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TOWARDS BETTER ENERGY

Destination sustainable aviation

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This document has been coordinated by **Jean-Pierre Hauet**, Chief Scientist, *Équilibre des Énergies*, **Cecil Coulet** and **Olivier Lagrange**, policy officers.

THANKS CONTRIBUTORS

THANKS

Members of *Équilibre des Énergies*

Air France KLM
Anne-Marie Couderc, President
François Delabre, Head of Institutional Affairs

Airbus
Guillaume Faury, CEO
Glenn Llewellyn, VP Zero Emission Aircraft

Aéroport de Paris
Amélie Lummaux, Chief, Sustainable Development and Public Affairs Officer
Sébastien Couturier, Director at Paris-Le Bourget
Airport & General Aviation Aerodromes

Safran
Thibaud Normand, VP Climate

TotalEnergies
Jean-Marc Durand, Head of Refining, BaseChem Europe, and Acting Director of Renewable Fuels

Other personalities and experts

European Parliament
Marian-Jean Marinescu, MEP, coordinator
of the EPP Group within the Transport Committee (TRAN)

French National Assembly
Jean-Luc Lagleize, Deputy

ISAE-SUPAERO
Scott Delbecq, Nicolas Gourdain, Jérôme Fontane, Florian Simatos, Hugo Mugnier, Thomas Planès

Aviation sans frontières
Gérard Feldzer, President,
former airline pilot, Air France instructor

International Air Transport Association (IATA)
Rafael Schvartzman, Regional Vice-President Europe

EUROCONTROL
Philippe Merlo, Director, European Civil-Military Aviation,

AURA AERO
Jérémy Caussade, President

Adina Valean,
EU Commissioner for Transport

How to integrate the air transport sector in a decarbonised society?

Air transport plays a vital role in our economy and daily lives, notably for the millions of us who live or come from islands and peripheral regions and states. It connects citizens with their families and their friends, creates jobs or business opportunities, and provides essential links for the cohesion of cities and regions that are difficult to access.

Clean mobility solutions are emerging in other transport modes like the road sector (electric cars are steadily becoming part of our daily lives), but low carbon air travel is not there yet. The sector is particularly difficult to decarbonise, due to its heavy reliance on fossil liquid energy, which is the only one for the time being able to ensure the energy density requested to lift and fly commercial planes. Aviation still represents around 3% of our economy's carbon footprint.

We're not quite yet there with low-carbon air transport. The sector is particularly hard to decarbonise because of its heavy dependence on liquid fossil fuel, which for the moment is the only fuel able to deliver the power required to fly commercial aircraft.

In the face of the COVID-19 pandemic, our society took the full measure of the importance of aviation for the circulation of people and goods. At the same time, this period coincided with intense work at policy and industry level to make air travel restart in a more sustainable way. I am optimistic when I see the latest commitments of the European and global aviation industries to reduce significantly the carbon footprint of air travel. We are not far away from delivering cleaner flights to people. We know that concrete solutions are coming soon: more direct flights, sustainable aviation fuels instead of fossil energy, more fuel-efficient aircraft or zero emission aircraft. I am convinced that the future of air mobility is sustainable. The key is to combine industry action and bold, efficient policies. Let me explain how I see the latter.

In 2020, the Commission adopted its Sustainable and Smart Mobility Strategy. This ambitious roadmap set the course of policy action to implement the European Green Deal, and comply with the EU's climate objectives of reducing emissions by 55% by 2030 and becoming carbon neutral by 2050. To decarbonise aviation, the strategy announced increased action, notably in the areas of air traffic management, carbon pricing measures, global market based mechanisms, funding of research and deployment of green projects, and boosting sustainable aviation fuels. In July 2021, the Commission adopted a set of regulatory proposals to implement into EU law the measures that will allow reaching the EU's climate objectives. Several of those measures contribute to accelerating the decarbonisation of aviation. The revision of the EU Emissions Trading System will oblige airlines to purchase allowances (carbon credits) for all of their carbon emissions by •••

2027. As the price of carbon credits is increasing, this will encourage airlines to accelerate the reduction of their emissions. We propose to implement into EU law the global carbon offsetting and reduction scheme (CORSIA), to offset emissions of international emissions beyond 2019 levels.
The Commission adopted a new regulation to ensure that airlines fly on increasing shares of sustainable aviation fuels (notably advanced biofuels and synthetic fuels), starting in 2025. The tax regime for aviation fuels is also revised to encourage airlines to use more sustainable aviation fuels, instead of fossil fuels. Infrastructure at airports will have to cater for electricity supply for stationary aircraft at gates and outfield posts, to avoid the use of engines running on fossil energy, when parked. Finally, the EU must continue to act as one block to push for ambitious sustainability policies at ICAO level, in particular to agree on a long-term goal for emission reductions.

The EU must remain united in its promotion of ambitious sustainable policies within the ICAO, especially if it is to achieve an agreement on the long-term aim of reducing emissions.

Alongside these legislatives proposals, the Commission is putting forward many other incentives to ensure this transition towards a green aviation. Just to mention some, Horizon Europe and the two Joint undertakings on Clean Aviation and SESAR (air traffic management) will mobilise significant funding in research and development. The Commission is setting up several industrial alliances to de-risk investments and create the necessary collaboration among investors, businesses and public authorities, for instance the Renewable and Low-Carbon Fuels Alliance, the Alliance on Zero Emission Aviation, or the Hydrogen Alliance.

These policy measures proposed by the Commission are an important part of the equation, but ultimately, real change will need to come from the industry. This is a very exciting challenge! As Commissioner for Transport and Mobility, I will follow very closely every step of aviation on its journey towards a low carbon future.

Let the children have their dreams

Brice Lalonde,
former minister,
President of *Équilibre des Énergies*

'*Flying is our true love. We are prepared to abandon everything for it. No other love can take its place. Woe to him who fails to grasp this*', wrote Jules Roy, one of France's aviator writers, as were Joseph Kessel, André Malraux, Romain Gary and Antoine de Saint-Exupéry - all giants of French literature. What child hasn't dreamed about the meeting between the Little Prince and the pilot? But now flying is being demonised. Greta Thunberg refuses to get on a plane so as not to burn aviation fuel. We even had the Green Party mayor of a big city who said, while cutting grants to the local flying club, that children should stop dreaming about flying! Banning dreams is going a bit too far. Mankind has always dreamt of flying.

And what would our European Union be like if Paris were no longer two hours away from Copenhagen, Vienna two hours from Athens or Berlin three hours from Madrid?

And its was dreams and the determination of the engineers and the pioneers that made air transport a reality - transforming geography, rubbing out oceans and mountains, bringing peoples together, improving each new generation of aircraft and making tourism the world's leading industry. How can we cross continents without having to build roads in the USA, Canada, Russia, Brazil or China? Or connect islands in Indonesia and the Pacific? And what would our European Union be like if Paris were no longer two hours away from Copenhagen, Vienna two hours from Athens or Berlin three hours from Madrid? How many of the thousands of students on the Erasmus programme each year would still decide to go and study in another European country?

Air transport has become a major economic player, stimulating business in the places it serves, giving them an advantage over other places that complain that they have been isolated and abandoned. In 2018 the aviation sector provided two million direct jobs in the European Union and almost 10 million indirect jobs, including in the supply chain and in tourism, Aviation is one of the last few sectors that the European Union, and France in particular, can boast of actually leading. Even though we have generally allowed Asia and the USA to take over car production and digital and energy transition techniques such as solar panels, aviation remains a European industry of excellence. Airbus is the world's leading aircraft builder today and Groupe ADP is high in the ranking of airport groups.

In the case of airlines, Air France-KLM is the leading cargo operator. Safran is the world's leading supplier to the aviation industry. Aviation's total contribution to European GDP in 2018 was in the order of 675 billion euro. The European Union has allowed too many businesses depart to other countries where they are now hothousing jobs and economic dynamism. Let's not make the same mistake with aviation.

Air transport has become a major economic player, stimulating business in the places it serves, giving them an advantage over other places that complain that they have been isolated and abandoned.

Aircraft companies are already working on reducing greenhouse gas emissions. Thanks to the combined efforts of TotalEnergies, Airbus and Air France-KLM in particular, new fuels have been powering flights in their entirety or in part for a year. Originally produced from biomass, in future they will have to be produced by combining hydrogen with CO_2 captured from the plant that issue it or from the atmosphere. These are SAFs (Sustainable Aviation Fuels). They will be carbon-neutral but more expensive to produce. A new generation of aircraft will follow - later. The electric plane is already in the air but for only short distances and with few passengers. The hydrogen-powered aircraft is on the horizon. Engines are also becoming increasingly efficient, guzzling ever less energy. Safran's LEAP engine already uses 15% less fuel than the previous model and the developers are working on an engine that will use 20% less fuel than LEAP.

Airports are working to reduce their own carbon footprints. They are transforming their buildings, cutting taxiing time, supplying planes with electricity when they're on the ground, and are preparing for hydrogen. Passenger and staff transit accounts for a significant proportion of aviation emissions and the sector is working on solutions to reduce it. Groupe ADP is part of a project to deploy electric air taxis, which will be tested at the next Olympic Games. How many years did it take for the automotive sector, which produces more emissions than aviation, to show the same level of commitment and proactivity to the reduction of its greenhouse gas emissions?

The aviation sector will doubtless not continue expanding at pre-Covid rates. Sustainable fuels are more expensive and less available than fossil aviation fuel. Mass tourism, to which aviation owes some of its growth, will have to adapt to decarbonised society. And airports do not necessarily need to transform themselves into temples of unbridled consumerism. Yet tourism contributes to development and aviation tightens the community that is our human destiny. Instead of acting as climate protection scapegoats, let's create a dynamic and sustainable aviation industry that continues to serve the universal human need to travel and connect with others.

Our EU decision-makers are working on bills that will be key to the future of the aviation sector. I hope that they will put as much hope and determination to create a sustainable aviation sector into their decisions as those XXth century pioneers did into making the first plane fly.

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SPECIAL EDITION AVIATION SPECIAL

Decarbonising aviation by 2050 really is possible

Jean-Pierre Hauet,
Chief Scientist, *Équilibre des Énergies*

Decarbonising aviation is essential if the sector, which is still recovering from Covid, is to return sustainably to growth, once more to meet the demands of the economy requirements and to fulfil people's wish to travel.

Some have too hastily concluded that decarbonisation is impossible, dooming air travel to a slow death by attempting to discredit those who use what they consider is an outmoded means of transport. *Équilibre des Énergies* and its members have made a careful assessment of aviation decarbonisation, interviewing senior managers and collecting the many contributions that make up this special issue of *EdEnmag*. Our conclusions are clear: decarbonising the aviation sector is possible but will not be easy. If the 2050 deadline is to be met, incentives and support must be provided in France, and more especially in the EU and internationally, to enable economic players to follow the timetable and move towards this goal.

THE FOUNDATIONS FOR THE DECARBONISATION OF AVIATION

A number of well-known studies have been carried out in the last few years into possible roadmaps for the decarbonisation of aviation[1]. *Équilibre des Énergies* asked its members to provide expertise and analysis, adding the opinions of independent experts in its review of the studies. These agree that there is no silver bullet for decarbonisation but that it can be achieved by combining several approaches including operations management, technical progress and the migration to sustainable fuels.

Operating improvements (air traffic management)

Steps to improve the efficiency of operations (air traffic/airport management) produce the fastest results. The Single European Sky initiative, introduced in 2004 with the first SES I package, delivered significant results and was backed up by the SES II package in 2009. This still leaves the potential for an estimated 10% improvement, achievable by improving flight paths in Europe.

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1. *Especially: Destination 2050, a route to net zero European aviation (February 2021) – Waypoint 2050 (September 2021).*

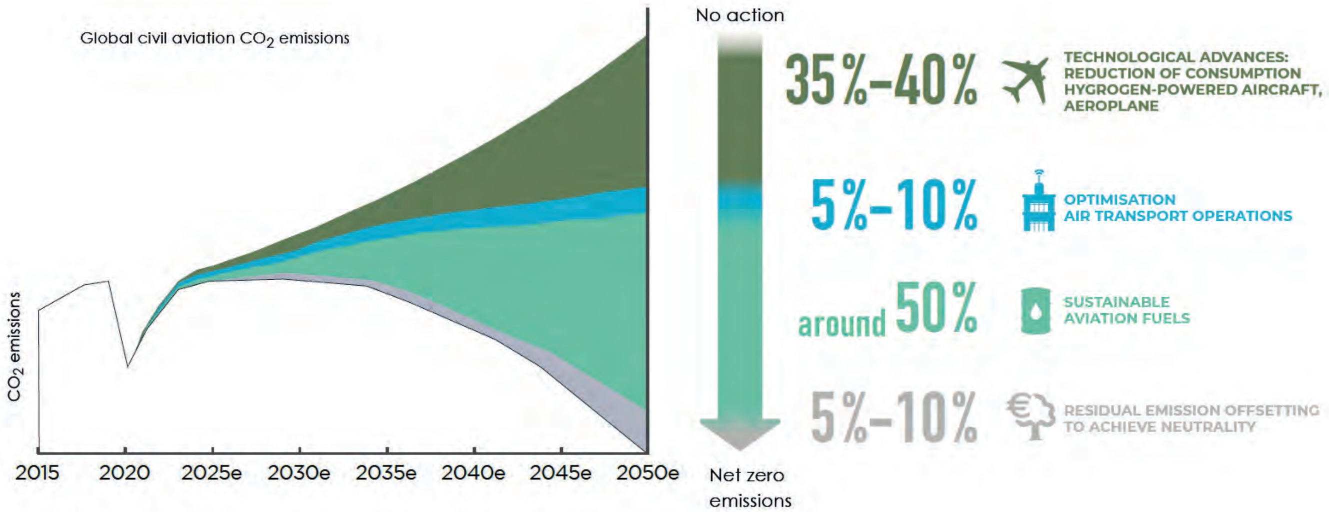

Fig. 1 : **The main levers for decarbonising air travel.** © Safran.

Technical progress

In the next few years technical progress will take the practical form of replacing fleets with new generation aircraft that are on the market and will cut consumption by around 15%. In the medium term, further technical progress following in the wake of the progress we have already made will improve decarbonisation through better aerodynamics, lighter aircraft and more efficient engines. Manufacturers forecast that the aircraft that come into service in around 2035 will use 20% less fuel than the present generation.

After 2035 hydrogen-powered aircraft for short and medium-haul routes could provide a technological breakthrough. Airbus is currently looking at three different concepts offering payloads of up to 200 passengers over 3 700 km.

In the meantime, electric hybridization will have been developed, with aircraft that are up to 100% electric (training aircraft and air taxis or even aircraft carrying just twenty passengers over 400 km).

Technical progress may in total account for 35-40% of emission reduction by 2050.

The challenge of sustainable aviation fuels

The biggest challenge to aviation decarbonisation is the development of SAFs (sustainable aviation fuels). These fuels now exist. Seven types of first-generation fuels have been approved by ASTM[2] for combination in various proportions with conventional aviation fuel. The fuels are essentially produced using the HEFA (hydro-processed esters and fatty acids) method, which processes waste cooking oil and animal fats and is the only technology to have reached the commercial stage so far.

Over the life cycle, SAFs produce up to 90% fewer CO_2 emissions than their fossil equivalent. Successful fully SAF test flights have demonstrated the effectiveness of this approach.

But current SAFs can meet only 0.01% of requirements since the quantities available are limited and their prices are high (around four times the present cost of aviation fuel).

Developing SAFs on an industrial scale poses a number of challenges:

- the technical challenge of pushing the manufacturing process further to include other potential types of basic resources (feedstock). The FT (Fischer Tropsch) process in particular could recycle raw materials such as agricultural or forestry waste or municipal waste but is not yet mature and will require very significant investment;
- the availability of biological resources is also a problem since no damage must be done to biodiversity or food crops. This means that we could be producing non-biological synthetic fuels (e-fuels) from low-carbon hydrogen, low-carbon electricity or CO_2 that has been recovered, including directly from the air;
- the financial challenge is that early SAF producers are at present reporting cost prices higher than those of HEFAs;
- competition is another concern since we cannot create a situation in which some airlines are required to use SAFs while other international airlines have no such obligation.

2. ASTM (American Society for Testing of Materials) drafts and publishes international technical standards, including for aviation fuels.

The European Commission is discussing ReFuelEU, a draft regulation that would make the use of SAF compulsory, rising gradually from 2% in 2025 to 63% in 2050, of which 28% e-fuels. France requires that fuels must be 1% SAF by 2022, 2% by 2025 and 5% by 2030.

Combining these three approaches (operating improvements, technical progress and sustainable fuels) should reduce aviation emissions to practically zero by 2050, according to a scenario similar to that shown in figure 1. Any remaining emissions in 2050 could be offset.

NON-CO_2 EMISSIONS

Although the focus is generally mainly on aviation CO_2 emissions caused by the combustion of aviation fuel, non-CO_2 impacts are not negligible. They are caused by the cirrus clouds produced by vapour trails, nitrogen oxide emissions and water and aerosol vapours - not forgetting the changes in cloud properties. Some of these impacts are cooling and others warming and even though expert opinions vary, the warming impacts are so great that it is now believed that non-CO_2 impacts could account for two-thirds of the global warming attributable to the aviation sector.

While non-CO_2 impacts are significant, unlike those produced by CO_2, they are of limited duration and therefore do not have a long-term impact on the atmosphere.

Combating the impacts of non-CO_2 impacts produces fast and significant results and gives us more time to reduce CO_2 emissions, which is an essential but difficult task.

It is agreed that SAF, which contains fewer aromatic compounds and therefore creates less soot and vapour trails, has a positive impact on aviation's non-CO_2 impacts.

THE ENVIRONMENTAL FOOTPRINT OF AIRPORTS

Airport emissions are hard to assess. They of course include direct emissions and emissions linked with energy purchases (the scope 1 and 2 emissions of the GHG Protocol). But these represent just a tiny proportion (around 3%) of scope 3 emissions, which are those created by airport stakeholders: emissions by parked aircraft and ground-handling equipment; passenger and staff airport access; decarbonisation of ground aircraft operations.

The Airport Carbon Accreditation Program is organised into accreditation levels that go up to 4+.

Every airport now has its own roadmap. The airports of Paris have level-3 accreditation and Lyon Saint Exupéry Airport has achieved level 3+.

DECARBONISATION INCENTIVES AND SUPPORT: GENERAL PRINCIPLES

Aviation can be decarbonised but it can't manage the job alone. It needs a consistent set of measures that combines incentives with support at the national, EU and international levels. In France, these policies must be built into the next five-year energy and climate planning law, while in the EU they must form part of the Fit for 55 package and its extensions. And they must take account of two essentials:

- **The French and EU aviation sectors must remain competitive**

Aviation is one of the last few sectors led by the European Union and France in particular. In 2018 the aviation sector provided two million direct jobs in the European Union and almost 10 million indirect jobs, including in the supply chain and in tourism. That same year, aviation's total contribution to EU GDP was in the order of 675 billion euro.

It is vital that the measures adopted to decarbonise European aviation do not make the sector less competitive. Smashing its competitivity would not make economic or environmental sense since European airlines would simply be replaced on their markets by foreign airlines that are not subject to EU environment laws.

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- **Decarbonisation times must be adjusted to meet the challenges specific to the aviation sector**

Air travel can be decarbonised but meeting the technical and economic challenges will be harder for aviation than for most other sectors.

If aviation is to be decarbonised, it must be given more time to achieve this than other sectors that already have generally deployed transition solutions, e.g. road travel and construction.

Energy transition will take longer for the aviation sector and so support mechanisms must be created to enable it to roll out sustainable fuels and new aircraft models on a large scale over the next few years.

THE MAIN MEASURES TO PROMOTE

1. More efficient air traffic management and air navigation services

In 2019 the European Union launched the Single European Sky 2+ package. This is now being discussed by the various EU institutions. Although some political obstacles remain, others have been removed, particularly in the wake of Brexit. It is now important to progress discussions as part of the tripartite meetings (trilogue) so that an agreement can be reached as soon as possible

2. Fleet replacement

To encourage airlines to replace their fleets, *Équilibre des Énergies* recommends including replacement among the sustainable activities defined by the Green Taxonomy and to make State airline aid conditional on an airline undertaking to replace its aircraft.

3. Earmarking a proportion of airport tax for aviation decarbonisation.

Airport tax makes up over 40% of the ticket price but the amounts collected are not earmarked for decarbonisation of the sector. Earmarking is also not mentioned in EU plans to tax aviation fuel and put an end to the free ETS quotas the sector has enjoyed. *Équilibre des Énergies* recommends that EU plans now under discussion should include earmarking a proportion of airport tax, including the income from the auctioning of currently free EU-ETS quotas, for the decarbonisation of the industry and the development of new technologies in particular.

4. Incorporation of mandatory quotas of sustainable fuel while ensuring European airlines remain competitive

Équilibre des Énergies believes that requiring incorporation of a mandatory quota is necessary to encourage airlines to migrate to sustainable aviation fuels (SAFs) as quickly as possible. It therefore supports the principle behind the mechanism proposed by the European Commission in ReFuelEU. But we must make sure that the mechanism does not make the EU's aviation sector less competitive. As a result:

- French and EU public authorities must continue lobbying the ICAO to harmonise the definition of SAF and to bring international CORSIA requirements into line with those of the European area;
- EU regulations must combine mandatory SAF incorporation with a certificate mechanism (book & claim) offering sufficient flexibility to put EU and international airlines on an equal footing and and enable them to refuel in hubs outside the European space.

5. Longer list of raw materials that can be used to produce SAFs

Équilibre des Énergies supports the principle of gradually extending mandatory incorporation of SAFs. However, although SAF production will therefore have to increase, this will be conditional on the availability of the necessary raw materials.

Équilibre des Énergies recommends that EU regulations and directives (ReFuelEU and RED) should lengthen the list of raw materials that can be used to produce SAFs to include especially the category-3 animal fats that at present can only be used to produce cosmetics and ground fuels.

6. Wider definition of e-fuels

In the draft ReFuelEU the Commission proposes that synthetic aviation fuels (e-fuels) should not be recognised as SAF unless their energy comes from renewable sources other than biomass. This means that electricity from renewable sources must be used. *Équilibre des Énergies* believes that low-carbon electricity should be included in the e-fuel definition to help decarbonise the aviation sector by increasing available SAF resources.

7. Priority access to biofuels for the aviation sector

Aviation is harder to decarbonise than other sectors that already have transition technologies (e.g. electric/hydrogen-powered travel). Its decarbonisation will largely depend on the use of large enough quantities of SAF.

Équilibre des Énergies therefore recommends that government policies earmark SAF primarily for the aviation sector. At EU level, it recommends that RED (Rewable Energy Directive) multipliers and consumption ceilings should be adjusted to reflect this priority.

8. Public-private partnerships to support the work needed to adapt airports

Airports play a key role in the rollout of sustainable aviation since they provide the infrastructure needed to develop alternative fuels. French airports are in advance of current regulations and are using their own resources to anticipate future airline requirements.

Équilibre des Énergies recommends helping airports roll out sustainable aviation through support systems, e.g. public-private partnerships.

9. An environmentally responsible airline label

In 2019 EASA (European Union Aviation Safety Agency) suggested a voluntary airline label to inform passengers and recognise airlines' efforts to support the environment.

Équilibre des Énergies calls for this initiative to be supported and for the creation as soon as possible of a label with criteria that include airline efforts to cut especially CO_2 emissions.

Équilibre des Énergies also calls for the examination of measures (e.g. lower airport tax or overflight charges) that will recognise the efforts airlines have made to meet label requirements.

10. Speed up of studies into non-CO_2 impacts

It is now recognised that increased use of SAFs will reduce non-CO_2 impacts. SAFs contain fewer aromatic compounds and therefore generate less of the soot that leads to the formation of vapour trails. But non-CO_2 impacts are complex and still little understood. Additional studies are needed before strategies can be created that will adjust flight paths to avoid zones likely to produce vapour trails without however lengthening routes excessively.

Équilibre des Énergies recommends that these should be undertaken both in France and in the EU to improve our understanding of vapour trail formation and other non-CO_2 impacts. ●

Air France-KLM will achieve net zero emissions in 2050

Anne-Marie Couderc,

Non-executive Chair of Air France-KLM

Covid hit Air France, like all airlines, hard. Our first question goes without saying: how is the Air France-KLM group now?

Anne-Marie Couderc: Over the last two years the Air France-KLM group has suffered the biggest shock in its history. In 2020 Covid put traffic 25 years back. The deep and persistent crisis triggered by Covid-19 has made the need for transformation very clear and made us bring forward our plan to bring Air France-KLM back into line with its European peers in terms of profit and to speed up our transition to sustainable aviation. We haven't just been waiting for traffic to pick up again. On the contrary, we've brought forward our entire strategy and transformation plans. The commitment of our teams has been wholehearted throughout this difficult period and I must thank them for it.

How do you see air traffic evolving in the longer term? Does the response to environmental concerns form a major part of your strategy? Young peoples' attitudes and the *flygskam* (flight shame) movement must of course be a cause for concern. What is your answer?

A.-M. C. : During Covid air transport proved its strategic importance with repatriations and the transport of masks, vaccines and now caregivers. As we transform, so our environment is changing too - and we are well aware of our environmental footprint. Over the last 18 months the pandemic has raised environmental awareness. Our approach to travel has evolved to be more about sustainability. Trips are less frequent and longer and combine travel for business with travel for pleasure. The sector is facing a double economic and environmental challenge. The drive behind relaunch must also be a drive for innovation. Covid has not suffocated our curiosity or our desire to travel and discover new things. And that makes me optimistic about the future of air transport, so long as we can manage the transition to a more sustainable model.

How has the pandemic changed your ambitions and aims in terms of cutting CO_2 emissions?

A.-M. C. : Air France-KLM began its environmental transition over 15 years ago. We didn't wait for this to become the main focus of public debate before making the commitments we are strengthening now. Today, it's one of our strategic priorities and a major demand of our customers, employees and shareholders. Our environmental ambition takes the form of a robust, realistic and transparent roadmap. The Air France-KLM group has set itself clear targets: to make a 30% cut in CO_2 emissions per passenger/km from their 2019 levels by 2030, and to achieve net zero emissions by 2050. And by 2030 to achieve net zero emissions for our activities on the ground. The policy we've submitted to the independent Science-Based Target Initiative for approval and for confirmation that it is in line with the Paris Accord is ambitious and demanding. Each of our airlines will work towards achieving that target - KLM through its Fly Responsibly programme and Air France through its recently launched Air France Act programme, both of which set out their new CO_2 emissions reduction policies.

These are all distant targets. How are you going to solve these problems in the here and now? More specifically, what changes can be made in the short term?

A.-M. C. : We have two big priority levers: fleet replacement and the incorporation of sustainable aviation fuels. In the short term, fleet replacement is the most effective way of reducing CO_2 emissions. The new aircraft in the Air France-KLM fleet send out a strong message that we are environmentally responsible. And that's why, despite this difficult period for us, we are still focusing 80% of our investment on the purchase of new aircraft: Airbus A350 for long-haul routes, Airbus A320neo and Airbus A220 for medium-haul routes, which emit up to 25% less CO_2 and have a 33-50% smaller noise footprint, depending on the plane.

The sustainable transformation of our activities is also embedded in all our businesses. We are using all currently available levers to cut greenhouse gas emissions to the bone at the everyday level (better flight paths and reduced payloads for our aircraft, no single-use plastics, systematic recycling of all our waste).

And what emissions we can't reduce, we offset. Our domestic and international flights are subject to ETS and CORSIA regulations and in addition to this we voluntarily and proactively make offsets for our domestic flights.

> We have two big priority levers: fleet replacement and the incorporation of sustainable aviation fuels

The French Climate and Resilience Act introduced restrictions for the aviation sector, particularly on short-haul flights. Do you think this is going in the right direction?

A.-M. C. : For decades the plane has been essential to the operation of this country and is still important in ensuring that certain regions of France are not isolated. Air France is committed to making a 50% cut in the CO_2 emissions of its domestic network by 2024. For this reason and as part of the undertakings we gave in spring 2020 when we received French government loans, Air France no longer operates routes out of Orly when an alternative, under 2½ hour train route is available: Orly-Nantes, Orly-Lyon and Orly-Bordeaux. So we've already shut down the routes covered by the Climate Resilience Act.

I'm a strong believer in intermodality. It's about complementarity, not competition, and ensuring that the low-carbon travel option is preferred whenever it's available. Air France and SNCF have been partners for 25 years and the TGV train has long replaced the plane on routes to Lille and Strasbourg. Links with the Paris-Charles de Gaulle hub remain to maintain our connections with the rest of the world.

Is zero-carbon aviation a long-term possibility? And if it is, how will it come about? Do you believe hydrogen-powered aircraft are a credible option?

A.-M. C. : After fleet replacement, the next most important decarbonisation lever is sustainable aviation fuels (SAFs). These can cut flight footprints by up to 80% over their life cycles. Since fuel accounts for 20-30% of our total costs, it's obvious that the price of SAF will be key to our ability to accelerate its incorporation.

We will do all in our power to support the creation of an SAF business in France and in the EU to ensure we become energy-independent at prices that are viable for all concerned.

As part of the Green Deal we are working to convince the Government and stakeholders of the need to develop a fair SAF industry in France and the EU and to prevent carbon leakage and unfair competition.

New energies such as hydrogen are another essential lever in energy transition. Aircraft incorporating these hydrogen and electric innovations will not be available before 2040 and will only be able to fly on short and medium-haul routes. That's why incorporating sustainable aviation fuels is the only way to decarbonise long-haul flights in the medium term. This will be half our work to 2050.

The EU and France in particular now have an opportunity to pioneer the development of the technologies of the future: hydrogen and e-fuels. By working on this now we are ensuring the successful environmental transition of our sector in the next fifteen years.

We are sometimes sceptical about commitments to protecting the environment. What does the Air France-KLM group do to assess its results and get them certified?

A.-M. C. : We take a transparent, honest and responsible approach to our customers, shareholders, all our staff and our partners.

ESG rating agencies give our Group unsolicited ratings that are in general better than those of our peers. A few weeks ago we decided to obtain a solicited ESG rating to improve our strategy and practices in this area. S&P Global Ratings gave Air France-KLM an ESG rating of 64/100. This means our position within the aviation industry on the management of the environmental challenges facing us is good.

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We've also just signed up to the SBTi (Science-Based Targets) initiative to give ourselves targets that are both science-based and in line with Paris Accord aims to keep global warming well below 2°C. We're one of the first European airline groups to decide to have its decarbonisation strategy approved by SBTi. We have opted for the scientific assessment of our ambitions and have made a further commitment to cutting CO_2 by 2030-2035, in addition to our existing commitment to net zero emissions by 2050. This is a very big commitment for the Group.

Would you be in favour of a label for the most environmentally aware airlines?

A.-M. C. : This could be a good idea for both airlines and their customers so long as it really is awarded for actual environmental action. It's a complicated task because no single indicator reflects the efforts the industry has effectively made in terms of e.g. emissions in absolute value terms, emissions per passenger or changes in emission figures.

The indicator would also have to reflect other environmental actions (waste, noise etc. reduction) and, even and more widely, the involvement of industry players to sustainable development, including the UN's 17-point sustainable development programme.

Respect for the environment is a plus in international competition. But it comes at a cost and excessive zeal could be very damaging to the competitiveness of the Air France-KLM group. How do you see the European Commission's Fit for 55 package and do you think it ought to be softened?

A.-M. C. : We welcome Fit for 55. The decarbonisation of the industry will have to come through the gradually increasing use of sustainable aviation fuels. Fit for 55 also shows how important the ETS is to managing EU targets for reducing greenhouse gas emissions.

We have greater reservations about the taxation of aviation fuel. Unless the income from the tax is allocated to emission reduction projects, the tax itself will simply be a significant additional burden on the sector at the very time it is having to pay for its environmental transition.

We also need to be careful about the unfair competition that will follow on these measures if the rest of the world does not follow the EU's lead or if some countries subsidise the environmental transition of their own aviation sectors. Unfair competition could appear over intercontinental flights operated by third country airlines that have hubs outside the EU and are to some extent free from the environmental constraints affecting EU airlines. This would not benefit the global climate.

We believe Fit for 55 must be accompanied by mechanisms that will prevent unfair competition and carbon leakage.

The ICAO is to hold a general assembly in September 2022. What role can the ICAO play in the decarbonisation of air transport, particularly through the CORSIA offset system?

A.-M. C. : The international stage is by its very nature the best place to deal with the cutting greenhouse gas emissions in line with Paris Accord targets.

'*Alone, I go faster, together, we go further*'. Despite the complexities of multilateral negotiations, the EU Member States spearheading the international environmental drive must, we believe, continue to push for stronger global climate action objectives and measures in the field of air transport. Even though the aims of the ICAO's CORSIA programme may at present appear inadequate in some areas, particularly when compared with EU targets, CORSIA itself started its pilot phase in 2021 and now applies to around 77% of the world's entire international air traffic. In 2027 when its second phase starts, CORSIA will apply to over 90% of international air traffic. This success proves that common international targets and measures are possible.

CORSIA at present caps emissions internationally through an offset system. To make this more effective and lower emissions globally, we call on the ICAO to make the incorporation of biofuel a global requirement. This would be a major step forward in decarbonisation and would send a clear signal to the industry producing sustainable aviation fuels.

We're working closely with all the players in the value chain to ensure France develops its own sustainable aviation fuel industry since this is essential to the generalised use of SAF in French airports

How can the Air France-KLM group influence the sector as a whole?

A.-M. C. : We are convinced that the only way to meet the sustainability challenge is by acting together. We work with all the players in our ecosystem: aircraft manufacturers, airports, fuel suppliers, air traffic control authorities and public authorities to achieve ever more ambitious targets.

We're working closely with all the players in the value chain to ensure France develops its own sustainable aviation fuel industry since this is essential to the generalised use of SAF in French airports.

After working together with TotalEnergies and Groupe ADP on the first long-haul flight to Canada powered by French-produced SAF in May, we repeated the experience on 1 October 2021 (with Air France, TotalEnergies, Métropole Nice Côte d'Azur and Nice Côte d'Azur Airport) with a Nice-Paris flight 30% powered by sustainable aviation fuel produced by TotalEnergies in its French plant.

All these combined efforts are essential if we are to support and develop a French sustainable aviation fuel industry. ●


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Ecological transition is at the heart of Airbus strategy

Guillaume Faury,
CEO of Airbus

After its fantastic growth, the aviation sector has been criticised by the environmental movements and has had to deal with the fallout of the Covid pandemic. How confident are you about recovery and what does the sector have to offer today?

Guillaume Faury: The aviation industry is just beginning to come out of the worst and longest crisis in its history to face two main challenges in the immediate future: sustainable recovery after Covid and the need to rebuild by focusing with determination on the decarbonisation of the sector - which will require unprecedented amounts of innovation and investment.

Aviation has a lot to offer society: it supports international cooperation, economic development and global cultural exchange. It connects places and people who can now in increasing numbers fly long and short distances. Since it began, aviation has given people the opportunity to travel, work and connect with and talk to each other, fulfilling a vital role in our societies.

And that role is part of a sustainable future. Through the International Air Transport Association (IATA) and the Air Transport Action Group (ATAG), the entire aviation industry has committed to carbon neutrality by 2050 and we believe we have the innovative capacity to pick up that challenge.

What role does environmental transition play in the Airbus strategy and what big milestones have you set yourselves?

G. F. : Environmental transition is at the heart of Airbus strategy and our *raison d'être.* We aim to be pioneers in a sustainable aerospace industry that helps create a safe and united world. We have committed heavily to reducing the environmental impact of our business and our aircraft all the way from design to end of life.

One of our most significant commitments is to have the first commercial zero-emission aircraft in service by around 2035. For this new technology to be possible, we need to encourage the creation of an ecosystem that will ensure hydrogen is available in existing airports and infrastructure, to fund research - including with government support - and to create legal frameworks that will apply across the entire industry.

Before talking about the future, do you think that present aircraft can still be improved?

G. F. : Only 13% of the fleets now in service is made up of latest-generation aircraft. Modernizing the other 80% with planes that are 20-25% more fuel-efficient would reduce the sector's global emissions considerably until the next generation of aircraft comes into service. These will be arriving over the next ten years with many technological improvements built into them: new materials, propulsion systems, wings, aerodynamics and the ability to use sustainable aircraft fuels.

Formation flying by the Airbus fleet: A220-300, A319neo, A330neo and A350-1000.
© Airbus - Sylvain Ramadier

Airbus has a long history of innovation and we're continuing to make advances in new aircraft architectures, propulsion systems and formation flights

The energy and environmental performance of your aircraft is of course key to making them competitive. Is Airbus still a technological leader ahead of its US and Chinese competitors?

G. F. : Recent commercial successes have made clear how competitive and attractive our products are, thanks to technology. We intend to retain that technological lead over our competitors.

That's why we believe it's vital to continue research into cutting-edge technologies and effective solutions for decarbonizing our present and future products. Airbus has a long history of innovation and we're continuing to make advances in new aircraft architectures, propulsion systems and formation flights. We also actively support the large-scale development of alternative energies, especially sustainable aviation fuels and zero-carbon hydrogen solutions.

A lot has been talked about hydrogen-powered aircraft. Do you think this is a technology that will see the light of day to account for a significant proportion of air transport ?

G. F. : Yes, we are certain it will. Hydrogen is one of the most promising zero-emission technologies. It's produced using zero-carbon energy and emits no CO_2 into the atmosphere either when powering the aircraft or during energy production. For the moment Airbus is focusing on short and medium-haul planes but we're looking forward to the technologies that will eventually go beyond this.

The general adoption of hydrogen is likely to be made easier as its cost drops significantly over the next decade. We support the development of a hydrogen economy and hydrogen hubs in airports. We therefore believe that aviation should form part of national, EU and world-wide hydrogen strategies.

How do you see the future of electric aircraft?

G. F. : It's a technology that could work for small planes. The next generation of Airbus urban air vehicles will be fitted with it following the Vahana and CityAirbus demonstrators. But in the case of a commercial aircraft like the A320, the weight of the batteries needed to deliver the power and energy required is a currently insurmountable obstacle.

We do however intend to use more batteries in our aircraft to supply electricity to some on-board •••

A Beluga being fuelled with SAF.
© JANE WIDDOWSON

All our aircraft are already approved to fly on a fuel mix containing up to 50% SAF, without any technical modifications or impact on operations or maintenance

systems and power non-propulsive functions both in flight and on the ground. The reduced use of combustion engines this will cause will shrink the CO_2 footprint of aircraft.

It seems that the main way to decarbonise aviation in the short term is to use sustainable fuels (SAFs) instead of aviation fuel. Are Airbus aircraft today compatible with them or will this need another technological leap forward? What milestones have you already planned?

G. F. : Replacing fossil aviation fuel with SAF will reduce CO_2 emissions by up to 80%. SAF is therefore essential to cutting emissions in the years to come.

Since 2008 Airbus has played an important role in adopting and certifying SAFs with test flights and strategic partnerships. All our aircraft are already approved to fly on a fuel mix containing up to 50% SAF, without any technical modifications or impact on operations or maintenance. Over 350 000 commercial flights have used SAF since 2011.

We aim to be certified 100% SAF over our entire range before the end of the decade. To achieve this, Airbus is running research programmes, such as ECLIF3 on the A350 and VOLCAN on the A319, that will also improve our understanding of the positive impact these fuels have on cutting non-CO_2 emissions.

Just as important will be a new ecosystem that allows the development of an industry producing and supplying this type of fuel internationally. Airbus has therefore entered into a number of public-private partnerships to encourage the development of that ecosystem.

In the EU and France in particular, aviation is an industry of excellence. What is needed to ensure it continues to develop and remains an international leader?

G. F. : Aerospace is indeed an industry of excellence in the EU and in France. We have a few big champions that are world leaders in their fields and thousands of SMEs that boast extraordinary levels of know-how. In France alone the sector provides over 300 000 direct and one million indirect jobs and every year generates around 20 billion euro in profit.

To maintain it, we first of all need to support research and innovation. That's what the government does through CORAC and what the regions do through IRT and innovation and development subsidies to SMEs. We also need to keep European industry competitive by stimulating investment, particularly in new technologies and new energies. But to maintain the sector, the authorities also need to avoid piling on regulations and taxes that will suffocate the sector instead of helping with its environmental transition. We are, for example, against a tax on aviation fuel on top of the EU's ETS that has already set a carbon price for aviation that is over€80 per tonne of CO_2.

What do you expect now from the EU and especially from the Fit for 55 discussions?

G. F. : The EU's aviation industry produced a clear roadmap for sector decarbonisation with the Destination 2050 report and in its target of net zero emissions on all domestic flights and all flights departing from EU airports. We support all the aims of this report, which are in line with the target of a50% cut in EU CO_2 emissions by 2030 and carbon neutrality by 2050.

But if the sector is to achieve these targets it must recover from Covid fast. This is why we're asking the EU to deliver a financial and regulatory framework that will allow air transport to recover and begin sustainable operations by aiming for a proper balance between support for investment on the one hand and environmental regulation on the other to ensure that European aviation remains competitive and sustainable.

The ICAO will be holding its 41th assembly from 27 September to 7 October 2022. What do you expect from it and can we hope to see a general move towards the adoption of common rules?

G. F. : The decarbonisation of aviation needs to be accompanied by fair competition rules that apply world-wide. The ICAO has an essential role to play here because it alone can create those rules. We expect it to set long-term aims for aviation and a level playing field by introducing rules that will apply in all its 193 member States on environmental matters, just as it has already done with great success in safety and security matters and the CORSIA carbon offsetting system.

There is of course an opportunity to create a strong EU-US alliance based on the ICAO's long-term targets and its climate objectives. But other countries that may have slightly different objectives will also have to be brought on board - countries that are wondering whether they have the resources to achieve those targets. It is essential that they are involved from the start of discussions so that the 2022 Assembly can produce a strong agreement that will have a real impact.

The decarbonisation of aviation needs to be accompanied by fair competition rules that apply world-wide.

Through the ATAG the industry has already shown that it can reorganise, come together and work on joint solutions for common problems. With such an ambitious objective, it is extremely important for governments to work with the industry to move together towards consensus. Discussions in the next few months will therefore be essential to the successful outcome of the 2022 ICAO Assembly. ●

Reinventing aviation

That the aeronautical sector is under attack from the absolutist preachers of decarbonisation is no longer a novelty. Citizens are advised not to go by plane, but by train, and aviation is advised to cut off flights.

Marian-Jean Marinescu,
MEP, speaker of the EPP Group in TRAN Committee

Short flights can be, say these preachers, travelled by rail; yes, they would take longer, but with environmental protection. Some think you can't have both. In this rather dogmatic and unfriendly climate towards polluting industries, aviation must make efforts to reinvent itself: to deliver electric planes or engines that consume less and, in addition to this, which use a mix with a higher percentage of alternative fuels.

For centuries, aviation has been a space for innovation. To me, reinventing and, if I could say, saving aviation will also come from research and innovation. And this is, in essence, my policy line on "Fit for 55": investing in research and innovation.

BRAINSTORMING: THE PATH FROM IDEAS TO SOLUTIONS

Last November, I hosted a virtual exchange of views with all parties involved in the decarbonisation of European aviation, from EASA to DG Move, ASD, Airbus, Neste, SAFRAN, etc. The pandemic has seriously affected the aviation sector. However, the big challenge now is the Green Deal and decarbonisation. Good news is coming from the industry: Airbus says it will deliver a hydrogen-based aircraft in 2035. Well, I personally consider this statement extremely bold, as hydrogen comes with a lot of challenges. Another challenge is the current freight crisis. Airbus, for example, has suppliers worldwide. The cost of transport has increased 20 times in this activity, mainly due to the crisis of containers, which are blocked in the US and China. Because of the pandemic, there are not enough staff to unload the ships queuing by hundreds in US or Chinese ports. A company like Airbus has a clear plan for the future, and and aims at achieving climate neutrality in 2050. But Airbus is a large company that can support research and development, which means it will adapt more easily to the challenge that comes with "Fit for 55", likewise SAFRAN (the engine manufacturer), which already uses 50% of alternative fuel for the engines it now proposes. The question is how will other companies that that are not as established as Airbus and SAFRAN and do not have the financial means to adapt. We in the EP will try through our regulations to facilitate this transition for every European company.

SES -10% LESS CO_2

On the other hand, an adjacent way to reduce aviation emissions is to implement the Single European Sky (SES). Last autumn I attended the annual Aviation Safety conference for the first time. The conference took place in Cologne, and I was invited as rapporteur of the European Parliament in the SES file to talk about air traffic control. I have noticed that the industry support for the rapid implementation of the new air traffic control system is very high. It makes sense: SES is a simple and safe way to reduce aviation emissions. All studies show that the implementation of SES can lead to a reduction of about 10% in CO_2 emissions. In the meantime, aviation has the time to develop the emission reduction solutions that we mentioned above. As I said, reducing emissions by 10% can be quite simple only through traffic control. Just one example: reducing the duration of a flight by a quarter of an hour, which would normally be 2 hours, translates into a 10% reduction in emissions, just because less fuel is used.

Unfortunately, this simple possibility of reducing emissions is not supported by some Member States. Where does this opposition come from when everyone says in chorus that we are working together to reduce emissions, it is for me, as an SES rapporteur, baffling. At the time this piece is being published a pilot can choose the direct route between two destinations or can use the new software that indicates the least polluting route. This system already exists in some Member State therefore, I do not understand why other Member States declare that this violates national sovereignty.

In reality, the big problem is money, the economic aspect of SES implementation. The overflight fee that passengers have to pay - because they are the real payers, not the airlines - when a plane flies over a state. The Cologne conference confirmed to me that my policy line in SES corresponds to what the majority of the aviation industry wants. Regarding SES, I am confident that the negotiations with the French Presidency of the Council will lead to progress on this file.

I think we need to collect massive, strategic and programmatically raw materials to produce alternative fuels for aviation.

MOBILITY - A FUNDAMENTAL EUROPEAN RIGHT

Unfortunately, these bottlenecks in the SES negotiations risk leading to a reduction in aviation emissions by limiting mobility and not by more efficient management, as proposed by the Single European Sky.

It is hypocritical for Member States to claim at the climate conference in Glasgow that they want to reduce emissions, and when they have a concrete proposal to reduce emissions in aviation, they show that they lack the political will. A good example that pictures the real situation at the moment in the Union: statements are statements, their implementation is a completely different story.

Nevertheless, I believe that mobility is a fundamental European right, and we must not allow it to be limited. And if we want to reduce emissions, limiting mobility must not be a solution at all. As for me, both as EPP coordinator in TRAN and as EP SES negotiator, I will continue my efforts for this file through direct meetings with the ambassadors of the Member States as well as with the civil aviation directorates. I hope to make progress in obtaining a text that is both in line with MS and EU commitments to reduce emissions while maintaining mobility.

FIGHT FOR YOUR SOLUTIONS!

Although I have often heard praise for ETS, I believe that ETS been proven to be a guaranteed success for the purpose for which it was invented: to reduce emissions. Is ETS an aviation solution? Not yet! ETS has been successfully applied in sectors where ETS was not the only decarbonisation solution. In the automotive industry, for example, there are already alternatives: alternative fuels, electric motors, hybrid solutions etc. This is not the case in aviation. Not yet. I think we need to collect massive, strategic and programmatically raw materials to produce alternative fuels for aviation. I do not think increasing taxation in aviation will provide results. In addition to this, all funds collected from the ETS must go mainly to industry: 95% to industry, and only 5% to the budget. CORSIA must be applied and the EU must have a single voice.

Finally, I would say that it is now the right time for the industry to present its points of view to all the political groups and all the commissions within the EP that have a say in the Fit for 55 legislative package. Explain the actual situation, present your plans and highlight the solutions and their implementation. It is in the interest of all of us, legislators, industry and passengers, for the aviation to remain one of the available options when it comes to exercising our right to mobility in the EU.●

Aviation is one of the jewels in France's industrial crown, and must remain so

As a key contributor to our international prestige, the aviation sector is vital to the French economy and essential to our balance of payments. As a member of the French parliament, I must strongly emphasise the importance of this sector to the economic dynamism of almost all the regions of France, thanks to its delivery of training, jobs and extremely high-level skills.

Jean-Luc Lagleize,
Deputy and co-chair of the Aerospace Sector study group at the French National Assembly,

I am however concerned about the two-fold crisis now afflicting the sector. Covid-19, which has caused very substantial damage to the sector's value chains, has also deepened the moral crisis from which the aviation industry had already been suffering for many years.

Aviation gets a bad press. Already demonised by environmental associations as the main cause of climate change today, violent aero bashing is now challenging its very right to exist. The *Flygskam*[1] movement has had a real impact on the public image of flying and therefore on passengers.

Yet the convictions of these extreme environmentalists are contradicted by the figures.

Aviation is responsible for 3% of the world's greenhouse gases (GHG). The sector's responsibility for global warming is far less than some of its critics would have us think. As a comparison, digital creates 10% of the world's GHG.

Of course this does not affect the fact that the aviation sector must face up to its responsibilities in the fight against global warming. The climate emergency means that it is imperative to accelerate the decarbonisation of the industry. But reducing air traffic in the way some environmentalists are demanding is not the answer. The aviation industry needs to speed up its transformation and adapt to environmental challenges.

Decarbonising aviation has become a new global competitive challenge in which France and the EU must develop a key competitive advantage over their US and Chinese rivals. It is also a component in strategic energy independence, which has become a particularly pressing and burning question.

Decarbonisation is a matter of survival and a problem the aviation industry can no longer avoid facing up to.

As a French member of parliament, I decided to get involved in developing real solutions for transforming the aviation industry. I have therefore been appointed co-chair of the Aerospace Sector study group at the French National Assembly, enabling me to work alongside the players concerned on aviation politics and legislation.

In June 2021, I was appointed to report on the fact-finding mission into the future of the French aviation sector. It was a mission close to my heart since its aim was to make concrete recommendations to public and private players on how best to adjust the aviation industry to meet the challenges of today.

The interviews I've conducted with my colleague, Sylvia Pinel, of people from an extremely wide range of aviation businesses across France have overwhelmingly demonstrated to me that the industry's understanding of the need to speed up its decarbonisation is real and collective. The proactive stance of companies, combined with the Government's commitment in this area, make the future of this industry appear very encouraging.

1. Flight shame.

Decarbonising the aviation sector requires overcoming two main challenges: fleet replacement and biofuel development

Aircraft building companies have always worked towards improving their customers' fleets. The new planes use 20-25% less fuel than the last generation and therefore produce 20-25% less GHG.

At the same time, some companies are investing in the development of all-electric planes, even though they can only be used on short flights.

Considerable effort is going into the development of biofuels. In the case of both sustainable aviation fuels (SAF) and hydrogen, energy companies are developing new know-how that is resetting the boundaries of our industry.

The French Strategic Advisory Board for Civil Aviation Research (CORAC) in particular plays a key role. Bringing together the State and industry, CORAC synchronises all technological research to provide effective support for the R&D undertaken by companies to decarbonise their businesses.

The French government for its part is committed to EU targets for reducing GHG in the medium and long terms and has given undertakings that match up to the challenges facing the aviation industry.

The response to the pandemic was generally infused with a determination to achieve environmental transition for air transport. The 15 billion euro support plan for the industry has been followed by a 300 million euro public-sector support fund for the diversification, modernisation and environmental transformation of processes.

Other commitments will also help decarbonise the industry: in September 2020 a French national hydrogen strategy was introduced; the incentive tax on aviation fuel introduced in the 2021 Finance Bill will come into force at the start of 2022; France 2030 and its aim of producing the first low-carbon aircraft by 2030, etc.

The interviews I've conducted with my colleague, Sylvia Pinel, of people from an extremely wide range of aviation businesses across France have overwhelmingly demonstrated to me that the industry's fully understanding of the need to speed up its decarbonisation is real and collective

I cannot however conceal my concerns about the restrictions on air transport emissions contained in the Climate-Resilience Act.

Banning flights if there is an alternative, under 2½ hour train route, regulating the increase of airport capacity and requiring all airlines to offset their carbon emissions on all their flights in mainland France - I believe that imposing these purely French measures passed by the French Parliament to French companies operating within a competitive international context goes against the flow in the complex environment Covid-19 has created and that all aviation and air transport sectors must now face.

My rather one-sided considerations have demonstrated to me that the aviation sector has failed to communicate effectively what is, after all, its significant commitment to succeeding in its energy transition. I hope that the report from this fact-finding mission will shine a light on the real environmental transition of this industry.

Decarbonising aviation is a collective job. Companies and the public authorities must give up on pointless debates about how much pollution air transport creates and instead focus on the innovations and commitments that are required immediately if aviation is to become a decarbonised sector by 2050.

We need to take action today if we want still to be flying tomorrow. ●

Aviation and transition - the time to act is now

Gérard Feldzer,
President of *Aviation sans frontières*, former airline pilot, Air France instructor

In just a few decades air transport has become a form of mass transport with passenger numbers that have risen from 9 million in 1945 to over 4.5 billion today (pre-Covid). 1 300 airlines fly over 26 000 planes out of 3 500 international airports. One aircraft takes off every second in the world and traffic is expected over the next 15 years to 7 billion passengers and 220 billion tonnes/km of freight. We need to change our technologies and habits…

Air transport has become a consumer product just like any other, especially since the arrival of low-cost airlines that, like supermarkets, offer loss-leaders. You can now get return flights within Europe for 49.99 euro. So people are travelling more because they're finding cheap deals than because they need to, or even for pleasure.

And like all consumer products, air transport has its positive side (R&D, job creation) and its negative side (noise and pollution). The finance and the environment need to fit together because the survival of air transport depends on this.

THE NEED TO ACT

It has been some years since the public and politicians realised how air transport contributes to global warming. Movements such as *flygskam* (flight shame) have pushed down aviation sector turnover slightly thanks to the strong commitment of key figures like Greta Thunberg. Rail and, in France, TGVs has become the biggest competitor of the plane over short and medium distances, with similarly, or even higher, priced tickets. Air transport is demonised for its high profile and reputation as a means of transport for high-income passengers/consumers.

So we cannot ignore the movement and the need for a technological breakthrough and behavioural change is becoming increasingly urgent.

PROPULSION AND FOSSIL FUELS

When I began my career as a pilot on Caravelles we were burning around 8 l/100 km per passenger. 30 years later with the Airbus 330 we were down to 4 litres and soon that will have shrunk to two.

Air transport today accounts for 3-5% of all greenhouse gas emissions, a huge range of discharges (CO_2, nitrogen oxide, sulphur dioxide (SO_2), ozone (O_3), vapour trails etc. - not forgetting the miscellaneous discharges, like fine particulate matter), all of which are caused by the combustion of aviation fuel. These compounds are detrimental to human, animal and plant health.

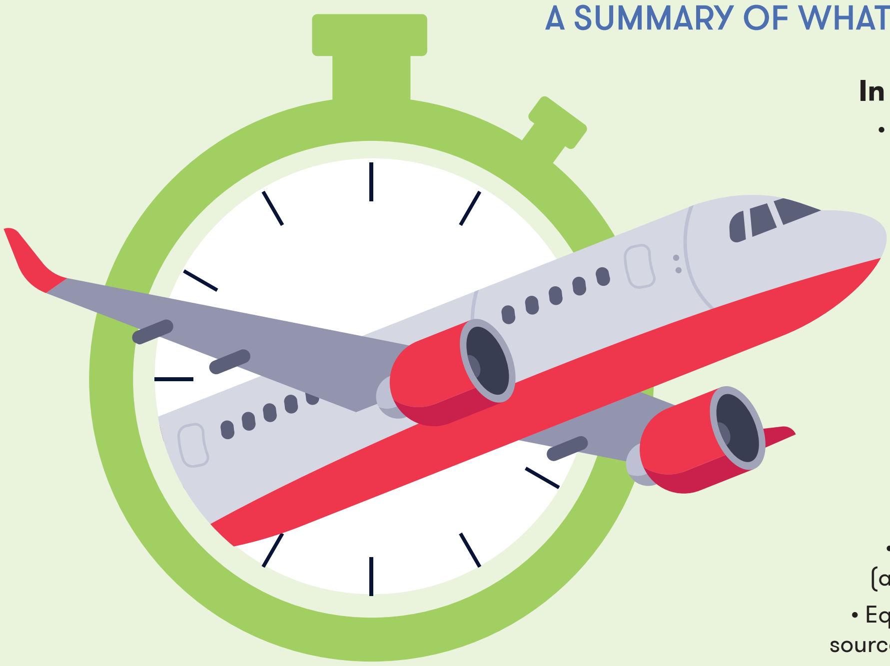
URGENT NEED FOR A TECHNOLOGICAL BREAKTHROUGH

The last real technological breakthrough was Concorde. Then, the challenge was to create a supersonic plane to fly passengers on a day to day basis. This challenge and that magnificent, innovation-rich aircraft made a major contribution to Airbus. But in the meantime, noise (120 decibels around the airport at take-off, the supersonic bang etc.) and pollution (10 l/100 km per passenger) became intolerable to some parts of society. And that's without the mind-boggling maintenance costs.

Thanks to progress, noise and emissions have been halved in the last 30 years but all of this could be compromised by air traffic growth. It's estimated that around 500 million people world-wide today suffer from aircraft noise.

All aircraft manufacturers are working on new generations of planes, engines, onboard energies, new aerodynamic shapes and materials (nanotechnologies etc.).

We could be seeing the under 100-passenger short and medium-distance



A SUMMARY OF WHAT WE NEED TO DO

In the short and medium terms:

- Replace airline fleets, introduce incentives through variable airport tax, and create an international agreement;
- Ban fuel transport*;
- Make continuous descent approach compulsory;
- Avoid taxiing using main engines. Encourage green taxiing and the use of fast tugs to bring planes to their takeoff positions;
- Smart emission offset through green investment (plantations etc.) e.g. Air France in association with A Tree for You;
- Immediately equip airports with renewables (and storage for them);
- Equip secondary aerodromes with renewable sources of electricity (500 aerodromes in France);
- Help general and leisure aviation invest in light, very low-emission aircraft;

* Since aviation fuel is cheaper at some airports, airlines ask pilots to bring more fuel than they actually require back with them when they return to base. This turns their planes into heavier flying tankers that use more fuel and produce higher emissions.

In the medium and long-terms:

- Pre-order green aircraft to accelerate technological change;
- Increase EU aid for research (decarbonisation R&D will cost $20 billion).

electric aircraft with around 2 hours' autonomy in the 2050s. But the bar is high because to obtain the equivalent of the energy produced by 1 kg of oil, you need 30 kg of batteries at present. And the liquid hydrogen carried by planes would have to be stored in tanks able to maintain a temperature of -256°.

The engineers are now working on a number of key technologies, such electricity generation by hybridizing batteries and hydrogen fuel cells. Some studies, including by ONERA, suggest dozens of electric blowers under the leading edges of the wing to improve thrust and reduce noise. Swing wings that alter their sweep depending on speed are also being studied.

Airports are also involved since on their own they emit one-quarter of all air transport greenhouse gases. This includes technical infrastructure, routing, terminals, etc., taxiing by planes using their engines and flight approach and takeoff.

FINANCIAL INCENTIVES

The lower tax air transport has enjoyed on oil products is becoming unacceptable to the majority of people who are now paying ever higher prices at the pump. We will probably see airport tax depend on the environmental performance of aircraft.

IATA, acting on behalf of almost 300 airlines, has announced a target of carbon neutrality by 2050 - a programme that is likely to cost around $ 1 800 billion. But if we do nothing, emissions will double in the next 30 years.

BIOFUELS

The advantage of these sustainable aviation fuels (SAFs), which are produced from waste oils, animal fats and soon from recovered CO_2, is that they can be used in existing engines without too many modifications. They provide a solution for cutting CO_2 emissions 80% below those of aviation fuel in the short term. The problem is production capacity. This is currently 100 million litres a year but the requirement in 2050 will be 450 billion litres. Furthermore, biofuel costs four to six times more than fossil fuel and might also be competing for agricultural land.

It's a big challenge. But the public will give a hearty welcome to virtuous aircraft manufacturers and airlines on the green aviation market. We've been talking about electric cars for 100 years and they're finally here. It'll be the same for air transport. But the time to act is now.

Flight 2050 to destination Net Zero Emissions

Often demonised as a sector, aviation meets an essential need to travel. It is taking a determined approach to decarbonisation, primarily based on Sustainable Aviation Fuels (SAF) development. Taxation is not a constructive solution but traffic management, through the Single European Sky initiative, must be improved. France has a vital role to play.

Rafael Schvartzman,

Regional Vice President Europe of the International Air Transport Association (IATA)

AVIATION COMMITS TO NET ZERO CO_2 EMISSIONS

Despite the difficult times with many restrictions still in place, especially those limiting freedom of movement, the wish to fly and to travel remains as strong as ever. Pandemic or not, aviation must therefore continue to reduce its environmental footprint. Despite being responsible for only around 2% of the world's CO_2 emissions, the sector is determined to play an increasingly active role in keeping global warming down to 1.5°C above pre-industrial levels set by the Paris Agreement on climate change.

The International Air Transport Association (IATA) has been committed to decarbonisation for over a decade, and at its annual general assembly last October, the sector committed to achieve net zero CO_2 emissions by 2050. As a global target, this is a challenge of totally Dante-esque proportions. 10 billion flights are forecast in 2050 but aviation must make a 1.8 billion tonne cut in its carbon emissions by then and, contrary to the situation for cars and trains, electric and hydrogen solutions for aviation are still only at an embryonic stage.

IATA's FlyNetZero commitment is supported by the entire aviation ecosystem via the Air Transport Action Group (ATAG), which brings together the main players in the sector (airlines, aircraft and engine manufacturers, air traffic controllers, etc.).

SUCCESS: A USER GUIDE

While three kilometres of train tracks will take us to the next village, three kilometres of runway will connect an almost infinite number of destinations that may be thousands of kilometres apart. Only aviation, the safest means of transport, can create that connection between people, societies, cultures, and economies. Its value and contribution - as the start of the pandemic so brutally made clear to us with the repatriation of people and the transport of medical per sonnel and equipment around the planet - are hard to dispute. But it still needs a neutral carbon footprint.

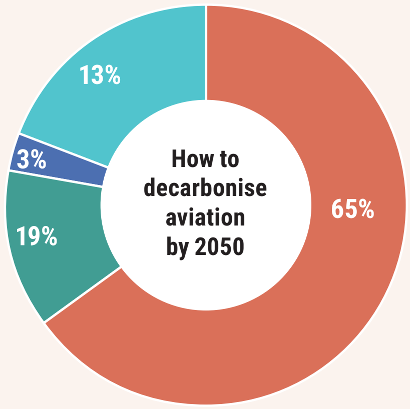
And the enemy is carbon - not aviation. Yet many people unfortunately confuse the two and far too often, for opportunistic reasons, therefore attacking the wrong target.

The commitment we gave in October now requires us to accelerate our efforts and to work unrelentingly to make aviation even greener. But we, the airlines, cannot solve this problem alone. Without constructive collaboration from governments and the competent authorities, we will be unable to achieve our goals.

Sustainable Aviation Fuels (SAFs) are the backbone of our plan for net zero CO_2 emissions by 2050. Hundreds of thousands of flights have already been operated on a SAF mix but the low levels of SAF production and its high price (3 to 5 times that of standard jet fuel) mean it is of only marginal use and needs the clear support of governments and competent authorities. Logistics and SAF financing need to be improved and incentives introduced to motivate users to privilege this solution.

Green taxes are not a viable option. Taxing aviation fuel for example will not make the industry greener. The

IATA's FlyNetZero commitment is supported by the entire aviation sector via the Air Transport Action Group



65% Sustainable Aviation Fuels (SAF) based on raw materials that do not harm the environment or compete with food and water..

19% Offset, including carbon capture and storage technology.

3% Continuous improvement of infrastructure and operating efficiency, focusing especially on the improvement of air traffic management.

13% Investment in new aviation technologies, including radical new solutions for aerodynamic propulsion and (electric/hydrogen) alternatives.

vast majority of these so-called green taxes flow into general national budgets and make no contribution whatsoever to the environment. Indeed, they are often used to finance other, already far better financed, means of transport. And finally, they cut down on the resources that aviation could use to invest in its own decarbonisation. The adoption of the Single European Sky initiative (SES2+) would reduce emissions by up to 10% (source: European Union) and is a perfect example of this. Rather than hiding behind excuses about sovereignty and giving in to threats from social movements created by the holders of monopolies that in no way encourage efficiency, some countries should rather play ball and promote this EU solution, at least for the good of the environment, but also to reduce flight delays, which also have a strong impact on it.

France, which will be in the spotlight as holder of the presidency of the Council of the European Union and host of the upcoming 2023 Rugby World Cup, and 2024 summer Olympics, has a positive role to play in making all parties work hand in hand together in our sector to tackle the decarbonisation challenge ●

Climate change: The impact on air transport

Nicolas Gourdain
lecturer and researcher, ISAE-SUPAERO

Mitigating the climate impact of aviation is a huge challenge but it is only one part of the environmental challenge. Climate change and its increasing impact over the next decades is forcing us to think about another aspect of this problem: adaptation.

When developing an effective policy for adaptation, the main priority is to identify and quantify all the potential impacts climate change can have on air transport. These are mainly of two kinds: direct impacts caused by changes in the atmosphere and oceans, and indirect impacts caused by behavioural changes.

SOCIETAL CHALLENGES...

These alterations can come from societal changes (e.g. the development of videoconferencing or a better understanding of environmental challenges) that modify demand (in Sweden in 2019 the number of passengers on domestic flights fell by 9% because of the *flygskam* movement). The changes can also be the result of variations in tourism (avoidance of destinations with recurrent extreme weather events). Some Mediterranean countries (like Greece) could therefore suffer big fall (up to 30%) in summer tourism from 2030. Regions subject to major heatwaves and fires could also see the number of their inhabitants drop. This is particularly the case for California, which has had no population shrinkage for over a century. These changes will require differentiate adjustment of services according to the part of the world concerned.

... AND ITS CONSEQUENCES FOR AIR TRAVEL

Climate change will also have direct impacts that fall into five main categories, as shown in figure 1: changes in rainfall and winds, changes in atmospheric temperature, rise in sea levels and extreme weather events.

Lower air density

Dozens of flights were cancelled in Phoenix (USA) in 2017 and in Dallas (USA) in 2021 because of intense heatwaves in which ground temperatures were close to 50°C. These extreme conditions have a huge impact on aircraft landing and takeoff because air density falls as the temperature increases. Engine lift and thrust are significantly reduced if ground temperature exceeds 35°C. Under these circumstances and for any given length of runway, the maximum takeoff weight of an aircraft must be reduced by decreasing the number of its passengers. For example, in Toulouse these weight restrictions could reduce the number of seats by 10% to 20% on short flights

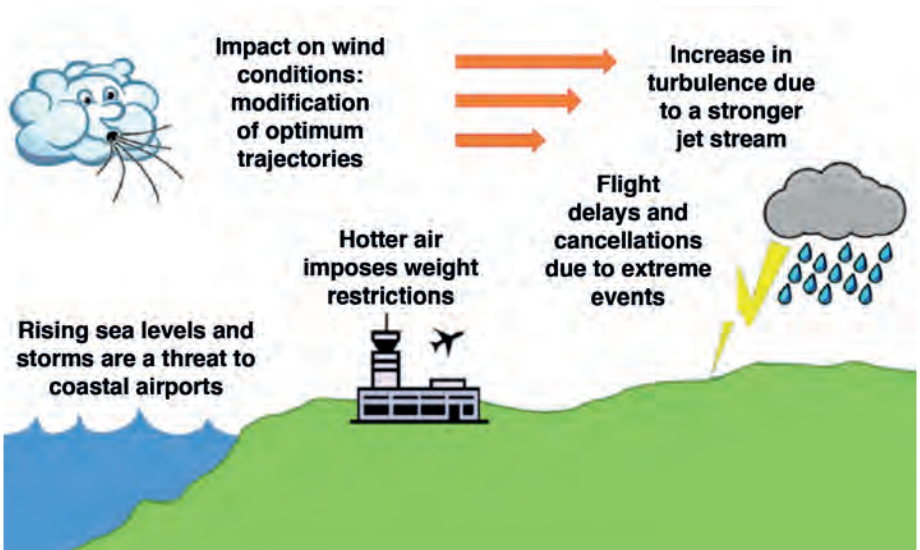


Fig. 1: **Possible impacts of climate change on air transport**. *Source: adapted from Puempel & Williams, 2016 ICAO report.*

Fig.2: Osaka-Kansai International Airport (Japan) in 2018 after Typhoon Jebi.
© The Asahi Shimbun

and ocurr for 4-5 days on average every summer by 2050. Airports in warm (Mediterranean) or humid (tropical) regions will be impacted even more.

More severe and more frequent turbulence

Climate change will also strengthen clear air turbulence, which already costs airlines hundreds of millions of dollars (damages to aircraft structure, passenger injuries). Global warming will increase both the likelihood and intensity of clear air turbulence. According to current scientific literature in a scenario of strong global warning (around 5°C), the likelihood of moderate to severe turbulence will increase by 30% world-wide on average in the second half of the 21st century and may exceed 150% in the North Atlantic (one of the busiest region for commercial flights).

Airport accessibility

Climate change will also have other consequences, primarily as a result of altered rainfall patterns and the risk of airport flooding. Almost 1 200 (different types of) airports world-wide are located in an area of low coastal elevation in South-East Asia, Australia and island regions (e.g. Indonesia and Polynesia). Among those airports, the 20 largest account for 18% of global passenger traffic and 25% of global freight. The adaptation of these airports (dykes, relocation) to maintain the same level of availability they have today will cost around $50 billions.

CONCLUSION

The mitigation of climate change is therefore urgent and necessary but it is not sufficient. The impacts on air transport presented in this article are just a few of the possible consequences of climate change on air transport. Their extent will largely depend on our collective ability to develop within a scope compatible with the Paris Agreement because most of these phenomena can be handled if warming is kept below +1.5°C. More than ever more interdisciplinary research (climate, engineering sciences, economics, law) gathering universities, industries and airlines, are needed to improve our understanding, suggest better ways of anticipating these impacts of climate change and to reduce uncertainties.

Non-CO_2 effects: the other climate impact of aviation

Jérôme Fontane and Florian Simatos
ISAE-SUPAERO

Contrary to popular belief, the greenhouse gases emitted by the aviation sector (CO_2 effects) stands as a small fraction of its current impact on climate. The other, non-CO_2 effects, are however short-lived, indicating the possibility of mitigation solutions in the short term.

Condensation trails over Lisbon.
© NASA-Photojournal-JPL.

NON-CO_2 EFFECTS

A specific feature of aircrafts is that they perturb the Earth's radiative balance as a result of interaction (non-CO_2 effects) between their engine effluents and the atmosphere. They result from the production of non-CO2 species during the combustion of aviation fuel: water vapour, NOx, carbon monoxide, sulphur compounds, hydrocarbons and soot particles. A number of these effluents trigger physical and chemical processes that alter climate in several ways. Some effects are warming and others cooling. Non-CO_2 effects are globally warming and account for almost two-thirds of the current climate impact of the aviation sector, which is measured in terms of effective radiative forcing (ERF)[1], i.e. 66 mW m^{-2} vs 34 mW m^{-2} for CO_2 effects.

THE FIVE NON-CO_2 EFFECTS

There are five non-CO_2 effects, the dominant one being the cirrus clouds induced by the condensation trails (contrails). Under certain atmospheric conditions, the white trails we these white trails that can be observed in the wake of the aircraft do not disappear but instead expand to form long, high-altitude cirrus clouds. While cirrus clouds are a natural phenomenon, aviation helps create more of them. They induce both a cooling (increased albedo) and a warming (increased greenhouse) effect but overall the warming effect predominates. The impact of these cirrus clouds on the climate is now assessed to be +57 mW m^{-2}.

The second effect, in terms of impact, is caused by NOx resulting from the oxidation of atmospheric nitrogen due to high combustion temperatures. NOx do not have a direct impact on climate but do contribute to chemical reactions that destroy and create some greenhouse gases (destruction of methane and creation of ozone). NOx induce an overall warming effect and their impact have been estimated to be +17 mW m^{-2}.

In addition to induced cirrus clouds and NOx, the three other non-CO_2 effects are:

1. An increase of the stratospheric water vapour concentration caused by flights in the lower stratosphere. This increases the greenhouse effect and therefore a warming effect estimated to +2 mW m^{-2};

2. Rise in the solar radiation reflected by aerosols. This increases terrestrial albedo which results in a cooling effect assessed to y -6 mW m^{-2};

3. Changes in the clouds properties which are currently not well understood: there is even no scientific consensus whether they induce a cooling or a warming effect.

These non-CO_2 effects are hard to quantify and **the accurate assessment of their impact on the ERF is subject to large uncertainties** as shown in figure 1. Hence, the aforementioned figures correspond to median values based on available estimates. For example, if the median value for the impact of induced cirrus clouds is 57 mW m^{-2}, there is a 10% chance that it will actually be above 98 mW m^{-2} or below 17 mW m^{-2}. Numerous ongoing scientific works are currently performed to reduce these uncertainties.

SHORT-TERM IMPACTS

Non-CO_2 effects are, by their very nature, fundamentally different from CO_2 effects. Part of the CO_2 emitted today will remain in the atmosphere for thousands of years, meaning that CO_2 effects are cumulative and long-lived.

1. ERF (effective radiative forcing) measures change in the radiative balance of the Earth's climate. It is expressed in terms of surface power density, here in milliwatts per square metre.

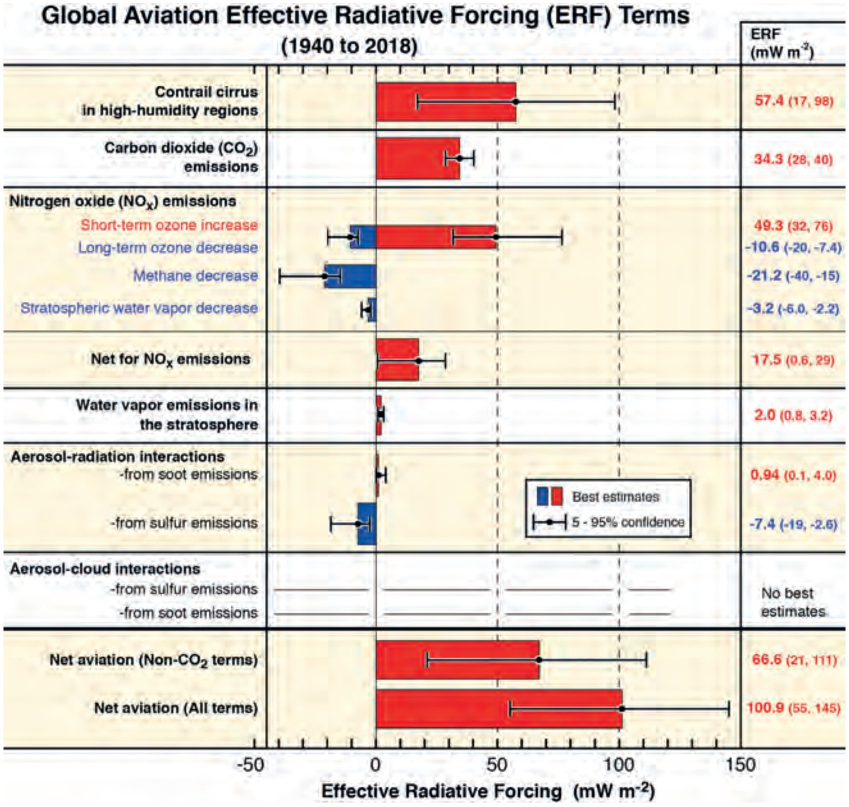


Fig. 2: **Each line represents the % annual variation of a given quantity** *Source: ISAE-SUPAERO Aviation and climate: a literature review.*

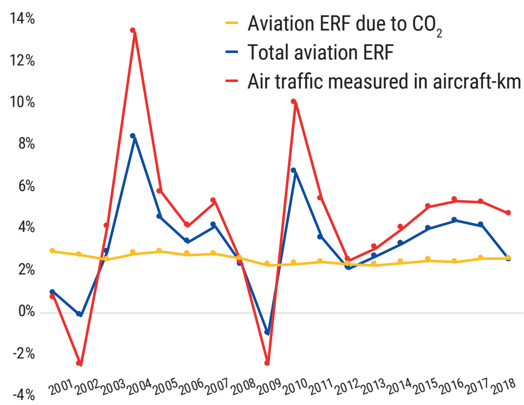


Fig. 1: **Estimated impact on climate of CO_2 and non-CO_2 effects, including error bars.**
Source: Lee et al., The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018, Atmospheric Environment, 2021.

Today's CO_2 emissions will continue to impact climate for centuries to come, whatever technological innovations and the traffic evolution.

On the other hand, non-CO_2 effects are short-lived. The cirrus clouds induced by contrails last few days at most while aerosols remain in the atmosphere for no more than a year. So if in the years to come technological solutions are able to reduce non-CO_2 effects or if air traffic decreases, the climate impact of non-CO2 effects **will decrease**. For example, following the global economic crisis in 2009 air traffic decreased by 2.4% and aviation's impact on climate dropped by 1%. Because non-CO2 effects are strong and short-lived, there is a correlation between variations in traffic and variations in climate impact. This correlation, observable in figure 2, goes both ways. For example, in 2004 traffic increased by 13% and aviation's impact on climate by 8%. Figure 2 clearly shows that this is specific to non-CO_2 effects because the yellow line (impact on climate of CO_2 alone) is very stable, reflecting their cumulative rather than short-term nature.

POTENTIAL MITIGATION LEVERS

There are currently two potential levers for reducing non-CO_2 effects in the short term. The most promising is to predict the formation of contrails induced cirrus clouds and then to modify the route of the aircraft which would produce these cirrus clouds. This is a particularly promising strategy because only a small part of flights are responsible for most of the climate impact of these induced cirrus clouds. A study conducted in Japanese air space estimated that 2% of flights are responsible for 80% of the impact that cirrus clouds have on climate. However there is still no scientific consensus regarding the maturity of this solution. Indeed, the modification of routes causes additional fuel consumption and therefore more CO_2 emissions. Consequently, the formation of cirrus cloud can be predicted with confidence, CO_2 emissions will be increased without getting any benefit in return.

The second potential lever is biofuels. These are synthetic fuels produced from biomass. Their chemical composition is very similar to that of fossil aviation fuel but they contain fewer aromatic compounds. These compounds produce the soot particles which promote the formation of contrails. Although research is needed to confirm the figures, aircraft fuel including a 50% mix of biofuels would reduce the climate impact of aviation by 10 to 25%.

CONCLUSION

As non-CO_2 impacts become better understood, they will become increasingly important in public debates and industrial strategies. Effective strategies for mitigating these impacts are likely to become available in the years to come, reducing significantly the climate impact of aviation. However, because of their fundamentally different nature compared to CO_2 effects,, this mitigation must come with efforts to cut CO_2 emissions. The two are not interchangeable and mitigating non-CO_2 effects does not prevent from reducing CO_2 emissions which, because they are cumulative, will increase global warming in the long term ●

Can we reconcile decarbonisation with an increase in air traffic?

Technological and energy innovations enable to foresee a low-carbon aircraft in the next decades. These innovations will have to be deployed within the entire fleets in order to reduce significantly the emissions of the aviation sector. Can this strategy match up to climate challenges? A methodology and analyses of transition scenario for the sector are presented to answer this question.

Scott Delbecq, Jérôme Fontane, Nicolas Gourdain, Hugo Mugnier, Thomas Planès, Florian Simatos,
ISAE-SUPAERO

ASSESSING THE SUSTAINABILITY OF A CLIMATE TRANSITION SCENARIO

Before presenting transition scenarios for the aviation sector, a scientific approach must be defined in order to assess their sustainability regarding climate change. The present analyses focus on CO2 emissions of the aviation sector only and do not consider non-CO2 effects such as cirrus clouds induced by condensation trails..

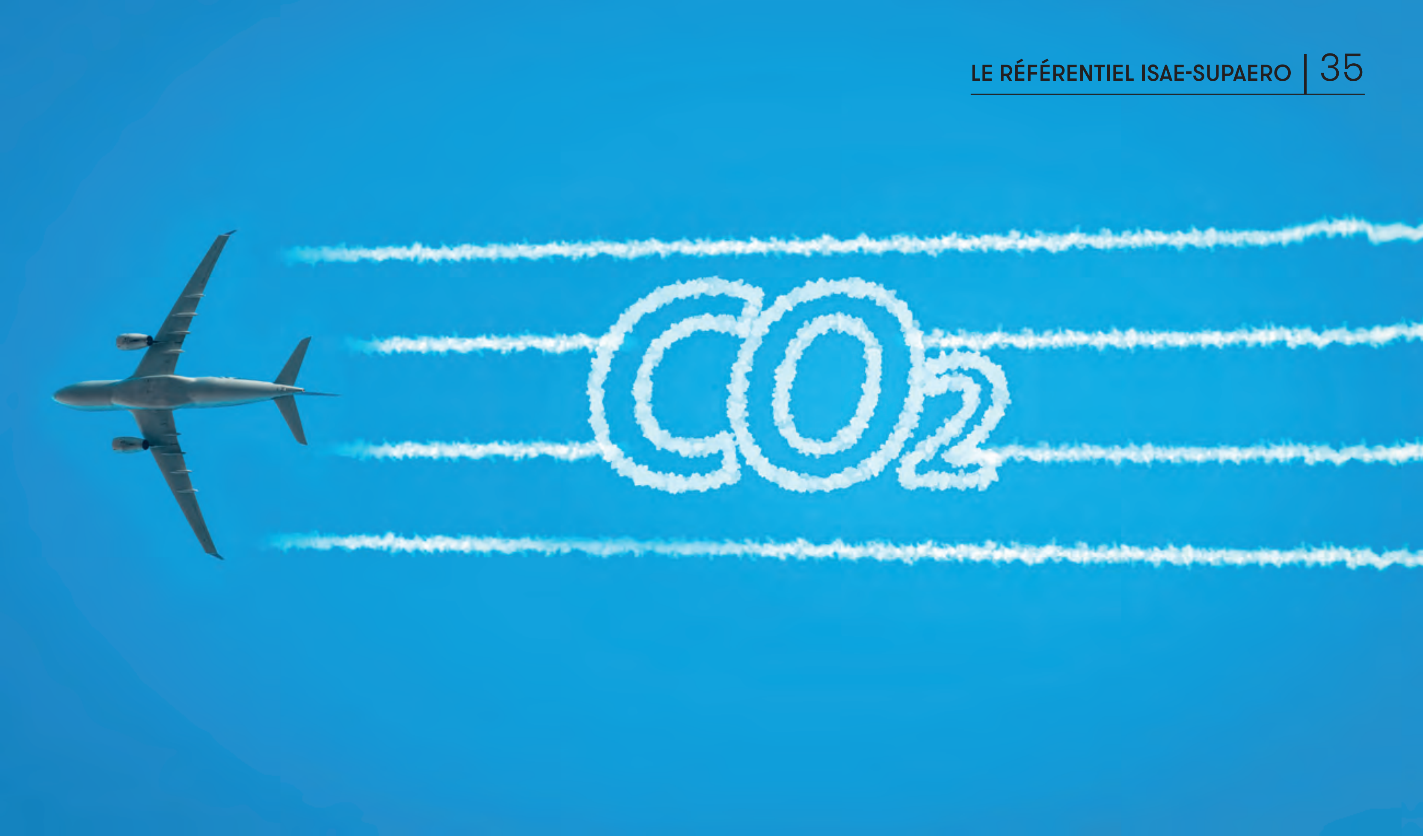
Paris Agreement and carbon budget

The aim of the Paris Agreement is to hold the increase in the global average temperature to well below +2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to +1.5°C. The IPCC has shown that this will require a substantial reduction in greenhouse gas emissions, especially CO_2.

Within this context, carbon budget is a concept commonly used when assessing mitigation strategies. The carbon budget is the maximum amount of cumulative CO_2 that humankind can emit while keeping global warming below a target temperature. The actual amount depends on the climate target and the likelihood of success considered. The IPCC has estimated that the remaining global carbon budget to keep warming at +1.5°C is 400 $GtCO_2$ (10 years of emissions at current rates), and 1 400 $GtCO_2$ at +2°C. These are median values that, in the light of current scientific knowledge, will enable us to achieve our climate targets with a 50% likelihood of success. And they correspond to net carbon budgets. So the carbon budget for +1.5°C can be observed if we emit 400 $GtCO_2$ and take nothing from the atmosphere, or if we emit (for example) 1 000 $GtCO_2$ while developing negative-emission technologies (afforestation, direct carbon capture etc.) that could remove 600 $GtCO_2$ from the atmosphere.

The carbon budget for the aviation sector

Once the carbon budget has been set, part of it must be allocated to the aviation sector. This is a political decision based on economic, social and technological priorities. In the following analyses, the share allocated to the aviation sector is therefore a variable and its impact on CO_2 emissions is examined by adjusting that variable.



The baseline for our adjustment of this share is 2.6 %. This value corresponds to the share of global CO_2 emissions attributable to commercial aviation in 2018. If the same allocation decision were made for each business sector, i.e. if each sector's share of the carbon budget were equal to its actual contribution to global emissions, this would be a undifferentiated approach where all business sectors would reduce their emissions at the same annual rate as of today.

A 2.6% allocation to the aviation sector is therefore the equivalent of requiring it to decrease its emissions at average speed. Larger or smaller allocations can be also considered, a larger allocation to aviation would automatically require other business sectors to reduce their emissions faster than average. Table 1 summarises the arguments regularly raised during public debates about the amount of this allocation.

Table 1: **Arguments concerning the proportion of the global carbon budget that should be allocated to the aviation sector.**

Allocation over 2.6%	Allocation under 2.6%
• Technologically, this is one of the hardest sectors to decarbonise (hard-to-abate). • Other sectors give more room for manoeuvre because they can decarbonise (or store carbon) inexpensively or faster. • Sector vital to the economy.	• Non-essential sector when compared with basic needs. • The Kyoto Protocol's differentiated approach requires greater reductions from sectors with the highest emissions. • Do not reward the biggest polluters.

ANALYSIS OF SUSTAINABLE AVIATION SCENARIOS

Our analysis of transition scenarios for the aviation sector is based on technological and operational assumptions. Once these are made, we can then examine the influence of the two remaining variables (share of the carbon budget allocated to the aviation sector and traffic evolution).

Technological and operational scenarios

Technological and operational assumptions rely on both the improvement of aircraft efficiency (engines, aerodynamics, load factor, operation, etc.) and also fuel decarbonisation (bio and electro-fuels, hydrogen). In the light of the scientific literature, it is reasonable to assume that the use of alternative fuels will reduce emissions by 75% over the full life-cycle compared to to fossil jet fuel. Two illustrative scenarios are considered and are described in table 2.

The scenarios yield emission factors of 89 and 17 gCO_2/RPK in 2050, compared to the current fleet emission factor of around 130 gCO_2/RPK, when the best current aircraft have an emission factor below 100 gCO_2/RPK. While better and worse-case scenarios cannot be ruled out, these scenarios present reasonable predictions for future technological developments.

Tradeoff between traffic level and share of the carbon budget

Once the technological and operational assumptions are set, a parametric analysis is made by adjusting the share of the carbon budget allocated to aviation. As the share changes, the rate of annual traffic evolution is adjusted to ensure that •••

Table 2: **Scenarios considered**

Scenario	Trend	Ambitious
Energy efficiency	Trend development of technologies and load factor	Acceleration of technological innovations, load factor and operations
Fuel decarbonisation by 2050	Nil	Entire fleet uses alternative low-carbon fuels
2050 emission factor	89 gCO_2/RPK	17 gCO_2/RPK

cumulative emissions are equal to the carbon budget for aviation. The resulting growth rate corresponds to the maximum sustainable growth rate.

Figure 1 shows sustainable air traffic growth rates for different allocations of a carbon budget for +1.5°C (green envelop) and +2°C (red envelop). In each case, the higher curve represents the ambitious scenario and the lower curve the trend scenario. The vertical dotted line represents the 2.6% baseline allocation and the dotted horizontal line industrial forecast of 3% annual growth in air traffic.

To limit warming to +1.5°C, allocating 2.6% of the global carbon budget to the aviation sector requires a major fall in traffic, whatever the scenario. To achieve 3% trend growth for air traffic, it would be necessary to allocated 6% of the global carbon budget to aviation for the ambitious scenario.

To limit warming to +2°C, the results are less equivocal. The trend scenario requires a 1.8% annual decrease in air traffic while the ambitious scenario would allow for a 2.9% annual growth on a 2.6% baseline allocation.

Technology alone will therefore not enable aviation to cut its emissions at the average speed needed to meet the most ambitious climate target if air traffic increases at the rate predicted by the industry. This means that there must be a political tradeoff between growth in air traffic and the share of the carbon budget allocated to the aviation sector.

CONCLUSION AND ENERGY CHALLENGES

While CO_2 emissions in 2050 are often considered the correct metric against which to assess the sustainability of a transition scenario for the aviation sector, from the climate viewpoint it is the cumulative emissions that count. Technological solutions will reduce emissions per RPK through the use of low-carbon aircraft. But **if traffic grows as industry predicts** technological solutions will not bring down sector emissions fast enough to comply with the objective of the Paris Agreement **within an approach where each sector must reduce its emissions at the required average speed**. The sustainability of any transition scenario for the aviation sector must therefore be based on a political trade-off between climate targets, growth in traffic and the share of the carbon budget allocated to the sector.

Beyond climate challenges, the availability of low-carbon energy must also be considered for the sector's transition to be successful. Unlike aviation fuel, potential alternative fuels are energy carriers that must first be produced from other primary energy sources. This production phase will cause potentially large loss in energy efficiency. The need for on-board energy will also rise if traffic grows faster than gains in efficiency. So if there is a major increase in traffic, aviation will need more primary energy (mainly biomass and electricity) than today, as illustrated in figure 2.

Determining the future availability of these energy resources is intricate. In the case of biomass, availability is limited, meaning that biofuels cannot on their own meet all aviation sector needs. The availability of electricity, which can be used to produce electro-fuels or hydrogen, is potentially much greater but socio-economic and technical factors limit its use, including the rate at which electricity generating facilities can be deployed. Thus the prospective energy scenarios at the horizon 2050 which are available today and compatible with the limitation of global warming assume around 100 EJ energy from biomass and a threefold increase in electricity production for the most ambitious scenarios can be up to three times greater (about 300 EJ) relative to current value. In most of these scenarios the global primary energy remains of the

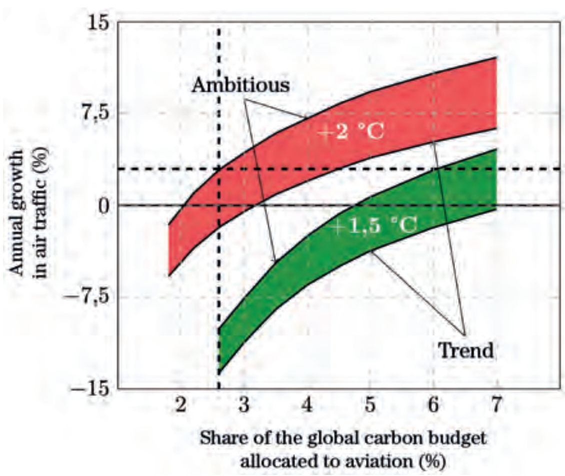


Fig. 1: **Annual sustainable growth in air traffic based on the carbon budget allocated to aviation.**

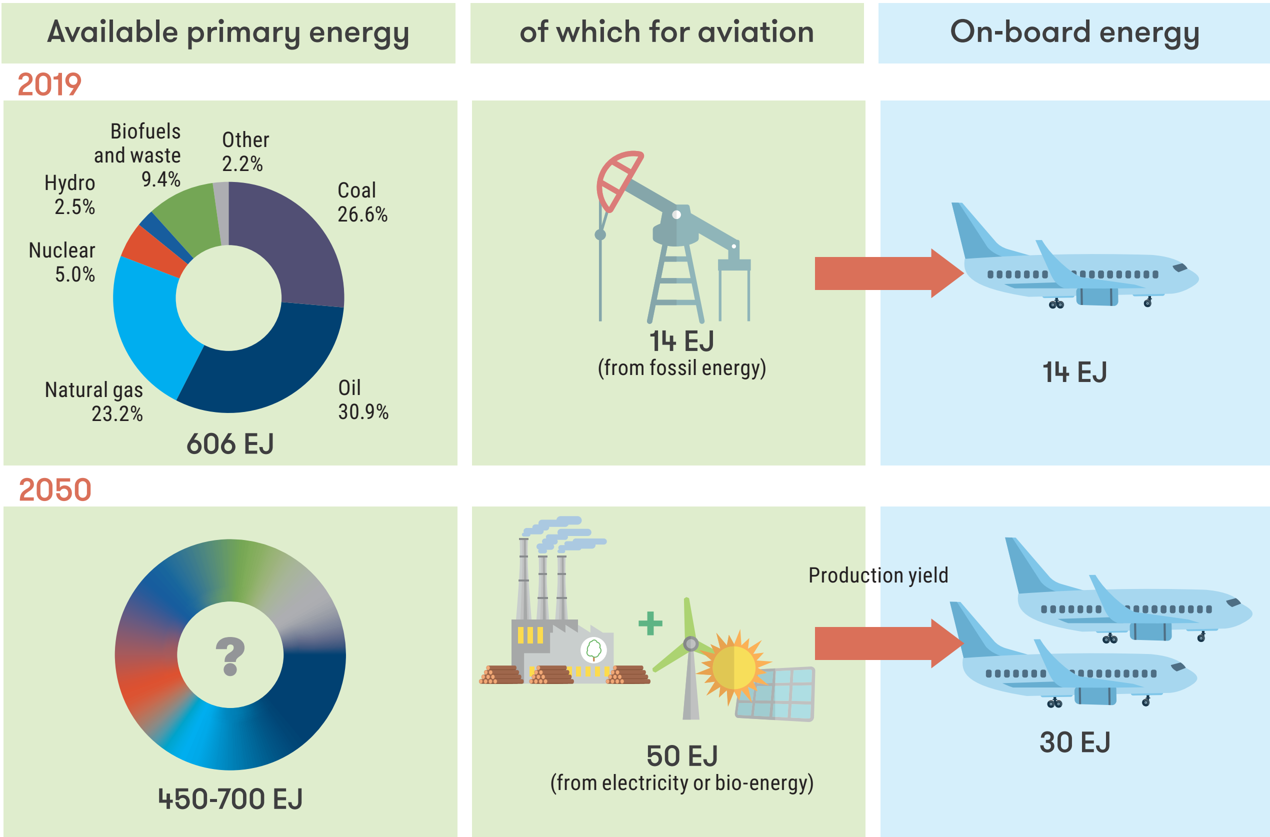


Fig. 2: **Schematic change in the proportion of primary energy required by aviation.**
2050 figures are illustrative only (the amount of on-board energy will depend on the energy efficiency of future aircraft and production yields will depend on the production methods used). The ranges shown for primary energy are based on the IPCC, IEA and IRENA forward-looking energy scenarios currently available.

same order of magnitude in 2050 as it is today, but a more massive deployment of electricity production is still possible.

In this context, the aviation sector would need more primary energy than nowadays, but also a larger share of the global primary energy. The reasoning behind this increase in requirements applies more generally to all business sectors hard to decarbonise, like heavy industry. On the other hand, we can expect a drop in the primary energy requirements of other areas of business whose energy efficiency could increase considerably, such as construction. Finally, a cross-sector analysis is needed to assess whether this increase in aviation's energy requirements can be met. ●

For further informations, see ISAE-SUPAERO Aviation and climate: a literature review.

ReFuelEU: deploying sustainable fuels in the aviation sector

SAF (sustainable aviation fuel) is the most effective and mature solution available for making large-scale cuts in aviation sector emissions. But SAF currently covers only a tiny fraction of the industry's needs.
In its draft RefuelEu the European Commission has provided a strong boost to its development.

Cecil Coulet,
Équilibre des Énergies

The draft of ReFuelEU - Aviation regulation (Regulation on ensuring a level playing field for sustainable air transport) was published on 14 July 2021 as part of the EU's Fit for 55 legislative package.

It creates the conditions required to deploy sustainable aviation fuels (SAFs). As SAF market penetration is currently very low, mainly because of its high cost and limited availability, measures are needed to accelerate its deployment and to encourage and support the industry in its transition to sustainable fuels.

Definition of key terms

Article 3 defines the key terms, especially those relating to SAF and synthetic fuels. The definition of SAF covers synthetic fuels, advanced biofuels within the meaning of RED[1] and biofuels produced from used cooking oil or category 1 and 2[2] animal fats.

Synthetic fuels, or e-fuels, are renewable fuels that are not of biological origin. Their manufacture uses low-carbon hydrogen and electricity and CO_2 recovered from the atmosphere.

Obligations of sustainable fuel suppliers

Article 4 introduces the mandatory inclusion of a minimum share of sustainable fuel in the fuel supplied to the aviation sector. The draft states that the minimum shares that must be supplied to all EU airports where yearly passenger traffic was higher than 1 million passenger are:

From 1 January	
2025	2%
2030	5% including at least 0.7 % synthetic fuels
2035	20% including at least 5% synthetic fuels
2040	32% including at least 8% synthetic fuels
2045	38% including at least 11% synthetic fuels
2050	63% including at least 28% synthetic fuels

Where a supplier fails to supply the shares required in a given reporting period, the missing share of SAF that should have been supplied will have to be supplied in the following reporting period, without prejudice to the administrative penalties Member States must introduce.

Article 4 states that the quotas and sub-quotas must be supplied at all EU airports. Suppliers may supply these shares as a weighted average over all the aviation fuel they supplied across Union airports until the end of 2029..

Obligations of airlines

Article 5 states that airlines must uplift 90% of their requirement in EU airports, i.e. airports supplying SAF in accordance with the previous article. Since no exceptions are allowed, this article will therefore come into force at the same time as the Regulation itself.

Obligations of EU airports

Article 6 provides that airports must take necessary measures to facilitate the access of airlines to SAF and provide the necessary infrastructure.

Penalties

Article 10 requires Member States to create one or more competent authorities to enforce the Regulation and fine aviation operators, airlines, fuel suppliers and airports that do not fulfil their obligations.

Article 11 specifies the penalties applicable to infrigements of these obligations.

1. Advanced biofuels use lignocellulose, which is dry plant matter, in contrast to conventional biofuels: agricultural waste, forestry waste, dedicated crops such as miscanthus.
2. Category 1 and 2 animal fats are recovered from animals found dead or sent for rendering. Category 3 fats come from animals whose carcasses have been declared fit for human or animal consumption.

Équilibre des Énergies believes that the European Commission's draft ReFuelEU - Aviation is moving in the right direction. Given the present low levels of SAF production and use, measures to support and speed up their deployment are essential. But several points require examination.

The EU has insufficient used cooking oil and animal fats to meet SAF deployment targets. *Équilibre des Énergies* recommends considering the possibility of expanding the list of permitted raw materials, without however including the use of raw materials from food and feed or agricultural crops. *Équilibre des Énergies* also recommends the use of low-carbon hydrogen and electricity to produce synthetic fuels instead of the renewable hydrogen and electricity required in the draft.

Équilibre des Énergies recommends introducing a book and claim system based on certificates so that, within each airport, airlines will be able to purchase SAF certificates, regardless of whether or not they have been supplied in SAF. This would introduce greater flexibility into SAF distribution and would reduce unfair competition between EU and foreign airlines making it possible to modulate the number of SAF certificates EU airlines will need to give back so that it corresponds to the portion of their flights covering the EU area.

To maintain the competitivity of the EU aviation sector, the integration of advanced advanced biofuels and synthetic fuels must be accompanied by financial incentives. In particular, the revenues from the Aviation EU ETS auctions should be targeted towards the development of SAF.

"Loi Climat-Résilience" (Climate and Resilience Law): aviation's contribution to decarbonisation

On 22 August 2021, the passing into law of the "Loi Climat-Résilience" concluded the discussions in the French "Assemblée Citoyenne pour le climat" (Citizens' Convention on Climate Change).

Olivier Lagrange,
Équilibre des Énergies

The Climate-Resilience Act of 22 August 2021

The chapter heading chosen for the seven proposals related to aviation is unambiguous "Limiting the harmful impacts of the aviation sector". It shows that the Citizens' Convention was committed to getting the aviation sector to contribute more significantly to the fight against global warming.

The Climate and resilience Law, which proposes additional provision to reduce greenhouse gas emissions by 40% by 2030, integrates several of those proposals in five articles:

- article 142 states that the Government should set itself a target of "*ensuring air transport pays an appropriate price for carbon by 2025, preferably through action at the EU level*";
- and article 144 proposes banning loss-leader sales of plane tickets by changing the EU legislation and making it possible to set up a minimum price for tickets.

The Members of the French Parliament were hoping these potentially controversial provisions could become priority issues during the French presidency of the Council of the European Union.

Article 147 requires airlines to offset their greenhouse gas emissions. From 2024 they will have to offset all of their emissions.

The law also introduces restrictions on:

- air transport by banning air transport of passengers "*when the national rail network offers several direct trains a day on the same route, with a journey time of under two hours thirty minutes.*" The Assembly had suggested a journey time of four hours. Decarbonised transport is exempt from the restrictions (article 145) ;
- the building and extension of airports if this will lead to a "net increase, after offset, of greenhouse gas emissions from airport activity, as compared with 2019 levels" (article 146)

Like all other sectors, the aviation sector needs to reduce its greenhouse gas emissions, which is why *Équilibre des Énergies* recommends speeding up the development and use of sustainable aviation fuels, through appropriate measures. *Équilibre des Énergies* does however also believe that the restrictions introduced by the Climate-Resilience Law could hinder the aviation sector's innovation and competitiveness, when this sector plays a key role in the French and European economy, without facilitating its energy transition.

The challenges presented by EU-ETS and CORSIA

EU-ETS, the EU carbon quota scheme, and CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) both aim to speed up the transition of the aviation sector to carbon neutrality.

François Delabre,
Head of Institutional Affairs - Air France KLM

The first applies to flights within the EU and the other to most flights outside the EU. The aims are the same but the underlying principles and ambitions are different. Those of CORSIA are considered to have less impact on airlines than those of the EU-ETS. They could mean EU airlines are penalised more than their international competitors.

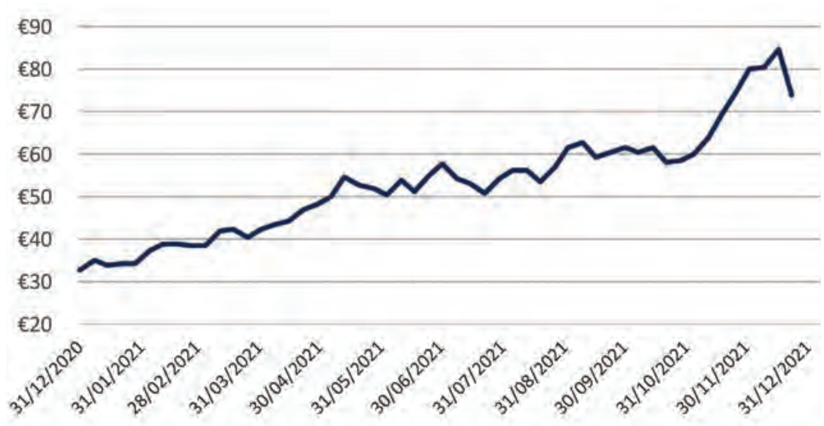
EU-ETS

Air transport has been involved in EU ETS since 2012 over the emissions on its flights within the EU. The system covers all domestic and international flights within an area that includes the EEA and Switzerland.

The aviation sector receives a number of quotas, calculated on the basis of 95% of its 2005 emissions. 82% of the quotas are provided free of charge at the moment, 3% are reserved for fast-growing airlines and 15% are auctioned. The free quotas are shared among the airlines pro rata of their traffic in 2010. Airlines therefore have a fixed number of free quotas and have to buy additional quotas at auction or on the ETS market to make sure all of their emissions are offset. In 2019 free quotas on average offset 44% of air transport emissions and the airlines had to buy the rest.

The revised ETS proposed for aviation as part of the Fit For 55 package is intended to be a response to bigger EU environmental ambitions. The main proposed measure is to reduce free aviation quotas from 82% to 0% between 2023 and 2027. From 2027 all emissions

Fig. 1: **Carbon quota prices on the EU-ETS.** *Source: ICE data*



from flights within the EU would then have to be offset by quotas that the airlines must buy at auction or on the ETS for fixed installations.

Quota prices have gone up a lot in the last few months to over €80/t in December 2021 (*figure 1*). Based on 2019 emissions and assuming a quota price of around €100/t, buying quotas will be a considerable expense of almost 7 billion euro a year to the EU air transport sector as a whole.

Fig. 2: **CORSIA carbon credit prices** *Source: Platts.*

CORSIA

International flights between the EU and the rest of the world are not subject to ETS. Instead, they are subject to CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) set up in October 2016 by the International Civil Aviation Organisation (ICAO) within a UN framework.

The carbon offset scheme forces participating States to work together to cap aviation emissions by requiring airlines to offset the proportion of their emissions that is in excess of the 2019 and 2020 average through certified international offset schemes.

CORSIA is being implemented in three stages:

- from 2019 all operators producing over 10 000 t CO_2 p.a. on international flights must report their emissions based on actual fleet consumption;
- from 2021 to 2026 flights between volunteer States will be subject to carbon offset;
- from 2027 to 2035 all flights between ICAO member States must be offset. There are however exemptions for socio-economic reasons or because of low levels of business.

The countries now committed to voluntary offset account for 77% of international traffic. This will rise to over 90% in 2027 when all ICAO members, unless exempted, must offset. It is estimated that by 2030 CORSIA will be offsetting 50-70% of all aviation sector emissions, although this will not apply to the domestic flights of participating States unless they are EU Member States, in which case they will be subject to EU-ETS.

CORSIA has produced eligibility rules for the alternative fuels that may be included in emission calculations and rules on the carbon credits that can be used during offset. COP 26 in Glasgow led to rules on how carbon credits can be used in international mechanisms to prevent them being counted twice by sellers and buyers. The prospect and signature of these agreements pushed up the prices of eligible CORSIA credits, which remain however far lower than prices for EU-ETS quotas (*figure 2*). ●

While CORSIA exists side by side with EU-ETS, its clearly less ambitious than the latter since it aims only to maintain the emissions *status quo.* Its rules on the use of alternative fuels and carbon credits are also less demanding than those of EU-ETS.

Yet CORSIA is proof that a global multi-lateral approach to decarbonising the aviation sector is possible. The ICAO's role in reducing aviation emissions should be strengthened, e.g. by setting international targets and a common policy of incorporating sustainable alternative fuels.

Care also needs to be taken to ensure that the EU's desire to lead the way does not harm EU aviation, to the immediate benefit of its third-country competitors. There is indeed a risk that EU ambition could cause EU airlines to lose business to their competitors, without any benefit to the global climate. Passengers deciding to fly with an EU airline to Asia will be routed to that airline's hub in the EU on a flight subject to ETS. If they decide to fly with a third-country airline however, they will be routed to that airline's hub on a flight subject not to ETS but CORSIA, which is less demanding. ETS and CORSIA may at present be contributing to unfair competition and carbon leakage.

It is essential that the Commission and the Member States amend Fit for 55 to reduce or eliminate this risk. At the same time, the multi-lateral approach through the ICAO must be continued and restated and EU Member States can work to strengthen the role of the ICAO within the global policy of decarbonising the sector.

The Single European Sky - the potential to cut emissions by 10 %

Air traffic is one of the keys to the decarbonisation of aviation

Air traffic management contributes significantly to the environmental performance of European aviation. The closer an aircraft stays to its optimum flight path, the less fuel it uses and the less CO_2 it emits. Vice-versa, the more congested air space becomes (as in 2018 and 2019) the less efficient flight paths become. It is estimated that European flight paths could be made around 10% more efficient. The Single European Sky has been designed to meet this challenge by creating a close tie between the European Commission, as decision maker, and EUROCONTROL, as the operating and technical arm of the partnership.

Pre-2004 - EUROCONTROL lays the foundations

EUROCONTROL was created in 1960 to improve the efficiency of air traffic in Europe. The foundations laid by EUROCONTROL on the eve of the Single European Sky included civil and military cooperation among all European States, a common master plan for modernisation, a top-flight research and simulation centre, an efficient route charging system, the Central Flow Management Unit (CFMU) and the Performance Review Unit (PRU).

Philippe Merlo,
Director, European Civil-Military Aviation, EUROCONTROL

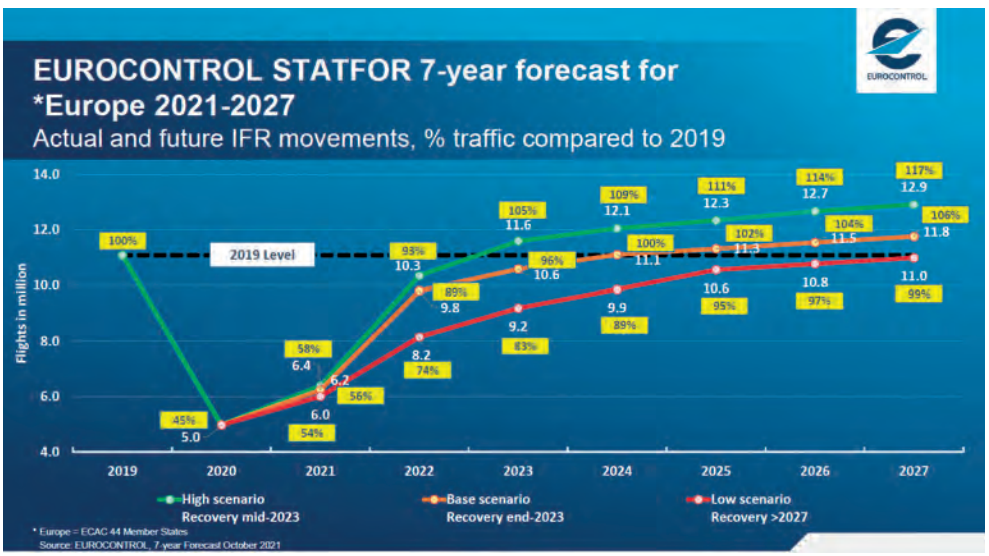
2004 - the European Union launches Single European Sky 1-SES 1

In 2004 air traffic became the shared responsibility of the European Union and its Member States. Single European Sky regulations were adopted straight afterwards. Close cooperation was immediately established between the European Union, which contributed its legislative might and financial strength, and EUROCONTROL that brought with it its operating and technical experience and its pan-European stretch (currently 41 member States, far more than the 27 present members of the EU). EUROCONTROL was to become a key figure in most Single Sky initiatives.

2007 - SESAR founded by the European Union and EUROCONTROL

SESAR, a joint undertaking created in 2007, was tasked with creating the technological cornerstone of the Single European Sky on the trajectory-based operations principle (business trajectory). EUROCONTROL is one of the two founder members alongside the European Union. EUROCONTROL has been tasked with coordinating the SESAR master plan and provides expertise in all key areas of air navigation, its knowledge of the system (CFMU), its route control experience (Maastricht control centre), its ability to experiment and simulate and its performance assessment and civil-military coordination know-how.

SESAR's mandate has recently been renewed. Over 80 technical and operational solutions have already been validated and made



Forecast of traffic to be handled by EUROCONTROL.

available to the industry. A development plan covering the entire innovation cycle (development, deployment, operations) is currently being implemented.

2008 - EUROCONTROL opens a centre of expertise dedicated to aviation's environmental footprint

Assessment of the environmental impact of aviation became a sensitive question at the start of the millennium. EUROCONTROL set up a dedicated unit to meet the requests for expertise coming from the European Union and its other member States. The Aviation Sustainability Unit is now Europe's benchmark centre of expertise on aviation's environmental footprint. Cooperation with the European Union is extremely close. The Unit provides operating data for international negotiations and CO_2 emissions monitoring (Emission Trading Scheme and CORSIA). It makes a major contribution to the SESAR innovation programme and to the assessment of environmental performance.

2010 - the European Union creates SES2 to assess performance and entrusts its management to EUROCONTROL

In 2010 the European Union created a performance assessment system for air navigation services and appointed EUROCONTROL to manage it until 2016. Although management was taken over by an independent body in 2016, EUROCONTROL continues to provide most of the expertise needed to set performance targets and monitor compliance by States and air navigation providers.

2011 - the European Union makes EUROCONTROL Network Manager (SES2)

The Network Manager position was created by the EU in 2011 following the crisis created by the Icelandic volcano Eyjafjallajökull in 2010. The job was immediately given to EUROCONTROL, which then reorganised to bring all the functions required into the same department: traffic flow management, organisation of air space, crisis management, traffic forecasting, delay monitoring and analysis, and radio-electric frequency and radar code management.

EUROCONTROL headquarters in Brussels
© sanderdewilde.com 2015

The Network Manager is now the backbone of the Single European Sky. The added value it brings and its key role in operations are recognised by all air transport operators: airlines, airports, air navigation service providers and military aviation.

The Network Manager has delivered impressive results. The combined efforts of the Network Manager and air service providers reduced delays from 2.9 to 1.5 minutes per flight between 2010 and 2017, i.e. by 48% (they went back up to over 2.1 min per flight in 2018 and 2019 owing to congested air space). Flight path efficiency also improved considerably (-25% route lengthening thanks to air space organisation 2011-2019, i.e. about 37 million nautical flight miles and about 400 kilotonnes of CO_2 less in 2019).

2014 - the European Union sets up SESAR Deployment Manager

SESAR Deployment Manager was created in 2014 to coordinate and accelerate the deployment of the new systems generated by SESAR. EUROCONTROL, as Network Manager, was involved from the start through a cooperation agreement. Its involvement was increased in 2021 when it became one of the founder members and the coordinator.

2019 - the EU launches the second stage of Single European Sky (SES 2+)

This strengthened the initiative further, especially its ability gradually to shrink aviation's environmental footprint. SES 2+ is currently being discussed by the EU institutions: Commission, Council and Parliament. A consensus appears to be forming about giving additional responsibilities to the Network Manager. EUROCONTROL will therefore be involved once again.

Conclusion: successful and promising cooperation

The almost 20-year cooperation between the European Union and EUROCONTROL to develop the Single European Sky has proved unique, pragmatic and fruitful. It is thanks to that cooperation that we now have an effective regulatory and operating framework with results for all to see. And we can have no doubt that cooperation will very soon be called on again to pick up the enormous challenge the decarbonisation of aviation presents.

Hydrogen the courage to dare

Hydrogen, one of the most promising zero-emission technologies, would enable many industries to achieve their climate-neutral targets. Airbus, one of the sustainable aerospace industry pioneers, has made this form of energy one of its priorities. Massive adoption of hydrogen by 2035 will depend on the company's ability to pick up the technological challenge and drive the transformation of an entire ecosystem.

© Airbus - Kristina Bandic

Glenn Llewellyn,
Vice President, Airbus, VP Zero Emission Aircraft

HYDROGEN IS AT THE HEART OF AIRBUS COMMITMENT

Just five years ago hydrogen power wasn't even on our list of viable technologies able to make a drastic cut in our emissions. But convincing data from other transport industries quickly changed all that. Today, the incredible potential hydrogen offers aviation in terms of its ability to make massive cuts in emissions is exhilarating.

Hydrogen is at the heart of the Airbus commitment to decarbonised aviation. Its deployment dovetails perfectly with the international and European aviation roadmap for a 55% cut in greenhouse gas emissions by 2030 (compared to 1990 levels) and net zero emissions by 2050.

For massive adoption of this form of propulsion by the entire industry world-wide, we will have to pick up several types of challenge together. The first is technical. We need to develop and certify an aircraft that uses liquid hydrogen as its primary source of energy.

THREE AIRCRAFT CONCEPTS

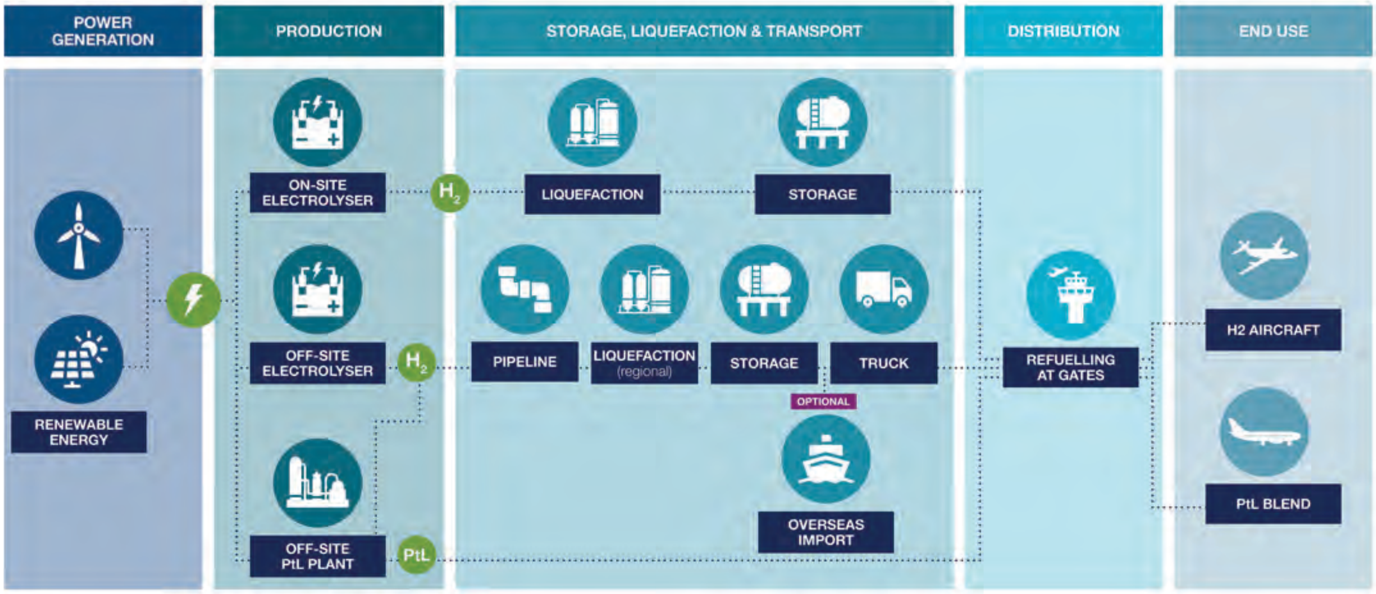
Airbus has committed to putting such an aircraft into service by 2035. This is Project ZEROe, a name that indicates our objective of developing a plane that emits no CO_2 when it comes into operation. We're working on three aircraft concepts, each for a different segment of the market.

The first is a turboprop (up to 100 passengers, 1 800 km), hydrogen-powered by modified gas turbine engines in combination with fuel cells.

The second is a turbofan (up to 200 passengers, 3 700 km). With a similar method of propulsion, it will replace medium-haul planes.

The third concept is a blended wing aircraft (up

Formation flight by the ZEROe concept aircraft
@ Airbus.



Decarbonised hydrogen ecosystem for aviation. *@ Airbus*

to 200 passengers, 3 700 km) whose enormous size offers many options for storing and distributing the hydrogen.

BIG TECHNOLOGICAL LEAPS FORWARD

The general idea is to test different technologies before making the final choices in 2025, with entry into service in the middle of the next decade. It's a very tight schedule because the technological leaps forward are so big. Within this very short timeframe we have to get the aircraft itself certified as meeting safety requirements.

Developing the technology by 2035 is an essential part of the challenge, but not the only one. Another, just as big, challenge will be ensuring that the hydrogen, which requires four times more storage space than aviation fuel, is available at the right time, in the right place, in the right amount and at an acceptable price.

The production and supply of this new energy source in airports will be critical factors that already demand the involvement of the ecosystem, especially airlines, airports, authorities, finance and ground and energy transport companies.

BIG INVESTMENTS. SHARED COMMITMENT

The investment needed for this energy transition is immense and we are looking at all possible solutions. A recent study by the International Energy Agency suggests that re-using existing infrastructure, especially the millions of kilometres of pipeline that currently transport natural gas, could be a cost-effective way of carrying big quantities of hydrogen from their production sites to airports, since small quantities could be carried by lorry. Some airports could also develop the infrastructure required to produce hydrogen on-site, particularly if they have a renewable energy source nearby.

Airbus is committed to increasing hydrogen use. For example, in partnership with Air Liquide and VINCI we are preparing to install a hydrogen gas station at Lyon-Saint-Exupéry Airport in 2023. This will initially serve both airport and partner ground vehicles (buses, lorries, maintenance trucks etc.) and also the heavy vehicles that drive around the airport perimeter. The next step will be to provide it with the infrastructure needed to refuel aircraft with hydrogen and then, in 2030, to produce this energy itself. In 2030 we will also be looking at whether the concept should be deployed across VINCI Airports' European network.

As the partnership shows, the ability to develop hydrogen within an airport ecosystem depends on the joint commitment of the partners and everyone's will to collaborate.

We know that the technical and logistical changes needed for the massive adoption of hydrogen must be the result of collective, solidarity-based, global action. Airbus has made a determined and pioneering commitment to this route, strong in its conviction that all its partners also have the courage to dare. ●

A fully electric plane? Yes we can

@ AuraAero

Jeremy Caussade,
President of AURA AERO

The electric biplane, INTEGRAL E.
@ AURA AERO

In a hangar in Toulouse Francazal Airport, a team of aviation start-upers is working in the very building that was the first French Air Force base. AURA AERO is a young company facing a big challenge: to get its totally electric INTEGRAL E biplane in the air by summer 2022. A 19-seater regional aircraft will follow. Jérémy Caussade, co-founder and President of AURA AERO talked to us.

Jeremy Caussade: There's no need to explain the benefits of the fully electric plane: no aviation fuel so no CO_2 and NOx emissions, no vapour trails (non-CO_2 impacts that are generally as damaging to the climate as CO_2 emissions) and less noise. It's not hard to understand that a fully electric plane, like an electric car, will have a simplified drivetrain that is easier to assemble and maintain - and as you know, maintenance is a key factor for aviation.

Contrary to popular belief, we already have the basic technologies for small planes and our company works on the principle of using only TRL 5 or 6 technologies[1]. The problem is integrating them eco-efficiently into a consistent system that has been improved to provide the right performance for particular segments of the market at a competitive price.

Your main niche is training, leisure and aerobatics twin-seater. Where are you with the development of the INTEGRAL range?

J. C.: *INTEGRAL E* is part of the INTEGRAL family of biplanes designed to keep operating costs down and to be safe, environmentally friendly and ergonomic. The R and S versions have a heat engine, a range of up to 1 100 km and are now being certified. We expect to build around fifteen in 2022 and around thirty in 2023.

INTEGRAL E has an electric engine powered by lithium batteries. It's now under development and we hope to have it flying in summer 2022 and first deliveries to start at end 2023. We've already got orders and are confident about the progress of the programme.

The battery is of course one of the key components. Could you tell us something about performance?

J. C.: We're in partnership with one of the giga-factory promoters of Li-ion batteries and the batteries on our planes will be state of the art and have a huge 200-300 Wh/kg capacity. We believe 400 Wh/kg will eventually be achievable. We're not saying anything about the aircraft's performance yet as there haven't been any test flights but all performance will be improved. Planes are designed to fly for up to 50 years and throughout their lives we can upgrade the batteries as technical progress advances. This is very different from cars, which have a far shorter life. But to be able to provide this service, the battery needs to be tightly integrated with the plane and we're positioning ourselves as a cell integrator assembling batteries that fit the aircraft's requirements.

1. *TRL: Technology Readiness Level.*

We may be offering several versions, depending on which range or weight is the priority.

You're also working on a more ambitious electric aircraft project for regional transport.

J. C.: Yes, we're developing a hybrid regional electric aircraft called ERA (Electric Regional Aircraft) that will be able to carry 19 passengers. It can also operate as a flying taxi or carry freight. It will have six battery-powered engines plus a turbo generator that when in hybrid mode can recharge the batteries. In purely electric mode, we're looking at a range of 400 km that can go up to 1 800 km in hybrid mode.

We're expecting a first flight to be at end 2024 and entry into service in 2027. The plane of course fills a gap in the market and we've already had one very significant letter of intent for orders.

Do you think it will be possible to go beyond ERA and develop bigger electric aircraft? What about hydrogen solutions?

J. C.: At present ERA is the biggest electric aircraft we can design. As I've told you, we only look at suitably mature technologies and hydrogen solutions are too far away for us.

How do you see the future of your company?

J. C.: We think we're making a positive contribution to the decarbonisation of air transport. We're showing that air transport is compatible with protecting the environment. Given the attacks made on aviation, the move to sustainable fuels is naturally essential, but it doesn't solve every problem. Electric planes have their place so long as the niche is right, and we are offering real solutions.

Our company was set up in 2018 by three co-founders who all came from the world of aviation, and now we have about a hundred employees. We're supported by Région Occitanie, Bpifrance and Innovacom, an innovation capital fund. But to meet market expectations and our goals, we're going to have to aim higher. We will be forming partnerships but we're going to need new financing. France mustn't ignore the industrial and technological breakthrough that the electric plane is going to be.

We're expecting a first flight to be at end 2024 and marketing in 2027

ERA, the hybrid regional electric plane.
@ AURA AERO

Drone taxis: science-fiction no longer

Urban air mobility is the new conquest of the skies - of low altitude skies. This is new, almost unexplored territory into which we are plunging, although we are armed with a huge number of drone-related technologies and the vertical takeoff electric vehicle. But many challenges still remain.

Sébastien Couturier,
Director at Paris-Le Bourget Airport & General Aviation Aerodromes

Low-altitude urban air mobility will precede zero-emission flights using mainly wholly electric vehicles, although some hydrogen-powered vehicles are now beginning to emerge. The technology, which is based on the principle of distributed propulsion, will also slash the noise footprint as compared with that of more conventional technologies, such as helicopters. The manufacturers are promising fast, flexible and accessible services with low infrastructure costs. As a method of transport, this will supplement existing types of mobility.

VERTICAL TAKEOFF TECHNOLOGY IS ALREADY WITH US BUT ACCEPTABILITY IS THE BIG QUESTION.

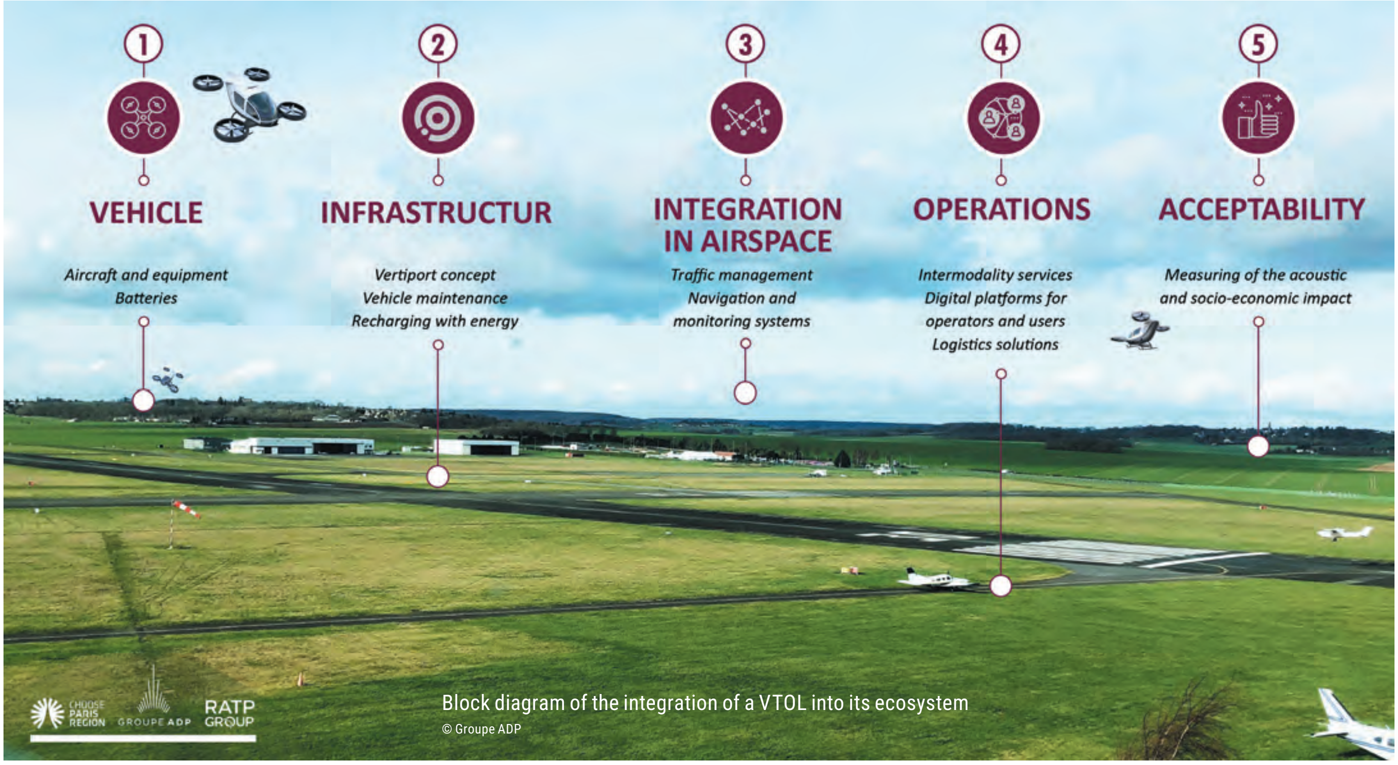
In the light of the huge increase in the number of electric drones on the market for a very wide range of purposes (logistic, medical, military) the market for electric urban air passenger vehicles is estimated to be worth 30 billion euro by 2035 (Oliver Wyman).

Within this booming environment, almost 200 vehicle projects have already found an estimated 3 billion euro in financing world-wide, with positions being adopted by car builders (Geely, Daimler, Toyota and Hyundai) and leading technology players (Tencent, Baillie Gifford, Uber etc.). The main eVTOL (electric Vertical Take Off and Landing) manufacturers, both big groups and start-ups, have already shown they can get vehicles to fly and are able to develop vehicles that can get certification within the next 2-4 years.

Although the technological maturity of these vehicles is progressing very fast, the big challenge is their acceptability, in terms of both integration into the urban environment (noise, architectural integration, safety etc.) and usage (type of service offered, accessibility, intermodality etc.).

Île-de-France, which is a leading region in economic terms, has an extraordinary industrial and research ecosystem, a global reputation and a very dynamic transport market, making it a good nursery for this emerging industry. The 2024 Olympic and Paralympic Games also provide an exceptional catalyst for energising companies and

Artist's view of a drone taxi flying over Paris.
© Groupe ADP



Block diagram of the integration of a VTOL into its ecosystem
© Groupe ADP

making France a benchmark on this global market, with a view to deployment by 2030.

A UNIQUE EXPERIMENTAL SITE IN ÎLE-DE-FRANCE AT PONTOISE AERODROME

Great attention is traditionally focused on the vehicle itself but at Groupe ADP we believe that equal attention should be paid to how this new method of transport integrates with infrastructure and air space. This was why we created a sandbox site last September.

Following multi-criteria analysis by Groupe ADP and DGAC (Directorate General for Civil Aviation) of aeronautical, access, site attractiveness and property availability constraints, Pontoise-Cormeilles-en-Vexin Aerodrome was selected for the first tests.

Stage one: creation of a secure test site at the aerodrome, open to the entire ecosystem and intended to welcome different manufacturers so that their ability to respond to the constraints of an actual operation can be evaluated and also to test integration with air traffic. The site will include a maintenance and storage area. The hangar will allow testing of the passenger path in the departure lounge while also housing the engineering offices and the vehicle preparation area.

AN ECOSYSTEM SUITABLE FOR THE CO-CONSTRUCTING USAGE, PLUS THE PROSPECT OF THE 2024 OLYMPIC GAMES

Supported by Choose Paris Region and the Île-de-France Region and in close collaboration with the Directorate General for Civil Aviation, the European Union Aviation Safety Agency (EASA) and Eurocontrol, the ADP and RATP groups issued an international call for expressions of interest (Re.Invent Air Mobility) to attract the best institutional, industrial and start-up players. The over 150 respondents included the sector's leading manufacturers and the 30 winners were announced at the start of January 2021 so that testing could begin in September 2021.

Within a framework that encourages innovation, the partners together with the regulator will be able to solve the many key problems, which have been organised into three areas: acceptability, technological maturity and regulatory environment.

In the first few years an on-board pilot will reassure passengers and ensure aeronautic safety. There could then be a gradual transition to pilotless modules through firstly assisted piloting, then remote piloting and finally full automation.

When preparing for a demonstration at the 2024 Olympic Games in Paris, the test and learn method, which is suitable for all innovation, will put manufacturer promises to the test. An experimentation platform unique in Europe will provide a real environment that brings together industrial companies, authorities and the general public in testing the various aspects of the system: customer path, integration with air traffic control, energy management, maintenance etc.

Offering far more than a technology lab, by including local communities and the general public, Pontoise will measure social acceptability and usages and demonstrate the value created for society. At a time when air transport is going through the biggest crisis in its history, we are going on an adventure worthy of the pioneers of aviation and we have some formidable advantages on our side. ●

Sustainable aviation fuels - a key solution to reduce carbon emissions

Given the many economic, technological and environmental challenges the aviation sector must meet, sustainable aviation fuels offer an effective, technologically tried, tested and already available way of achieving the ambitious targets set for reducing its emissions

Jean-Marc Durand,
Senior Vice- President Refining, BaseChem Europe, and Acting Director of Renewable Fuels, TotalEnergies

A GLOBAL CHALLENGE, MANY SOLUTIONS SIDE BY SIDE

In 2019 before the start of the pandemic, aviation fuel consumption was around 300 Mt, or almost 6% of total world consumption of petroleum products. In terms of CO2 emissions, it translated into circa one billion tons, almost -3% of the world's global emissions.

2021 was a tipping point for the aviation sector as it adopted a new ambitious target to achieve net-zero carbon emissions by 2050 requiring a combination of measures including optimization of routes, increased energy efficiency (new aircraft and improved ground operations), and the use of Sustainable Aviation Fuels (SAF) which will be the largest contributor.

"*TotalEnergies, as a multi-energy company and a major player in the production and distribution of aviation fuels, is in line with the ambition of the sector to cut its emissions. Our company is sharing the same goal which is to achieve carbon neutrality by 2050 together with the society. For over 10 years TotalEnergies has been developing sustainable solutions to decarbonize aviation. Since our first flight using SAF provided by TotalEnergies back in 2014, we have supplied hundreds more with a progressive increase in SAF content. Last May 2021, TotalEnergies*

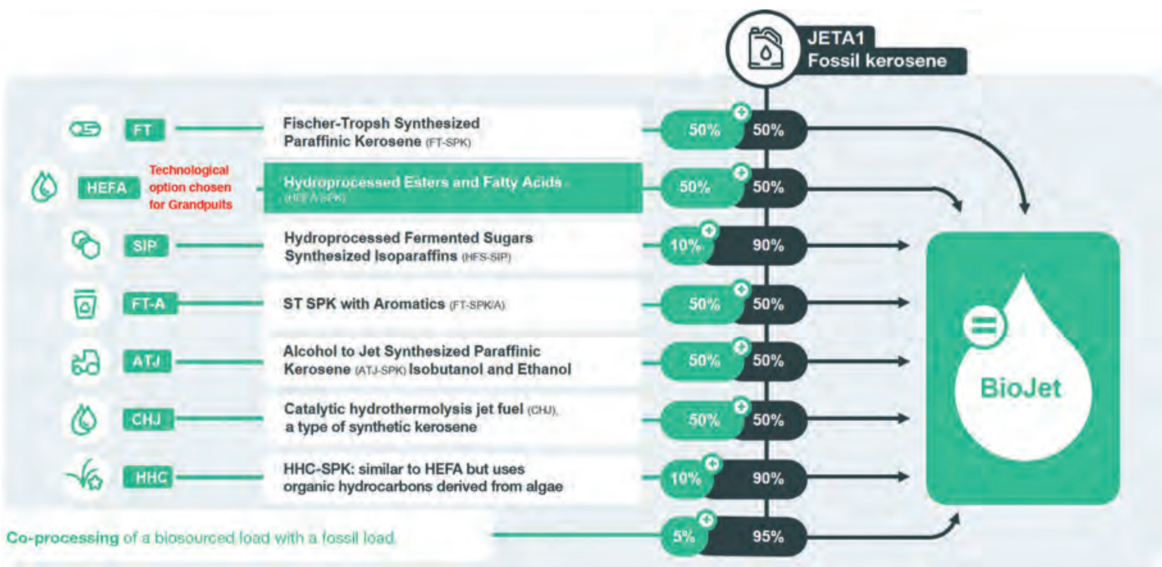


Fig. 1: **The seven SAF production technologies.** *@TotalEnergies*


Fig. 2: View of the future zero-crude Grandpuits platform.
@Detienne Augustin - CAPA Pictures – TotalEnergies.

supplied SAF at a blended rate of 10% for the first long-haul flight from Paris to Montreal. Later that year, in October, we supplied a 30% SAF blend for a Nice to Paris flight Since June 2021 we have been supplying SAF on a permanent basis to business and commercial flights out of Le Bourget Airport, Clermont-Ferrand Airport and more recently Bordeaux Airport", said Joël Navaron, President of TotalEnergies Aviation

WHAT IS SUSTAINABLE AVIATION FUEL OR SAF?

SAF stands for sustainable aviation fuel. It's the term used in the aviation industry for an alternative to fossil fuels produced from sustainable raw materials . We need to distinguish 'neat SAF or Synthetic Blending Component (SBC)', the pure renewable , and SAF, which is a mix of conventional aviation fuel (Jet A-1) and the renewable molecule itself. Neat SAF has usage characteristics similar to those of Jet A-1 and can cut CO2 emissions by up to 90% across the life cycle when compared to its fossil fuel equivalent.

At present, seven technologies pathways for producing SAF have been approved by ASTM (American Society for Testing of Materials), the body that drafts and publishes international technical standards, including for aviation fuels.

Some of those technologies have reached advanced industrial maturity and are already used to manufacture SAF that can be included in an up to 50% mixture with conventional fuel:

- **HEFA** (Hydroprocessed esters and fatty acids) is the most widely used technology because it is the only one to have reached the commercial stage so far. The raw material comes from circular economy waste, such as used cooking oil;
- **ATJ** (alcohol to jet) is at the pre-industrialization stage but could provide attractive flexibility in terms of raw materials, e.g. industrial gases and lignocellulose (plant waste) that can be used to produce ethanol;
- **FT** (Fischer Tropsch) fuels. This method uses advanced raw materials, such as agricultural and forestry waste or municipal waste. This technology requires massive investment to be deployed at at large scale.

Other technologies are also being studied, including co-processing in which a biogenic feedstock is blended with the fossil kerosene (ASTM allows a 5% blend limit) within existing conventional refinery resulting in a SAF already blended and ready for use in existing infrastructure.

Recently, the industry has been working on developing e-SAF (electro-fuels) which are synthetic fuels made from combining green hydrogen (produced from renewable electricity) and a source of CO2 captured directly from the air or industrial waste. This technology, still in its development stage, provides a quasi-unlimited source of feedstock (electricity and carbon) but requires massive investments (currently at least 10 times HEFA based technology on a ton of SAF produced basis). .

"*In addition to our ongoing industrial SAF based on the HEFA pathway, we are also looking at other technologies, explained Jean-Marc Durand, Senior Vice-President Refining, BaseChem Europe, and Acting Director of Renewable Fuels, TotalEnergies. We are ramping up our R&D work to be able to produce e-fuels that will meet future demand and requirements*".

We are investing in R&D to develop e-fuels that will meet future demand

•••

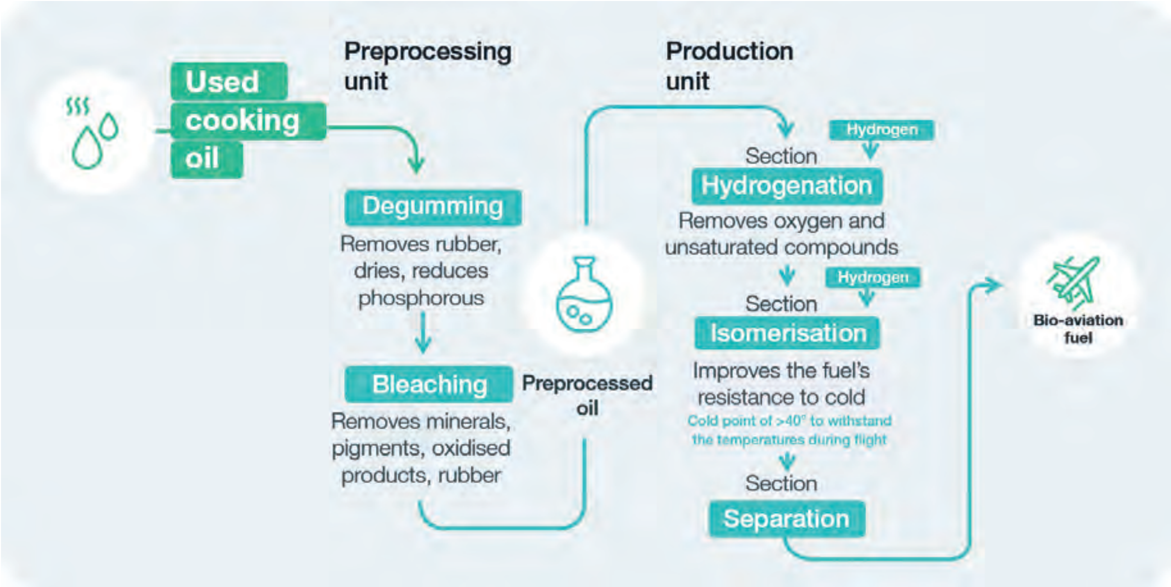


Fig. 3: **: SAF production using the HEFA method.** *@TotalEnergies*

MANUFACTURING SAF USING HEFA TECHNOLOGY

TotalEnergies has decided to focus initially on HEFA, which is currently the most mature technology. In September 2020 the company announced that it would be transforming its Grandpuits refinery in the Paris region into a zero-crude platform. This future plant will convert wastes and residues (such as used cooking oil (UCO) into SAF using the HEFA process. The new unit is expected to come into operation in 2024.

Before SAF can be produced from used cooking oil, the oil has to be pre-treated to clean it and prevent damage to refinery units. The pre-treated oil then goes through a standard refining process where it is hydrogenated and isomerized. Isomerization lowers the freezing point of the oil to below -40°C so that it can withstand low temperatures.

The future Grandpuits biorefinery has been scaled to maximized retrofit of existing equipments. It will produce 220 000 tons of SAF a year.

SAF consumption today is roughly 100 000 (expected SAF volumes in 2022), which is less than 0.01% of total global aviation fuel market, and would not even cover the over 170 000 t that will be needed by 2025 to meet demand in France alone. According to IEA (International Energy Agency), demand for SAF could reach 20 million tons a year by 2030 and 60 million tons by 2040. But many obstacles still need to be removed before SAF can be deployed on a large scale to meet IEA forecasts

RAW MATERIALS: A CHALLENGE THAT NEEDS TO BE MET

EU regulations do not allow the use of vegetable oils so the industry is turning towards circular economy raw materials, such as used cooking oil, animal fats, lignocellulose biomass (non-food plant waste) and forestry and household wastes. Some of these raw materials are not yet readily available and collecting them is not simple.

More massive use of SAF also depends on cost. The cost of producing SAF from HEFA pathway is at least three times greater than that of conventional aviation fuel. "*We now know that biofuels, which by nature are renewable, are the best alternative, said Joël Navaron. But their cost is high and the raw materials needed to manufacture them are limited. This is the present challenge we need to face together since fuel accounts for about 30% of the cost of operating an aircraft.*"

JOINT DEVELOPMENT OF A SAF INDUSTRY WITH MEMBERS OF THE AVIATION SECTOR

Despite these obstacles, the entire aviation sector (engine and aircraft manufacturers, airlines, energy companies, etc.) are on board and gearing up to create a new sustainable aviation fuel industry. Several, particularly public-private, initiatives have been created. Clean Skies for Tomorrow is one of them. This initiative is part of the World Economic Forum mission to decarbonize seven hard to abate sectors including aviation and maritime.

Industrial partnerships are also being formed to remove existing technical constraints. TotalEnergies and SAFRAN, for example, signed a strategic partnership in September 2021 to develop technical and commercial solutions to meet the air travel decarbonization challenge. One of its short-term aims is to be able to use SAF without first mixing it with fossil jet and to do everything needed to make sure SAF can be used on its own in today's engines. To achieve this, TotalEnergies and SAFRAN are working together on research pilots. Last November at Marignane in the South of France a helicopter made a 100% SAF flight. An Airbus A319neo has also made a 100% SAF test flight. These are just the first in a long series of tests to examine in detail the impact 100% SAF has on engines and their environment. It is also contributing to the new regulatory framework that is essential to this crucial change.

Given this complex situation in which financial and technical obstacles are combined with a cooperative dynamic, one of the main levers required is a global regulatory framework for aviation that will accelerate the development of the SAF industry.

EU regulations are gradually changing. In July 2021 the European Commission unveiled Fit for 55, which set a tar- get of a 55% cut in EU greenhouse gas emissions by 2030 from 1990 levels. Among the many measures proposed in ReFuelEU - Aviation are 95% EU-produced biofuels and a requirement that airlines and aviation fuel suppliers must incorporate SAF from 2025, with penalties for failing to do so. The current proposal is to gradually increase the proportion of SAF according to the still provisional time- table shown in table 1.

Table 1: **Timetable for the inclusion of SAF in aviation fuel, as per the draft ReFuelEu (July 2021).**

Deadline	Minimum % SAF	of which minimum % of e-fuels
2025	2%	
2030	5%	0.7%
2035	20%	5%
2040	32%	8%
2045	38%	11%
2050	63%	28%

Many countries, such as the USA (California) and the Netherlands, have introduced incentives to promote the use of SAF. Norway (2020), Sweden (2021) and France (2022) have also made incorporation compulsory.

Public policies are therefore being introduced in the form of incentives, requirements and calls for projects to support the industry and to start preparing now, together with the rest of the aviation industry, for tomorrow.

Airports catalysts of low-carbon air transport

CDG Boarding pier at concourse K terminal 2E.
©Arnaud Gaulupeau, Groupe ADP)

If they are to become true low-carbon connectivity platforms, airports must invest not just to cut their internal emissions but also to support the decarbonisation of their stakeholders, a field led by the other air transport players. Groupe ADP has decided to sign up to this difficult task.

Amélie Lummaux,
Chief, Sustainable Development and Public Affairs Officer, Groupe ADP

WHAT IS A LOW-CARBON AIRPORT?

373 airports in 76 countries around the world are now members of the Airport Carbon Accreditation (ACA) scheme set up by Airports Council International (ACI). 58 of these airports are accredited carbon-neutral (ACA3+) and nine have policies for reducing their internal CO_2 emissions that meet the targets set globally to fight climate change (IPCC's 1.5°C scenario). Groupe ADP's Paris airports have an active policy for reducing their emissions (-65% in absolute terms compared with 2009) and are committed to carbon neutrality by 2030 at latest.

But these encouraging results nevertheless raise questions that have been put by many observers. What does carbon neutrality mean for in the ACA scheme?

The definition is very clear. It means reducing CO_2 emissions per passenger in accordance with scopes 1 and 2 of the GHG Protocol[1] (direct emissions and emissions associated with the purchase of energy), offsetting residual emissions on the same basis and also the emissions produced through the business travel of airport operator employees by using high environmental quality carbon credits, and engaging in real action to encourage the reduction of stakeholder emissions that fall within scope 3 of the GHG Protocol. The airports that have signed up to the scheme transparently publish emissions maps, the methods they use to cut the emissions and the amount of offsets (if any) that they buy. These figures are all independently audited.

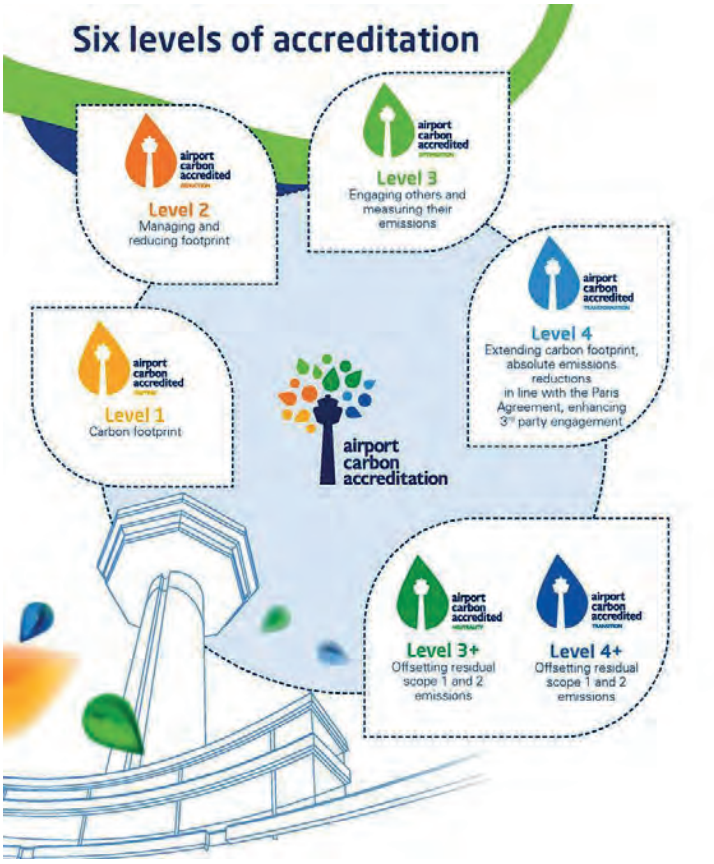


Fig. 1: The six accreditation levels of the Airport Carbon Accreditation scheme.

WE NEED TO GO BEYOND SCOPES 1 AND 2

Critics however are many and attention must be paid to them. In practice, scope 1 and 2 emissions represent 3-5% of all airport CO_2 emissions. These are produced not just by scope 1 and 2 installations (terminals, transport, car parks, etc.) but also by passenger and employee access, parked and LTO (landing and taking off) cycle aircraft and ground-handling. Access-related emissions account for around one-third of all emissions reported to the ACA, and aircraft LTO cycle and ground-handling emissions two-thirds.

This gives rise to two immediate considerations: while action taken under direct responsibility (scopes 1 and 2) may be essential, it cannot be sufficient given the extent of scope 3. Airport operators must therefore facilitate energy transition along the entire value chain, from platform access to in-flight aircraft emissions. Both use of their understanding of emissions, as required by the ACA scheme (this applies to the airport's entire sphere of influence), and setting an example are essential actions that must be taken.

ALL AIRPORT OPERATORS MUST TAKE ALL NECESSARY ACTION

All must identify every lever that will help reduce its impact on climate change to zero. In the case of airport infrastructure, this is essentially the impact of CO_2. On its Ile de France platforms, Groupe ADP has for many years been building plant that produce heat from renewables (geothermal plant already operate at Paris-Orly and are planned at Paris-Charles de Gaulle and there is a biomass plant at Paris-Charles de Gaulle), is converting its entire vehicle fleet to low-carbon fuels (33% by end 2020), renovating buildings to make them more energy efficient (-28.4 % kWh/m^2 by end 2020 vs. 2015) and buys only green energy (since the start of 2021), an increasing proportion of which comes directly from a renewable electricity producer in accordance with the Corporate Power Purchase Agreement. As a result of these actions, between 2009 and 2019 the airports of Paris cut the amount of CO_2 they emitted into the atmosphere by 111 000 tonnes. Internal CO_2 emissions must continue to fall in the years to come to below 12 000 tonnes before offset by 2030.

The standardised reporting recommended by ACA, blazing a trail in this area for an entire economic sector, will make it easier to bring airport operators around the world on board, will make their actions easier to understand and will allow them to set themselves •••

1. Reporting standard developed jointly by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) and recognised internationally by governments and business associations.

together new milestones and targets. In 2020 at the height of the air transport crisis triggered by Covid, ACA announced two additional ACA levels, including ACA 4. This is achieved when an airport has set itself a target for cutting emissions in absolute terms that is in line with world climate agreements and has included new emission producers, including site equipment. For Groupe ADP, which manages 28 airports in 15 countries across the globe that vary enormously in terms of the maturity of their climate actions, the ACA scheme is a formidable driver. Six airports in our network were certified carbon-neutral in 2020 (Amman, Izmir, Ankara, Antalya, Delhi and Hyderabad) and at the start of 2021, 23 airports in the network undertook, like our Ile de France platforms, to follow suit by 2030.

BUT THESE EFFORTS WILL BE FAR FROM SUFFICIENT IF WE MAKE THEM ON OUR OWN.

All companies are now being challenged about their scope 3 (stakeholder emissions) and required to take action along their entire value chains, from suppliers to clients. This is certainly particularly the case for airports whose business model is essentially based on providing a certain number of services over a given geographic territory.

Airports have already started working on a number of priority actions for emissions within their spheres of influence. Although there are many challenges, the aim must be an emissions target for airports in the widest sense, as standalone territories.

Parked aircraft and ground-handling equipment

The first stage in transition is to deal with emissions from parked aircraft and ground-handling equipment. Since 2015 all contact stands at Paris-Charles de Gaulle and Paris-Orly supply alternative energy resources for auxiliary power units (APU) to enable them to produce electricity, 10 years ahead of the first deadline set in the European Commission's draft Alternative Fuels Infrastructure Regulation (AFIR). This has produced a huge cut in emissions. By 2030 at latest, all contact and apron stands will supply electricity and allow the connection of electric heating and air conditioning equipment. Ground-handling equipment (vehicles carrying baggage and freight, tugs, fork lifts, platforms, various types of lorry (e.g. aircraft refuelling carts) is also is the middle of a transformation encouraged by airport operators. Recently renewed ground-handling licences at Paris-Charles de Gaulle and Paris-Orly set a target of 75% of all vehicles and equipment to be low-carbon by 2025 and over 90% by 2030. Efforts to cut aviation fuel use during taxiing are also helping reduce CO_2 emissions on the ground.

Access to airport platforms

Passenger and employee access to airport platforms forms an entirely separate project on its own. The number of authorities involved (Government, local authorities, transport organising authorities) and the huge number of final decision-makers (100 million passengers in a normal pre-Covid year in Paris, and over 120 000 direct jobs) make this a particularly complex question. Improving access to public transport is the absolute priority at all sites. The imminent opening of lines 14 and 18 of the Grand Paris Express to Paris-Orly, the CDG Express, line 17 and several high-quality bus routes to Paris-Charles de Gaulle and Paris-Le Bourget will be a significant improvement but will not solve the access problems on their own. Groupe ADP is also working to roll out low-carbon mobility infrastructure (437 recharging points for electric vehicles by end 2020, with a continuing sharp rise in their number until 2025) and to transform usage (car-sharing and active mobility).

Aircraft

Decarbonising aircraft ground operations is itself an essential project requiring considerable investment. Airport electrification and the associated increase in network power that this will involve will be one of the main challenges this decade. But this is barely recognising the elephant in the room: in-flight aircraft emissions.

At the start of 2021 all Groupe ADP airports together drafted and signed a charter (Airports for Trust) setting them new targets. The charter's main message is that the Group's main concern is in-flight aircraft emissions that account for almost 85% of all Ile de France platform emissions under scope 3 of the GHG Protocol. Groupe ADP is convinced that airport operators have a key role to play in ensuring that European aviation is zero-carbon by 2050.

In February 2021 *Destination 2050*, a roadmap for the total decarbonisation of the European air transport industry by 2050, was published. It gives a detailed description of the methods to be used: improved operations, fleet replacement, sustainable aviation fuels and breakthrough technologies (electric aviation and hydrogen). To achieve this goal, Groupe ADP must transform the management of energy flows on its platforms and facilitate the supply, at the lowest possible cost, of sustainable aviation fuels and hydrogen. This will mean working with new players (energy companies and manufacturers) whose role within the airport ecosystem continues to grow. Creating the energy hub, including upgrade of the rail-air connection and replacing air by train travel wherever necessary will certainly be the most important challenges in the transition to a sustainable airport model for tomorrow.

RECONCILING TRAVEL WITH ENVIRONMENTAL TRANSITION

And after all this will we still be able to fly and can we reconcile travel with environmental transition? There are many solutions the aviation sector can bring to the question of how we create a way of living that has a low environmental impact, is not regressive and defends our aspirations of exploring the world that surrounds us. Although each is inadequate on its own, together they mean that transition is possible for the sector. Reducing the emissions of airport installations, decarbonising

Solar farm at Paris-Charles de Gaulle Airport. ©JM Jouanneaux, Groupe ADP

ground operations and access, and aviation transition to non-fossil fuel mobility are the main elements in our collective roadmap.

The main thing now is to work on what will make transition a success: the sector's ability to invest in transition and links with other sectors of the economy to make sure decarbonisation strategies are compatible with each other. These are certainly the main levers the sector needs to operate to achieve its goals.

Protecting airports' ability to invest

In the EU, airport ability to invest is subject to airport regulations that are enforced in France by the *Autorité de régulation des transports* (Transport Regulation Authority). In terms of the challenges described above, this ability must increasingly become a way of ensuring fair and sustainable economic transition in the spirit of what lies at the bottom of all regulations: facilitating positive indirect benefits. That depends on airports being able to make medium and long term investments that help improve not just the quality of the service they offer their passengers or airline efficiency and competitivity but also the environmental transition of the sector as a whole and therefore protect the industry itself and jobs.

Maintaining competitivity and fair competition

The rest of the sector (airlines, manufacturers) are of course also facing major expense: SAF (4-10 times the price of fossil aviation fuel), fleet replacement and breakthrough technology R&D. It is essential that the EU's Fit for 55 package now being discussed in Brussels makes sure that our industry is in fair competition with third-country airlines and hubs. Maintaining the competitivity of EU aviation will be key to ensuring we can continue to invest in transition and prevent carbon leakage. The sector must also congratulate the French public authorities for their decision to support research with a view to the marketing by the mid-2030s of the first liquid hydrogen-powered, medium-haul zero-carbon aircraft. The projects offers France a unique opportunity to take the lead in the green aviation of tomorrow.

WORKING TOGETHER

It is now a fact: no sector can achieve environmental transition on its own. Low-carbon hydrogen and electricity supplies, the allocation of biomass resources and the creation of energy transport infrastructure at national and continental levels are concerns that can only be addressed through calm and constructive inter-sector dialogue facilitated by the public authorities. The air transport sector has now made a fully transparent presentation of its vision for transition in *Destination 2050* to make that transition possible.

If they are to become true low-carbon connectivity platforms, airports must invest not just to cut their internal emissions but also to support the decarbonisation of their stakeholders, a field led by the other air transport players. This can only be achieved through a public-private partnership based on a common understanding of the challenges and objectives.

An international action plan to decarbonise airports

Las Americas Airport,
Dominican Republic.
© Govin Sorel.

VINCI Airports has created an international action plan for decarbonising its airports. Its three aims are: to pioneer environmental transition as an airport operator, to help airlines and passengers move towards more sustainable solutions and to have a positive impact on the decarbonisation of its regions.

Interview with Joffrey Maï.

Joffrey Maï,
Head of Environment and Sustainability
VINCI Concessions

Decarbonising air transport is now a priority for the entire sector, What are the stages and targets VINCI Airports has set for its energy transition?

As part of the fast international growth of its business, VINCI Airports has been implementing an environmental action plan in all its airports since 2016. In 2019 the plan was strengthened with five specific targets: halving our direct carbon emissions, protecting biodiversity at all our platforms, sending zero waste to landfill, halving water consumption and obtain the ISO 14001 certification for our all our business units.

When we signed the Toulouse Declaration in February 2022 at the aviation summit organised by the French presidency of the Council of the European Union, VINCI Airports committed to new targets: net zero carbon emissions at all its EU airports by 2030, 20 years before the Paris Agreement deadline, and by 2026 for Lyon-Saint Exupéry Airport. This will therefore be the first commercial aviation airport in France to achieve carbon neutrality.

In practical terms, how will you meet these targets?

VINCI Airports' decarbonisation policy is based on improving our energy performance and developing our own energies. This reduced our overall direct carbon footprint by 28% between 2018 and 2021. At the same time, we are working to sequester our residual emissions through forestry carbon sinks.

Our airports are also members of the ACI's Airport Carbon Accreditation (ACA) scheme. Of our 39 accredited airports, 26 are level 2 and three level 4. London Gatwick and Lyon-Saint Exupéry are level 3+ and are therefore certified carbon-neutral.

The aviation sector has many stakeholders, including airports. How do you influence other members and help facilitate their energy transitions?

Yes, decarbonising the entire air mobility chain is one of VINCI Airports' biggest concerns. To support airlines we are for example developing APU-off[1] solutions, which provide alternatives to the use of aircraft auxiliary power units. At Phnom Penh International Airport in May 2021 we installed Fixed Electrical Ground Power (FEGP) and Pre-Conditioned Air (PCA) units at aircraft parking bays, reducing polluting emissions, CO_2 and noise.

You also play a key role in supplying sustainable aviation fuel (SAF) to help airlines cut their emissions. What is your policy on facilitating supply?

SAFs make an immediate positive impact on the decarbonisation of aviation. We therefore responded to the French government's July 2020 call for expressions of interest (Biofuels) in growing airline use of these biofuels. Our supply of bio-sustainable fuels at Clermont-Ferrand Airport in Auvergne, which started on 19 April 2021, was a first for France and our first customer was Michelin Air Services. During COP 26, London Gatwick Airport also provided the resources needed to supply biofuels in partnership with EasyJet.

> VINCI Airports' decarbonisation strategy is based on improving our energy performance, developing our own energies and sequestering residual emissions through our forestry carbon sink programme.

To encourage the use of sustainable aviation biofuels and fleet replacement with new, more energy-efficient planes, we have introduced variable landing fees so that lower-emission aircraft pay lower fees. Grenoble and Chambéry Airports introduced the system on 1 January 2021, followed by Clermont-Ferrand, Rennes, Dinard and Toulon airports on 1 April 2021 and Lyon-Saint Exupéry Airport at the start of 2022.

In addition to increasing SAF use, we are also involved in the development of hydrogen to accelerate the decarbonisation of the aviation sector. We have joined forces with Airbus and Air Liquide to grow the use of hydrogen in airports and to build the European network of airports needed to handle future hydrogen aircraft. Lyon-Saint Exupéry, as the pilot airport, will receive the first facilities in 2023. Our aim is to turn airports into hubs that can supply renewable hydrogen to their entire ecosystems and hinterlands.

How do you facilitate the supply of decarbonised energy across all your infrastructure?

In order to decarbonise the energy used in our infrastructure we rely heavily on renewables. We have a huge solar energy programme with almost 30 MWc already installed. We also ensure the strategy covers our airports' regions by reinjecting some of the renewable energy we produce into their grids.

The strategy has been introduced in the Dominican Republic where the facilities we have installed in our six airports give VINCI Airports 6.8 MWc of solar energy, the highest level of of private production for self-consumption in the country. We will soon have plant with grid injection connections at Lyon Saint-Exupéry and Stockholm Skavsta airports. In order to develop these new projects we work with SunMind, a subsidiary

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1. An APU (auxiliary power unit) is usually a turbo-generator that produces energy for landed aircraft to run their on-board systems (power, pneumatic and hydraulic pressure, air conditioning) when their main engines are switched off.

Solar panels - Airport in the Dominican Republic. © GOVIN SOREL.

Lyon-Saint Exupéry Airport. © Eric Soudan.

of VINCI Concessions that designs, finances, builds and maintains solar plant.

Decarbonisation also requires an electric mobility policy. We therefore increased the number of electric charging stations at our airports for their users from 92 in 2019 to over 200 in 2021.

We have a smart energy management policy that replicates the policy deplayed at Kansai International Airport where we introduced an energy dashboard linked to a building energy management system fed by operating data to improve the energy efficiency of equipment and infrastructure. In practice, the system analyses data from the airport's aircon and heating systems, based on operations and activity, with the aim of saving energy.

These moves help VINCI Airports reduce its emissions, but what do you do about those you can't eliminate?

For its residual emissions in 2021 VINCI Airports introduced a new programme for the development of forestry carbon sinks. Located as close as possible to our airports and managed in partnership with local companies, our forestry carbon sinks also help the environmental industries of the region.

At Lyon-Saint Exupéry Airport we are working with ONF (French Forest Agency) and the *département du Rhône* on accredited low-carbon forestry carbon sink projects. The first of these projects is in the Department's Cantinière Forest where we are restoring, reforesting, maintaining and managing 3.6 hectares with species specifically chosen for their resilience and ability to absorb CO_2. Carbon sinks will be able to absorb the 500 tonnes of residual emissions produced by the airports in Lyon by 2026.

We have since introduced the same programme in Portugal near the airports at Faro and Porto Santo and in the Algarve and Madeira in partnership with the Institute for Institute for Nature Conservation and Forests (the Portuguese equivalent of the ONF).

Biodiversity and the circular economy also lie at the heart of all your work. What is your strategy for meeting these challenges and adapting to specific circumstances that will of course vary from airport to airport?

Airports are located in areas that are rich in flora and fauna and that's why we're committed to the protection of natural environments and biodiversity. Our airports are committed to zero pesticides by 2025 and already reduced their use by 80% between 2018 and 2021. And finally, we're obtaining ISO 14001 certification across our network. 23 airports have already got it.

Creating a circular economy is another of our priorities and we are aiming for zero waste to landfill by 2030. This is a real challenge in some countries that do not yet have fully operational recovery and recycling industries.

In the Dominican Republic we have installed waste sorting centres thanks to a partnership between Aerodom and Dominicana Limpia, a local association promoting and accelerating the recovery and sorting of waste in the Dominican Republic.

In Salvador in Brazil, the airport's efforts to improve energy efficiency and the management of wild animal risk, plus a new on-site waste treatment facility have


Cantinière Forest, Lyon airports' first carbon sink. © CD69-JULIEN BOURREAU.

enabled us to achieve zero liquid discharge through full re-use of all treated water. A waste sorting facility has also been built at the airport, which is now therefore zero landfill. We intend to replicate this approach in the Brazilian airports that have joined our network in 2022. ●

VINCI Airports in figures

- **More than 50 airports in 11 countries**
- **1st private airport operator in the world**
- 1st airport operator to introduce an **international environment strategy**
- **15 000 employees** world-wide
- **86 million passengers** in 2021
- **28% cut in the carbon footprint** of our airports since 2018
- **39 airports with ACA** (Airport Carbon Accreditation)
- **38% waste recovery** in 2021 at the international level
- **83% cut in pesticides** 2021-2018
- **28.5 MWc of solar panels** (own use and injection into the grid)
- **2030 targets** (based on 2018 figures):
  - - 50% carbon emissions (scopes 1 and 2)
  - Net zero emissions for our European airports
  - - 50% water use
  - Zero landfill
  - Zero pesticides

The technological levers for decarbonising aviation

3D weaving of carbon fibres.
© Adrien Daste (Safran).

Achieving carbon-neutral aviation by 2050 is a technological challenge that seemed out of reach less than a decade ago. Today the aviation sector is ready to meet it. But there is no single solution - just a a set of advances that need to be approached from several directions. Some are extensions of previous advances. Others are real technological breakthroughs.

Thibaud Normand,
VP Climate, Safran

Since its creation the aviation sector has been working to become more efficient and offer ever greater connectivity to as many people as possible around the world. Aircraft fuel consumption per passenger.kilometre has therefore halved in the last 30 years. But the urgency of fighting climate change means the aviation sector must make a big technological breakthrough if it is to hit the target it set itself of net zero by 2050. Safran and the other aviation leaders have been working for many years on this and have produced a credible roadmap for the decarbonisation of the sector based on three main paths (*figure 1*):

- major improvement in aircraft energy performance with a contribution of 35-40% to the decarbonization emissions;
- transition to various low-carbon fuels, contributing for around 50%;
- improvement in operational efficiency to achieve a 5-10% reduction.

Assembly line for the LEAP engine.
© Adrien Daste (Safran).

MAJOR IMPROVEMENT IN AIRCRAFT ENERGY PERFORMANCE

For aviation like for other sectors improved energy efficiency is the first step in the decarbonisation strategy as it lowers the pressure on resources and supports the transition to decarbonised energies.

Replacing fleets with new generation aircraft is the quickest and main way of cutting aviation fuel consumption in the short term. The new generation short and medium-haul planes entered into service since 2016 (Airbus A220 and A320neo, Boeing 737MAX), burn, for example, 15% less fuel than those of the previous generation. But at present they account for under 20% of short and medium-haul fleets.

Replacement is part of the continuous, around 1.5% p.a., improvement in fleet efficiency in the last few decades. The achievement of net zero by 2050 will however require the next generation of aircraft, which will come into service in the 2030s and form the majority of fleets by the middle of that decade, to make a technological leap forward. Safran believes that tomorrow's short and •••

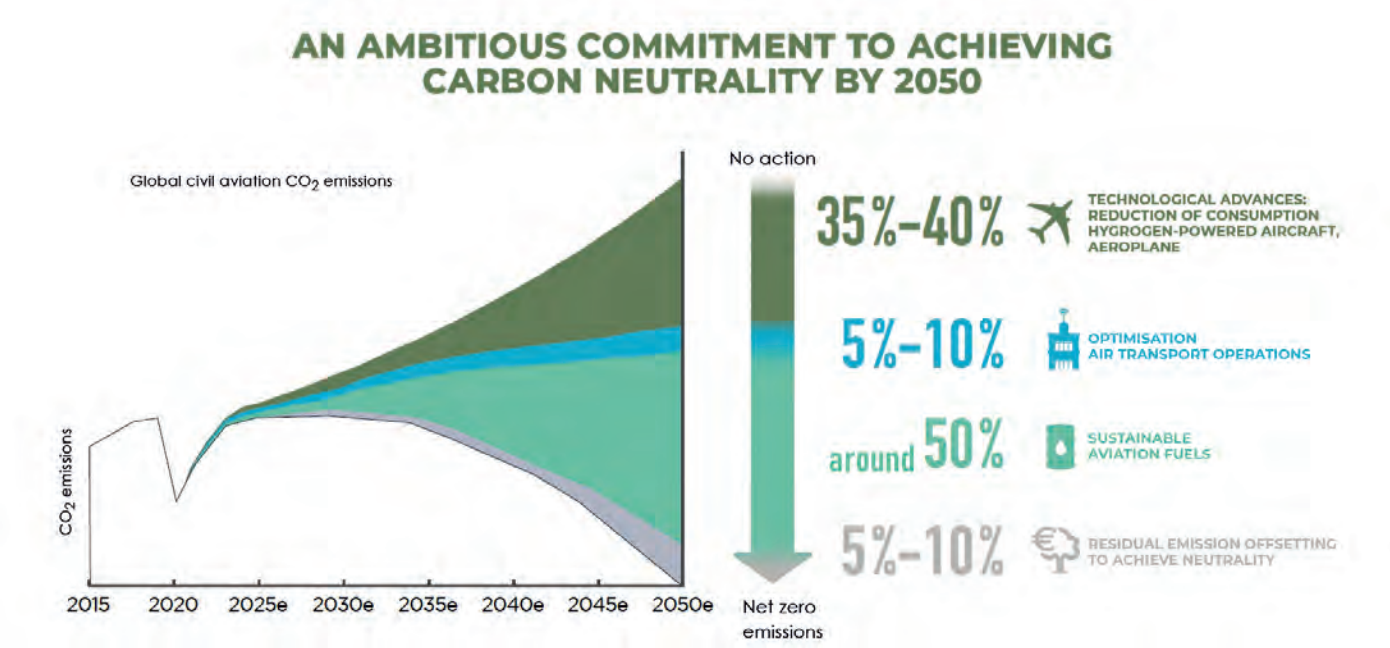


Fig. 1: **Safran's vision of the main levers in the decarbonisation of civil aviation.** © Safran.

Turbojet efficiency improvement factors:

In recent decades improvements in turbojet efficiency have primarily fallen into two main areas:

- increasing combustion temperature to improve thermal performance. Current civil aviation engines achieve temperatures of around 1 500°C, requiring complex alloys and cold upstream air to cool the turbine blades; and
- double flow architecture: a primary air flow through the combustion chamber and a secondary airflow through only the first compression stage - the fan that can be seen at the front of the engine. By providing thrust without combustion, the secondary flow improves engine efficiency. The bypass ratio, which measures the proportion of the secondary flow, has gradually increased over time. In the LEAP engine, the secondary flow is 10 times greater than the primary flow that undergoes combustion. This has increased engine size and therefore presents major challenges, particularly in terms of the bulk and speed of the fan blades. To solve these problems Safran has developed fan blades in 3D composite materials that are lighter than titanium, while Pratt&Whitney has developed a gearbox that turns the fan more slowly.

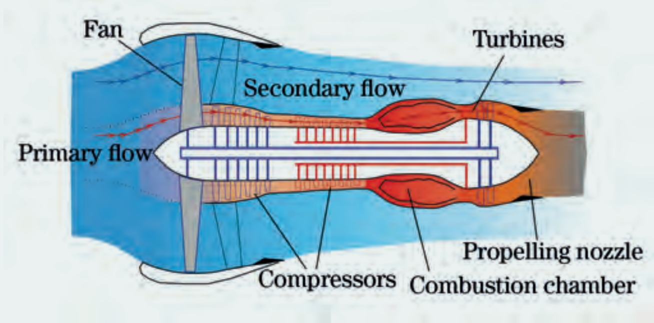


Figure 2: Cross-section showing how a double flow turbojet engine operates. The primary flow is indicated by the red arrow and the secondary flow by the blue arrow as they exit the engine. *Source : Référentiel ISAE-SUPAERO – Aviation et climat (September 2021).*

Progress in these two main areas relies especially on innovative materials that are more resistant to constraints and high temperatures, are lighter, etc.

medium-haul aircraft that will come into service around 2035 could cut energy consumption per passenger.km by 30% - double the gain usually achieved by new generation planes. To achieve this level of performance all paths for technological improvement in all available areas will have to be combined.

Engines

The efficiency of new generation short and medium-haul planes is mainly down to their better engines. CFM International's[1] LEAP engine uses 15% less fuel than the CFM56 it replaces, primarily thanks to technological progress in materials and processes (composite materials, additive manufacturing, high temperature alloys, etc.) that have allowed higher combustion temperatures, improved engine propulsive efficiency and reduced the weight of its components.

Future medium and long-haul planes will continue to use gas turbines as electrical propulsion using batteries or fuel cells is not viable for more than a few hundred kilometres in big aircraft.

To make yet another efficiency leap forward, Safran and its partner GE Aviation in june 2021 presented their vision of the engines of the future with RISE (Revolutionary Innovation for Sustainable Engines), a technological programme for cutting fuel consumption 20% from LEAP levels by 2035. RISE will develop technological innovations in current areas of improvement (materials able to withstand high temperatures, gearbox) and also breakthrough technologies, especially electric hybridization and open-fan architecture (*figure 3*).

The electric hybridization of engines could improve their operation at different flight stages by, for example, providing power at critical stages, meaning that the turbojet engine could be scaled better.

Open-fan architecture pushes the increase of the dilution ratio to its limits, creating maximum propulsion efficiency. By removing the engine nacelle, the diameter of the fan can be greatly increased without problems of weight or frictional drag. The RISE fan will therefore be twice as big as that of LEAP. This breakthrough architecture is based primarily on innovations in the reduction of engine noise. It also requires close collaboration with aircraft manufacturers to find the best aerodynamic setups for fitting the engine into the plane since current aircraft architecture is not the only option (rear engines, under high-wing engines, etc.).

Aerodynamics

As well as winglets - aerodynamic structures added to the tip of the wing and already widely used in current fleets - significant progress is now expected from longer, improved design wings and from their active in-flight control to approximate laminar flow. Research is also being done into architecture, e.g. the braced high wings currently being studied by NASA.

Weight reduction

Reducing the weight of aircraft is one area of improvement in which much work has already been done in the last few decades, but potential for further improvement remains. The challenge is to reduce the weight of aerostructures through greater use of composites (already very advanced in Boeing 787 and Airbus A350 but not much used in current short and medium-haul planes) and of on-board systems: landing gear, electrical systems, cabin interiors (1-2 kg gain per seat in 2 generations or around 7 years). In addition to lighter materials (e.g. titanium and composites) and more additive manufacturing should also cut mass through workpiece geometries that are better suited to the desired constraints.

1. Joint venture 50% Safran and 50% GE Aviation, the world leader in short and medium-haul airplane engines.

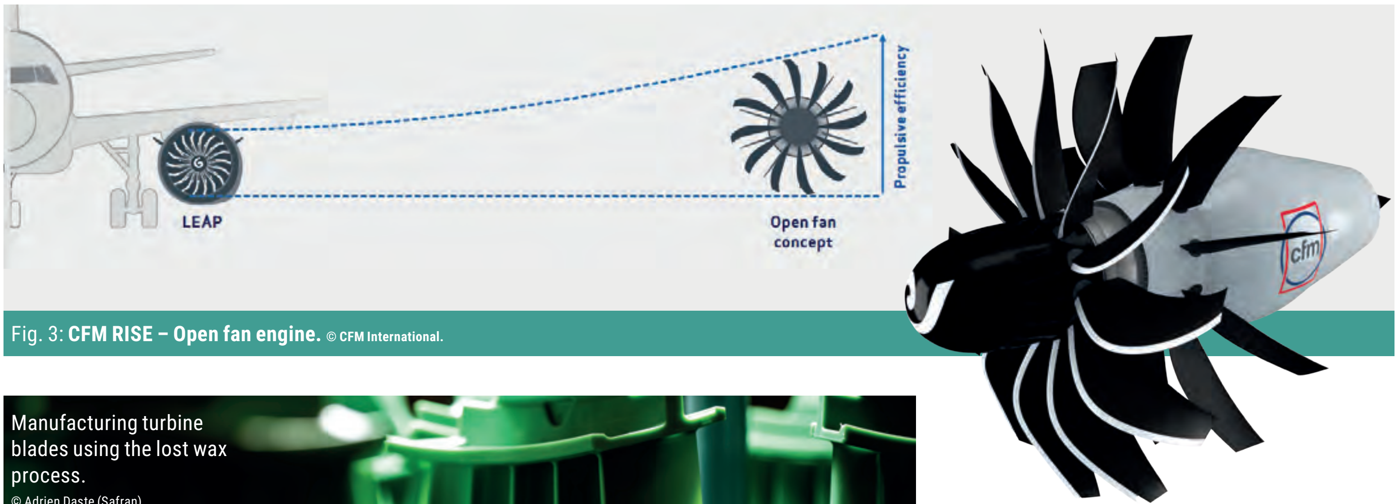


Fig. 3: **CFM RISE – Open fan engine.** © CFM International.

Manufacturing turbine blades using the lost wax process.
© Adrien Daste (Safran).

Increasing system electrification

Safran's involvement along the aircraft's entire energy chain has allowed it to identify the significant gains that are possible through gradual aircraft electrification, separately from the hybridisation of the propulsion system. Electrifying non-propulsion systems (e.g. actuators for thrust reversers and landing gear, defrosting and air-conditioning systems) would allow hydraulic, pneumatic and mechanical systems to be replaced by electrical systems that can often reduce the network load and improve engine fuel consumption.

ENSURING AVIATION SECTOR TRANSITION TO LOW-CARBON FUELS

Flying requires carrying a lot of energy in a small space, which is why batteries will probably remain a limited option for commercial aviation. Two types of complementary rather than competing fuels have been identified for the decarbonisation of aviation: sustainable fuels close to aviation fuel in their formulation (e.g. biofuels and synthetic fuels) and hydrogen. The cost of these new fuels and competition for the resources required to produce them (biomass, renewable electricity) make a breakthrough in aircraft energy efficiency a matter of urgency. And a breakthrough is just as necessary for hydrogen since the amount of fuel that can be carried will be the key factor in the design of these aircraft.

Advanced biofuels and synthetic fuels

Sustainable liquid fuels that can be mixed with kerozene and eventually used on their own are essential to decarbonisation and cutting the emissions of current fleets and present-generation aircraft. They will remain essential to the decarbonisation of long-haul flights for which hydrogen is not the ideal solution.

They are also available immediately. Over their life cycle, advanced biofuels produce cut carbon emissions by about 80% when compared with aviation fuel, and are already mature technologies. Seven types of product have been approved for combination with aviation fuel, plant producing biofuels from used oil are already up and running and many other types of production will become industrially mature over the next few years. Complementing advanced biofuels, synthetic fuels produced from hydrogen and recovered CO_2 should see strong growth in the 2030s.

The roadblocks to the development of these fuels have more to do with their cost and the absence of regulatory incentives than with technological challenges created by the aircraft themselves or their engines. Current aircraft can already cope with up to 50% sustainable fuels when mixed with aviation fuel.

Although still very far from achieving this target, the aviation sector is already working on the use of 100% sustainable fuels. Since aircraft have long working lives, fleets in operation in 2050 will be made up of planes delivered from the end of this decade. The main aircraft manufacturers are therefore committed to delivering planes that are able to fly on just sustainable fuels by 2030. No major difficulties are involved. The main task will be to adapt some materials in the fuel system because certain aviation fuel components contribute to their sealing.

In addition to cutting carbon emissions over their life cycle, sustainable aviation fuels could also have a positive effect on non-CO_2 impacts[2]. Advanced biofuels contain fewer aromatics and their combustion creates fewer of the soot particulates that give rise to vapour trails.

2021 saw major progress in this area, with a number of test flights by French industries, supported by DGAC (Directorate for Civil Aviation). An Airbus A319neo fitted with a Safran

•••

Final assembly of economy-class seats. © Frank Rogozienski/CAPA Pictures/Safran.

LEAP motor flew on sustainable fuels only in the VOLCAN project for improving understanding of the emissions created by these new fuels and their effect on non-CO_2 impacts[3]. There have also been helicopter flight demonstrations.

Liquid hydrogen

Hydrogen's main attraction is that it produces zero carbon emissions in flight. There are two technologies for using hydrogen to fly airplanes:

- fuel cells - the challenge here is power and cooling density, and the fact that they appear suitable only for regional aircraft in the medium term; and
- hydrogen combustion in gas turbines that are quite similar to current engines for short and medium-haul aircraft, which form the majority of most commercial fleets.

The limits posed by the intrinsic nature of liquid hydrogen mean that this is a technological solution that complements advanced biofuels and synthetic fuels rather than competes with them. It will will be usable only in new generation, breakthrough planes in the middle of the next decade and only in a limited segment of air transport (regional flights and short-haul planes and some of the medium-haul segment).

Hydrogen as a fuel presents big challenges to the aviation industry, in addition to the upstream issues (production of decarbonised electricity, airport supply, costs , etc.). While hydrogen as an energy vector is three times lighter than aviation fuel[4], it takes up four times more space in its liquid state (and even more as a gas). Hydrogen therefore needs to be stored in its liquid state at -253°C and in far bigger tanks than those used for aviation fuel. The geometry of the tanks themselves (spherical/cylindrical) means they must be fitted into the fuselage rather than in the wings and their mass and volume will restrict the size of hydrogen aircraft. In addition to different architecture, managing hydrogen thermodynamics from the tank to the engine is another technological challenge that presents safety aspects (risk of leakage and the easy inflammability of this fuel). It will finally be necessary to consider the impact of hydrogen combustion on global warming, including how water emissions affect the formation of vapour trails. Test flights will be required for this.

These technological challenges are the subject of research projects supported by the French public authorities and include HYPERION - bringing together Safran, Airbus and ArianeGroup in the architectural design of future hydrogen propulsion systems - and CirrusH2 that is looking at the impact these aircraft have on vapour trails.

IMPROVING THE EFFICIENCY OF AIR AND GROUND OPERATIONS

Complementing the technological improvements of aircraft and the move towards low-carbon fuels, is a set of operational levers that could improve efficiency by an additional 5-10% by the middle of the century: electric taxiing (e-taxi), more direct routes thanks to dynamic air traffic management, continuous climb and descent, etc. Although the relevant technological innovations have been clearly identified, these decarbonisation methods also depend on major organisational change in air traffic control in the next few years[5].

2. See also the article by Jérôme Fontane and Florian Simatos Non-CO_2 impacts - aviation's other impact on the climate
3. Non-CO_2 impacts are the effect on climate of high-altitude NOx emissions and vapour trails.

TO CONCLUDE: UNPRECEDENTED INNOVATION IS NEEDED TO MEET THE CLIMATE CHALLENGE

A long tradition in improving its performance means the aviation sector has a credible decarbonisation roadmap that is based on many technological levers. These improvements can together produce an around 90% cut in emissions per passenger.kilometre by 2050 from 2005 levels, helping towards carbon neutrality.

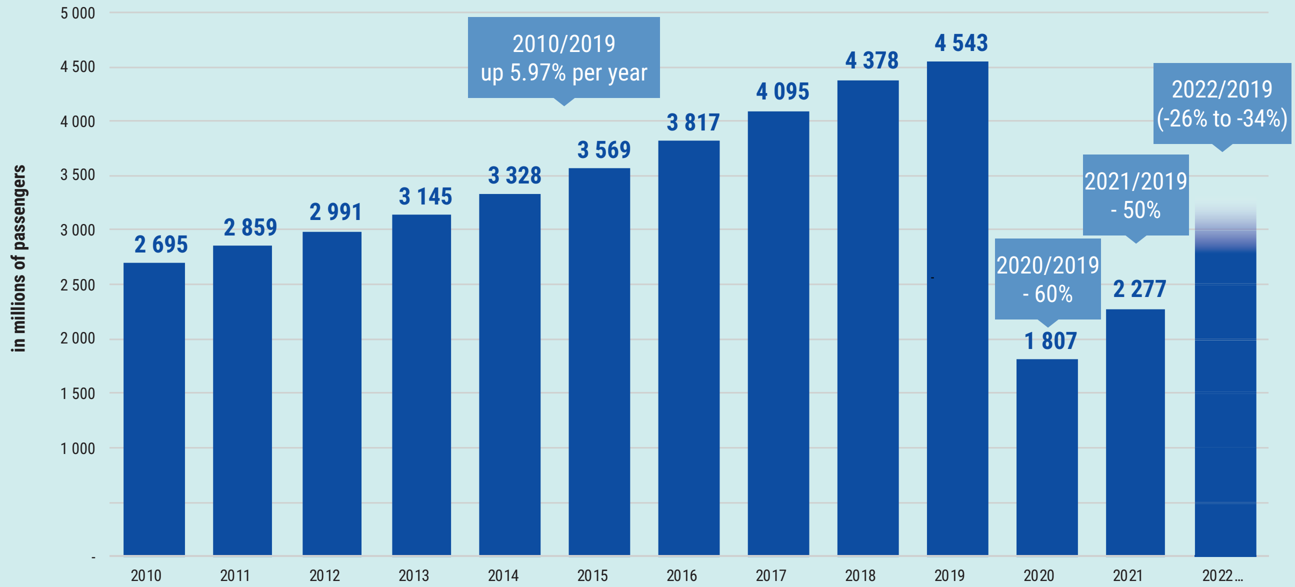
The challenge facing the entire sector is less about the technical feasibility of any particular solution than about speeding the entry into service of each innovation and combining them all in the next generation of aircraft to produce a real breakthrough. Faced with the climate emergency the Safran group, its employees and more generally the entire aviation industry have taken action in this direction. ●

First flight of an emergency helicopter using sustainable aviation fuel.
© ADAC Luftrettung/Theo Klein.

4. The mass energy density of hydrogen is three times that of aviation fuel but its volumetric energy density is four times less.
5. See also the article by Amélie Lummaux: Airports as catalysts for low-carbon air transport.

Aviation key figures

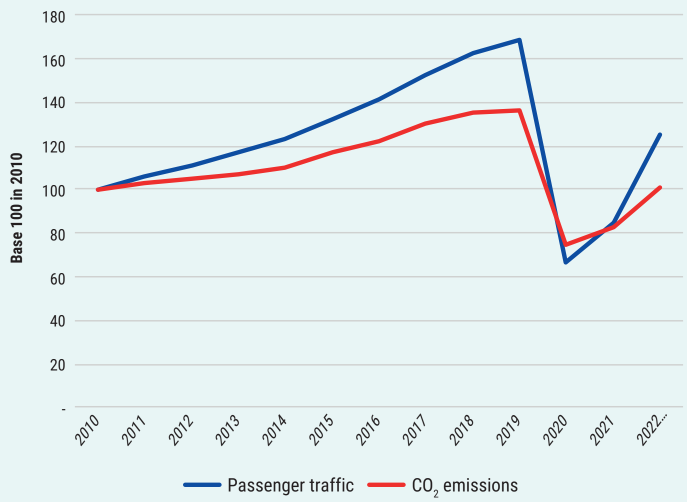
Traffic increase is gradual but could accelerate.



Global air traffic.

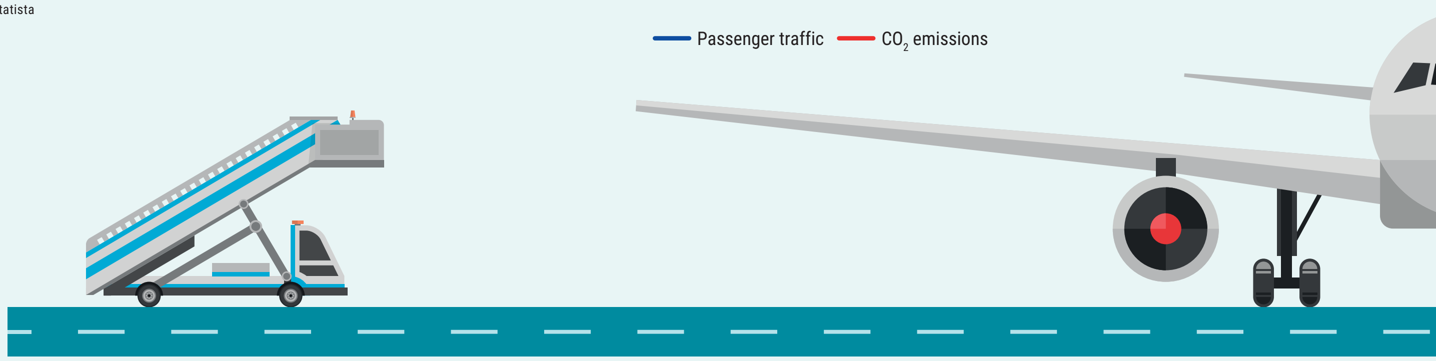
Source: ICAO (year-beginning estimates for 2022).

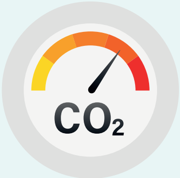
On average, air transport CO_2 emissions increase at almost half the rate of passenger numbers.



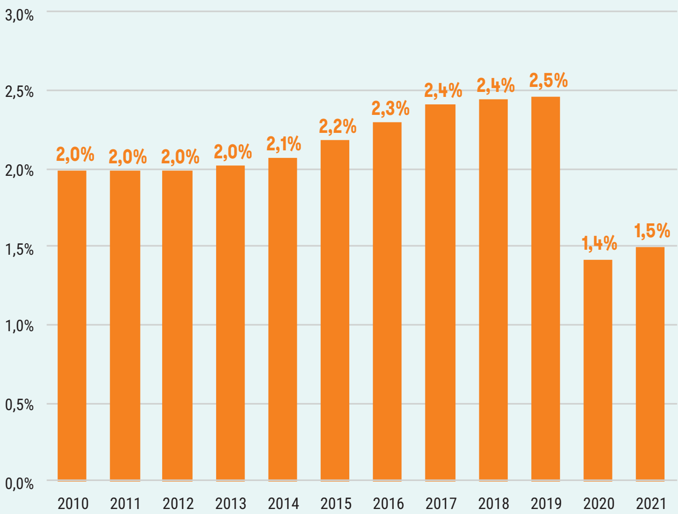
Comparing the evolution of passenger air traffic with the evolution of the aviation sector's CO2 emissions worldwide.

Source: Statista





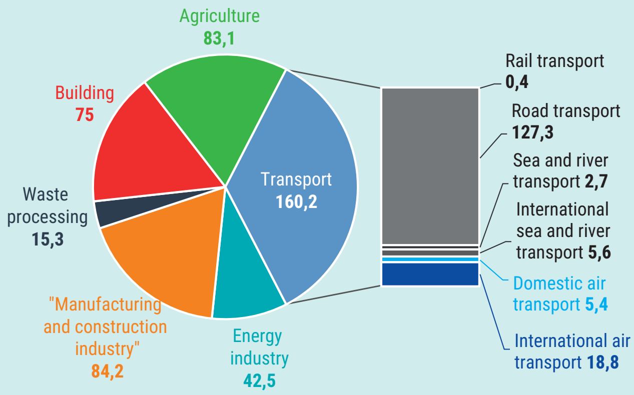
The share of carbon emissions caused by air transport keeps increasing despite technical progress but remains extremely limited compared to other transport modes



Aviation sector emissions and total CO_2 emissions worldwide.

Source: Statista

In France, the contribution of air transport to total greenhouse gas emissions is no more than a few %, even when taking international traffic into account.



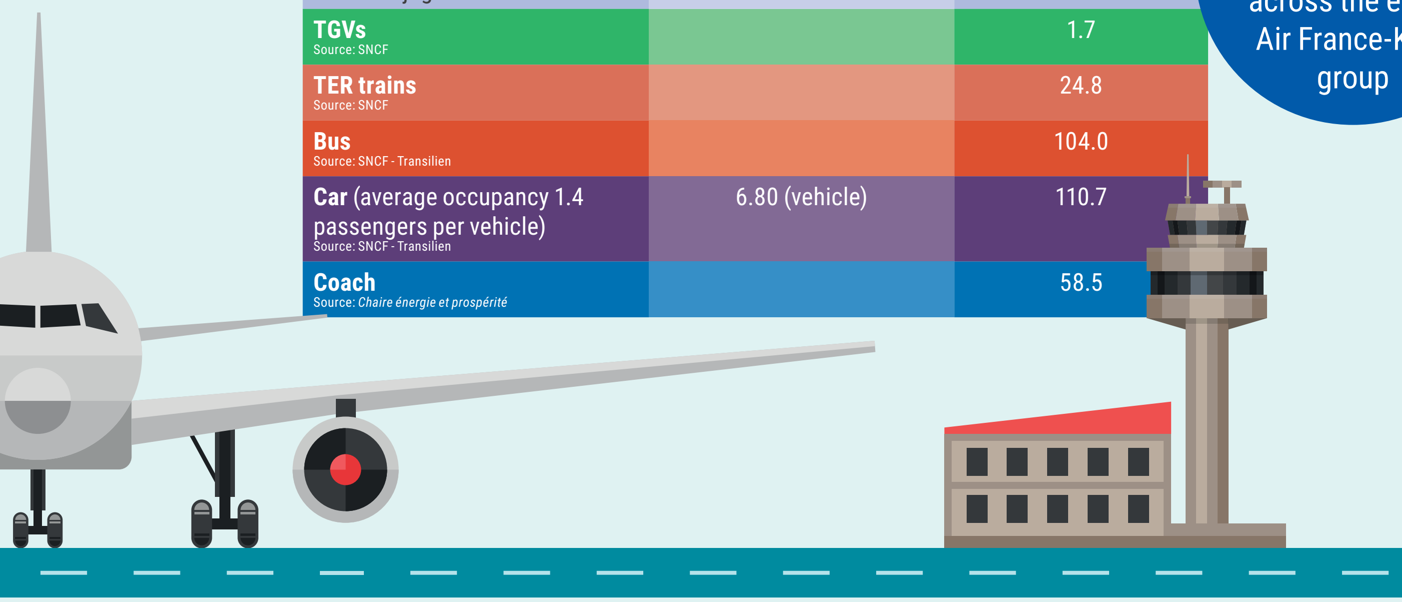
Greenhouse gas emissions in France in 2019 (million tonnes of CO_2e), including international transport.

Source: CITEPA-Secten.

Where available, the train is the transport mode with the lowest GHG emissions but air transport performs better than road transport by car and its carbon footprint will continue to improve

	Fuel per passenger (l/100 km)	CO_2 emissions per passenger (g/km)
Aircraft Source: Air France online calculator		
Paris-Brest	3.81	95.0
Paris-Nice	3.64	91.0
Paris-Madrid	3.76	94.0
Paris-New York	3.13	78.0
Paris-Beijng	3.00	75.0
TGVs Source: SNCF		1.7
TER trains Source: SNCF		24.8
Bus Source: SNCF - Transilien		104.0
Car (average occupancy 1.4 passengers per vehicle) Source: SNCF - Transilien	6.80 (vehicle)	110.7
Coach Source: *Chaire énergie et prospérité*		58.5

2030 TARGET:
under 3 l/100 km
per passenger across the entire Air France-KLM group



Information, analyses, debates, interviews with key energy and ecological transition figures throughout the year at **equilibredesenergies.org**

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10, rue Jean-Goujon 75008 Paris - info@equilibredesenergies.org - Tel. : +33 1 53 20 13 70. President: Brice Lalonde.

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AVIATION SPECIAL

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