercial scale, and scale is one of the keys to getting unit costs down.

The experience of many energy technologies has been that as production capacity expands significantly economies are achieved through scale itself and through learning. The table on page 4, produced by the International Energy Agency, shows that for every doubling of capacity installed – which can be relatively small in absolute terms for a young industry – unit costs have fallen between 5% and 20%. This is not necessarily a recipe for success. It has to be the right fuel technology that is scaled up. Some of the unit cost reductions in these existing fuel technologies came from technological progress. Not all fuels will have this potential. Another key lesson from history is that governments have had many failures in 'picking winners'.

Working with nature to reduce costs and improve sustainability

While the industrial technologies needed to convert current biomass sources into fuels shows varying degrees of promise to ride a lower cost curve to affordability, there is an even greater potential for improvement when looking at emerging biomass technologies. The biological and agronomic science behind an entire portfolio of next generation biomass types is a relatively un-explored domain of lower cost, higher sustainability fuels.

Significant research on identifying and further developing new sources of biomass for energy has only emerged in the past decade, and the potential for dramatic reductions can be expected. Past biological improvement achievements coupled with new technology tools in the ability to achieve biomass improvements, suggests clear opportunities are ahead of us. Much of the overall cost and sustainability of biomass fuels depends on the biomass itself, not the conversion step into fuels: in the end, it's all about the biomass.

Previous generations of biomass fuels were based on crops optimised for food production and involved very high levels of inputs which characterised the mid-20th century approaches agricultural improvement – more water, more arable land, and more petroleum-based fertiliser. The 21st century brings about significant constraints on the continued availability of those inputs. However, these constraints are driving a significant amount of new investment into biomass sources for energy which can thrive in such constrained conditions. Just as many plants respond favourably to stressors, so too are the scientific and commercial research and development communities responding this new 21st century agronomic environment. High sustainability factors and lower cost fuels are seen by some as negatively correlated – i.e. high sustainability means expensive. This relationship is changing and the drivers are new biomass approaches which use sustainability as an enabling design tool rather than a barrier to be overcome.

A pluralistic approach

The answer in today's early stage development in aviation biofuels must be to take a pluralistic approach. Private venture capital is already providing some support to some of what currently appear to be the most promising fuel technologies. Others, such as those based on algae feedstock which look promising but still require major research and development, have received some support from governments. But the one or several biofuel technologies that will succeed may still be in the laboratory. Research and commercialisation funding is required for a range of potentially successful biofuel technologies, from which a winner, or winners will emerge.

It is possible that a commercially viable aviation biofuel will emerge, unaided by government support, from the private sector. However, despite impressive progress in early stage development, there is little sign of this happening at commercial scale.

There is still a considerable way to go before aviation biofuels become economically viable. Given the importance of decarbonising the air transport sector there is a strong case for government support to accelerate the scaling up of this young aviation biofuels industry, to bring forward the date when these new fuels become economically viable.

→ CASE STUDY

Local fuel for local flights in one of the fastest-growing markets

A number of initiatives are currently aimed at developing a sustainable aviation fuel industry in China. Boeing and PetroChina Company Limited are leading a thorough evaluation of the potential for establishing a sustainable aviation biofuels industry in China. The project will look at all phases of aviation biofuel development including agronomy, energy inputs and outputs, lifecycle emissions, infrastructure and government policy support. Other United States participants include Honeywell's UOP and United Technologies Corporation, while Chinese participants include the Civil Aviation Authority of China, the State Forestry Administration, and Air China.

In addition, Boeing and the Chinese Academy of Science's Qingdao Institute of Bioenergy and Bioprocess Technology (QIBEBT) are collaborating on algae-based aviation biofuel, developing algal growth, harvesting and processing technologies. The Joint Laboratory for Sustainable Aviation Biofuels is located in Qingdao and managed by Boeing Research and Technology China and QIBEBT, and has a strong emphasis on commercial applications.

Lastly, Air China and Boeing have planned two significant flights using regionally sourced biofuel. The inaugural Chinese biofuel flight, powered by sustainable fuel produced from Chinese jatropha oil, will demonstrate the potential for a domestic supply chain in China. PetroChina, Honeywell's UOP and Pratt & Whitney are also partners in this effort. A second, trans-Pacific flight will demonstrate and celebrate international collaboration on biofuel development.

→ **CASE STUDY**

Born in the USA

If there is one word that has really signified the work done so far to bring aviation biofuels to life, it is 'collaboration'. The different players in the aviation industry are used to working together for common operational goals, but the emerging world of aviation biofuels has introduced airlines, manufacturers and airports to a completely new set of partners – fuel supply chains, the agricultural community and a wider range of government agencies.

As one of the founders of the Commercial Aviation Alternative Fuels Initiative (CAAFI®) is fond of saying, "another way of looking at the challenges we face is to see them as opportunities for excellence." This attitude has been a driving force of the CAAFI coalition. Co-founded in 2006 by the United States Federal Aviation Administration (FAA), Air Transport Association of America (ATA), Aerospace Industries Association (AIA) and Airports Council International North America (ACI-NA) at a meeting held in The Boeing Company's headquarters, this coalition's aim is to make commercially viable, environmentally friendly alternative aviation fuels a reality. Its step-wise approach has been to identify the challenges to the deployment of such fuels and to take them on, either directly or by working to help leverage the efforts of others toward the common goal.

Indeed, tremendous progress has been made toward commercial deployment of sustainable alternative aviation fuels in the United States by pulling together the various interested stakeholders – aviation fuel users including commercial airlines and the US military, fuel producers, airports, airframe and engine manufacturers, government agencies with remits related to aviation or alternative fuels more generally and universities – and coordinating and combining their initiatives. Although the coalitions and stakeholders go beyond CAAFI, this organisation serves as an 'umbrella group' for the various US activities, helping coordinate a range of actions. CAAFI is organised into four teams, each dedicated to 'opportunities for excellence' in the areas that otherwise might present obstacles to sustainable alternative aviation fuels:

- research and development;
- certification and qualification;
- environmental demonstrations; and
- the business case.

A look at each of these areas shows progress made and remaining opportunities that will benefit from further collective action.

Research and development

Many commentators have remarked about how far aviation alternative fuels have come in such a short time. That such fuels are 'real' has been made clear by the many and successful test flights and rig tests that have been conducted, using a variety of fuels and feedstocks. This success can largely be credited to two factors, the shared vision that aviation alternative fuels need to be interchangeable with today's petroleum-based fuels and focused research, development and testing of fuels around that vision.

CAAFI determined early in its inception that replacing aircraft and aircraft engines to accommodate new fuels would be cost-prohibitive, as would having to put in place wholly separate fuel storage and delivery systems at airports. The US military came to the same conclusion. Thus, commercial and military stakeholders in the US have largely focused their efforts on alternatives that can be 'dropped-in' to existing infrastructure, so-called 'drop-in' fuels. This focus has given 'drop-in' alternatives priority in nearer-term research and funding, with alternatives that would require new aviation architecture – such as hydrogen – being addressed in the longer term research projects.

With the US Air Force goal to have one-half of its jet fuel nonpetroleum-based by the year 2016 and the US Navy goal to supply 50% of its total energy consumption from alternative sources by 2020, the US military services have undertaken significant activities in research and development and fuel approval and deployment. Also, the FAA has dedicated some of its research dollars under the Continuous Lower Energy, Emissions and Noise (CLEEN) programme for research and development of aviation alternative fuels, while US engine and airframe manufacturers have undertaken significant testing, in addition to that done by fuel producers. To allow researchers, fuel producers and potential users to have common understandings of where a particular alternative is in its development and help coordinate development efforts, the CAAFI coalition developed a fuel readiness level (FRL) framework tool. Covering fuels from concept through full commercialisation and identifying the criteria and requirements the fuels must satisfy, this tool also helps determine when a particular alternative is sufficiently beyond the research and development stage to proceed to certification and qualification.

Certification and qualification

Any alternative jet fuel must satisfy the regulatory and standards-making organisation specification requirements for jet fuel. In the United States and much of the world, the recognised jet fuel specification is set by ASTM International. Until very recently, ASTM D1655, 'Standard Specification for Aviation Turbine Fuels', was the only ASTM jet fuel specification. Based on a process forwarded by CAAFI stakeholders, an ASTM research report assembled under the supervision of the Emerging Turbine Fuels subcommittee, and rigorous review by engine companies and other experts, ASTM approved D7566, 'Aviation Turbine Fuel Containing Synthesized Hydrocarbons'. This specification allows for alternatives that demonstrate that they are safe, effective and otherwise meet the specification and fit-for-purpose requirements to be deployed as jet fuels, on a par with fuels under ASTM D1655.

The initial issue of D7566 enables use of fuels from the Fischer-Tropsch (FT) process in up to a 50% blend with conventional jet fuel. FT fuels can be generated from a variety of feedstocks, including biomass (biomass to liquid) and natural gas to liquid, in addition to coal to liquid and combinations thereof. Most critically, however, the ASTM D7566 specification is structured, via annexes, to accommodate different classes of alternative fuels when it is demonstrated that they meet the relevant requirements. One such annex is for hydrotreated renewable jet (HRJ) blends (also referred to as bio-derived synthetic paraffinic kerosene, or 'Bio-SPK'), with other

alternatives (such as hydrolysis / fermentation, lignocellulosic bioconversion, pyrolysis / liquefaction) to follow as data from technical evaluations is obtained.

Environment

A significant driver for the deployment of alternative aviation fuels is the benefit they may bring in reducing emissions from aviation, whether associated with local air quality or global climate change. CAAFI and other groups have made significant progress in confirming the methodologies for lifecycle analysis of alternative aviation fuels and in supporting or performing case studies that use these methodologies. Two cooperative US initiatives have produced significant work product in this regard. For example, an interagency working group led by the US Air Force and coordinated with CAAFI stakeholders developed critical guidance on how to perform lifecycle emissions analysis for aviation fuels. Working with that, researchers as the Massachusetts Institute of Technology, funded under a partnership supported by many CAAFI stakeholders, produced a comprehensive case-study analysis on potential alternatives. This work, as well as work on broader sustainability criteria, is being further advanced by the CAAFI Environment Team under two work streams that are expected to further firm up environmental guidance that may help fuel purchasers incorporate relevant environmental criteria into future purchase agreements.

Business case

Fuel costs are a significant portion of an airline's operating costs – in many cases, the greatest portion. Given that airlines typically generate razor-thin profit margins even in good years – and incur substantial losses in bad years – any fuel used by the airlines must be competitively priced and reliably provided. US aviation stakeholders are working hard, through CAAFI and other coalitions, to help make alternative aviation fuels readily available and price-competitive.

A key aspect to ensuring availability of these fuels is sending market signals that aviation is a ready, willing and optimal buyer. One initiative in this regard has been the strategic alliance between ATA and the US military, through its procurement arm (the Defense Logistics Agency). The US Air Force consumes about as much jet fuel in a year as a mid-sized airline would. However, the combined demand of US commercial airlines and the US military amounts to more than 1.5 million barrels of jet fuel per day, a volume that is more attractive to fuel providers who also may be considering supplying other fuel users, such as ground transport. The strategic alliance allows for pooling this demand and the consideration of joint purchasing agreements, but also provides another mechanism for sharing experience on fuel certification and environmental impacts. Already, two pre-purchase agreements for aviation biofuels have been announced between US commercial airlines and alternative fuels producers, with more commercial and military announcements in the works.

A key to helping make alternative aviation fuels price-competitive with petroleum-based fuels is to avail these fuels (and the feedstocks that go into making them) of government and other incentive programmes. In July 2010, the US Department of Agriculture (USDA), ATA and Boeing signed a resolution memorialising their commitment to work together on a 'Farm to Fly' initiative "to accelerate the availability of a commercially viable sustainable aviation biofuel industry in the United States, increase domestic energy security, establish regional supply chains and support rural development". This initiative is aimed at helping align US agricultural policy, which includes encouragement for growing energy crops, with the interest of the US airlines and military in sustainable alternative aviation fuels. Issues such as availability of crop insurance, means of reducing costs of energy crop feedstocks and bio-refinery opportunities are among those coming out of this initiative.

International benefits

While CAAFI started as a US initiative, it now has over 300 stakeholder participants from all around the globe, allowing for shared experiences and further leveraging. Not only will many of the developments in the US bring benefits to the global market, but developments elsewhere will further stimulate US initiatives. The key will be to continue to look for opportunities for excellence together.

→ CASE STUDY

Collaborative action in the Pacific Northwest

Sustainable Aviation Fuels Northwest (SAFN) is a regional initiative in the Pacific Northwest of the United States sponsored by Alaska Airlines, The Boeing Company, the Port of Seattle, the Port of Portland, Spokane International Airport and Washington State University. These organisations have convened a diverse regional stakeholder group to determine the feasibility of developing regionally sourced, sustainable aviation fuels in the Pacific Northwest.

This regional assessment is being facilitated by the non-profit Climate Solutions, which has coordinated a series of workshops spread over nine months and is working on a report reflecting the consensus recommendations. The workshops, data analysis, and ongoing working groups are contributing to a final report which will:

- *identify major barriers, opportunities and options for development of a sustainable aviation fuels industry in the Northwest;*
- *examine and analyse potential feedstock pathways available in the Pacific Northwest to supply sustainable aviation fuels, including oilseeds like camelina, forest residual waste, algae, waste materials and sugars;*
- *clarify the importance of evaluating and demonstrating the sustainability of biofuel production and include a framework for applying sustainability principles;*
- *illustrate potential trade-offs among various outcomes and alternative pathways; and*
- *evaluate the potential logistics and compatibility issues related to the introduction of sustainable biofuels at regional airports.*

Through this process, SAFN stakeholders will identify a set of "flight plans" to create Northwest supply chains for sustainable aviation fuels. Importantly, the project will look at how the biomass and refining process can be used to supply both biofuel for use in aircraft and biodiesel for use in ground-based vehicles, ensuring that the most use can be made from the biomass possible. The stakeholders represent a wide range of interests, including aviation leaders, biofuel developers, growers, forest managers, federal, state and local governments, industry associations, environmental and conservation groups, universities and industries.

→ **CASE STUDY**

Plan de vuelo hacia los biocombustibles sustentables de aviación en México

Expertise in aviation biofuels is being fostered all over the world. In Mexico, a government agency which provides jet fuel to the nation's airports is taking a lead role in fostering this important green growth opportunity. The challenges are the same as for a lot of nations with similar diversity of landscapes and economic profiles, but it has to be said that with the Plan de Vuelo, Mexico is engaging in an impressive display of 'joined-up thinking'.

The Mexican Federal Government, following the objectives that the international aviation industry has established, has started an ambitious programme of action to ensure the development and viability of sustainable aviation biofuels in the country. This comprises an active participation within the ICAO framework via the Dirección General de Aeronáutica Civil (DGAC, Mexican Civil Aviation Authority), as well as the design and implementation of a comprehensive far-reaching road-mapping exercise called the "Flight Plan Towards Sustainable Aviation Biofuels in Mexico", coordinated by Aeropuertos y Servicios Auxiliares (ASA, Airports and Auxiliary Services).

ASA is the sole supplier of jet fuel in Mexico, responsible for all into-plane operations and the management of over 60 fuel farms in the Mexican airport network. In the global context, Mexico represents 2% of the world's jet fuel market, as it provides close to 10 million litres a day for approximately 2,300 flights comprising what could be termed a "small but big market".

When considering its position along the supply chain of aviation fuel, being the last link gives ASA a unique viewpoint from which it can act as the promoter and catalyst of the budding aviation biofuel industry in Mexico. ASA's position as an intermediary client between PEMEX (Mexico's state-owned oil company) and the airlines, gives it an exceptional lever with which to pull all interested stakeholders along the aviation biofuel value chain.

The flight plan

The main idea behind the Flight Plan Towards Sustainable Aviation Biofuels in Mexico is to analyse the existing and missing links in the supply chain for sustainable biofuels. It is similar to a road-mapping exercise in that it looks into the market drivers, the associated products and services, and the technologies that could help an aviation biofuel industry get off its feet. The main objectives of the Flight Plan are to diagnose the state in which the different parts of the supply chain are, to involve all the interested stakeholders, and communicate to society at large the benefits that aviation biofuels can bring.

A series of workshops for the Flight Plan were designed using a schematic view of the supply chain. Given that the premise of biofuels is that they will lower the carbon footprint in comparison to fossil fuels, the first workshop was organised to look into the general problematic of this type of energy, and specifically to the sustainability issues that need to be observed across the supply chain.

The other workshops were organised so that all the points across the supply chain could be analysed, including:

- raw materials and extraction;
- infrastructure and refining; and
- financing, legislation, logistics and distribution.

A two-pronged approach was followed in which specific subject matters were addressed, as well as looking into cross-sectional or longitudinal themes that are present across the supply chain. The exercise started with a contact list of around 100 people, and as it progressed, it grew over 10 times to a network of over 1,000 stakeholders. With an average audience of 120 persons throughout this project, all the principal actors, as well as governmental, financial, private, academic and research institutions, gathered in the same forum sharing their ideas, proposals, experience and commitment in this huge global challenge. It is important to note that in the design and implementation of the Flight Plan, ASA received the support of several organisations, especially from The Boeing Company and the Roundtable on Sustainable Biofuels (RSB).

Analysis of the supply chain

Mexico is the fourth most diverse country in the world with 5,870,921 hectares with high productive potential. The analysis of the different feedstocks resulted in several candidates that could be developed into second generation sources: jatropha, castor, salicornia, agave and algae. Most of these plants are indigenous to the country and have been harvested for many generations as they grow in the wild in many regions of the countryside. In fact, there is advanced biofuel feedstock production in a number of Mexico's states, taking into account local species and most suitable crops for each growing condition.

The production of vegetable oil is an important topic, since much of the installed capacity is underused. For many years, the vegetable oil industry has been in on standby, as many of the usual vegetable oil generating feedstocks have not been produced in Mexico for some time due to lack of water or adequate land. In the end, the oil extracted to produce a biofuel is independent of the source, so the promotion of viable second generation sources is critical. One consideration is the use for the residual biomass that is produced, and the secondary markets where it can be utilised. There is also another important issue to be considered – the current crude vegetable oil cannot meet the current specification for the refining process, and so pre-refining is needed.

In terms of the refining industry, Mexico has historically been handicapped in the production of the necessary fuels to feed the requirements of its economy. However, in the production of jet fuel, the country has always been self sufficient. It is in the interest of ASA to guarantee the production of aviation biofuels, so that Mexico has the capacity to meet its future internal demand. ASA has, therefore, found an economic case for planning specific refining capacity. In fact, by 2020 with the right funding structure in place, it is expected that up to four aviation biofuel specific refineries will be operating in Mexico, generating 800 million litres of sustainable aviation biofuel. There are important legal obstacles that need to be overcome, as some of the by-products of the refining process can only be managed by the national oil company – PEMEX. Beyond this, the current biggest jet fuel market in the world is just north of the country, so any surpluses that are produced will certainly find willing buyers.

Towards the end of the supply chain, the point where the blending of the product will take place will depend on the capacity of ASA's installations, as dedicated infrastructure needs to be considered. This will not be a problem in the beginning, but it is bound to show some constraints as the industry develops and as the quantities of aviation biofuel that need to be blended become significant. The storage of the product has also shown some challenges, as the difference in densities between the biofuel and the fossil fuel have to be taken into account.

Longitudinal analysis

As part of the analysis of the supply chain, consideration was given to several themes that are present across the specific stages. These include the financial, legal, and sustainability perspectives.

From the financial perspective, several institutions were invited to give their ideas as to how the markets would react to the measures that are being implemented across the globe, such as the European Union's Emissions Trading Scheme, or the Clean Development Mechanisms promoted by the UNFCCC. The impacts of such measures are to be an integral part of the financial viability of these types of fuels.

The legal perspective was explored to look into the different clauses of Mexican law that could have an impact in the development of this industry. The Mexican Constitution has a legacy of stringency with respect to energy created from fossil fuels, but there are new laws covering the growth of bioenergetics that show promise, which are still in the advancement stages.

The sustainability perspective was addressed from the viewpoint of the framework provided by the Roundtable on Sustainable Biofuels (RSB). The twelve principles were analysed in detail, and the parallels with the Mexican environmental law were put into perspective.

Next steps

The Flight Plan Towards Sustainable Aviation Biofuels in Mexico has proved to be an invaluable exercise to identify the existing and missing links along the value chain of this new type of energy.

As ASA works on putting together the pieces of the puzzle to define the successful path Mexico will be following in the next few years, the results that will benefit Mexican society, such as the reduction in greenhouse emissions, the promotion of agriculture in marginal land, new jobs, and a major boost for a new industry, are well underway.

New lines of research have emerged and the challenge is to find the necessary funding to pursue them. This, together with the implementation of the defined action items are the necessary next steps to follow so that a necessary aviation biofuel industry is established in Mexico.

→ CASE STUDY

Brazilian Alliance for Aviation Biofuels

The Brazilian Alliance for Aviation Biofuels (Aliança Brasileira para Biocombustíveis de Aviação – ABRABA) was created in May 2010, with the objective of promoting public and private initiatives seeking development of sustainable aviation biofuels with positive carbon lifecycle and certification according to local and international fuel standards.

Founding members of ABRABA include members from aviation, fuel technology and agricultural backgrounds: Algae Biotecnologia; Amyris Brasil; Brazilian Association of Jatropha Growers; Aerospace Industries Association of Brazil; Azul Linhas Aéreas; Curcas Diesel Brasil; Embraer; GOL Linhas Aéreas Inteligentes; TAM Linhas Aéreas; TRIP Linhas Aéreas; and the Brazilian Sugarcane Industry Association (UNICA).

ABRABA will act as a flagship institution integrating the efforts of different players and will support the use of sustainable biofuels as one of the key growth factors for the aviation industry in a low carbon economy. Integrating the Brazilian renewable fuel experience and capability with aeronautical technology expertise, it will foster further economic and social development, as well as significant contribution to environmental protection.

For more information, visit the ABRABA website: www.abraba.com.br

→ COLLABORATION

Pure Sky in Germany

German airline Lufthansa will be undertaking the first long-term trail of biofuel use in daily commercial flights on an Airbus A321 between Hamburg and Frankfurt for six months in 2011. This city-pair flight will allow the industry to study long-term aspects of biofuel use and supply. The project team includes research institutes such as Bauhaus Luftfahrt and DLR and is backed by the German government within the framework of its aviation research programme.

→ **CASE STUDY**

Waste not, want not

Biofuel does not always come from crops. In innovative projects that solve several problems at once, British Airways and other airlines have formed relationships with a company which will produce large amounts of aviation biofuel by processing municipal waste – reducing the industry's dependence on fossil fuels and at the same time reducing the amount of waste in landfills.

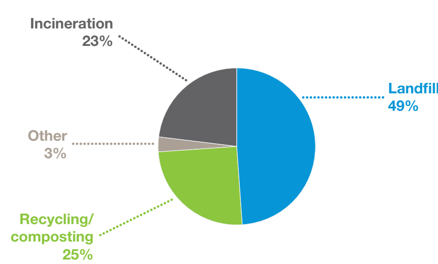
The British Airways and Solena partnership was formed in 2009, when the two companies agreed to work together to develop a unique project for London. Solena, a renewable energy technology company based in Washington DC offered a pathway to sustainable aviation fuels by converting waste biomass into fuels, renewable energy and heat. Although at the time, many biofuel demonstration flight trials had taken place, a full commercial-scale facility for renewable jet fuel had not been constructed. British Airways believes that sustainable fuels offer a unique opportunity for aviation to decarbonise over the short-medium term.

The consumption of jet fuel represents 99% of British Airways' carbon footprint and while the airline continues to implement sustainable practices in other aspects of its business, a main focus now is on the jet fuel that powers aircraft and emits large volumes of greenhouse gases. This is the area for change that offers both the biggest opportunity and challenge. British Airways has an ambitious target to reduce net carbon dioxide emissions from its business by 50% by 2050. It is hoped that renewable sustainable fuels will help to achieve this goal.

The potential for releasing the energy locked up in the UK's waste has been a priority for some time. The UK Department for Environment, Food and Rural Affairs (DEFRA) has a waste strategy for England which says: "recovering energy from waste which cannot sensibly be recycled is an essential component of a well-balanced energy policy and… [DEFRA] expects energy from waste to account for 25% of municipal waste by 2020/21."

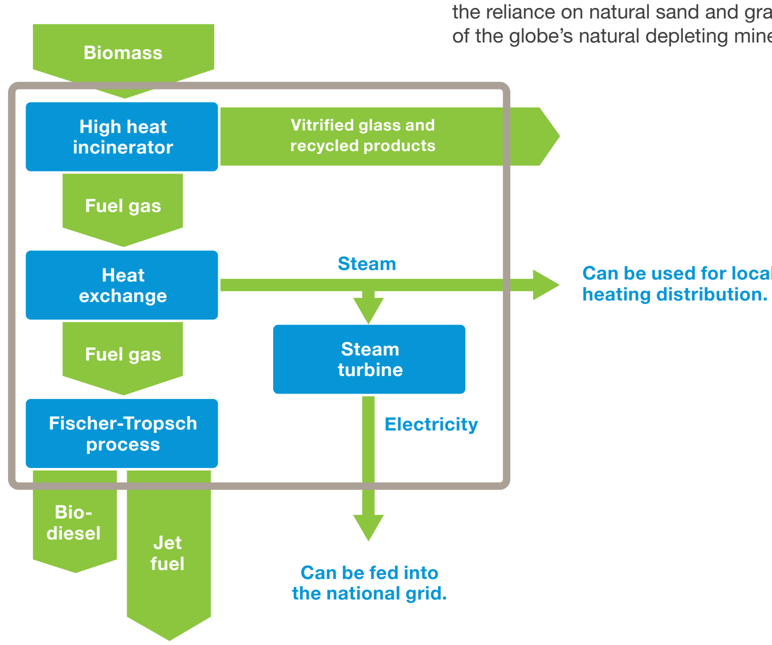
Waste is a significant problem for London, where almost half the city's four million tonnes of municipal waste is sent to landfill, often transported long distances to the disposal site. The Greater London Authority sees great potential in recovering energy from waste and the Mayor proposes a zero waste to landfill target by 2025.

Breakdown of London's municipal waste management methods in 2008/9



The technology

Solena's patented plasma technology is able to convert all forms of biomass into clean renewable energy. Operating at very high temperatures, the system can convert virtually any type of organic material, including waste (e.g. food waste from households and businesses) agricultural and forestry residues, into energy.



The technology is "fuel flexible" so as a thermal conversion platform it can convert low-value hydrocarbon-bearing biomass into a renewable biosynthetic gas (or "BioSynGas"). Planned input capacity for the plant is 500,000 tonnes of waste per year.

Linked to a Fischer-Tropsch unit, the BioSynGas is then converted into biofuels to produce 1170 barrels of aviation biofuel and 630 barrels of bionaphtha per day. Using GE power generation systems, the Solena Plant will produce 20 MW net of green renewable power, which can be sold to the local electricity supply grid.

Excess steam may be produced and utilised in a district heating system. Thus, the plant can benefit its neighbours and have a major effect on CO_2 and greenhouse gas reduction.

The process generates no harmful pollution or toxic ash. The only waste by-product is an inert glass-like material, which is an ideal alternative building aggregate, thus reducing the reliance on natural sand and gravel – one of the globe's natural depleting mineral assets.

What makes this project different?

A number of energy-from-waste projects are being developed in the UK at the moment. This one is different for a number of reasons:

- It is not a conventional waste to energy facility, a chemical plant or a refinery. It is a clean renewable next generation aviation biofuel production facility processed from waste and biomass waste.
- The fuel will have low lifecycle greenhouse gas emissions – up to 90% less than the emissions associated with fossil kerosene.
- The end fuel will be cleaner burning than kerosene (zero sulphur and low aromatic content produce less soot and fine particulates), providing air quality benefits when the fuel is burned.
- A zero waste philosophy means that all materials are recycled, conversion of carbon-based materials is in excess of 99%, there is no bottom ash or fly ash and non-carbon based materials are converted into vitrified slag for use in the construction industry.
- Gasification and Fisher-Tropsch technologies are proven processes being employed worldwide. Solena is developing similar plants in the US States, as well as in other countries. Importantly, the Solena / British Airways partnership is providing the first such plant to produce biofuel in Europe.
- British Airways will directly use the aviation biofuel and is moving into a contractual relationship to purchase the fuels produced.
- It will be a world-class development and the first of its kind in Europe. The end product is a real alternative to fossil fuel for the aviation industry and thus has a long-term viable future.
- Innovative design and technology means the plant will be energy self-sufficient and sustainable in its own right.

The next steps

The project partners plan to locate the facility in East London, close to the source of the waste and close to British Airway's operations in the South East (the nearest airport is London City, from which British Airways runs both short- and long-haul services). During construction, the project will generate around 1,000 jobs in London. From 2014, when the plant is in full operation, 200 permanent jobs will be created. This will be the first development of its kind in Europe, and should provide a proven pathway for a number of other global cities to generate valuable resources from waste.

At the time of this publication going to press, Solena had already signed biofuel plant initiatives with British Airways, Qantas and Alitalia airlines.

→ CASE STUDY

A road map for sustainable aviation fuels downunder

In Australasia, the Sustainable Aviations Fuels Road Map project has been developed in collaboration with the Australasian section of the Sustainable Aviation Fuel Users Group (Air New Zealand, Boeing, Qantas, and Virgin Blue) together with the Defence Science and Technology Organisation. The project is being coordinated by Australia's national science agency, the Commonwealth Scientific and Industrial Research Organisation. SAFRM is a comprehensive regional assessment, examining all phases of developing a sustainable biofuel industry, including biomass production and harvest, refining, transport infrastructure and actual use by airlines. Participants are working to identify the barriers, opportunities and implications of producing sustainable bio-derived jet fuels at scale, including:

- *commercial viability;*
- *environmental sustainability;*
- *alternative biomass feedstocks suitable for growing in that particular region;*
- *key policy, commercial and research actions needed.*

This assessment draws on the diverse expertise of a broad range of stakeholders to map out future scenarios, including biomass producers, refiners, airport operators, environmental and government organisations, airlines, academic representatives, and airline and engine manufacturers.

→ COLLABORATION

Sustainable Bioenergy Research Center

This consortium in the United Arab Emirates – involving Boeing, Etihad Airways and Honeywell's UOP, and hosted by Masdar Institute of Science and Technology – drives technological development in arid land and saltwater-tolerant terrestrial biomass.

→ CASE STUDY

A massive opportunity lies just off shore

Sometimes, the biggest breakthroughs come from surprising places. Around the world, the aviation industry, academic institutions and biofuel companies are working together to accelerate the development of one of the most promising sources of aviation biofuel in the long-term – the microscopic and ubiquitous plants that can be grown almost anywhere known as algae.

It is widely agreed that the contribution of fossil fuels to global climate change is a major issue that industry and society has to urgently address. Biomass from micro algae has been demonstrated at laboratory scale to be a viable source of low carbon bio-fuel for aviation. The challenge ahead is to industrialise this process at a very large scale so that its outputs can begin to make significant contributions to global aviation fuel needs. And yet the demands on scarce land and fresh water from aquatic biomass cultivation must be kept to an absolute minimum or avoided altogether.

The Sea Green project is a near-shore ocean-based facility for the sustainable production of large volumes of biomass for aviation biofuels. It is designed to use the expanse of the world's near shore oceans to rapidly grow micro algae as biofuel feedstock at a faster rate than any other initiative and capture CO_2 from the atmosphere and seas at the same time. The Sea Green concept would envisage very large floating structures to be placed in the ocean close to shore on which the cultivation of micro-algae would occur. This can be done in an environmentally-friendly, sustainable facility with a negative carbon mechanism that does not compete with agricultural land, does not require fresh water and does not damage the environment.

Once the micro-algae have been cultivated, they will be sent for processing much like any other biomass on land.

The benefits of moving off-shore

As a project, Sea Green is unique in combining technologies for very large floating structures with microalgae cultivation, delivering major advantages when compared to conventional land-based aquaculture. The use of an off-shore facility would mean higher biomass production and revenues using lower energy because biomass movement is achieved by harnessing ocean currents. The technology can be scaled up or down very easily, to provide for local fuel needs. And, because it can use convenient ocean, sea or even suitable lake locations, there is no requirement to use scarce agriculture land or fresh water resources.

It is estimated that the concept will be able to produce 35 times more biomass than agriculture energy crops, twice as much biomass as land based aquaculture and additionally is more energy efficient through harnessing the agitation and nutrient transport benefits of ocean waves and currents. Sea Green also mitigates against many of the recognised issues arising from the conventional land-based methods of producing biomass. The advantages arise from four potential scenarios:

- securing locally produced biofuel as a strategic asset for fuel source diversity;
- selling harvested biomass to be processed into biofuels or speciality products;
- sharing intellectual property rights revenue from licensing the Sea Green design family;
- reducing pressure on scarce land and fresh water resources.

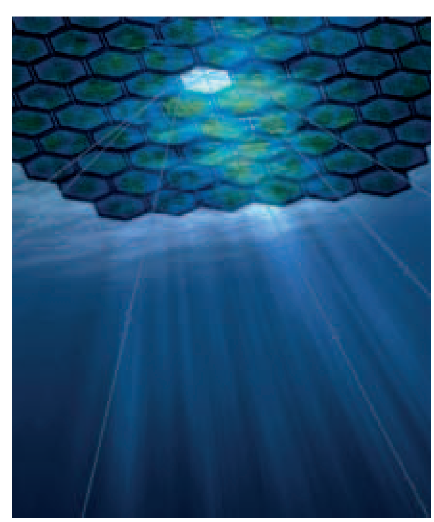
Bringing the concept to life

To make this vision a reality requires a staged process of testing, scale up, pilot plant and production plant construction with all key stakeholders actively engaged from the outset. The stakeholder engagement is being achieved by the formation of a Sustainable Use of Renewable Fuels (SURF) consortium that will take a structured approach to addressing five major considerations for the successful use of biofuels from a renewable source like micro-algae. These will include: environmental impact; processing; capacity and distribution; commercial and legislation and regulation. Specific studies will look at future sustainability modelling and environmental lifecycle assessment. Formation of the Consortium was announced at the Aviation & Environment Summit in Geneva in September 2010. SURF is made up of Airbus, British Airways, Rolls-Royce, Finnair, Gatwick Airport, the International Air Transport Association and Cranfield University.

The Sea Green project is undertaking staged scale-up and industrialisation of a process for large-scale floating biomass production from micro-algae. Modelling and front end engineering design activities have been completed by Cranfield University.
The sub-sequent staged process has the following steps:

- laboratory testing at the 1-litre to 10-litre scale to define overall performance parameters;
- testing in a small-scale pilot facility on the Cranfield University campus which is growing and processing algae for biofuels at the 1000-litre scale;
- production of quantities of aviation biofuel at approximately 10,000-litre scales for its use as commercially available test samples for engine testing;
- development and construction of a larger scale production facility to initially meet the needs of a specific aviation market sector – say for business aviation.

It is envisaged that the first commercial quantities of products from Sea Green will become available within three years.



The six easy steps to growing a viable aviation biofuels industry

Many of the technical hurdles facing aviation in its move towards sustainable aviation biofuels have now been overcome and much of this work has been achieved within the industry. Now, commercialisation and scaling up of the supply of aviation biofuels is the most important task.

As shown in the selection of case studies in this publication, the industry has been forging ahead with pilot projects in a number of countries worldwide. But airlines and the rest of the industry cannot do it alone – political support and financial investment will have to come from a number of stakeholders. This section outlines six suggested steps that policymakers can consider in helping their air transport system grow with less carbon-intensive fuel, whilst in many cases also investing in green growth jobs and a new sustainable industry. These steps are presented in no particular order:

1 Foster research into new feedstock sources and refining processes

There are many different types of feedstock and pathways that enable feedstock to be converted into biofuel, and important technological developments will unlock still more pathways. Early generation biofuels used feedstocks derived from food crops such as rapeseed and corn. However, these feedstocks can be used as food for humans and animals, raising important questions about their sustainability. In response to these concerns, the industry is now focused on exploring the use of advanced-generation biofuel sources that are truly sustainable.

Several pathways are being considered for the development of sustainable aviation biofuel and these are illustrated below.

The industry is unlikely to rely on a single feedstock. Some feedstocks are better suited to some climates and locations than others. Therefore, it is expected that ultimately there will be a portfolio of biofuel sources developed and a variety of regional supply chains.

Much of the current research and development work on alternative fuels is focused on biodiesel and bioethanol projects for land transport. Ultimately, this will delay land transport's switch to more sustainable energy sources, such as electricity and hydrogen fuel cells.

Policy enablers include establishing funding programmes for academic research through existing or new university, research institution or industrial research projects, broadening or re-focusing university research of biofuels to include aviation-specific projects.

2 De-risk public and private investments in aviation biofuels

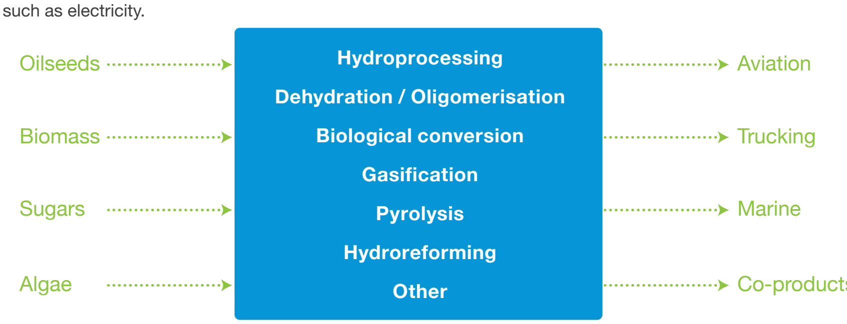
To be economically viable, sustainable aviation biofuel must be priced at a level the market will find acceptable. At present, aviation biofuel is not cost competitive with current jet fuel. However, traditional jet fuel is forecast to become more expensive. By contrast, sustainable aviation biofuel will become less expensive as the industry develops. Policies incentivising biofuel development and use can hasten this trajectory and achieve greater emissions reductions in a shorter timeframe.

A better appreciation of the scope for reduction in the price of sustainable aviation biofuel is gained by examining the cost drivers. For the technology pathway that is nearest commercial viability, it is estimated that 85% of biofuel production costs relate to the cost of feedstocks. As the technology to harvest and process these feedstocks progresses, as agronomy and plant breeding produce cultivars with better, more robust yields, and as sustainable biomass become available in commercial quantities the price will drop. In fact, since aviation biofuel testing started a few years ago, prices for these feedstock inputs have already dropped significantly. Support for research and development will enable continued improvements for feedstock pathways. Production is the second major component of the total cost of the fuel. The oil industry has already established refining infrastructure and thus currently has a limited need for additional capital investment. However, in the case of sustainable aviation biofuel, the production infrastructure has yet to be developed and some of what needs developing could be synergistic with existing petroleum infrastructure, but not all.

There are also significant subsidies in place for biodiesel production in Europe and the US, which could hamper the establishment of aviation biofuel production.

These incremental upfront capital investment costs are a potential barrier to commercialisation. In this context, governments can play a role in reducing this risk through measures such as loan guarantees, tax incentives, grants and co-financing for pilot and demonstration projects. They can also provide a level playing field with biodiesel by providing similar fiscal and price incentives in order to catalyse establishment of the sector.

Advanced aviation biofuels will come from a range of feedstocks and processing methods. They should be prioritised for aviation and other 'heavy' transport uses over those forms of transport that have alternatives such as electricity.



3 Provide incentives for airlines to use biofuels from an early stage

If a policy or incentive mechanism is a key part of making renewable energy project economics attractive, changes to these factors pose a risk: a long-term, stable policy regime with a sound legal basis is essential for serious investment to take place.

Unlike some other renewable sectors, sustainable aviation biofuels are not subject to feed-in-tariffs or mandates. The EU ETS is a policy mechanism that may incentivise sustainable aviation biofuel development, but the price of oil is a far greater driver so its impact will probably be limited in the near-term. The market for sustainable aviation biofuels is primarily driven by other factors including reducing dependence on fossil fuels and improving the carbon footprint of the industry. Consequently, sustainable aviation biofuels are subject to very limited policy risk.

Policymakers can foster development of aviation biofuel by recognising the unique role it can have in reducing the aviation's environmental impacts. Aircraft cannot use alternative renewable energy sources available to other sectors such as plug-in, wind, solar or hydroelectric power. Thus, crafting policies that create a level playing field for biofuels vis-à-vis other energy sources, and aviation vis-à-vis other sectors, is a key element in aviation biofuels commercialisation.

4 Encourage stakeholders to commit to robust international sustainability criteria

Sustainability standards are being established that will provide suppliers, investors and customers with clear guidelines as to what is considered to be a sustainable biofuel. For example, in the EU, the Renewable Energy Directive (RED) contains specific criteria addressing this. The Switzerland-based Roundtable on Sustainable Biofuels (RSB) has a sustainability standard developed through a multistakeholder process that ensures the sustainability of production, processing and implementation. Sustainability is not just a matter of the choice of feedstocks – it is also a matter of how they are cultivated, harvested, processed and transported.

Some key sustainability criteria for aviation fuels could include the following elements:

- will not displace, or compete with, food crops or cause deforestation;
- minimise impact on biodiversity;
- produce substantially lower life-cycle greenhouse gas emissions than conventional fossil fuels;
- will be certified sustainable with respect to land, water and energy use; and
- deliver positive socio-economic impact.

As a global transportation sector, aviation needs a harmonised standard to ensure that sustainability criteria are enforceable and equally applied across the industry. A patchwork of standards would inhibit the development of a commercially viable market. While there are myriad standards in place, both regulatory and voluntary, a critical element will be for aviation biofuel stakeholders to enable greater cooperation between standards to increase transparency, decrease the cost of compliance, increase end-user visibility to the biomass, and increase the incentives for next generation fuel pathways. It is also vital that a unified accounting structure be established to verify the origin and sustainability credentials of biofuels for aviation.

The development of an accepted set of globally harmonised standards will help ensure that investment is directed at biofuels that meet acceptable sustainability criteria, thus minimising this form of risk. Criteria need to be mutually recognised around the world. For aviation, global standards are needed wherever possible, due to operational routing of aircraft, common global equipment and worldwide fuel purchasing requirements.

→ CASE STUDY

A multi-stakeholder approach in Brazil

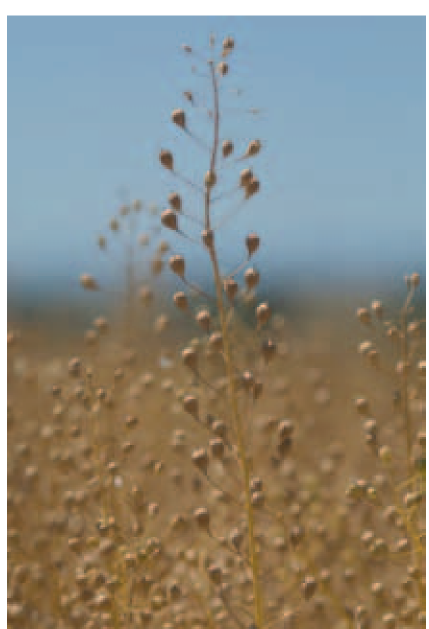
JETBIO, a Brazil-based company specialising in biofuels projects, is leading the development of an integrated project aimed at producing and supplying sustainable aviation biofuel to airlines. The initiative is supported by TAM Airlines, Airbus, AirBP and Bio Ventures Brasil.

The project addresses the Implementation of a sustainable aviation biofuel value chain, bringing together the key players to foster:

- *jatropha research and development for locally adapted elite cultivars and scale-up;*
- *logistics optimisation;*
- *installation of aviation biofuel production capacity by 2013; and*
- *lifecycle carbon emissions analysis and sustainability studies of the value chain.*

JETBIO has adopted a multi-feedstock approach for aviation biofuel production, focusing on the development of cost-efficient and sustainable sources such as jatropha and sugar-cane derived biomass. In the mid- to long-term, once scale and costs reach adequate levels, these alternatives will gradually replace currently available feedstock.

The Southeastern region of Brazil was selected for the construction of the renewable jet unit, as it represents at least 60% of the jet fuel and 40% of the diesel consumption in the country. Furthermore, the region benefits from nation's best logistics and industrial infrastructure. The project aims at starting aviation biofuel production by the end of 2013 to supply initially the São Paulo and Rio de Janeiro airports, from where a majority of international flights operate in Brazil.



5 Understand local green growth opportunities

Sustainable aviation biofuel doesn't only bring environmental benefits for aviation, it can also foster the development of a new industry. Given the diversity of feedstocks that aviation is considering, there are few places on earth that could not support some development of a new, sustainable, energy industry. These can range from growing large quantities of jatropha, halophytes or camelina in the most appropriate environments, to establishment of algae farms on land or off-shore, to smaller scale biofuel facilities in cities utilising municipal waste.

By bringing the aviation industry, government, biofuel, agriculture and academic expertise together, analyse the optimum opportunities that exist in your country for aviation biofuel production including the most effective feedstock sources and infrastructure requirements. A number of regional development banks are also working on ways to encourage the process. The contacts at the back of this publication may provide advice for how to get this process started.

6 Establish coalitions encompassing all parts of the supply chain

Experience has shown that there are many benefits to be gained from collaboration across the various stakeholder groups involved in all aspects of aviation biofuel production and use. These groups can bring together parties that have not traditionally needed to work together, such as:

- Airlines, airports, aircraft and engine manufacturers;
- Academic institutions;
- Fuel refining companies;
- Agricultural companies and farmers groups;
- Local, regional and national Departments of Agriculture, Defence, Transport, Economic Development and Enterprise;
- Regulators – aviation, transport and agricultural;
- Chambers of commerce and industry;
- Environmental and sustainable development NGOs.

Throughout this publication are examples of stakeholder-oriented processes, all of which are groups of regional and national stakeholders, who have convened to work through the sustainability, supply, investment and long-term planning issues and maximise the opportunities within their respective regions.

Within coming years, many significant commercial, policy and sustainability outcomes will result from such comprehensive regional stakeholder processes. These processes serve to enable commercial parties, while also giving confidence to governments and civil society organisations that sustainable aviation fuels efforts are following a contemplated path.

Those seeking to better understand potentials for this industry should engage with the processes identified in this publication to understand next steps in each region.

→ CASE STUDY

Testing on a range of aircraft

A number of test and demonstration flights have taken place on commercial jet aircraft in the past few years, but none yet on turboprop regional aircraft. Canadian aircraft manufacturer Bombardier is part of a group of companies working towards demonstrating the use of camelina seed oil in a Q400 aircraft in 2012.

The project is being supported by Sustainable Development Technology Canada, an agency created by the Canadian Government. Each of the partners in the consortium is working on a different aspect of the project:

- *Targeted Growth Canada – leading the consortium and crop optimisation and growth;*
- *Sustainable Oils – pre-refining the camelina oil;*
- *Honeywell UOP – secondary refinery to aviation biofuel;*
- *Bombardier and Pratt & Whitney Canada – technical evaluation;*
- *Porter Airlines – providing the aircraft.*

Camelina provides benefits over traditional petroleum-based fuel because it reduces greenhouse gas emissions by up to 80%, reduces sulphur dioxide and is not competitive with food production because it can be grown in rotation with wheat and on marginal land. The strategic benefit to farmers is that it allows them to drive additional revenue from acreage with a low-cost input crop with two end user markets – the oil for fuel and "meal" for livestock and dairy industries.

The aviation industry has established a plan for reducing emissions. Sustainable aviation biofuels are an important part of that plan and, as you will have seen in this publication, the industry and its partners have made significant progress. There is confidence that biofuels can be a very significant part of every airline's future. From policymakers, the industry is looking for encouragement and the right set of legal, fiscal and policy responses to ensure this exciting new energy stream can bear fruit as quickly as possible.

→ CASE STUDY

First camelina biofuel value chain in Europe

Airbus and TAROM Romanian Air Transport together with a group of key stakeholders have established one of Europe's first projects aiming to establish a sustainable aviation biofuel processing and production capability. The Romania based project aims to provide a biofuel made from camelina as a sustainable substitute to fossil based jet fuel.

The project is developed by a consortium of partners led by TAROM, and joined by Honeywell's UOP, CCE (Camelina Company España) and Airbus. UOP contributes aviation biofuel refining technology and knowledge, CCE contributes knowledge on camelina agronomy, including technologies on camelina growth, agricultural monitoring networks and plant science, and Airbus contributes technical and project management expertise while sponsoring the sustainability assessment and life cycle analysis studies.

The first part of the project is focused on feasibility studies on agricultural, technological and aeronautical development and sustainability assessment.

The project will also assess the existing refining facilities in order to identify the Romanian production capability. The feedstock chosen for this project is the camelina plant due to its energy potential, its rotational crop qualities, its green house gas reduction efficiency and low water requirements. Camelina is indigenous to Romania, it can be readily farmed and harvested by family farmers and has a high quality animal feed by-product.

→ CASE STUDY

First large-scale algae biofuel value chain

Qatar Airways, together with Airbus, Qatar Petroleum, Qatar University Science and Technology Park and Rolls-Royce have come together as partners in the Qatar Advanced Biofuel Platform (QAPB) consortium to develop the first large-scale algae bio-jet fuel value chain in the world.

The first part of the project was a research and technology study on local micro-algae species made by Qatar University and the development of a lab-scale biofuel production facility.

Currently, the project is being developed from lab-scale to the demonstrator-scale. This part of the project will take 18 months to put in place, with a substantial multi-million dollar investment. Importantly, the CO_2 required for the algae growth is being captured from a Qatar Petroleum refinery. The chosen location for the demonstrator plant gives the possibility to scale up to commercial scale once the concept has been proven.

An important part of the project is around knowledge transfer. The knowledge gained from the project will be used by Qatar University in order to develop a bioengineering course.

The QAPB is the first large-scale production of algal feedstock to be transformed into bio-jet fuel in the world.

→ CASE STUDY

Just do it for sustainable aviation fuel: SkyNRG

Following a KLM biofuel demonstration flight in 2009, the airline joined with North Sea Group and Spring Associates to launch SkyNRG. A joint venture with a single mission to make the market for sustainable and affordable aviation fuel. Although all players believe cost will eventually decrease when technology and scale advances, the founding companies realised a 'just do it now' attitude was required to speed up this development. In this light, first commercial volumes are essential in engaging investors, governments, NGOs and customers and to accelerate a market tipping point.

To create these first volumes, SkyNRG has taken a downstream, bottom-up approach and are aggregating demand from aviation players across the world. They literally help 'make' the market by delivering a full 'feedstock to flight' proposition that will help establish green routes across the world, whilst doing everything possible to keep it affordable for the customer by smart supply and partner strategies.

On top of selling and promoting sustainable aviation fuel, SkyNRG is putting a lot of effort in guaranteeing sustainability as they believe it to be the most crucial factor in making this emerging market a success. Next to their Roundtable on Sustainable Biofuels partnership they have also installed an independent Sustainability Board consisting of leading NGO's and scientists advising on all feedstock and technology decisions.

Contacts and further reading

The aviation industry has built up significant expertise in the area of alternative fuels. If you are interested in receiving further information or researching the potential for growing a sustainable aviation biofuels industry in your own country, these organisations may be able to assist.

Airbus
www.airbus.com/innovation/future-by-airbus/alternative-fuel

Air Transport Association of America (ATA)
www.airlines.org/Environment/AlternativeFuels/Pages_Admin/AlternativeFuels.aspx

Aeropuertos y Servicios Auxiliares, an independent agency of the Mexican Government
www. asa.gob.mx/wb/webasa/asa_combustibles

Boeing
www.boeing.com/aboutus/environment/index.htm

Bombardier
www.bombardier.com/en/aerospace

CFM International
www.cfm56.com/cfm-value/environment/alternative-fuels

Commercial Aviation Alternative Fuels Initiative (CAAFI®)
www.caafi.org

Cranfield University Clean Technologies School of Engineering
www.cranfield.ac.uk/aerospace/index.html

Embraer
www.embraer.com/en-US/amb-responsability/Pages/Home.aspx

GE Aviation
www.geaviation.com

International Air Transport Association (IATA)
www.iata.org/whatwedo/environment/Pages/alternative-fuels.aspx

Honeywell UOP
www.uop.com/processing-solutions/biofuels/green-jet-fuel

Pratt & Whitney
www.pw.utc.com/vgn-ext-templating/v/index.jsp?vgnextoid=91a2d544b5ac0210VgnVCM1000004f62529fRCRD

Rolls-Royce
www.rolls-royce.com/civil/customers/fuelling_debate.jsp

Roundtable on Sustainable Biofuels
http://rsb.epfl.ch

Sustainable Aviation Fuel Users Group (SAFUG)
www.safug.org

The links below, and more, can be found at www.enviro.aero/biofuels/reference

Sustainable Aviation Fuels Northwest Project:
www.climatesolutions.org/programs/aviation-biofuels-initiative

Farm to Fly:
www.airlines.org/Energy/AlternativeFuels/Documents/farmtoFlyPresentation071410.pdf

Research and papers on aviation biofuels:
www.climatesolutions.org/programs/aviation-biofuels-initiative/safn-bibliography

Biofuel testing summary report:
www.safug.org/assets/docs/biofuel-testing-summary.pdf

Green Skies Thinking, a report looking at why aviation should be a priority user of biofuels by the UK organisation Policy Exchange:
www.policyexchange.org.uk/publications/publication.cgi?id=129

Report on the lifecycle carbon assessment of camelina:
http://onlinelibrary.wiley.com/doi/10.1002/ep.10461/full

IATA Alternative Fuels Report:
www.iata.org/ps/publications/pages/alternative-fuels.aspx

Report on the lifecycle carbon assessment of jatropha, a Yale University study conducted with funding from Boeing which undertook the first sustainability assessment of jatropha using real world field data from actual jatropha farms. The results on lifecycle carbon assessment are in this abstract:
http://pubs.acs.org/doi/full/10.1021/es1019178

Governments' Unique Role in Sustainable Aviation Biofuel:
www.safug.org/assets/docs/SAFUG_Brochure.pdf

Press report on the lifecycle carbon assessment of biofuels from halophytes:
www.thenational.ae/news/uae-news/environment/plant-seeds-could-produce-jet-fuel

Comparative carbon benefits of using biomass in aviation vs ground transport vs power generation:
www.future-science.com/doi/abs/10.4155/bfs.10.70?journalCode=bfs

American Institute of Aeronautics and Astronautics paper on a bio-SPK:
www.newairplane.com/environment/#/SustainableAviationBiofuel/SustainableBiofuel

ASAs Flight Plan for Biofuels in Mexico:
http://plandevuelo.asa.gob.mx

www.flyonbiofuels.org

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Germany charges ahead in decarbonising domestic flights with new e-fuel roadmap

By Nikolaus J. Kurmayer and Sean Goulding Carroll | EURACTIV.com May 11, 2021

One third of fuel used in domestic flights by 2030 will come from sustainable sources, according to a new German roadmap on the market ramp-up of power-to-liquid (PtL) kerosene unveiled on Friday (7 May).

The plan for increased use of sustainable aviation fuels (SAFs) aims to have an annual production of 200,000 tonnes of green kerosene by 2030.

Politicians and representatives of interest groups came together on Friday (7 May) to announce that they had come to an agreement on the German roadmap towards production of sustainable PtL kerosene, a type of electro-fuel.

"By switching to electricity-based kerosene, we can save millions of tons of CO2 emissions in aviation," said Andreas Scheuer, Germany's transport minister, adding that the PtL roadmap will further the technological leadership of German companies.

"With electricity-based kerosene based on green hydrogen, we are showing that flying and climate protection are not contradictory," added Peter Altmaier, minister of the economy and energy.

PtL kerosene is created from water, CO2, and electricity. If the electricity used stems from renewable sources, PtL kerosene is practically carbon neutral.

PtL kerosene is still far from competitive, which is why the German plan foresees a two-pronged approach of subsidising research as well as production of PtL kerosene. It furthermore envisions a demand-side opt-in programme by which the relevant industries agree to purchase certain quantities of the fuel despite the higher price point.

The German roadmap was released ahead of the publication of the ReFuelEU Aviation initiative, an EU proposal to increase the use of sustainable aviation fuels (SAFs) such as PtL across the bloc.

SAFs are seen as an efficient way to decarbonise aviation, a notoriously carbon-intensive sector, as they can be blended with kerosene without requiring changes to the aircraft engine.
They are widely supported by the aviation industry as a means to cut emissions while low-carbon jet technology, such as electric aircraft and hydrogen jets, reaches maturity.

However, SAFs have seen limited uptake to date, as the lack of supply has made them considerably more expensive than their fossil-fuel counterpart.

It is expected that the EU proposal will set a staggered mandate for the use of SAFs, obliging all aircraft refuelling at airports within the bloc to use green jet fuel. Doing so is intended to bolster the SAF market, increasing supply and dropping the cost.

A source with knowledge of ReFuelEU told EURACTIV that the proposal will likely set a SAF mandate of 2% in 2025, moving to 5% in 2030, 20% in 2035, 32% in 2040, and 63% in 2050.

A submandate for PtL is also being considered, potentially starting at 0.7% in 2030 and increasing to 25% by 2050.

The initiative, which will be published "before summer" according to EU transport commissioner Adina Vălean, will likely take the form of a regulation, meaning it will be immediately applicable across all EU countries.

The signatory parties to the German roadmap pledged to shape the development of criteria for renewable PtL kerosene at both EU level and internationally.

"Our goal is CO2-neutral flying. To achieve this goal, replacing fossil kerosene with sustainable aviation fuels is essential," said Peter Gerber, CEO of Brussels Airlines, adding that he could envision guaranteed purchasing agreements to ensure PtL kerosene makes it to market.

"Electricity-based fuels are an updraft for CO2-neutral aviation. After all, aircraft for regular air traffic cannot fly electrically for the foreseeable future," added German environment minister Svenja Schulze, who said the roadmap will improve legal certainty for airlines and encouarge investments in renewables.

Legal certainty has been something of a rare commodity for companies in Germany over the past years, with changes in the political consensus prompting arbitration proceedings, and federal court judgements overruling legislation in multiple instances.

These include struggles of companies involved in the Nord Stream 2 pipeline project, or the stagnating expansion of wind farms, upon which the PtL roadmap hinges.

[Edited by Frédéric Simon]

Use of e-fuels for aviation

Calculation made in January 2020, by Jakob Graichen, Öko-Institut Germany

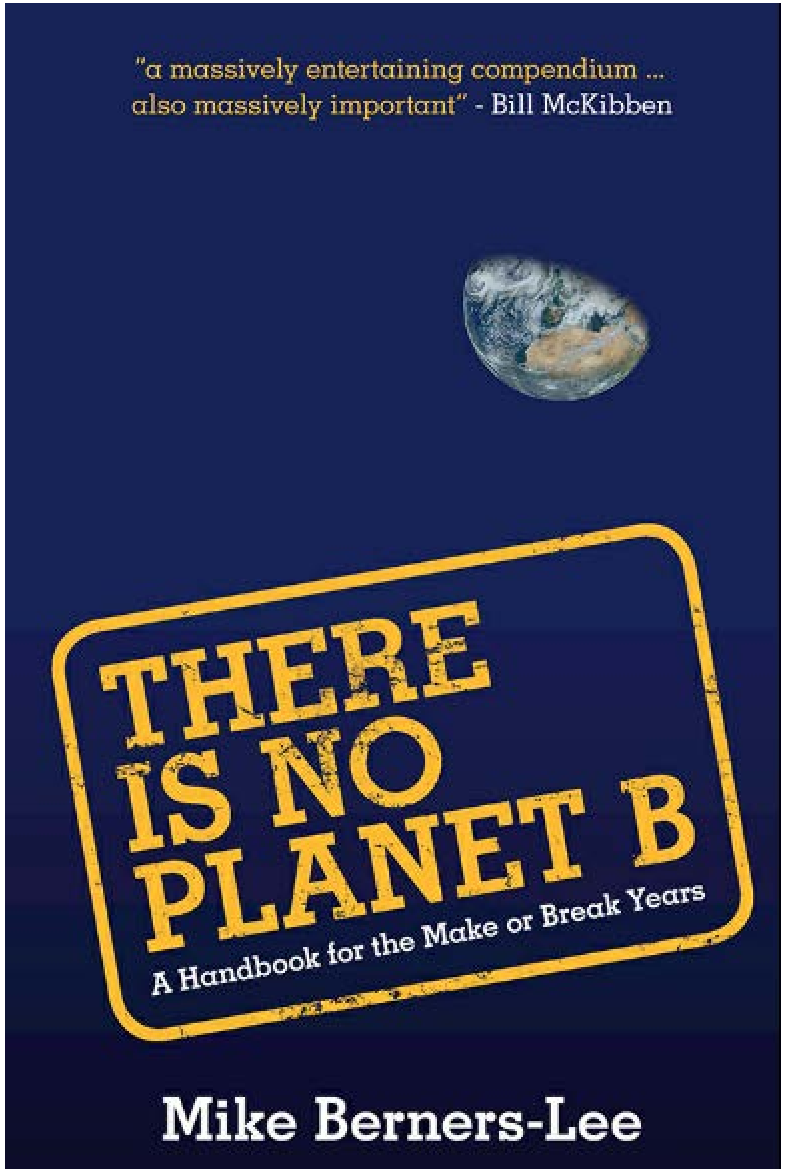
According to IRENA, the total worldwide renewable electricity production in 2017 was 22,287,413TJ (6,190,948 GWh).

When producing e-fuels through the conversion of electrical power into liquid fuel (Power to Liquid) the energy loss in the conversion is about 50 %. Which means that you need approximately 2 TJ of electrical power to produce 1 TJ of e-fuel. This is already an optimistic estimate when referring to e-kerosene. The process of making e-kerosene always produces waxes and diesel as byproducts, which is although not included in the conservative calculation.

Kerosene consumption: The IEA World Energy Outlook states global aviation CO_2 emissions of 915 Mt in 2017. Burning 1 TJ of kerosene emits 73,3 tons of CO_2. With this factor we can calculate that the aviation industry burned 12,482,947 TJ of kerosene in 2017.

Putting these numbers into perspective, this means that the worldwide renewable energy production would not be able to cover the electricity needed by the aviation sector. Even if we used the whole worldwide renewable electricity production to provide kerosene for the aviation sector, it would cover only about 90% of their energy consumption. **The aviation sector already today uses 12% more kerosene than could be produced even if we used the whole worldwide renewable electricity production.**

https://stay-grounded.org/wp-content/uploads/2020/08/Use-of-E-Fuels-for-Aviation-Calculation-Graichen-for-Stay-Grounded-2020.pdf



THERE IS NO PLANET B

A Handbook for the Make or Break Years

Mike Berners-Lee

CAMBRIDGE UNIVERSITY PRESS

THERE IS NO PLANET B

A Handbook for the Make or Break Years

Mike Berners-Lee thinks, writes, researches and consults on sustainability and responses to the challenges of the twenty-first century. He is the founder of Small World Consulting (SWC), an associate company of Lancaster University, which works with organisations from small businesses to the biggest tech giants. SWC is a leader in the field of carbon metrics, targets and actions.

About his first book – *How Bad Are Bananas? The Carbon Footprint Of Everything* – Bill Bryson wrote 'I can't remember the last time I read a book that was more fascinating, useful and enjoyable all at the same time'.

His second book (co-written with Duncan Clark) – *The Burning Question: We Can't Burn Half the World's Oil, Coal, and Gas. So How Do We Quit?* – explores the big picture of climate change and the underlying global dynamics, asking what mix of politics, economics, psychology and technology are really required to deal with the problem. Al Gore described it as 'Fascinating, important and highly recommended'.

Mike is a professor in the Institute for Social Futures at Lancaster University, where he develops practical tools for thinking about the future, and researches the global food system and carbon metrics.

What is the catch with energy efficiency?

It goes hand in hand with an even greater increase in demand for whatever the energy is used for.

In 1865 William Stanley Jevons spotted that if the UK used coal more efficiently it would end up wanting more of it, not less[27]. This phenomenon has become known as the Jevons Paradox. Energy efficiency leads, by default, to an increase in total demand, rather than the decrease that is often assumed. It applies just as widely today as it did in 1865 and it has game-changing implications for energy and climate policy. It may be counter intuitive at first but makes perfect sense on reflection. Look at it this way. Imagine if it took a tonne of coal to keep a family warm for one night and that family saves up to enjoy one warm winter evening – a New Year celebration perhaps. Now imagine that a more efficient burner is invented, and the same tonne of coal can keep them warm for two nights. Coal has just become twice as valuable to them, so they make extra effort to buy enough to keep themselves warm for three nights in the year. They might spend one of those nights fitting new insulation so that the coal becomes even more useful to them and the other night working by the fire to earn the extra money they need for their increased coal budget. However, the price of coal per tonne comes down a bit to help them because demand is going up so much and economies of scale are kicking in along with a stack of investment in new extraction technologies. And so it goes on. This is just a caricature of how the Jevons Paradox works, but I hope it demonstrates the principle.

Over the years we have become many times more efficient in our production of just about everything. LED lighting is hundreds of times more energy efficient than oil and gas lamps. Microchips are millions of times more efficient at storing data than paper and the cloud more efficient still. Electric trains are many times more efficient than steam trains, let alone horses. Yet our energy usage has risen hand in hand with those efficiencies and is actually *enabled* by them.

In fact, we can see that we don't use more energy *despite* the efficiency gains, but rather we are able to use more energy *because* of the efficiency gains. Wow! Feel free to pause at this point and reflect on the gigantic policy implications of this perspective. It means that whilst efficiency gains help us get more benefit from any given amount of energy, they also end up leading to an increase in total consumption unless that is deliberately constrained.

Just before you go ripping out all your double glazing and deflating your tyres, note that I am not saying that efficiency gains cannot be useful in the future. But I *am* saying they are no good at all on their own.

(It is only fair to write that the Jevons Paradox has been hotly debated over the years. More detail on this and why the deniers are wrong is in this endnote[28].)

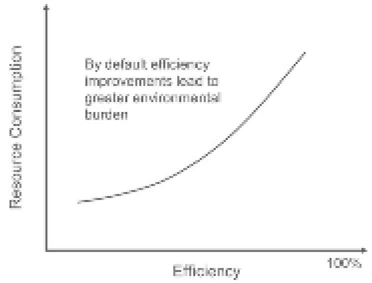


Figure 3.8. The Jevons Paradox.

Given the catch, what can efficiency do for us?

We badly need more efficiency, but we also need to learn not to squander it with increased consumption.

We have to make efficiency work for us in a different way than we are used to. From now on when we get an efficiency improvement we have to deliberately bank the savings rather than allowing the default outcome in which our consumption appetite increases and the savings are lost through a myriad of rebound effects. This is a critically different approach to adopt at the point of consumption. The way to make it work is to have a **constraint on total use of resources**, and in particular fossil fuels. When fossil fuel use is forced downwards, rebound effects will cease. The dynamic will change. Efficiency will suddenly become a force for wellbeing that will, for the first time, come without hidden, detrimental environmental consequences. Under these conditions, efficiency will be one of the key routes to having the things we need and want. Another key route is clean energy production as covered above. Later in the book we will come to a third critical route, which is to actually *want less* of some of the things that are most damaging to the world. Is that really such a mad concept? We will see.

Is the digital economy enabling a low carbon world?

A popular storyline in the ICT industry is that the efficiency gains that it makes possible throughout the world more than compensate for its own carbon footprint – and that therefore ICT brings about the low carbon world[29]. It is true that digital information storage is millions of times more efficient than paper storage. And video conferences are thousands of times more efficient than flights for face to face meetings as a result. However, it is also true that because of the increased efficiency of information storage, we now store millions and millions of times more information – as well as keeping some of our paper storage. And whilst a video conference sometimes saves a flight it also sometimes marks the start of a relationship that *leads* to a flight that would otherwise not have happened. In the absence of a global carbon cap, an infinite number of rebound pathways eliminate any carbon benefits from efficiency savings. ICT enables more efficient logistics – leading, through rebound to an even greater rise in transportation.

So the ICT industry's claim that it brings about efficiency improvements is true. This does makes a carbon cap easier to achieve without sacrificing quality of life. However, unless that industry pushes hard for that cap, it cannot claim to be enabling the low carbon world – quite the opposite in fact.

Now we've seen enough about energy dynamics to be able to look at what it might actually take to cut global emissions.

Why is cleaning our electricity just the easy part of the transition from fossil fuels?

Electricity from renewables can replace two and a half times the same energy in coal or oil going into a power station. Replacing heat sources is harder.

Different kinds of energy are useful for different things, but transferring from one type to another almost always incurs losses. In particular, to get electricity from oil or coal entails putting it through steam turbines at a power station where over 60% of the energy dissipates as heat that is usually not used for anything and less than 40% is turned into electricity[30]. Solar, wind and hydro power don't have this problem because they are in the form of electricity from the start. This means that if it is electricity that you need, a kilowatt hour of any of these is worth about two and a half kilowatt hours of coal or oil. This mark-up factor gives renewables a huge boost in the early stages of the clean energy transition.

A similar mark-up also applies to land vehicles for almost the same reason. The efficiency of electric motors compared to internal combustion engines means that a unit of electricity can power a car two or three times further than the same energy in the form of liquid hydrocarbon.

However, once we get to the point at which all our electricity is already coming from renewable sources, and all our transport has been electrified, we start having to use renewables to replace fossil fuel as a source of heat. At this point, they suddenly lose their mark-up advantage because a unit of electricity can heat a home or a blast furnace no more than the same energy in the form of coal, oil or gas. At this point the transition gets a lot tougher. When we hear anyone talking about the percentage contribution of renewable energy sources, we need to be very clear about whether it is the percentage in the whole energy mix or whether they are looking at just the easy bit; the electricity mix.

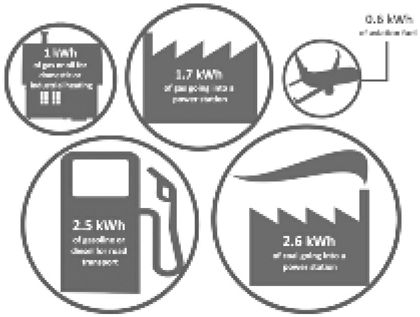


Figure 3.9. The amount of fossil fuel that 1 kWh (kilowatt hour) of renewable electricity can replace depends greatly on what we want to use it for. (The circles are to scale by area.)

The final crunch in the clean energy transition comes when we start having to use renewable energy for things, like aviation, which currently require liquid hydrocarbons. If we have to produce liquid hydrocarbon from renewables we probably have to apply a mark-*down* factor of about 0.6. In other words, it takes about 2 kWh of solar electricity to produce just 1kWh of aviation fuel.

How much fossil fuel can a kWh of renewable electricity replace?

2.6 kWh of coal going into a power station
1.7 kWh of gas going into a power station
2.5 kWh of gasoline or diesel for road transport
1 kWh of gas or oil for domestic or industrial heating
0.6 kWh of aviation fuel

APPENDIX 19

Introduction to CORSIA

By ICAO Secretariat

Addressing climate change requires cooperation among all States to reduce the impact of greenhouse gas emissions on the global climate. The international civil aviation sector plays a key role in the global efforts to address climate change. While it presently accounts for about 1.3% of the global CO_2 emissions, its contribution is projected to increase in the coming decades as the world becomes more connected. ICAO and its Member States have recognized the impact of the emissions from international aviation on the global climate, and have resolved to minimize this impact, while ensuring the sustainable growth of international aviation.

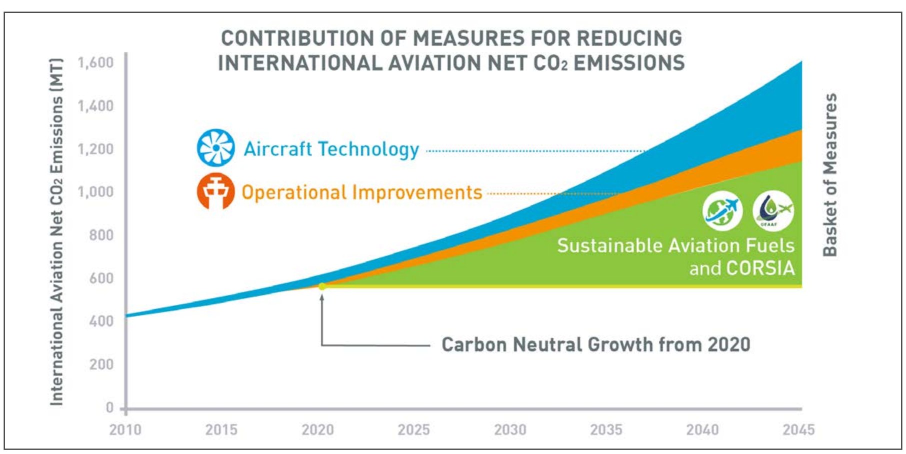
In 2010, the 37th Session of the ICAO Assembly adopted two aspirational goals: i) to improve energy efficiency by 2 per cent per year until 2050, and ii) to achieve carbon neutral growth from 2020 onwards. These goals are to be met with the implementation of a basket of measures that includes technological innovations, operational improvements, sustainable aviation fuels, and market based measures.

Since the 2010 Assembly which requested the Council to explore the feasibility of a global market-based measure scheme for international aviation, various options for such a global scheme were discussed and analyzed by the Council and experts around the world, in light of key principles such as environmental integrity, cost effectiveness, and simplicity of such a scheme. Following the important milestone at the 2013 Assembly, which decided to develop a global market-based measure for international aviation, further discussions on its design features and implementation mechanisms were undertaken, including possible means to address special circumstances and respective capabilities of States.

At the 39th Session of the ICAO Assembly in 2016, States finally adopted a global market-based measure scheme for international aviation, in the form of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), to address the increase in total CO_2 emissions from international aviation above the 2020 levels (Assembly Resolution A39-3).

CORSIA is the first global market-based measure for any sector and represents a cooperative approach that moves away from a "patchwork" of national or regional regulatory initiatives through the implementation of a global scheme that has been developed through global consensus among governments, industry, and international organizations. It offers a harmonized way to reduce emissions from international aviation ensuring that there is no market

FIGURE 1: ICAO Global Environmental Trends on CO_2 Emissions and Contribution of Measures for Reducing International Aviation Net CO_2 Emissions



distortion, while respecting the special circumstances and respective capabilities of ICAO Member States.

CORSIA complements the other elements of the basket of measures by offsetting the amount of CO_2 emissions that cannot be reduced through the use of technological improvements, operational improvements, and sustainable aviation fuels (Figure 1) with emissions units from the carbon market. It is estimated that between 2021 and 2035, the international aviation sector would have to offset about 2.5 billion tonnes of CO_2 emissions to achieve carbon neutral growth.

HOW CORSIA WORKS

CORSIA will be implemented in three phases: a pilot phase from 2021 through 2023, a first phase from 2024 through 2026, and a second phase from 2027 through 2035. For the first two phases (2021 to 2026), participation is voluntary. As of June 2019, 80 States – representing 76.63% of international aviation Revenue Tonne-Kilometres (RTKs) – have announced their intention to participate in the CORSIA from its outset. From 2027 onwards, participation will be determined based on 2018 RTK data. Specifically, CORSIA will cover all States with an individual share of 2018 RTKs higher than 0.5 per cent of total RTKs or whose cumulative share in the list of States from the highest to the lowest amount of RTKs reaches 90 per cent of total RTKs. According to Assembly Resolution A39-3, Least Developed Countries (LDCs), Small Island Developing States (SIDS) and Landlocked Developing Countries (LLDCs) are exempt from participation (even if they fulfill these RTK conditions), but they can participate in the Scheme on a voluntary basis.

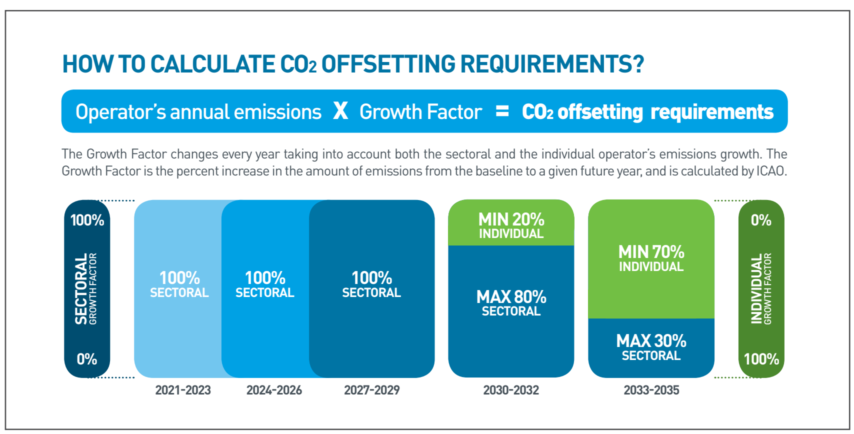
To eliminate market distortion, emissions coverage under CORSIA is based on a route-based approach. This means that emissions from **all** aeroplane operators performing international flights between two States where both the origin and destination States participate in CORSIA are covered by the offsetting requirements of the Scheme. In contrast, emissions from international flights between two States where the origin and/or destination States do not participate in CORSIA are excluded from the offsetting requirements of the Scheme. The route-based approach ensures that all aeroplane operators with flights on the same international routes are treated equally irrespective of whether the States to which they are attributed participate in CORSIA. According to Assembly Resolution A39-3, exemptions also apply to aeroplane operators with less than 10 000 tonnes of annual CO_2 emissions, to aeroplanes with less than 5 700kg take-off weight, and to humanitarian, medical and firefighting operations.

Once participating States and routes covered by the CORSIA are defined (starting in 2021), the amount of CO_2 offsetting requirements for individual aircraft operators is calculated, as follows (see Figure 2):

a) from 2021 through 2029, the amount of CO_2 offsetting requirements is calculated by multiplying the operators' annual emissions with the international aviation sector's growth factor every year, following a so-called 100 per cent sectoral approach; and
b) from 2030 onwards, the amount of CO_2 offsetting requirements is calculated taking into account both the sector's growth factor and the growth factor of an individual operator; the individual factor's contribution to the calculation will be at least 20 per cent from 2030 to 2032; and at least 70 per cent from 2033 to 2035.

Starting in 2022, CORSIA will be periodically reviewed, every three years, by the Council. The review will include, among other features, the assessment of its impact on

FIGURE 2: Calculation of offsetting requirements under CORSIA



the growth of international aviation, and the results of this assessment will serve as an important basis for the Council to recommend, as appropriate, adjustments to the scheme for the consideration by the Assembly.

CORSIA IMPLEMENTATION

The success of the implementation of CORSIA relies on the establishment of a robust and transparent monitoring, reporting and verification (MRV) system, which includes procedures on how to monitor the fuel use, collect data and calculate CO_2 emissions; report CO_2 emissions data; and verify CO_2 emissions data to ensure accuracy and avoid mistakes.

At the request of the 39th ICAO Assembly in 2016, the Council requested the Committee on Aviation Environmental Protection (CAEP), to develop Standards and Recommended Practices (SARPs) and related guidance material to facilitate the implementation of the MRV system under the CORSIA. Part of the CAEP work included the development of criteria for the eligibility of emissions units that are to be purchased and cancelled by aeroplane operators for the purposes of the Scheme.

In fact the implementation of CORSIA required a "package" of CORSIA-related SARPs and guidance which comprise of three distinct but interrelated components:

a) Annex 16, Volume IV, which provides the required actions by States and aeroplane operators (the "what" and "when") to implement CORSIA;
b) Environmental Technical Manual (Doc 9501), Volume IV, which provides the guidance on the process (the "how") to implement CORSIA; and
c) Five CORSIA Implementation Elements, which are reflected in 14 ICAO documents and are approved by the Council prior to their publication. These ICAO documents are directly referenced in Annex 16, Volume IV and are essential for the implementation of CORSIA.

The Council adopted the First Edition of Annex 16, Volume IV in June 2018. Following its adoption, the First Edition of Annex 16, Volume IV became applicable on 1 January 2019.

The First Edition of the Environmental Technical Manual (Doc 9501), Volume IV was issued under the authority of the ICAO Secretary General in August 2018. This manual will be periodically revised to make the most recent information available to administrating authorities, aeroplane operators, verification bodies and other interested parties in a timely manner, aiming at achieving the highest degree of harmonisation possible.

The ICAO Council has been undertaking work, with the contribution of the CAEP, on the development of the five CORSIA Implementation Elements, namely:

- **CORSIA States for Chapter 3 State Pairs** is the list of States participating in CORSIA and will be used to define route-based emissions coverage every year from 2021 onwards;
- **ICAO CORSIA CO_2 Estimation and Reporting Tool (CERT)** aims to simplify the estimation and reporting of CO_2 emissions from international flights for those operators with low levels of activity to fulfil their monitoring and reporting requirements under CORSIA (for more details, see the dedicated article in this chapter);
- **CORSIA Eligible Fuels** cover aviation fuels used for the purposes of CORSIA to reduce the offsetting requirements of aeroplane operators (for more details, see the dedicated article in this chapter);
- **CORSIA Eligible Emissions Units** are emissions units from the carbon market that can be purchased by aeroplane operators to fulfill the offsetting requirements under CORSIA (for more details, see the dedicated article in this chapter); and
- **CORSIA Central Registry (CCR)** is an information management system that will allow the input and storage of CORSIA-relevant information reported by States, as well as calculations and reporting by ICAO, in accordance with the CORSIA MRV requirements as contained in the Annex 16, Volume IV (for more details, see the dedicated article in this chapter).

In June 2018, to ensure that *No Country is Left Behind*, the Council endorsed the ICAO ACT-CORSIA (Assistance, Capacity-building and Training for the CORSIA) Programme, emphasizing the importance of a coordinated approach under ICAO to harmonize and bring together all relevant actions and promote coherence to capacity building efforts related to CORSIA implementation.

By the end of June 2019, CORSIA buddy partnerships under ACT-CORSIA had been established, involving 15 donor States and 98 recipient States. For more details on ACT-CORSIA see the dedicated article in this chapter.

CONCLUSIONS

CORSIA offers a success story of firsts: the first sector-wide carbon offsetting programme; the first such programme to tackle emissions from a single industry on a global level; the first time international aviation will experience carbon neutral growth; the first global partnership to help build capacity on CORSIA in all countries of the world. But being first also comes with great challenges that the Organization was able to address with the support of its Members States, industry, other actors and society as a whole.

While ICAO celebrates its successes over the last 75 years, it also acknowledges the challenges ahead. Starting in 2019, ICAO and its Member States are working together to implement the first stages of CORSIA focusing on ensuring that States have in place the necessary regulatory frameworks to facilitate the smooth implementation of CORSIA. More activities are scheduled and will continue over the coming years and decades. The international aviation sector is ready to tackle the future challenges and ensure that international flights are going to be built on a much greener foundation, but this will only be possible with the cooperation and support of all stakeholders involved.

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APPENDIX 20

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Institute for Applied Ecology

How additional is the Clean Development Mechanism?

Analysis of the application of current tools and proposed alternatives

Berlin,
March 2016

Study prepared for DG CLIMA

Reference: CLIMA.B.3/SERI2013/0026r

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Contents

List of boxes

List of figures

List of tables

Abbreviations

CAR	Climate Action Reserve
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFL	Compact Fluorescent Lamp
CO_2	Carbon Dioxide
CORSIA	Carbon Offset and Reduction Scheme for International Aviation
CP	Crediting Period
CPA	Component Project Activity of a PoA
DOE	Designated Operational Entity
EB	Executive Board of the CDM
ETS	Emissions Trading Scheme/System
f_{NRB}	Fraction of non-renewable biomass
GHG	Greenhouse Gas
GS	Gold Standard
JCM	Joint Crediting Mechanism
LED	Light Emitting Diode
MP	Methodologies Panel under the CDM EB
MRV	Monitoring, Reporting & Verification
NDC	Nationally Determined Contribution
NRB	Non-renewable Biomass
OECD	Organisation for Economic Co-operation and Development
PDD	Project Design Document
PMR	Partnership for Market Readiness (Initiative of the World Bank)
PoA	Programme of Activities
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VCS	Verified Carbon Standard

Executive summary

With the adoption of the Paris Agreement, which establishes a mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development (Article 6.4), it is clear that the Clean Development Mechanism (CDM) as a mechanism of the Kyoto Protocol will end. However, in terms of its standards, procedures and institutional arrangements, the CDM certainly forms an important basis for the elaboration and design of future international crediting mechanisms.

While this study provides important insights to **improve the CDM up to 2020**, the approach taken in this study could **also be applied more generally both to assess the environmental integrity of other compliance offset mechanisms**, as well as to avoid flaws in the design of new mechanisms being used or established for compliance. Many of the shortcomings identified in this study are inherent to crediting mechanisms in general, not least the considerable uncertainty involved in the assessment of additionality and the information asymmetry between project developers and regulators.

A fundamental feature of both the CDM and the mechanism under Article 6.4 is that they aim to achieve environmental integrity by ensuring that only real, measurable and additional emission reductions are generated. This study analyzes the opportunities and limits of the current CDM framework for ensuring environmental integrity, i.e. that projects are additional and that emission reductions are not overestimated. It looks at the way in which the CDM framework has evolved over time, assesses the likelihood that emission reductions credited under the CDM ensure environmental integrity and provides findings on the overall and project-type-specific environmental integrity of the CDM. In addition, it provides lessons learned and recommendations for improving additionality assessment that can be applied to crediting mechanisms generally, including to mechanisms to be used for compliance under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), and to mechanisms to be implemented under Article 6 of the Paris Agreement.

To ensure robust judgements, we have systematically analyzed the determination of additionality, the determination of baseline emissions and other issues that are key for environmental integrity. Towards this goal, we have evaluated those general CDM rules that are particularly relevant for environmental integrity and assessed in the case of specific project types the likelihood that they deliver real, measurable and additional emission reductions. Based on our analysis **key findings** include the following:

- Most **energy-related project types** (wind, hydro, waste heat recovery, fossil fuel switch and efficient lighting) are **unlikely to be additional**, irrespective of whether they involve the increase of renewable energy, energy efficiency improvements or fossil fuel switch.
- **Industrial gas projects** (HFC-23, adipic acid, nitric acid) are **likely to be additional** as long as the mitigation is not otherwise promoted or mandated through policies.
- **Methane projects** (landfill gas, coal mine methane) have a **high likelihood of being additional**.
- **Biomass power projects** have a **medium likelihood of being additional** overall because the assessment of additionality very much depends on the local conditions of individual projects.
- The additionality of the current pipeline of **efficient lighting projects** using small-scale methodologies is **highly unlikely** because in many host countries the move away from incandescent bulbs is well underway.

- In the case of **cook stove projects**, CDM revenues are often insufficient to cover the project costs and to make the project economically viable. Cook stove projects are also likely to considerably **over-estimate the emission reductions** due to a number of unrealistic assumptions and default values.

Overall, our results suggest that 85% of the projects covered in this analysis and 73% of the potential 2013-2020 Certified Emissions Reduction (CER) supply have a low likelihood that emission reductions are additional and are not over-estimated. Only 2% of the projects and 7% of potential CER supply have a high likelihood of ensuring that emission reductions are additional and are not over-estimated.

Our analysis suggests that the **CDM still has fundamental flaws in terms of overall environmental integrity**. It is likely that the large majority of the projects registered and CERs issued under the CDM are not providing real, measurable and additional emission reductions.

When considering the Paris Framework, the most important change from the Kyoto architecture is that all countries have made mitigation pledges in the form of Nationally Determined Contributions (NDC). An important implication is that host countries with ambitious and economy-wide mitigation pledges have **incentives to limit international transfers of credits** to activities with a **high likelihood of delivering additional emission reductions**, so that transferred credits do not compromise the host country's ability to reach their own mitigation targets. A second important implication is that countries should **only transfer emission reductions where this is consistent with their NDC**, implying that baselines may have to be determined in relation to the host country's mitigation pledges rather than using a 'counterfactual' business as usual scenario as a default.

Taking into account this context and the findings of our analysis, we recommend that the role of crediting in future climate policy should be revisited:

- We recommend potential buyers of CERs to limit any **purchase of CERs** to either **existing projects which risk discontinuing GHG abatement** when the incentive from the CDM ceases, such as landfill gas flaring or to new **projects among** the few project types identified t**hat have a high likelihood of ensuring environmental integrity**.

- Buyers should **accompany purchase of CERs with support for a transition of host countries to broader and more effective climate policies**. In the short–term, where offsetting is used, it should only be on the basis that purchase of CERs does not undermine the ability of host countries to achieve their mitigation pledges.

- Given the inherent shortcomings of crediting mechanisms, we recommend focusing **climate mitigation efforts** on forms of carbon pricing **that do not rely extensively on credits** and on measures such as results-based climate finance that does not result in the transfer of credits or offsetting the purchasing country's emissions. International crediting mechanisms should play a limited role after 2020, to address specific emission sources in countries that do not have the capacity to implement alternative climate policies.

- To enhance the environmental integrity of international crediting mechanisms such as the CDM and to make them more attractive to both buyers and host countries with ambitious NDCs, we recommend limiting such mechanisms to **project types** that have a **high likelihood of delivering additional emission reductions**. We also recommend reviewing methodologies systematically to address risks of over-crediting, as identified in this report.

- We also recommend provisions that provide strong incentives to the Parties involved to ensure the integrity of international unit transfers. This includes robust accounting provisions to **avoid double counting** of emission reductions, but could also extend to other elements, such as implementation of **ambitious mitigation pledges** as a prerequisite to participating in international mechanisms.

With the adoption of the Paris Agreement, implementing more effective climate policies becomes key to bringing down emissions quickly on a pathway consistent with well below 2°C. Our findings suggest that **crediting approaches** should play a **time-limited and niche role** focusing on those project types for which additionality can be relatively assured. Crediting should serve as a stepping-stone to other, more effective policies to achieve cost-effective mitigation. Continued support to developing countries will be key. We recommend using new innovative sources of climate finance, such as revenues from auctioning of emission trading scheme allowances, rather than crediting for compliance, to support developing countries in implementing their NDCs.

Summary

Aim of the study

With the adoption of the Paris Agreement, which establishes a mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development (Article 6.4), it is clear that the role of the CDM as a mechanism of the Kyoto Protocol will end. However, in terms of its standards, procedures and institutional arrangements, the **CDM** certainly forms an **important basis** for the elaboration and design of future mechanisms for international carbon markets. One key feature of both the CDM and the mechanism under Article 6.4 is that they should generate **real and additional** emission reductions. In other words, emission reductions that are credited and transferred should not have occurred in the absence of the mechanism and should not be overestimated. This study analyzes the opportunities and limits of the current CDM framework and the way in which it has evolved over time and been applied to concrete projects. It provides findings on the **overall and project-type-specific environmental performance of the CDM** in the form of estimates of the **likelihood that the CDM results in real and additional emission reductions**. In addition, it provides lessons and recommendations for improving additionality assessment that can be applied to future crediting mechanisms.

Methodological approach

The main focus of this study is to assess the extent to which the CDM meets its objective to deliver “real, measurable and additional” emission reductions. In order make well-founded judgements about the overall and project-type-specific likelihood of additionality of CDM projects, we systematically analyze CDM rules and how they have been applied to real projects in practice. We examined the rules for 1) **additionality assessment**, for 2) the **determination of baseline emissions** and 3) a number of **other issues** including the length of crediting period, leakage effects, perverse incentives, double counting, non-permanence, monitoring provisions and third party validation and verification. We approach these aspects from two different perspectives: we evaluate 1) **general CDM rules** that are particularly relevant for the delivery of real, measurable and additional emission reductions and we evaluate 2) **specific project types** with a view to assessing how likely these project types deliver additional emission reductions. To assess the impacts of our analysis, we further estimate the **potential 2013-2020 CER supply** from different project types.

Project-types-specific results

Table 1-1 (p. 13) below provides an overview of the findings on environmental integrity based on the detailed analysis of individual project types. **Most energy-related project types** (wind, hydro, waste heat recovery, fossil fuel switch and efficient lighting) are **unlikely to be additional**, irrespectively of whether they involve the increase of renewable energy, efficiency improvements or

fossil fuel switch. An important reason why these projects types are unlikely to be additional is that the revenue from the CDM for these project types is small compared to the investment costs and other cost or revenue streams, even if the CER prices would be much higher than today. Moreover, many projects are economically attractive, partially due to cost savings from project implementation (e.g. fossil fuel switch, waste heat recovery) or domestic support schemes (renewable power generation).

Table 1-1: How additional is the CDM?

	CDM projects			Potential CER supply 2013 to 2020		
	Low	Medium	High	Low	Medium	High
	… likelihood of emission reductions being real, measurable, additional					
	No. of projects			Mt CO_2e		
HFC-23 abatement from HCFC-22 production						
Version <6		5			191	
Verson >5			14			184
Adipic acid		4			257	
Nitric acid			97			175
Wind power	2.362			1.397		
Hydro power	2.010			1.669		
Biomass power		342			162	
Landfill gas		284			163	
Coal mine methane		83			170	
Waste heat recovery	277			222		
Fossil fuel switch	96			232		
Cook stoves	38			2		
Efficient lighting						
AMS II.C, AMS II.J	43			4		
AM0046, AM0113			0			0
Total	**4.826**	**718**	**111**	**3.527**	**943**	**359**

Sources: Authors' own calculations

Industrial gas projects (HFC-23, adipic acid, nitric acid) can generally be considered **likely to be additional** as long as they are not promoted or mandated through policies. They use end-of-pipe-technology to abate emissions and do not generate significant revenues other than CERs. HFC-23 and adipic acid projects triggered strong criticism because of their relatively low abatement costs, which provided perverse incentives and generated huge profits for plant operators. In the case of HFC-23 and nitric acid projects, perverse incentives have been adequately addressed. With regard to **adipic acid** projects, the risks for **carbon leakage have not yet been addressed**.

Methane projects (landfill gas, coal mine methane) also have a **high likelihood of being additional**. This is mainly because carbon revenues have, due to the GWP of methane, a relatively large impact on the profitability of these project types. However, both project types face **issues with regard to baseline emissions and perverse incentives** and may thus lead to over-crediting.

Biomass power projects have a **medium likelihood of being additional** since their additionality very much depends on the local conditions of individual projects. In some cases, biomass power can already be competitive with fossil generation while in other cases domestic support schemes provide incentives for increased use of biomass in electricity generation. However, where these conditions are not prevalent, projects **can be additional**, particularly if CER revenues for **methane avoidance can be claimed**. Biomass projects also face other issues, in particular with regard to demonstrating that the **biomass used is renewable**.

The additionality of **efficient lighting** projects using small-scale methodologies is **highly problematic** because there were large PoAs in countries in which the move away from incandescent bulbs was well underway. The **new methodologies** address these problems but they are **not mandatory** and the small-scale methodologies are, while the remaining small-scale methodology could still allow for automatic additionality for CFL programmes.

For **cook stove** projects, CDM revenues are often insufficient to cover the project costs and to make the project economically viable. Particularly in urban areas, the additionality of these project types is questionable. Cook stove projects are also likely to considerably over-estimate the emission reductions due to a number of unrealistic assumptions and default values.

Overall environmental assessment

Based on these considerations, we estimate that **85% of the covered projects and 73% of the potential 2013-2020 CER supply have a low likelihood** of ensuring environmental integrity (i.e. ensuring that emission reductions are additional and not over-estimated). Only **2% of the projects and 7% of potential CER supply have a high likelihood** of ensuring environmental integrity. The remainder, 13% of the projects and 20% of the potential CER supply, involve a medium likelihood of ensuring environmental integrity (Table 1-1, p. 13).

Compared to earlier assessments of the environmental integrity of the CDM, our analysis suggests that the CDM's **performance as a whole has anything but improved**, despite improvements of a number of CDM standards. The main reason for this is a **shift in the project portfolio towards projects with more questionable additionality**. In 2007, CERs from projects that do not have revenues other than CERs made up about two third of the project portfolio, whereas the 2013-2020 CER supply potential of these project types is only less than a quarter. A second reason is that the **CDM Executive Board (EB)** has not only improved rules but also **made simplifications** that undermined the integrity. For example, positive lists have been introduced for many technologies, for some of which the additionality is questionable and some of which are promoted or required by policies and regulations in some regions (e.g. efficient lighting). A third reason is that the **CDM EB** did not take effective means to **exclude project types** with a low likelihood of additionality. While positive lists have been introduced, project types with more questionable additionality have not been excluded from the CDM. Standardized baselines provide a further avenue to demonstrating additionality but do not reduce the number of projects wrongly claiming additionality. The improvements to the CDM mainly aimed at **simplifying requirements and reducing the number of false negatives** but did not address the false positives.

The result of our analysis therefore suggests that the **CDM has still fundamental flaws in terms of environmental integrity**. It is likely that the large majority of the projects registered and CER issued under the CDM are not providing real, measureable and additional emission reductions. Therefore, the experiences gathered so far with the CDM should be used to improve both the CDM rules for the remaining years and to avoid flaws in the design of new market mechanisms being established under the UNFCCC.

Recommendations for improving general additionality rules

For an additionality test to function effectively, it must be able to assess, with high confidence, whether the CDM was the deciding factor for the project investment. However, additionality tests can never fully avoid wrong conclusions. **Information asymmetry** between project developers and regulators, combined with the economic incentives for project developers to have their project recognised as additional, are a major challenge. We carefully scrutinised the **four main approaches** used to determine additionality. Our analysis shows that **prior consideration** is a necessary and important but not sufficient step for ensuring additionality of CDM projects and that this step largely works as intended. The subjective nature of the **investment analysis** limits its ability to assess with high confidence whether a project is additional. Especially for project types in which the financial impact of CERs is relatively small compared to variations in other parameters, such as large power projects, doubts remain as to whether investment analysis can provide a strong 'signal to noise' ratio. The **barrier analysis** has lost importance as a stand-alone approach of demonstrating additionality. Non-monetized barriers remain subjective and are often difficult to verify by the DOEs. In general, the **common practice analysis** can be considered a more objective approach than the barriers or investment analysis due to the fact that information on the sector as a whole is considered rather than specific information of a project only. However, the way in which common practice is currently assessed needs to be substantially reformed to provide a reasonable means of demonstrating additionality; it is important to reflect that market penetration is not for all project types a good proxy for the likelihood of additionality.

Against this background, we recommend that the **common practice analysis** is given a **more prominent role in additionality determination** though only after a significant reform:

- The 'one-size-fits-all' approach of determining common practice should be replaced by **sector- or project-type-specific guidance**, particularly with regard to distinguishing between different and similar technologies and with regard to the threshold for market penetration.
- The **technological potential** of a certain technology should also be taken into account in order to avoid that a project is deemed additional although the technological potential is already largely exploited in the respective country.
- The common practice analysis should at least cover the **entire country**. However, if the absolute number of activities in the host country does not ensure statistical confidence, the scope needs to be extended to other countries.
- As a default, all CDM projects should be included in the common practice analysis, unless a methodology includes different requirements.

We further recommend that the **investment analysis** is excluded as an approach for demonstrating additionality for projects types in which the 'signal to noise' ratio is insufficient to determine additionality with the required confidence. For those project types in which the investment analysis would still be eligible, the project participant must confirm the all information is true and accurate and that the investment analysis is consistent with the one presented to debt or equity funders. The **barrier analysis** should be abolished entirely as a separate approach in the determination of additionality at project level (though it may be used for determining additionality of project types). Barriers that can be monetized should be addressed in the investment analysis while all other barriers should be addressed in the context of the reformed common practice analysis.

In addition, we recommend improvements to key general CDM rules:

- **Renewal and length of crediting periods:** At the renewal of the crediting period the validity of the baseline scenario should be assessed for CDM project types for which the baseline is the 'continuation of the current practice' or if changes such as retrofits could also be implemented in the baseline scenario at a later stage. Crediting periods of project types or sectors that are highly dynamic or complex should be limited to one single crediting period. Moreover, generally abolishing the renewal of crediting periods while allowing a somewhat longer single crediting period for project types that require a continuous stream of CER revenues to continue operation may be considered.
- **Positive Lists:** The review of validity should also be extended to project types covered by the microscale additionality tool. In addition, positive lists must address the impact of na-

tional policies and measures to support low emission technologies (so-called E- policies). To maintain environmental integrity of the CDM overall, positive lists should be accompanied by negative lists.

- **Standardized baselines:** Once established in a country, their use should be made mandatory and all CDM facilities should be included in the peer group used for the establishment of standardized baselines.

- **Consideration of domestic policies (E+/E-):** The risk of undermining environmental integrity by over-crediting emission reductions is likely to be larger than the creation of perverse incentives for not establishing E- policies. Therefore, adopted policies and regulations reducing GHG emissions (E-) should be included when setting or reviewing crediting baselines while policies that increase GHG emissions (E+) should be discouraged by being excluded from the crediting baseline where possible.

- **Suppressed demand:** An expert process should be established to balance the risks of over-crediting with the potential increased development benefits. In addition, the application of suppressed demand could be restricted to countries where development needs are highest and the potential for over-crediting is the smallest.

Recommendations to improve project type specific rules

Industrial gas projects: Adipic acid production is a highly globalised industry and all plants are very similar in structure and technology. Therefore, a global benchmark of 30 kg/t applied to all plants would prevent carbon leakage, considerably reduce rents for plant operators, and allow the methodology to be simplified by eliminating the calculation of the N_2O formation rate. After issues related to perverse incentives have been successfully addressed through ambitious benchmarks, **HFC-23** and **nitric acid** projects would provide for a high degree of environmental integrity. However, industrial gas projects provide for low-cost mitigation options. These emission sources could therefore also be addressed through domestic policies, such as regulations, or by including the emission sources in domestic or regional ETS, and help countries achieve their Nationally Determined Contributions (NDCs) under the Paris Agreement. Parties to the Montreal Protocol are also considering regulating HFC emissions. We therefore recommend that HFC-23 projects are not eligible under the CDM.

Energy-related project types: We recommend **that these project types should, in principle, no longer be eligible** under the CDM. However, in least developed countries, some project types, particularly wind and small-scale hydropower plants, may still face considerable technological and/or cost barriers. These project types may thus remain **eligible in least developed countries**. In cases in which **biomass power generation** is not competitive with fossil generation technologies, CER revenues can have a significant impact on the profitability of a project, particularly if credits for methane avoidance are claimed as well. We therefore recommend that only biomass power projects avoiding methane emissions remain eligible under the CDM, provided that the corresponding provisions in the applicable methodologies are revised appropriately.

With regard to **demand-side energy efficiency** project types with distributed sources – **cook stoves** and **efficient lighting** – we have identified concerns which question their overall environmental integrity. However, if cook stove methodologies were revised considerably, including more appropriate values for the fraction of non-renewable biomass and if approaches for determining the penetration rate of efficient lighting technologies were made mandatory for all new projects and CPAs while the older methodologies are withdrawn, we recommend that these project types should remain eligible.

Methane projects: Landfill gas and **coal mine methane** projects are likely to be additional. However, there are concerns in terms of over-crediting, which should be addressed through improvements of the respective methodologies, particularly by introducing region-specific soil oxidations factors and requesting DOEs to verify that landfilling practices are not changed. With regard to landfill gas, we recommend that this project type only be eligible in countries that have policies in place to transition to more sustainable waste management practices.

Implication for the future use of international carbon markets

The **CDM has provided many benefits**. It has brought innovative technologies and financial transfers to developing countries, helped identify untapped mitigation opportunities, contributed to technology transfer, may have facilitated leapfrogging the establishment of extensive fossil energy infrastructures and created knowledge, institutions, and infrastructure that can facilitate further action on climate change. Some projects provided significant sustainable development co-benefits. Despite these benefits, after well over a decade of gathering considerable experience, the **enduring limitations** of GHG crediting mechanisms are apparent.

Firstly and most notably, the **elusiveness of additionality** for all but a limited set of project types is very difficult, if not impossible, to address. Information asymmetry between project participants and regulators remains a considerable challenge. This challenge is **difficult to address through improvements of rules**. Secondly, international crediting mechanisms involve an **inherent and unsolvable dilemma**: either they might create **perverse incentives for policy makers** in host countries not to implement policies or regulations to address GHG emissions – since this would reduce the potential for international crediting – or they **credit activities that are not additional** because they are implemented due to policies or regulations. Thirdly, for many project types, the **uncertainty of emission reductions** is considerable. Our analysis shows that risks for over-crediting or perverse incentives for project owners to inflate emission reductions have only partially been addressed. It is also highly uncertain for how long projects will reduce emissions, as they might anyhow be implemented at a later stage without incentives from a crediting mechanism – an issue that is not addressed at all under current CDM rules. A further overarching shortcoming of crediting mechanisms is that they do **not make all polluters pay but rather they make them subsidize the reduction of emissions**. Most of these shortcomings are inherent to using crediting mechanisms, which **questions the effectiveness of international crediting mechanisms as a key policy tool** for climate mitigation.

The future role of crediting mechanisms should therefore be revisited in the light of the Paris Agreement. Several **elements of the CDM could be used** when implementing the mechanism established under Article 6.4 of the Paris Agreement or when implementing (bilateral) crediting mechanisms under Article 6.2. However, the context for using crediting mechanisms has fundamentally changed. The most important change to the Kyoto architecture is that all countries have to submit NDCs that include mitigation pledges or actions. The Paris Agreement therefore requires countries to **adjust their reported GHG emissions** for international transfers of mitigation outcomes, in order to **avoid double counting** of emission reductions. This implies that the baseline, and therefore additionality, may be determined in relation to the mitigation pledges rather than using a ‘counterfactual’ scenario as under the CDM, and that countries could only transfer emission reductions that were beyond what they had pledged under their NDC. A second important implication relates to the incentives for host countries to ensure integrity. Host countries with ambitious and economy-wide mitigation pledges would have incentives to ensure that international transfers of credits are limited to activities with a high likelihood of delivering additional emission reductions. However, our analysis showed that only a few project types in the current CDM project portfolio have a high likelihood of providing additional emission reductions, whereas the environmental integrity is questionable and uncertain for most project types. In combination, this suggests that the future supply of credits may mainly come either from emission sources not covered by mitigation pledges or from countries with weak mitigation pledges. In both cases, host countries would not have incentives to ensure integrity and credits lacking environmental integrity could increase global GHG emissions.

At the same time, demand for international credits is also uncertain. Only a few countries have indicated that they intend to use international credits to achieve their mitigation pledges. An important source of demand could come from the market-based approach pursued under the International Civil Aviation Organization (ICAO), and possibly from an approach pursued under the International Maritime Organization (IMO). For these demand sources, avoiding double counting with emission reductions under NDCs will be a challenge that is similar to that of avoiding double counting between countries. A number of institutions are exploring the use of crediting mechanisms as a vehicle to disburse results-based climate finance without actually transferring any emission reduction units. This way of using crediting mechanisms could be more attractive to developing countries; they would not need to add exported credits to their reported GHG emissions, as long as the credits are not used by donors towards achieving mitigation pledges. The implications of non-additional credits are also different: they would not directly affect global GHG emissions, but could lead to a less effective use of climate finance. However, donors of climate finance aim to ensure that their funds be used for actions that would not go ahead without their support. Given the considerable shortcomings with the approaches for assessing additionality, we recommend that donors should not rely on current CDM rules in assessing the additionality of projects considered for funding.

Taking into account this context and the findings of our analysis, we recommend that the role of crediting in future climate policy should be revisited:

- We recommend potential buyers of CERs to limit any **purchase of CERs** to either existing **projects that are at risk of stopping GHG abatement** or the few project types that have a **high likelihood of ensuring environmental integrity**. Continued purchase of CERs should be accompanied with a plan and support to host countries to **transition to broader and more effective climate policies**. We further recommend to pursue the purchase and cancellation of CERs as a form of **results-based climate finance** rather than using CERs for compliance towards meeting mitigation targets.

- Given the inherent shortcomings of crediting mechanisms, we recommend **focusing climate mitigation efforts on** forms of carbon pricing that do **not rely extensively on credits**, and on measures such as results-based climate finance that do not necessarily serve to offset other emissions. International crediting mechanisms should play a limited role after 2020, to address specific emission sources in countries that do not have the capacity to implement broader climate policies.

- To enhance the integrity of international crediting mechanisms such as the CDM and to make them more attractive to both buyers and host countries with ambitious NDCs, we recommend **limiting** such mechanisms to **project types** that have a **high likelihood of delivering additional emission reductions**. We recommend reviewing methodologies systematically to address risks of over-crediting, as identified in this report. We further recommend revisiting the current approaches for additionality, with a view to abandoning subjective approaches and adopting more standardized approaches. We also recommend curtailing the length of the crediting periods with no renewal.

- Given the high integrity risks of crediting mechanisms, we recommend provisions that provide strong incentives to the Parties involved to ensure integrity of international unit transfers. This includes robust accounting provisions to **avoid double counting** of emission reductions, but could also extend to other elements, such as **ambitious mitigation pledges** as a prerequisite to participating in international mechanisms.

In conclusion, we believe that the CDM has had a very important role to play, in particular in countries that were not yet in a position to implement domestic climate policies. However, our assessment confirms, alongside other evaluations, the strong shortcomings inherent to crediting mechanisms. With the adoption of the Paris Agreement, implementing more effective climate policies becomes key to bringing down emissions quickly on a pathway consistent with well below 2°C. Our findings suggest that **crediting approaches** should play a **time-limited and niche-specific role** in which additionality can be relatively assured, and the mechanism can serve as stepping-stone to other, more effective policies to achieve cost-effective mitigation. In doing so, continued support to developing countries will be key. We recommend using new innovative sources of finance, such as revenues from auctioning of ETS allowances, rather than international crediting mechanisms, to support developing countries in implementing their NDCs.

Top airlines’ promises to offset flights rely on ‘phantom credits’

British Airways, easyJet and other major carriers state that by supporting forest conservation projects they can offset emissions. A new investigation shows the bold claims can’t be verified

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Britaldo Silveira Soares Filho was on a boat on Brazil’s Rio Negro river the first time he was asked to help rubber-stamp a carbon offsetting project.

The professor and expert in deforestation modelling spent three days on the boat in 2007 — along with an array of other academics focused on the Amazon rainforest — tasked by a Brazilian NGO with examining the science behind a forest conservation programme.

Later, in an office in São Paulo, he decided he didn’t want his world-leading software used for the project or others like it. To this day airlines hope backing schemes like this will help them hit climate targets.

“It’s a scam,” he said. “Neither planting trees nor avoiding deforestation will make a flight carbon neutral.”

Fossil fuels have long been the cheapest and most efficient way to fuel planes, and sustainable fuels that can be used at scale are still a long way off. But the aviation sector, which has pledged to cut emissions in half by 2050, while still allowing more and more people to fly, desperately needs to find ways to reduce its carbon footprint quickly. Increasingly airlines are turning to offset programmes to help achieve this — including reduced deforestation projects where companies buy carbon credits from projects that promise to preserve forests.

Last year, British Airways announced that its passengers could “fly carbon neutral” by buying credits for protection schemes in threatened forests. EasyJet relies on offsetting projects in Peru and Ethiopia as part of its drive to “become a more carbon neutral airline” and Delta, one of the world’s biggest airlines, uses avoided deforestation projects to support its claim that it is set to become the “first carbon neutral airline globally”. Air France, Iberia, Qantas and United Airlines have all unveiled similar programmes designed to offset passenger emissions through protecting forests.

But a detailed examination of how these schemes calculate their carbon savings by *Unearthed* and the Guardian, with SourceMaterial, has found evidence that raises serious doubts about the ability of these projects to offset emissions in line with the claims of major airlines. The investigation also suggests that the current flagship system for offsetting emissions through avoided deforestation may not be fit for purpose.

We analysed 10 reduced deforestation offsetting projects relied on by major airlines as part of their emissions reduction pledges and certified by Verra, the biggest issuer of carbon credits in the world. We conducted satellite analysis of deforestation in and around projects backed by BA, easyJet, and United Airlines, examined project documentation, interviewed multiple leading experts, and commissioned on-the-ground reporting.

The investigation revealed that, although projects often provide benefits to the environment and local communities, attempts to quantify, commodify and market the resulting carbon savings as a "carbon offset" are based on shaky foundations.

We found that despite multiple audits the reduced deforestation offsetting schemes used to justify eye-catching promises of carbon neutrality and guilt-free flying cannot prove they have produced enough carbon savings to justify these bold claims.

Avoided deforestation schemes generate and sell carbon credits based on the amount of deforestation they claim to prevent. In order to work out these carbon savings, they try to predict how much deforestation would take place if the project didn't exist. Although the scenario is hypothetical, offsetting schemes use deforestation rates in comparable areas of nearby forest, so-called reference regions, to come up with an estimate.

The key findings that emerged from the investigation:

- Satellite analysis of tree cover loss in the projects' reference regions, carried out by leading consultancy McKenzie Intelligence Services, found no evidence of deforestation in line with what had been predicted by the schemes.
- The analysis of schemes backed by BA, easyJet and United suggest the scale of the carbon benefits they offer is impossible to verify and may be exaggerated.
- The offsetting market may not be fit for purpose because projects calculate their climate benefit using what some experts viewed as simplistic methodologies that fail to account for the impact of markets and governments on deforestation.
- One environmental expert whose deforestation modelling software was used by many projects said flawed methodologies could generate "phantom credits" that represent "no impact on the climate whatsoever".
- Discussing a project backed by BA, a government official responsible for reduced deforestation projects in Peru called the calculations behind offsetting schemes a "Pandora's box" and "arbitrary".
- Projects are only set to last a short period of time, sometimes only a couple of decades, meaning that the carbon savings claimed by airlines for forest preservation are not guaranteed over the longer term.
- One of the projects is run by two logging companies that cut down ancient and rare trees.

"It's a scandalous situation," Philip Fearnside, an ecologist at the National Institute for Research in Amazonia, said of the current state of the REDD+ system. "Most of this is pure public relations."

The findings come as the carbon offset market is reaching a crucial turning point. The UK chancellor Rishi Sunak is aiming to make London the global hub for the trade of voluntary carbon offsets and former Bank of England governor Mark Carney is leading an effort to grow the sector with a task force of organisations involved in the market.

They also come as Verra, the largest issuer of avoided deforestation credits is overhauling its methodologies to help the market scale-up and following repeated media stories about the validity of the credits it produces.

In a statement, Verra said that *Unearthed* and the Guardian did not understand how its methodologies work, that the investigation was "fatally flawed" and had not produced fact-based journalism, ignoring their success at preserving forests.

> The Verra methodologies are not robust enough. That means there is room for projects to generate credits that have no impact on the climate whatsoever
>
> *– Thales West, former REDD+ auditor*

A guessing game

Protecting forests is crucial if the world is to avoid catastrophic climate change and carbon offsets are intended to offer a mechanism to achieve this.

Since at least 2005, the UN has been discussing the idea of paying to protect forests. The idea was formalised in a collection of policies known as Reducing Emissions from Deforestation and Degradation (REDD), later REDD+, to fund conservation projects in developing countries, with the goal of mitigating climate change. The first REDD+ project began issuing carbon credits in 2011.

There is no central body to regulate these projects and carbon offset markets, meaning various companies have carved out a niche issuing carbon credits and certifying standards. These include Verra, the certifier of all the projects analysed in this investigation. It has certified nearly 1,700 projects around the globe, including projects that prevent deforestation. Today if a company needs to cut its emissions quickly, it can buy offsets from a Verra-certified project that stops trees from being cut down in an area of threatened forest.

A project has to go through a series of checks before it gets certified, to show that it will help conserve an area that faces a real threat of deforestation. Crucially, it needs to prove "additionality" — that the trees would not have been saved if the project had not existed.

To do this, a project calculates a baseline scenario of deforestation it predicts would happen if it didn't exist. This is the yardstick a project measures itself against and the basis on which it generates carbon credits for preventing deforestation. The higher the baseline, the more credits a project can issue.

A selection of offsetting projects backed by major airlines

A Flourish map

Illustration: Georgie Johnson/Unearthed

But the way baselines are calculated makes it possible for projects to overestimate their climate benefit by miscalculating the level of deforestation that would occur if they didn't exist.

To come up with a baseline a project identifies a "reference region", which is usually an area of forest near the project with similar characteristics. Projects use estimates of deforestation in this region — sometimes along with specific threats to the project area itself such as a new road or population growth — to assess the threat of deforestation in the project area itself.

> Aviation companies buying REDD+ credits are just postponing action. It would be better to spend money investing in research on more efficient jets or alternative fuels
>
> *– Britaldo Silveira Soares Filho, deforestation modelling expert*

The decision of which region to choose introduces further complications. An offsetting project supported by easyJet in a remote area of forest in the Madre de Dios region in Peru, for example, used a much more heavily populated area as a reference region, meaning its deforestation potential was much higher.

Importantly, reference regions are not intended as a control — a way of validating how much deforestation would have taken place in the real world without the project. That means there is no way to check if deforestation would have fallen without the project, due to factors beyond the its control. The carbon savings sold to consumers by airlines are defined by models that are not tested against reality. It's a situation that concerns some scientists and experts.

Verra does not accept these concerns but is adapting its methods. The US-based not-for-profit is planning significant changes to baselines. Instead of choosing reference regions, historic and future deforestation will be calculated at the national level before being broken down locally. Projections of future deforestation will be based on past deforestation in that region, removing the possibility to pick and choose their reference regions. Verra also says baselines will be based only on recent deforestation and will be reviewed every four to six years.

But gaps remain. Credits will still be issued to projects for avoiding deforestation regardless of major changes in national policy; projects can issue credits even if deforestation in the country they are based in continues to rise; there is no guarantee forests will not be cut down in future after projects — some of which are only scheduled to last 20 years — end and, crucially, there remains no way of verifying if projects' claims for their impact, based on historical models, are accurate in the real world.

The changes will also only apply going forwards. The credits sold by airlines today, and in the past, won't be affected.

Alexandra Morel, an ecosystem scientist at the University of Dundee, told us that it's difficult to judge if the emissions reductions claimed by REDD+ projects are real.

"It's impossible to prove a counterfactual," she said. "Rather than just valuing what forests are actually there, which are actively providing a carbon sink or store right now, we have to surmise which forests would still be here versus which ones are the bonus forests that were spared from the theoretical axe. It is so abstract."

"The Verra methodologies are not robust enough," said Thales West, who previously worked for five years as an auditor of REDD+ schemes. "That means there is room for projects to generate credits that have no impact on the climate whatsoever."

West, a scientist at the New Zealand Forest Research Institute, said that Verra generates many carbon credits from projects where the benefit is much easier to quantify, such as those related to renewable energy use and reforestation, or tree-planting. "The problems come with these REDD+ methodologies," he said, "where you simulate these deforestation baselines because there's no perfect way to create those."

Verra's proposed changes, West said, "will likely make the problem smaller, but the problem will still be there". He pointed out that using historical rates to predict the future means changes in the wider world, like fluctuations in agricultural prices or shifting government policies, will be ignored.

West was the lead author of a study published in September 2020, which looked at 12 projects offering carbon credits for avoiding deforestation in the Brazilian Amazon. The research found that the schemes had been too simplistic in drawing up their baselines.

By focusing on average historic deforestation rates, the projects had failed to account for the impact of government policies introduced in the mid-2000s — long before President Jair Bolsonaro took office — which reduced deforestation. "We find no significant evidence that voluntary REDD+ projects in the Brazilian Amazon have mitigated forest loss," the study concluded.

One of the projects the study examined was the Floresta de Portel REDD+ project in Pará, northern Brazil, which is part of Air France's commitment to offset all the emissions from its domestic flights. West's study found that despite claims the project was protecting the area from devastating deforestation levels, it had very similar deforestation levels to an unprotected control area West identified nearby.

Since this study, under the presidency of Jair Bolsonaro, deforestation levels have shot up in Brazil. But even if this now means some of the predictions of forest loss by REDD+ projects in Brazil have come true, it does not vindicate Verra's methodologies, said West.

"It's not ideal to rely on luck to generate carbon credits. You want to rely on a methodology that is robust enough, so it doesn't have to rely on perfect conditions."

When asked to comment on its support for the Portel project, an Air France spokesperson said carbon offsetting is "part of a larger scheme to address our GHG emissions". Michael Greene, a spokesperson for the Floresta de Portel project, said the project had acted as a bulwark against the impacts of illegal loggers and cattle ranchers, noting how deforestation was now increasing.

Modelling carbon savings

To try to predict deforestation more accurately, Verra currently permits projects to use a piece of software called Dinamica EGO. This allows users to forecast land-use changes over time and was developed by Soares Filho.

Unearthed and the Guardian found 13 projects that cited Dinamica EGO when discussing how they designed their projects.

But this software was never intended for use by REDD+ projects. Dinamica's website features the disclaimer: "We do not support the application of deforestation modelling to fix REDD baselines for crediting purposes."

Instead, Dinamica was designed to be used to monitor the potential impact of specific policy decisions, said Soares Filho. In 2006, for example, he and his colleagues used it to model the devastating impact the expansion of the cattle and soy industries could have in the Amazon basin. What the software can't do, Soares Filho said, is make a definitive estimate about future forest loss in a given area, due to all the different factors that come into play.

Soares Filho said: "Models are used to avert an undesirable future, not predict the future. Models are not crystal balls. Models are a sign to help devise policy and evaluate policy choices."

Farm Africa, the charity that manages one of the projects backed by easyJet that used Dinamica EGO, said in response to our story: "We remain confident that the deforestation scenarios the model produced are the best that science could provide at that time." They also stated that they were not aware of Dinamica's online disclaimer and were not sure if it was present on the website when the analysis was conducted in 2013.

For Soares Filho, the issue goes beyond the use of one model. "Aviation companies buying REDD+ credits are just postponing action," he told the Guardian and *Unearthed*. "It would be more efficient investing in research on more efficient jets or alternative fuels, for example. But of course, it is always more expensive than a REDD+ project."

"Deforestation modelling to fix REDD+ baselines results in phantom carbon credits," he added.

'Fly carbon neutral'

The projects used by airlines are subject to multiple audits and checks by Verra and independent third parties. But we have learned that projects do not have to check whether their predictions about the threat of deforestation, which form the basis of all carbon credits issued, turn out to be true, because there is no control region.

To get an indication of whether or not the projects' future deforestation forecasts had come to pass, *Unearthed* and the Guardian commissioned a new satellite analysis. Of the 10 schemes that we examined, four, backed by BA, easyJet and United, had made deforestation projections about a surrounding reference region that could be easily examined.

A view of a section of the interoceanic highway in Peru. The road connects Peru's coast with western Brazil. One easyJet backed scheme claims it poses a risk to an area of pristine rainforest some 30km away. Photo: STR/AFP via Getty Images

If tree cover loss turns out to be lower in those areas it could indicate that the original projections had been inaccurate — meaning more credits were issued than should have been.

The comparison is not perfect. Reference regions are often right next to or surrounding projects and so can be influenced either positively or negatively by what takes place in the project area. There is also the difficulty of comparing reality with an imagined scenario. However, the predictions projects make for deforestation in these areas provide the only data available to analyse the impact of these schemes and the strength of the carbon accounting compared to what actually happened.

For the analysis, McKenzie Intelligence Services (MIS), a London-based company that specialises in geospatial imagery analysis and intelligence, used annual tree cover loss data developed by Dr Matt Hansen at the University of Maryland, in collaboration with researchers from Google, the US Geological Survey and NASA.

The approach has limitations. Most significantly the satellite analysis has not been backed up by on the ground checks, meaning it's estimates of deforestation can be inaccurate. This type of data also involves "year-to-year uncertainties" described by Global Forest Watch, an organisation that hosts Hansen's data on its website. To ensure the analysis was as robust as possible, we used overall or average figures.

The findings were stark. The analysis found no evidence that the predicted levels of deforestation materialised in the reference regions of projects supported by BA, easyJet, and United.

The organisations behind each project claimed that the reason predictions of severe forest loss had not come to pass was because of their positive impact on reducing deforestation in their surrounding areas.

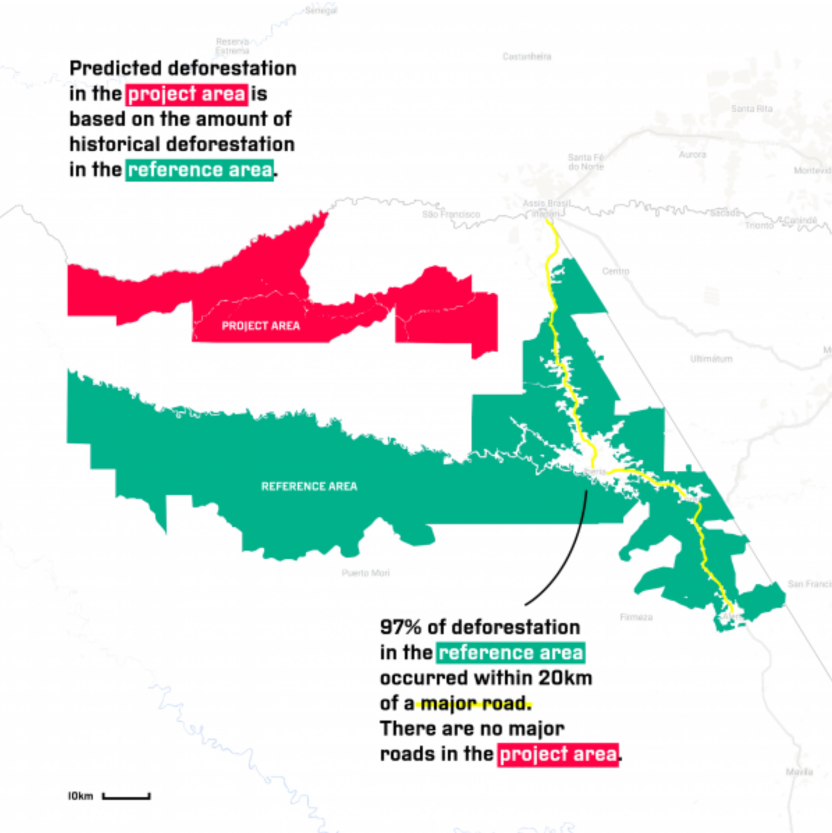
"Additionality is incredibly hard to prove," said Crystal Davis, the director of Global Forest Watch. "While I don't think your analysis proves by any means that the project baselines were over-inflated, it does demonstrate that post-facto assessments of the integrity of baselines is really hard to do. That's a big problem."

She added: "I'm encouraged to see major efforts underway to create even more public-facing transparency and accountability around REDD+ crediting."

'Real life Paddington'

Our analysis of two projects in Peru reveals some of the difficulties inherent in trying to prove the climate benefit of offsetting schemes.

EasyJet supports a project that claims to protect a remote area of forest in the Madre de Dios region of the country. But the reference region used to assess the threat of deforestation is a much more heavily populated area, encompassing the city of Iberia. At the time this reference region was analysed, it was split in two by an unpaved road, which has since become a major highway, connecting Peru and Brazil. MIS found that deforestation in this area was mostly concentrated around the highway and settlements, barely penetrating into the deeper jungle that more closely resembles the Madre de Dios project area.



Those behind the Madre de Dios scheme in the Peruvian Amazon claim the project area is threatened by the interoceanic highway. Illustration: Georgie Johnson/Unearthed

Asked to comment on the findings of this investigation, an easyJet spokesperson told us the airline "employs a rigorous process to select the schemes we buy credits from".

Hundreds of miles north of Madre de Dios, in central Peru, the Cordillera Azul national park is home to several threatened species, including the spectacled bear, otherwise known as the "real life Paddington". The project has become central to British Airways' claim that passengers can "fly carbon neutral" by offsetting their flight.

CIMA, the NGO behind the project, focused on population growth when estimating potential deforestation. It argued that without additional resources as a REDD+ project, immigrants moving into the surrounding area would cut down trees in order to farm the land, predicting a huge increase in deforestation.

But the area was already a national park that had enjoyed protected status for seven years by 2008 when it started claiming credits. CIMA wrote in 2012 that "no illegal logging activities have been observed by park guards in or immediately around the project area since 2006".

Asked whether he thought Cordillera Azul would have suffered high rates of deforestation without the REDD+ project, Deyvis Huamán, a REDD+ official in Peru's ministry for the management of protected areas, said: "No, I don't think so. You put yourself in the worst-case scenario, mining might come in or illegal loggers, and it could be a problem.

"It's a Pandora's box when you do those calculations because it's in the formulas where you can manage those numbers, and decide whether to generate more or fewer credits… it's kind of arbitrary sometimes. You can put values on drivers of deforestation, highways, the price of gold, the price of wood. So you put a value on the strongest driver and it might exist or it might not."

CIMA told us that, according to its understanding, the Peruvian government "is very pleased with the contributions made by the early initiatives working on protected areas in Cordillera Azul and elsewhere, as it is providing funding and has given invaluable experience for the next steps to come, as a result of the Paris agreement."

Responding to this investigation, a BA spokesperson said the airline aims to reach net-zero by 2050, using a range of initiatives, including carbon offsetting. They added: "We work with our partners and project developers to choose the highest quality, independently verified projects and do due diligence to ensure they provide real carbon, economic, social and environmental benefits."

Permanence

It takes thousands of years for emitted fossil fuel carbon to leave the atmosphere. A portion of the carbon produced by a flight you took yesterday will stay in the atmosphere for millennia. In the case of the kind of unplanned deforestation schemes we looked at, an area of forest needs to stay intact for many decades in order to properly offset carbon emissions.

To deal with this problem, offsetting standards bodies set minimum lengths of time for projects to last, but these vary dramatically. A hundred years is typically the time period used by the Intergovernmental Panel on Climate Change, and other respected organisations, to assess the global warming potential of greenhouse gases.

None of the schemes we examined for this story — backed by BA, Delta, easyJet, Air France, United, Iberia and Qantas — had a lifespan of 100 years. Some are only scheduled to last for a couple of decades.

Iberia said in response to the findings in this story that they chose to support a Verra-certified REDD+ project "due to the information available back in 2019 and the due diligence assessments carried out." The airline said it was "working on updating" its offsetting program in light of the pandemic. Qantas did not respond to a request for comment.

When asked by *Unearthed* and the Guardian about the risks of their project areas being deforested before carbon had been properly sequestered, some schemes said that their projects would be renewed if a threat to the project area still existed at the end of its life. Others pointed to agreements with governments to keep projects going beyond the lifespan set out in project documents at the start of the schemes.

During a project's life, Verra forces schemes to maintain a buffer of credits — a kind of insurance against loss of trees, for example, due to forest fires. Verra told *Unearthed* and the Guardian that when a project comes to an end all remaining credits in a buffer are automatically cancelled to offset future losses. In addition, Verra argues, the work of REDD+ schemes, like shifting communities away from destructive farming practices, means that the benefits brought by these projects last longer than any projects crediting period. But it admitted it does not check if this actually happens.

Verra has disputed the independence of the investigation and described it as a "hit piece" due to Greenpeace's opposition to carbon credits, adding that many of the criticisms were now outdated that did not reflect what was currently happening with REDD+ carbon credits.

BA and easyJet have both made significant climate announcements based, in part, on carbon offsetting. Photo: Jason Alden/Bloomberg via Getty Images

Paris agreement

Recent global treaties on climate change have given increased urgency and importance to the issue of how robust offsetting projects are.

Governments are increasingly considering actions to reduce deforestation, in part because, under the Paris climate agreement, countries can include reducing deforestation in their emissions reductions plans.

We understand from sources that Norway, the world's biggest financial supporter of forest conservation, believes national level projects deliver more significant and meaningful reductions in deforestation than voluntary schemes. The country has entered bilateral agreements with governments in several tropical countries, including Indonesia and Gabon, providing financial incentives to reduce forest loss.

> Airlines and other polluters need to be more careful in how they market their support for these projects to customers
>
> *– Barbara Haya, University of California, Berkeley*

Governments are able to take a more holistic approach to forest protection, Frances Seymour, distinguished senior fellow at the World Resources Institute, told *Unearthed*. Airlines and other polluters should purchase credits from regional or national governments, rather than individual projects, to reduce deforestation, she said.

"Stopping deforestation requires actions that only governments can perform: clarifying land tenure, enforcing the law, regulating permits, and rewarding conservation through tax and credit policies," Seymour explained. "Individual projects can address local drivers of forest loss at local scale, but not economy-wide drivers at large scale."

While Verra's proposed changes would mean projects were integrated into national "baseline" predictions of deforestation, they will still issue credits themselves. The risk remains that consumers could pay airlines to achieve reductions in deforestation that are actually the result of global economics or government policy rather than the work of the projects themselves.

Cordillera Azul is one of a number of projects that may have to adjust its baseline to match more conservative estimates from Peru's government. "With Cordillera Azul's methodology you say, I can verify 1.5 million credits per year," noted Huamán, from Peru's ministry for the management of protected areas. "But the [new post-Paris] national reference level says in that same area you can only generate 100-200 thousand credits."

Important conservation work

Many of the schemes we've looked at during the course of the investigation are doing important and often difficult work, conserving forests and ecosystems. Some of the environmentalists we have spoken to for this story see REDD+ as a way of funding conservation work in dangerous parts of the world. In the absence of support from governments and other organisations, offsetting has filled a gap.

But even when projects appear to be doing good work, there can be complications. The Madre de Dios project, backed by easyJet, is in the unusual position of being run by two logging companies.

These companies, Maderacre and Maderyja, are certified by the Forest Stewardship Council and insist that they operate in a sustainable way that goes beyond requirements set by the Peruvian authorities. They argue that sustainable logging of this type can increase carbon absorption by promoting tree regeneration.

But while this type of forestry management protects younger trees as they grow, figures from Peru's forest inspections agency show that the loggers have cut down old trees, which serve a crucial role for ecosystems, including carbon-rich shihuahuaco trees and rare species like Spanish cedar and mahogany, which both appear on the IUCN red list, listed as "vulnerable". Julia Urrunaga, director of Peru programmes at the Environmental Investigation Agency said "it's absurd" that a logging company should get paid for carbon credits while it cuts down old shihuahuaco trees that can take 1,000 years to reach full maturity. The project developers say they follow international rules on endangered species.

Like many REDD+ schemes, the Madre de Dios project also says it supports local Indigenous communities, who themselves often play a crucial role in sustainably using and defending forested land in their territories. But *Unearthed* has seen minutes from a meeting showing that the companies behind the scheme opposed a government proposal to expand an Indigenous reserve bordering the project area in 2017. The government was concerned that the isolated Mashco Piro tribe were being threatened by encroachment from outsiders. A representative from the Madre de Dios project argued that existing reserves were "more than sufficient" and logging concessions were a "productive conservation model".

Project developer Greenoxx told *Unearthed* and the Guardian that it would welcome any decision by the authorities regarding the location of the Indigenous reserve, and noted it did not have any formal power over the decision. The NGO also highlighted its work with Indigenous communities living near the project area, claiming: "Our project is effectively contributing to the protection of their territory."

A 'fig leaf' for big companies

With the global offsetting market set to take off in the coming years, Barbara Haya, a research fellow at the University of California, Berkeley who focuses on climate mitigation, told us: "Airlines and other polluters need to be more careful in how they market their support for these projects to customers and they need to have a better understanding of the climate impact of the projects they support, before making big claims."

"It's great if companies want to support conservation projects if these actually have positive impacts," Gilles Dufrasne from Carbon Market Watch told *Unearthed*. "But they shouldn't say that this compensates for their own emissions. It simply doesn't."

Alexandra Morel said that the current voluntary REDD+ set up places too much emphasis on scrutinising the claims of projects in poorer countries and not enough on polluters. She said the voluntary REDD+ system "relies on a level of scrutiny that puts the onus on the most vulnerable to dramatically change their lives, while the offsets go to us who are so unwilling to change ours."

United Airlines' own CEO, Scott Kirby, has called offsetting "a fig leaf for a CEO to… pretend that they've done the right thing for sustainability when they haven't made one bit of difference in the real world".

Asked why, in that case, United has supported the Alto Mayo project in Peru, a United spokesperson declined to comment directly.

Former Bank of England governor Mark Carney is leading an effort to reform and grow the offsetting sector. Verra is represented on Carney's task force, as is easyJet. The group is currently discussing how best to expand the voluntary carbon offsetting market. Whether or not to allow projects like the ones discussed in this investigation to be part of the market in future is a key sticking point.

Also on the task force are banks and other investors, who, if the UK Chancellor Rishi Sunak gets his way, will be key players in a new, multi-billion dollar market trading carbon credits in London.

It will be vital then for these credits to represent value for money and, more importantly, value for the climate.

Additional reporting: Mitra Taj

Editing by: Laura Paddison

A version of this story was also published by the Guardian.

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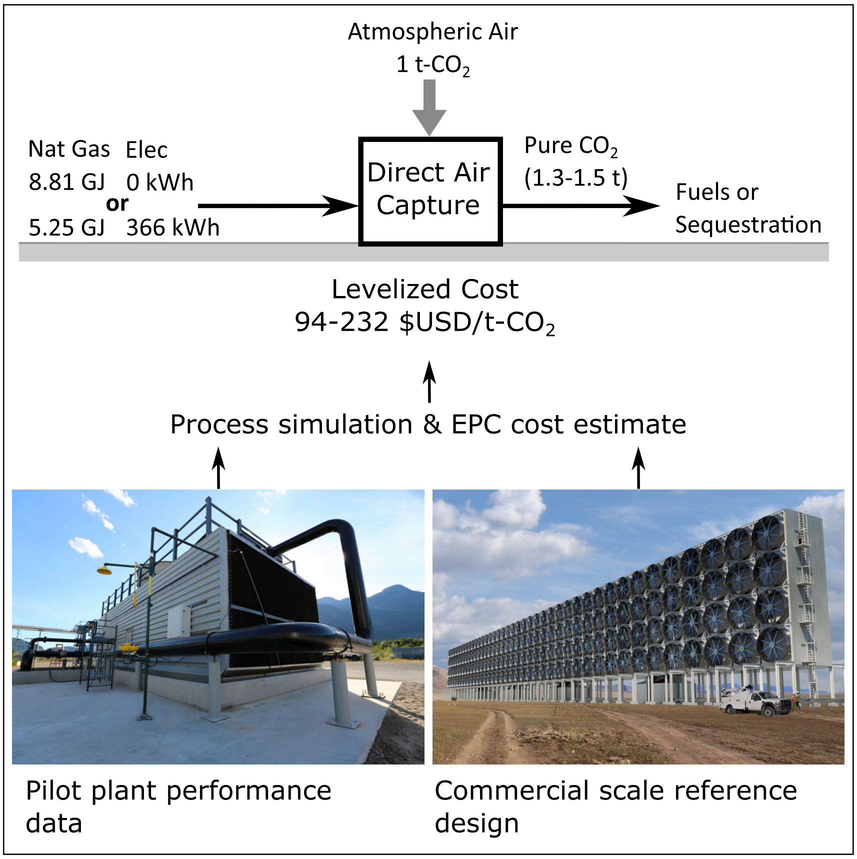
A Process for Capturing CO_2 from the Atmosphere



First direct air capture paper for which all major components are either drawn from well-established commercial heritage or described in sufficient detail to allow assessment by third parties. Includes energy and materials balances, commercial engineering cost breakdown, and pilot plant data. When CO_2 is delivered at 15 MPa, the design requires either 8.81 GJ of natural gas, or 5.25 GJ of gas and 366 kWhr of electricity, per ton of CO_2 captured. Levelized cost per t-CO_2 from atmosphere ranges from 94 to 232 \$/t-CO_2.

David W. Keith, Geoffrey Holmes, David St. Angelo, Kenton Heidel

keith@carbonengineering.com

HIGHLIGHTS

Detailed engineering and cost analysis for a 1 Mt-CO_2/year direct air capture plant

Levelized costs of \$94 to \$232 per ton CO_2 from the atmosphere

First DAC paper with commercial engineering cost breakdown

Full mass and energy balance with pilot plant data for each unit operation

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