TOWARDS **CARBON NEUTRAL** AIR TRAVEL

GIFAS

Since 1990, successive reports from the IPCC* have confirmed that human activities are responsible for global warming, have analyzed its effects and have compiled various scenarios for temperature change based on greenhouse gas emissions. The sixth IPCC report, published in March 2023, revealed the alarming news that these emissions have continued to rise, with current rates leading to an average increase in temperatures of 2.4-3.5°C by 2100. The document also set out possible ways of reducing the main greenhouse gases that could limit warming to 2°C and 1.5°C, in line with the targets of the 2015 Paris Agreement (see below). Tackling this global challenge will require coordinated action from every nation and every economic sector.

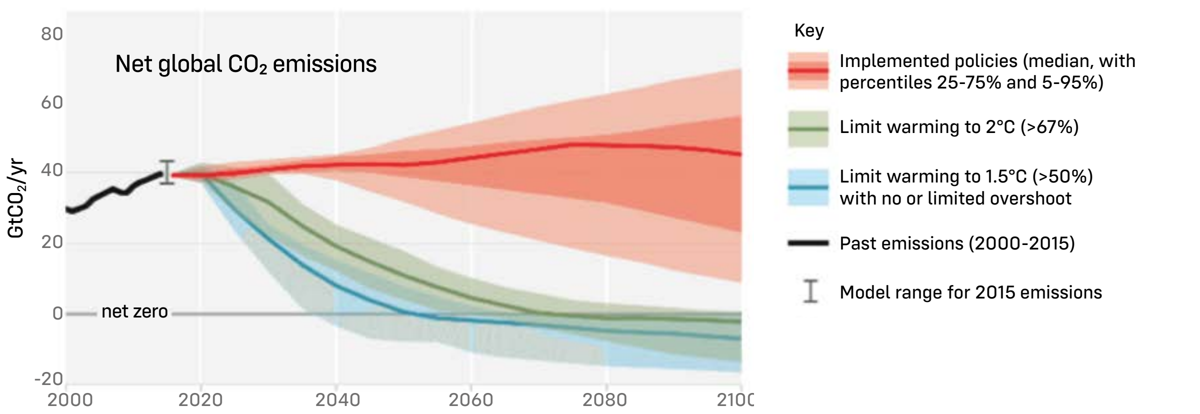


Figure SPM.5 from IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland..

A global movement for a shared objective

In just a few decades, air transport has moved from a period of pioneers and exceptional trips to the era of an open world where all people and all regions are connected, spurring interaction and exchanges between isolated and insular populations and territories, and supporting economic development. Major progress in security, efficiency and costs have seen air transport's roll-out on an international scale, offering access to an increasingly wide audience. From industry players to institutions, manufacturers and airlines, every stakeholder is invested in ensuring this adventure continues and that the same travel opportunities are available to future generations, all while positioning the industry at the cutting edge of a global movement to reduce our societies' environmental impact.

This will require an unprecedented effort and is embodied by the objective of making aviation carbon neutral by 2050 to contribute limiting warming to 1.5°C in 2100.

After more than 15 years of concerted action to reduce the carbon emissions linked to air transport, in October 2022, the ICAO** rallied 185 countries around the goal of achieving carbon neutrality by 2050, **making the aviation industry the first sector to commit to an objective of this scope on a global scale.** Many countries, including those in the EU and USA, are in the process of outlining their strategies for achieving this objective and specific roadmaps for every region of the world are currently being drafted to take into account their specific historic, economic and geographical contexts.

*IPCC: Intergovernmental Panel on Climate Change

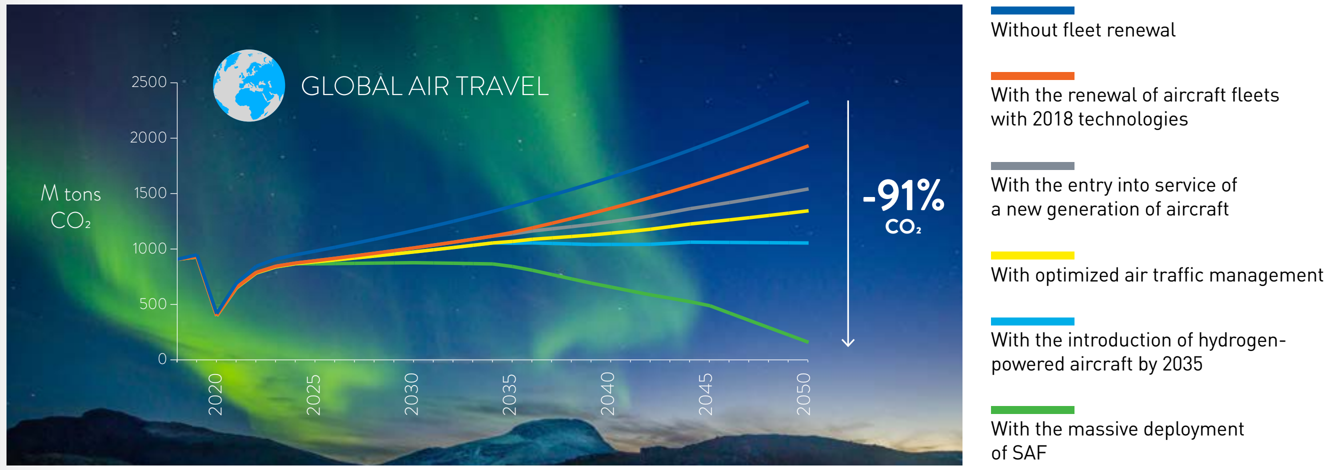
**ICAO: this United Nations agency created in 1944 defines international standards for the safety and sustainable development of air transport, and sets and updates standards for CO_2 emissions, noise, etc. ICAO has defined and instituted a transitional carbon offset scheme (CORSIA).

*Shifting to carbon neutral aviation **by 2050***

Air transport is responsible for approximately 2.5% of anthropogenic CO_2 emissions. Nonetheless, this rate has remained stable for two decades, despite the increase in air traffic. As emissions of carbon dioxide—the main greenhouse gas—are proportional to the amount of fuel burned, reducing fuel consumption will directly reduce CO_2 emissions. Advances in technology and operations have enabled to halve emission rates (per passenger mile) in the last 30 years, and the latest generation of aircraft consume less than **2 liters per 100 km per passenger. This steady progress in aircraft energy efficiency will not be enough to offset the growth in global demand for air transport, and a major effort will have to be made in 3 areas:**

- Fleet renewal, initially with today's technology* and then with future generations of super-efficient aircraft that will come into service in the **middle of the next decade.**
- **More efficient operations on the ground and in the air** will be ready for roll-out this decade, further reducing fuel consumption, with additional **10% savings expected by 2050.**
- In parallel to reducing fuel consumption, development and widespread adoption of **alternative fuels that will lead to the aviation industry's energy transition between now and 2050.**

Based on this, several decarbonization scenarios have been compiled and published to examine public policies and assess and offer support for the collective strategies of industry players.



© Onera - Aviation decarbonization scenario (international air transport scope) based on the CORAC's scenarios

IT'S NOT THAT SIMPLE...

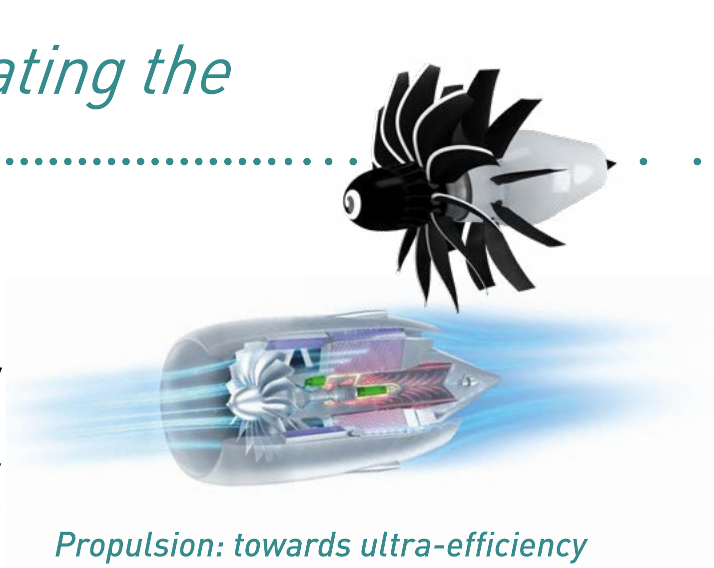
- ***The laws of physics** do not allow the rapid and widespread adoption of certain solutions.*
- ***Time is of the essence,** but designing and introducing next-generation aircraft takes on average 15 years.*
- ***The high cost of alternative fuels** limits their use and then slows widespread production.*

NOR IS IT ALL BAD...

- ***A long tradition of innovation** has made it possible to overcome major challenges.*
- *There is a **global cooperation** on ambitious objectives.*
- ***A truly organized industry,** high-level research centers.*
- ***Although no single solution exists,** there are a wide array of routes to net zero.*

* The latest-generation aircraft account for only 20% of the current world fleet.

*Designing and operating the planes **of tomorrow***



Technological advances have enabled the renewal of fleets with aircraft that are safer and more energy efficient. **While energy gains between successive generations of aircrafts have until now been around 15%, the goal today is to design planes that use 20-30% less energy than the generation currently in service, and which are capable of being powered entirely by sustainable fuels and are adapted to operations designed to optimize energy use.**

Current programs are primarily focused on the future generation of regional and short and medium-range carriers. Various possibilities for progress are already known, such as reducing drag, increasing lift, lightening structures, incorporating more electric and avionics systems while reducing mass, and increasing engine output. Other options are more innovative and involve the development of hybrid electric aircraft and hydrogen power. **Many technological solutions are being explored, and full-scale demonstrations are scheduled to select and combine the best options.**

Architecture and configurations

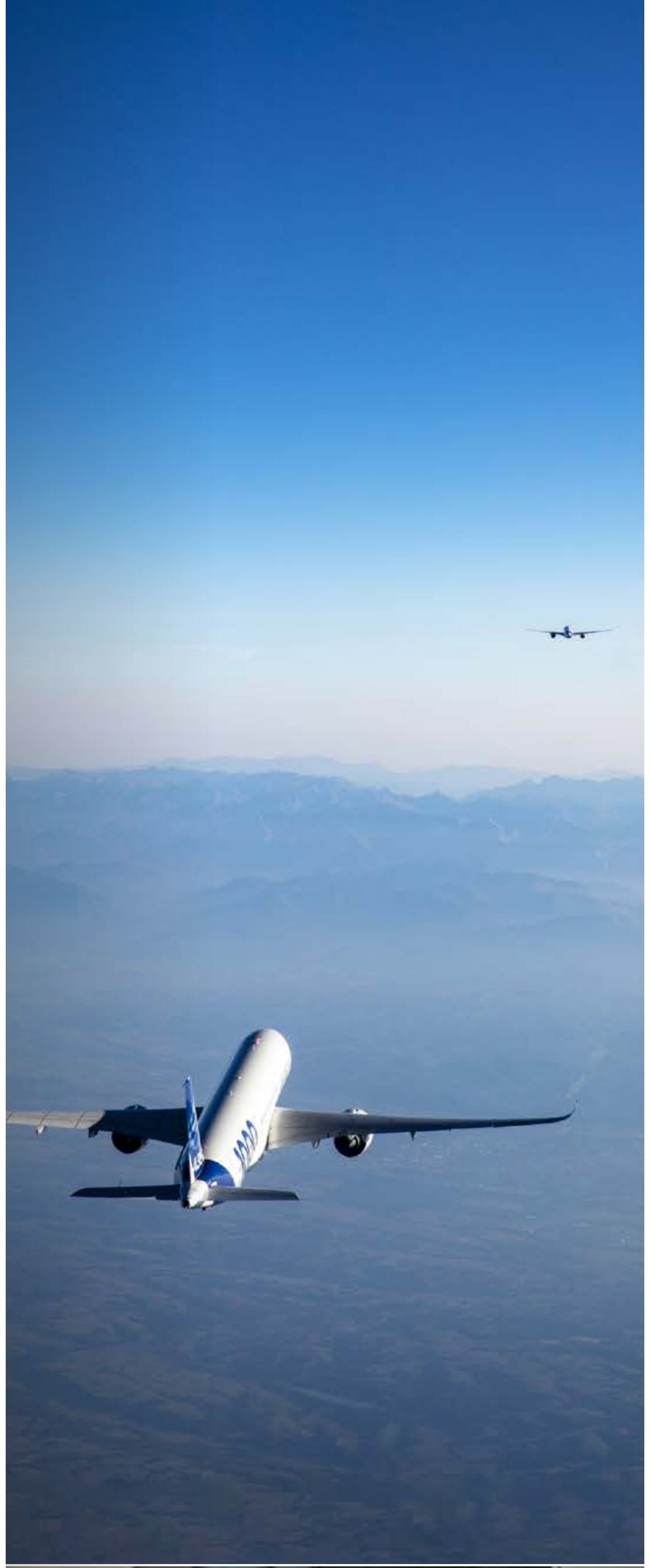
Conventional architectures will need to evolve to adapt future aircraft to the constraints posed by larger-diameter engines; in the case of hydrogen-powered aircraft, a complete redesign of tanks and fuel distribution systems will be needed. **Radically disruptive designs like the blended wing are also being investigated.** Additionally, increasing lift and reducing drag will lead to the design of **super-efficient wings**, such as high-aspect ratio wings, alongside active control systems that enable wing shape optimization in all flying conditions.

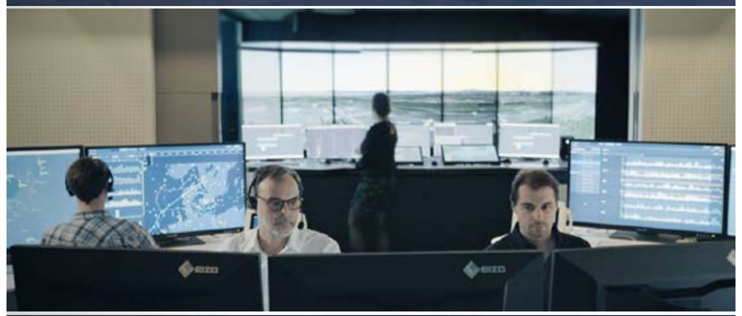
Propulsion: towards ultra-efficiency

For future short and medium-range carriers, **the use of open-fan architecture** will mark a new era in the propulsive efficiency of turbojets and significantly increase bypass ratio. This breakthrough configuration offers 20% energy savings and would require optimization in a special aircraft architecture. **Other options involve operating jet engines at higher pressures and optimizing engine output.** Finally, the hybrid use of electric power to run engines during specific flight phases is the subject of active research by various engine and aircraft manufacturers.

More electric aircraft, hybridization

The electrification of on-board systems (braking, air conditioning, landing gear equipped with electric engines, etc.) is already under way and will continue with a reduction in the proportion of energy supplied by engines to these systems. **The use of electric power to support propulsion** has been explored, with **hybrid solutions** that combine turbojets and a battery-powered electric propulsion chain. Such hybridization techniques have already been tested on light aircrafts and are likely to play a major role in the development of future aircraft, including regional.





Hydrogen power

Hydrogen offers several advantages. It is accessible in large quantities through the electrolysis of water, it produces no CO_2, and its combustion produces three times more energy than the same mass of kerosene... yet it takes up four times as much space in liquid form at -253°C. **Research is actively being carried out on the use hydrogen to power the turbojets of regional and short-range carriers, but there are many hurdles to overcome**, such as redesigning aircraft architecture to accommodate larger tanks and finding solutions for cryogenic storage.

Hydrogen can be used in fuel cells to power an electric engine, for on-board energy, or for electric propulsion in small aircrafts, given the high energy and power required for propulsion. In all cases, to ensure carbon neutrality, hydrogen will need to be produced from decarbonized electricity.

Operations

Optimizing in-flight and on-the-ground operations is a fast and effective way to make energy savings. Solutions include improving overall traffic management and creating more fuel-efficient flight paths (continuous descent, flight optimization using satellite data). Optimizing traffic flow and individual aircraft trajectories will require innovative software solutions that maximize ground-to-air collaboration. New innovative procedures are also being developed, such as formation flying, inspired by migratory birds, which sees a chase plane use the aerodynamics of a lead plane to consume less energy.

Cutting the emissions linked to ground operations will mean converting ground vehicles to electricity and hydrogen, using electric systems on the ground when stationary, reduced-engine taxiing and developing electric actuation for equipment (brakes, thrust reversers, etc.).

New energy sources

Sustainable aviation fuels are chemically similar to kerosene but, unlike fossil fuels, neutral in the carbon cycle. They can be split into two major categories:

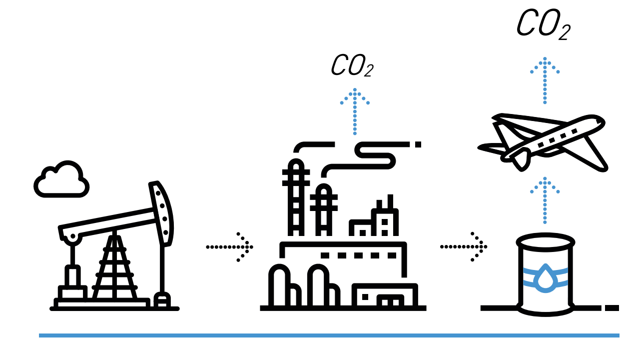
• **Advanced biofuels,** produced from lignocellulosic biomass, i.e. raw materials (plants) developed by capturing carbon dioxide (CO_2) through photosynthesis, and from used cooking oils or animal fats.

• **Electrofuels** (or e-fuels) produced by synthesizing CO_2 captured from air (direct capture or from industrial effluents) and decarbonized hydrogen.

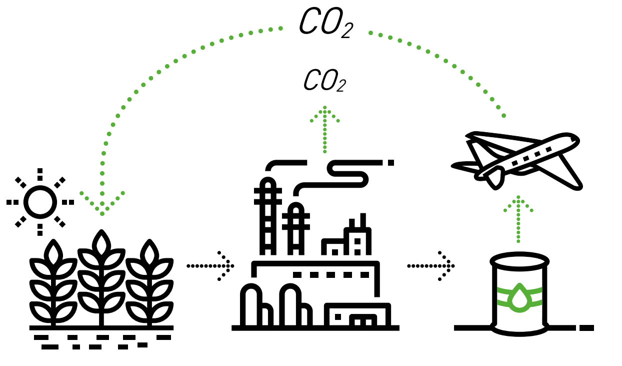
9 sustainable aviation fuel production processes are currently certified for blends of up to 50% with kerosene and have been used for many commercial flights. Current studies aim for a **100% incorporation ratio by the end of the current decade.**

To be sustainable throughout their life cycle and reduce CO_2 emissions by more than 70%, aviation biofuels will eventually need to be produced from lignocellulosic resources (forestry or agricultural waste) or lipidic resources (used oil, animal fat), without competing with food industries or impacting land use. To maximize the use of biomass, the efficiency of many processes could be significantly increased by adding decarbonized hydrogen (electro-biofuels). The technologies for producing advanced biofuels are commercially ready and require a massive deployment of the sector to reach target levels of incorporation.

Electrofuel production is still in the pilot stage, but many projects are in development across the world, as this pathway offers a great many advantages for the sustainability and availability of raw materials (without the need for biomass).



Kerosene fossil fuel



Kerosene bio fuel

Nonetheless, its cost still widely exceeds that of other biofuel pathways; it requires access to decarbonized electric energy.

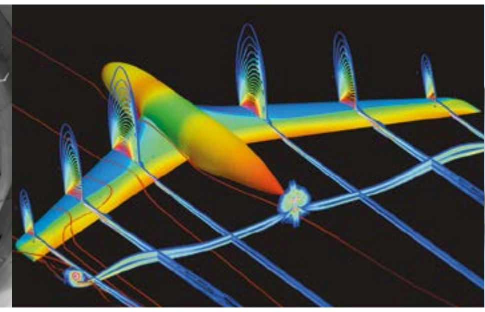
The production of sustainable fuels increased ten-fold in 2022 compared with 2021 but still only represents 0.1% of the aviation fuel used in the world. **Immediate acceleration of the production of these alternative fuels is therefore essential. To trigger a virtuous cycle of growth in supply and demand, voluntary policies will need to be implemented.** A balance will need to be found between these different pathways types of energy, depending on the specific industrial context of each region of the world, to optimize resources, biomass and decarbonized electricity. Within the European Union, a sustainable fuel incorporation rate of 70% is targeted for 2050, including 35% of e-fuels.

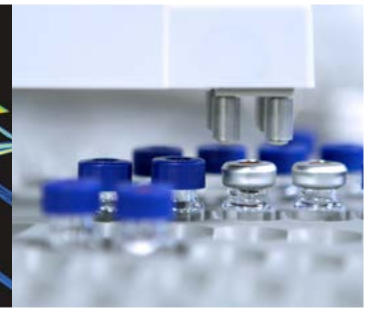
Mobilizing an entire ecosystem

The various responses to the challenge of carbon neutral aviation by 2050 will need to take shape in an extended ecosystem, with the sector's manufacturers working together with the scientific community and the energy industry to take into account their specific dynamics, which will define the main stages involved in decarbonization.

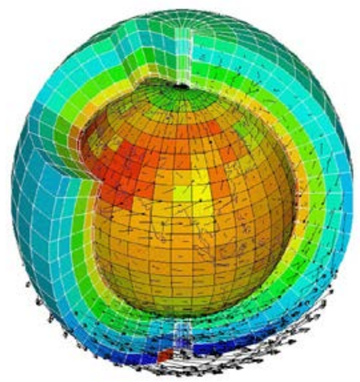
By the middle of the next decade, reductions in carbon emissions will be achieved by **renewing fleets** with next-generation aircraft, implementing **a wide range of more fuel-efficient in-flight and ground procedures,** and the introduction of **sustainable fuels in an industrialization phase for their production,** with the goal of representing at least 20% of all energy use in 2035. At the same time, research centers and design offices will carry out **large-scale, coordinated work, aiming to prepare and approve technologies for the active introduction of next-generation aircraft in the regional and short and medium-haul carrier segments.** These efforts will come in addition to the transition of all industrial facilities to new, more efficient, and lower-energy development and production methods.

By 2035, the 30% increase in energy efficiency offered by these new programs, together with the **widespread adoption of optimized operations** and the **large-scale roll-out of sustainable fuels including hydrogen options,** will make it possible to accelerate the reduction in emissions, with a residual emission rate in 2050 lower that 10-20% of the 2019 emissions level, according to forecasts based on all these hypotheses. Achieving effective carbon neutrality will therefore require the application of offsetting schemes whose approval will need to be monitored in line with international standards, like CORSIA, the ICAO's offsetting scheme for international flights.





In parallel, **research completed by the international scientific community will need to specify and model the complex ways in which air transport impacts climate, looking beyond CO_2** (chemical reactions from nitrogen oxides produced by combustion, effects on nebulosity), and consolidate its representation in climate models. **This research is also essential for guiding technological, operational and energy options carried out by industry.**



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"As for the future, your task
is not to foresee it,
but to enable it."

Antoine de Saint-Exupéry

GIFAS, GROUPEMENT DES INDUSTRIES FRANÇAISES AÉRONAUTIQUES ET SPATIALES

8, RUE GALILÉE, 75116 PARIS
+33 (0)1 44 43 17 00
WWW.GIFAS.FR

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