The Fight for a Net-Zero Aviation

The Augmented Infrastructure Part III

ARDIAN

Foreword

This study provides an **airport-centric perspective** on the decarbonization of the aviation sector. Although airports themselves are not direct emitters of the majority of carbon emissions generated by the aviation industry, they have a crucial role to play in enabling the transition of the whole sector.

In this study, the term decarbonization refers in priority to the **reduction of existing carbon emissions** inherent to the industry. Carbon-related compensation mechanisms are thus not treated per se as decarbonization measures, rather as complementary solutions only to be leveraged alongside the realization of the full decarbonization potential of the industry.

Within the scope of this study, "net-zero" means the reduction of gross CO2 emissions of the air transport industry to reach as much as possible their complete removal. The remaining CO2 emissions would be compensated through nature based solution or technologies such as carbon capture. This definition is in line with key standards such as *The Science Based Targets initiative* (SBTi) net-zero.

Emissions from air cargo, whilst not negligible, only represent c.15% of the total emissions of the aviation sector, which is why this study mainly focuses on **air passenger transportation.** Furthermore, even though the governance of goods and passenger air transport differ to some extent, the majority of the solutions mentioned in this study are also considered applicable to air cargo.

This study does not neglect the non-CO2 climate impacts of the aviation industry. If the overall impact of these short atmospheric lifetime gases is today well understood, the mitigation options are still the subject of discussions and not considered in this study. In addition, these gases are not considered in most greenhouse gas accounting framework, including the Kyoto protocol.

Glossary

AAM: Advanced Air Mobility
ACA: Airport Carbon Accreditation (which ranks airports between levels 1, 2, 3, 4 and 4+ depending on scope of action taken to reduce their direct and indirect carbon emissions)
ACI: Airport Council International
ADP: Aéroports de Paris
APU: Auxiliary Power Unit
ATAG: Air Transport Action Group
CCUS: Carbon Capture Usage and Storage
CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation
DAC: Direct Air Capture
ETS: Emission Trading Scheme
EVTOL: Electric Vertical Take Off and Landing aircraft
EV: Electric Vehicles
GESAC: Gestione Servizi Aeroporti Campani, operating Naples and Salerno airports
GHG: Green House Gases
ICAO: International Civil Aviation Organization
ICT: Information and Communication Technologies
OEM: Original Equipment manufacturer
SAF: Sustainable Aviation Fuel
SAGAT: Società azionaria Gestione Aeroporto Torino
SEA: Società per azioni Esercizi Aeroportuali, operating Milan Malpensa and Linate airports
SGP: Société du Grand Paris
UAM: Urban Air Mobility

Editorial

To meet the targets of the Paris Agreement and reduce the impact of climate change, it is imperative that all industrial sectors **decarbonize** quickly, and the **aviation industry is no exception.**

To achieve this, **two ways of thinking** have emerged in recent years. For some, the only viable option to limit the sector's impact will be to limit air traffic. For others, it seems that salvation will come from technological breakthroughs and sector innovation, that will have the ability to make flying completely carbon free.

Ardian believes in the need of a **third approach**, which combines these two ways of thinking.

Reducing the sector's environmental impact will involve **changes in air travel habits** and the sector must prepare for that. While such perspective is possible for regions with alternative transport infrastructure, in others, where air traffic is expected to increase substantially in the coming years sobriety might be more challenging. Furthermore, air traffic will in any case remain crucial for the economy. Therefore, **innovation** must be put at the service of decarbonizing the aviation industry.

To combine these two approaches and enable the sector's transition, given their central position in the ecosystem, airports have a crucial role to play.

By becoming "augmented", i.e. by leveraging on increased operational intelligence to improve their efficiency and decrease their negative externalities, airports are in a stronger position to effectively address their **scope 3 emissions**, which remains the key bottleneck to the decarbonization of the sector, and to pave the way for new experiences both for passengers and other ecosystem players alike. This is why, all our airports are now equipped with our Scope 3 CO2 emission measurement tool Air Carbon.

Mathias Burghardt
Head of Infrastructure and Member of the Executive Committee, Ardian

Summary

1. **The Aviation Experience**: what could it look like in the future
2. **The Challenges**: the urge to rethink the whole air transport ecosystem model to reduce its impact
3. **The Action Plan**: a combination of technological breakthrough, operational optimization and shifts in behavior will lead to net-zero
4. **The Strategic Vision**: the augmented airport, a key catalyst for the industry decarbonization

1.

The Aviation experience
What could it look like in the future

1.1 Net-zero airport management

Zoe's typical day as an airport manager - 1/2

1 |

Zoe arrives at the airport by **express train** which was inaugurated last year, thanks to the close collaboration between the airport, the national railway company, the local and national authorities as well as the EU.

2 |

Upon arriving at the HQ, she consults in real time the **hydrogen needs** of all the aircraft as well as the vehicles of the public transport network that are supplied by the airport. Zoe checks with her **energy supplier** to ensure that the quantities delivered will be sufficient to meet the airline and ground service needs.

3 |

Using the **Air Carbon** tool, Zoe is able to **model the impact of introducing a carpooling lane** on the airport's **scope 3 emissions**. The tool is also used to monitor the airport's decarbonization trajectory in relation to the new multi-year sustainability plan requested by the shareholders.

4 |

Zoe holds a video conference with a newly established airline interested in opening a route to the airport. Zoe presents the panel of **financial incentives** that are in place such as lower landing fees on the basis of higher percentage of hydrogen aircraft in the fleet for medium haul routes.

Zoe's typical day as an airport manager - 2/2

5 |

The airport's own operations and stationary aircrafts are now powered by renewable electricity produced on site. The sun is shining bright today, and Zoe is made aware of an **electricity production surplus from the on-site solar panels** that feeds directly into the grid, thanks to the airport's ability to trade energy.

6 |

Zoe receives a proposal from an **Electric Vehicle Aircraft (EVTOL)** company which is looking to create a route to the city center and take advantage of the airport's existing **vertiports**. She asks her **environmental engineers** to simulate this new route using the characteristics provided by the company, whose proposal will only be accepted after a confirmation of its impact.

7 |

At the end of the day, Zoe looks at her airport's **performance report** generated through Air Carbon: she sees a reduction in **taxiway times** as well as **overall customer waiting times** and associated energy and **carbon emission savings**. She is also able to understand the impact of the newly implemented **optimized take-off route** on the airport's scope 3 emissions and run simulations of other efficiencies in operations she could implement.

1.2 Net-zero flying experience

Arthur flies to his brother's wedding - 1/2

1 |

Arthur needs to fly to his brother's wedding.
He chooses the airline that offers the best CO2 emission/air ticket price ratio for his trip, to limit the impact on its personal carbon footprint.

2 |

The plane ticket Arthur buys includes a metro ticket for the day of his flight, for the newly opened metro line connecting his neighborhood to the airport, as well as an **Electric Vehicle Aircraft (EVTOL) ticket** connecting the airport to the city center for when he arrives.

3 |

Before boarding, Arthur decides to watch planes land and take off from the airport rooftop. The **noise levels** are more tolerable than before: thanks to the progressive replacement of conventional aircraft and **electric taxi systems deployment**, planes now are quieter and some have impressive aerodynamic designs.

4 |

When the plane takes off, Arthur realizes his journey so far has been almost **seamless**. Waiting lines at security checks and boarding have vanished as flight schedules have improved due to greater collaboration between the airport and carriers. And **no more aircraft taxi jams on the apron**, thanks to better collaboration between air traffic control and carriers.

* Taxi refers to the movement of an aircraft on the ground, usually between runways and passenger boarding / alighting

Arthur flies to his brother's wedding - 2/2

5 |
Arthur has **brought his personal tablet** to watch a documentary during the flight, which he streams thanks to the plane's high-speed wifi.
For a few years now, **energy-consuming screens** embedded in airplane headrests have been phased out, even in long-haul flights.

6 |
During the flight, transparent information is vocally given to passengers about the percentage of **Sustainable Aviation Fuels** used by the aircraft, and the environmental impact of the flight. In average the impact of flight has been reduced by nearly 50% since 2022*. Arthur also learns about the **inaugural hydrogen flight** of the airline that took place last month between Cairo and Paris.

7 |
After landing, Arthur gets off the plane and takes an **electric** bus to his arrival terminal. On this short journey, he drives past the airport's **CO2 capture station**.

8 |
After collecting his luggage, Arthur boards the **shared EVTOL** he booked while booking his plane ticket. During the flight to access the city center, Antoine receives a detailed notification of his total trip **CO2 emissions** and the ways he can **compensate** it thanks to the **Air Carbon application**.

*estimate based on ATAG (Air Transport Action Group)-Waypoint 2050 third scenario (2021)

The Challenges

2. The urge to rethink the whole air transport ecosystem model to reduce its impact

While unprecedented in its magnitude, the COVID19 crisis has not fundamentally changed air traffic growth patterns

The aviation sector has recently suffered from the worst decline in air traffic in its history…

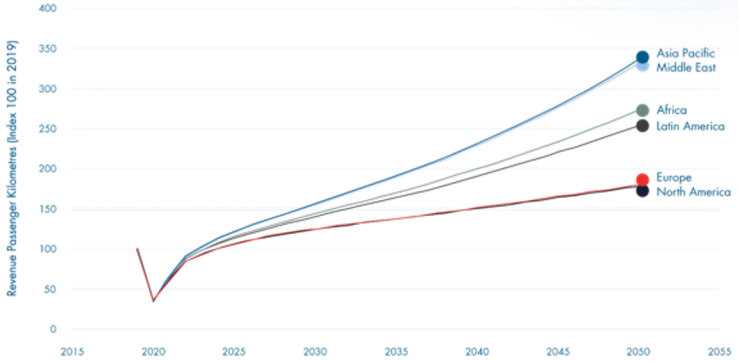
The COVID19 pandemic had an immediate impact on both traffic and revenues. Globally, 1.8 billion passengers flew in 2020, a decrease of 60.2% compared to the 4.5 billion who flew in 2019. Similarly revenues decreased by 69% between 2019 and 2020.

… but traffic growth is back, mainly driven by developing countries.

During summer 2022, air traffic bounced back to about 70% of 2019 global levels (81% for domestic use and 65% for international use), due to strong growth from European and North American countries. Recovery is expected to accelerate even faster in the coming months, in Asian, Middle Eastern, African and Latin American countries, both for domestic and international travel.

Globally by 2050, **10 billion passengers are estimated to travel by plane per annum**, which means that traffic is expected to more than double from 2019 to 2050. Developing countries are expected to contribute two thirds of this growth.

From an aircraft manufacturer point of view, Airbus is foreseeing a **growth of the number of planes in circulation by 105%**, while Boeing expects the **global air fleet to grow by 82% by 2041**, in response to the anticipated surging demand.



Regional passenger growth forecasts 2019 - 2050
(source: Waypoint 2050)

"During summer 2022, traffic at Milan Airports reached nearly 90% of pre-COVID19 levels. We expect a full recovery of traffic by 2024."

Armando Brunini
CEO, SEA Milan Airports

Sources: IATA, ATAG, OECD, Boeing

From an environmental perspective, action needs to be taken to avoid a negative outcome

Emissions from the sector might appear relatively limited …

Today, aviation accounts for **2-3% of global CO2 emissions**. Kerosene burnt from commercial flights, in particular medium and long-haul flights, contributes the most to these emissions.

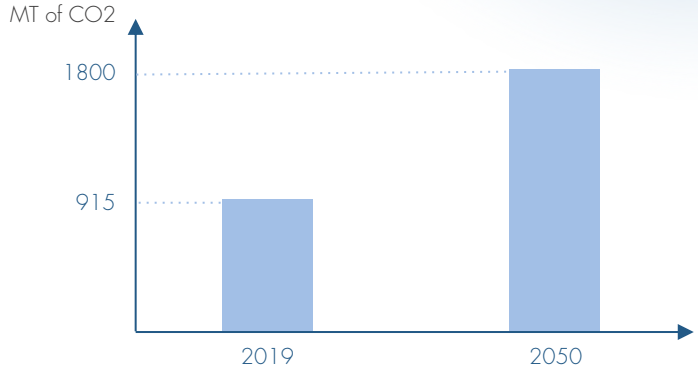
However the impact of flying vs. other means of transport is much higher. For every kilometer traveled, a passenger in a short haul flight will emit nearly 3 times more CO2 than a standard passenger car.*

… but would likely increase significantly in the short term if no action is taken.

Despite a **25% decrease of CO2 emissions per passenger over the last 15 years** as a result of technological innovation relating to engine efficiency, aircraft aerodynamics, etc., globally it is estimated that **global emissions from international aviation have more than doubled since 1990** and carbon emissions resulting from the aviation sector continue to increase globally due to continuous traffic growth.

In a scenario where aviation would be the only sector not to take the necessary actions to contribute to reaching the 2°C target of the Paris Agreement, air traffic has the potential to contribute **22% of global CO2 emissions by 2050.**

*comparison based on ADEME's emission factors and the hypothesis of 2 passengers per car (average car occupancy in Europe is known to be about 1.7 passenger)



Carbon emissions from the aviation sector following the ATAG traffic growth scenario (10 billion passengers annually by 2050).

"From an environmental perspective, things are worrying. There is no way the sector can continue doing business as usual."

Teodora Serafimova
Transport Regulation Researcher, European University Institute

Sources: ADEME, ATAG, European Commission, Eltis

The aviation sector still has a crucial economic and social role, which cannot be disregarded

The aviation sector is an important contributor to both global and local economies and a key connection between territories.

Aviation is a crucial industrial sector, whose economic weight is significant:

- **4.1%** of Global GDP is carried out by the aviation sector.
- **35%** of the world trade shipments value is transported by air freight.
- If the aviation sector were a country, its GDP would be the 17th highest (equivalent to GDP of the Netherlands).
- **88 million** - the number of jobs supported by aviation globally, either directly, indirectly or induced.
- In France, the aviation sector is estimated to be responsible for 1 million jobs, equivalent to **4%** of all working jobs, of which **30%** are highly skilled jobs (e.g. aviation design and construction).
- At a local scale, the three airports of the Paris Metropolitan Region are responsible for c. **473 800 jobs** in the region, which represents c. **8% of the total workforce of the region.**

"The actual economic and social weight of the aviation sector must also not be ignored when looking ahead."

Mathias Burghardt
Head of Infrastructure and Member of the Executive Committee, Ardian

Sources: ATAG, BL Evolution, Secafi, Progexa, Groupe ADP

The sector is starting to take clear commitments to reach the net-zero target

To avoid serious social and economic consequences, the whole sector (institutions and industrials) is taking actions to become more sustainable, mainly through **decarbonization** actions:

- As part of the **2015 Paris Agreement**, the aviation sector is compelled to cut its carbon emissions to limit global warming below 2°C, ideally to 1.5°C, compared to pre-industrial levels.
- At **COP26** in 2021 in Glasgow, the whole sector affirmed its willingness to achieve net-zero by 2050 through Air Transport Action Group (ATAG).
- At an EU level, the European Climate Law entered into force in July 2021, as a result of the European Green Deal which was introduced in 2019. It adds to the net-zero 2050 goal a stage of at least 55% reduction of net emissions of greenhouse gas by 2030, compared to 1990 emissions with the **Fit for 55 package**, a set of proposals to update EU regulation in order to make it fit for accompanying the transition of the EU industry towards the EU 2030 climate goals.
- Introduced in early 2022, the Toulouse Declaration is the first signed agreement between private and public players that reaffirms the willingness of the sector to be net-zero by 2050, and therefore emit one third of 2019-level emissions in 2050.

These recent sector-level commitments should provide the impetus and the sector as a whole to further accelerate on decarbonization. In 2022, four pioneer airlines have publicly committed to emissions reduction target that are in line with the Paris Agreement according to SBTi (Science Based Targets Initiative) - and 19 others are in the process of doing so.

"For a couple of years, the whole sector has embraced the net-zero objective. All ecosystem players are now on the same wavelength which is encouraging for actions to be taken."

Olivier Jankovec
Director General, ACI Europe

"The aviation sector is smaller than you might think. This characteristic gives aviation stakeholders the ability to collaborate quickly and act more nimbly as a collective through organizations like ATAG and institutions like ICAO."

Veronica Bradley
Director of Environmental Science, Clean Fuels Alliance America

Sources: ATAG, Transport & Environment

The Action Plan

3. A combination of technological breakthrough, operational optimization and shifts in behavior will lead to net-zero

Calls for more sobriety have emerged as a first response to the climate emergency

Directly from passengers…

Initiated in 2018, the **"Flygskam"** (Flight Shame) movement has been gaining momentum amongst travelers. As a result, people are starting to consider a shift in their flying habits.
Some customers have actually started to fly less frequently. For example, it is estimated that about **1 out of 4 Americans, French and Germans are already acting on reducing** their use of air transport.

Other customers are shifting to rail. In Sweden, interrail ticket sales, valid across all European rail networks for a given period of time, have increased by 50% since 2017.

… and increasingly from ecosystem players.

While sobriety in habits directly from passengers is still marginal, some institutional players are starting to take action to foster more sobriety.
In June 2022, the Dutch government took the decision to **limit the annual maximum number of flights** at Amsterdam Schiphol Airport, in which it holds the majority of shares, to 440,000; a 12% reduction compared to 2019 traffic levels.

Sobriety thus means rethinking the priority uses of air travel in a resource constraint environment

In this context, usage and supply for air traffic would need to be rethought and prioritized keeping the imperative to decarbonize our economies in mind. Airports would become **intermodality hubs** by combining decarbonized transport terminals and air terminals in a seamless experience for passengers and offering additional sustainable services to passengers in order for their baseline to not be overly reliant on traffic volume growth.

Sources: 6-t, Rolland Berger, Chaire Pégase

Besides sobriety, the sector's "license to operate" depends on the simultaneous activation of different levers

In order to fulfill the aviation sector's commitment to achieve net-zero by 2050, different technological levers should be activated. While all of them bring operational challenges which need to be tackled, they all have the potential to support the sector's transition in the medium to long term. These decarbonization levers are:

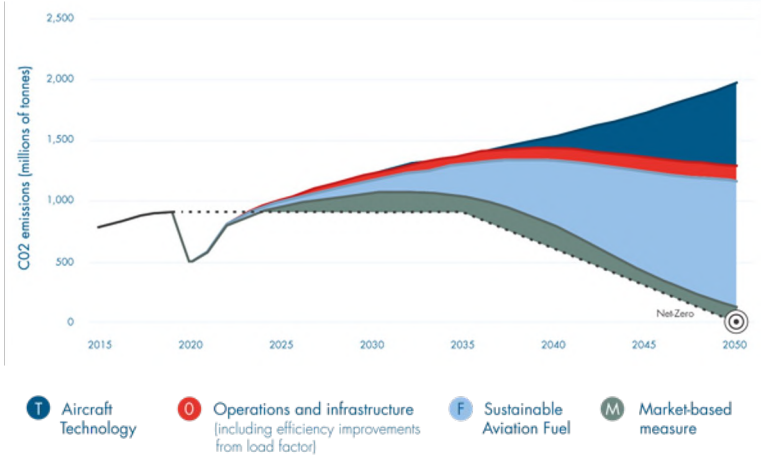
- The deployment of **sustainable aviation fuels on a large scale.**
- **Aircraft technology** improvements (related to engine, aerodynamics, hydrogen or elec-supported propulsion systems, …).
- Improvements in the **efficiency of airports' operations and infrastructure.**

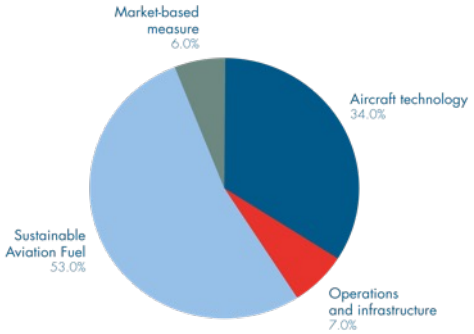
Carbon offsetting mechanisms can also be activated to reach net-zero targets, but only in addition to decarbonization measures. This chapter details those levers and their expected impact on the sector's evolution, following the **third scenario of the ATAG Waypoint 2050 study** (also referred as aspirational and aggressive technology perspective) which is the vision most widely supported by the actors interviewed.

"The cost of not acting is huge. If we do not make the appropriate efforts today and miss our carbon objectives, the situation will be much more challenging for the whole industry."

Grégoire Carpentier
Co-Founder, Aéro-Décarbo - Project Leader for the Aviation Sector, The Shift Project

Aviation transition pathway and expected impact of the actionable levers according to ATAG Waypoint 2050 scenario n°3.





Note: This scenario relies less on the development of SAF relatively to other scenarios developed, and focuses efforts on technology improvement to drive emission reduction. This scenario is more conservative on the expected gains from operation and infrastructure. This scenario itself should not be understood as the maximum potential CO2 emission reduction of different technologies, but more as an **alignment framework** for ecosystem stakeholders to make the sector sustainable.

The sector's decarbonization will first rely on the uptake of sustainable aviation fuels on a large scale...

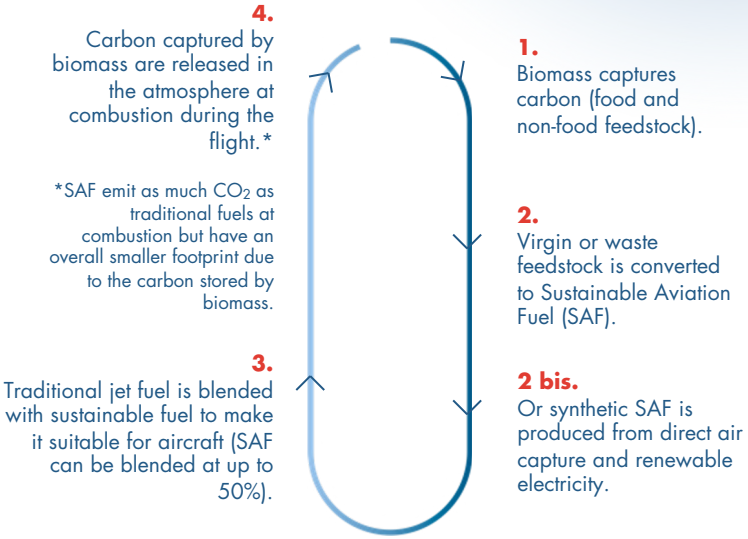
As **kerosene burning** is the major source of aviation-related carbon emissions, accounting for more than **95% of an aircraft lifetime CO2 emissions**, finding ways to cut emissions associated to the fuel process has the highest potential impact on the sector transition.

In that regard, **sustainable aviation fuels (SAF)** are the most promising alternatives to kerosene in the short term, and are **expected to account for 53%** of the **sector's decarbonization by 2050** according to ATAG's scenario 3. It is also the only technical option currently viable for long-haul flights.

SAF refers to a class of fuels that have very similar chemical properties to traditional fossil-derived jet fuel, but produced from sustainable feedstocks such as used cooking oil, solid waste, energy crops, that are known to be "carbon-sinks". SAF can then be blended with conventional jet fuel, or replace it all together.

When using SAF, the carbon footprint reduction comes from the fact that carbon emitted in SAF production, transportation, distribution and combustion is more or less compensated by carbon quantities used as input in SAF production process.

Thus, from a global lifecycle point of view, it is estimated that SAF has the potential to **reduce lifecycle carbon emissions by up to 80% compared to conventional fossil-derived jet fuel.**



"Supporting the development of alternative SAF supply chains and leveraging innovative financial mechanisms such as SAF-credits will be critical to accelerate the sector decarbonization."

Antoine Bateman
Sustainability Senior Manager – Climate Expert, Ardian

Sources: ATAG, EU Parliament

SAF: what are we talking about exactly?

SAFs can actually be divided into two categories.

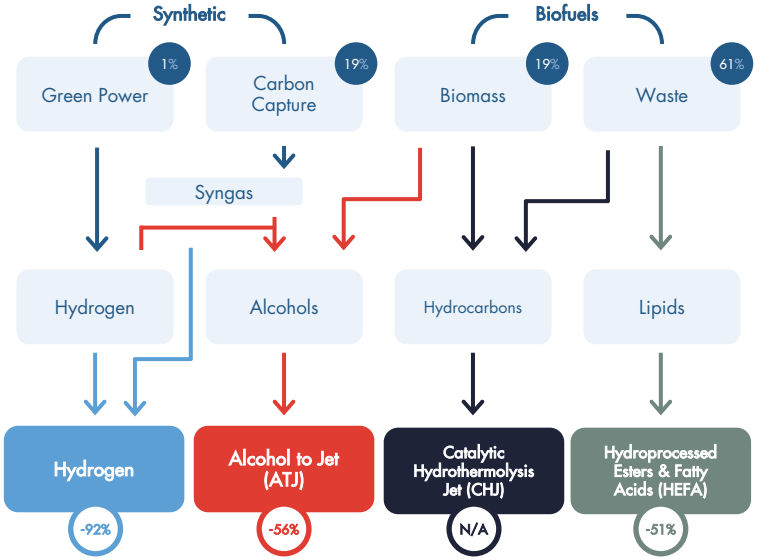
1| Biofuels produced from sustainable feedstocks, either waste or biomass, distinguished between **three different categories:**

- **First-generation biofuels** derived from feedstocks that are typically used for food (palm oil, sugar cane, corn, …)
- **Second-generation biofuels** derived from non-food biomass, e.g. waste oils, agricultural or forestry waste.
- **Third-generation biofuels** derived from microorganisms (algae, yeast).

Biofuels are produced using three different manufacturing technologies; Hydroprocessed Esters and Fatty Acids (HEFA), Catalytic Hydrothermolysis Jet (CHJ), and Alcohol to jet (ATJ).

2| Synthetic fuels (or e-fuels) are produced from CO2, either stored or captured, and hydrogen, through the Fischer-Tropsch process or also Alcohol to Jet.

Estimated advanced SAF production and associated pathways by 2025.



Average carbon dioxide emissions reductions (vs. ICAO jet fuel baseline value of 89gCO2e/MJ).

Sources: ADEME

To make SAF a reality, several challenges need to be overcome...

Given the weighting in ATAG's third scenario (53%), the availability of SAF is considered a critical component in the decarbonization of the aviation sector. It is estimated that if we are to reach the net-zero target by 2050, c. 330 million tons of SAF will be needed globally, which is a significant increase considering 2021 production levels were c. 120,000 tons globally. This scaling up of SAF will depend on several factors:

Firstly, the availability of the **feedstocks (solid and lipid)** required and their collection, making sure not to negatively impact other sectors in need of similar resources (road transportation, building industry…)

Secondly, for SAF to be widely available, a dedicated SAF industrial sector will need to come to life, led by energy supplier pioneers. From dedicated SAF production facilities, through to **retrofitting of existing refineries**, to dedicated supply chains, which will require significant investment.

Thirdly, the **global energy mix will need to decarbonize**, as some SAF, such as e-fuels, will require large quantities of electricity to produce hydrogen from electrolysis. This also calls for **the development of right policies to enable new investments to be made in renewable energy** infrastructure globally.

Lastly, changes to engine structures or infrastructure will be needed to be able to fly safely using more than 50% of SAF.

"SAF appears to be the main decarbonization lever for aviation, but will need cooperative actions to become a reality."

Armando Brunini
CEO, SEA Milan Airports

"The main challenge for SAF on a global scale is the development and scaling up of the production which will require the adoption of a systemic approach by all industry players."

Edward Arkwright
Deputy CEO, Groupe ADP

Ecosystem players have understood the importance of SAF, and have started to take actions

To launch and scale the availability of SAF, public actors are starting to take actions.

For example, on July 7 2022, the **European Parliament** voted to adopt draft rules for the ReFuelEU initiative, part of the Fit for 55 package which aims to **increase SAF** from **2% in 2025** to at least **85% of EU aviation fuel** by 2050, as well as the obligation for EU airports to facilitate the access of aircraft operators to SAF.

Elsewhere, in the US, through the **Sustainable Skies Act**, the federal government implemented a subsidy scheme via a dedicated tax credit to boost SAF production.

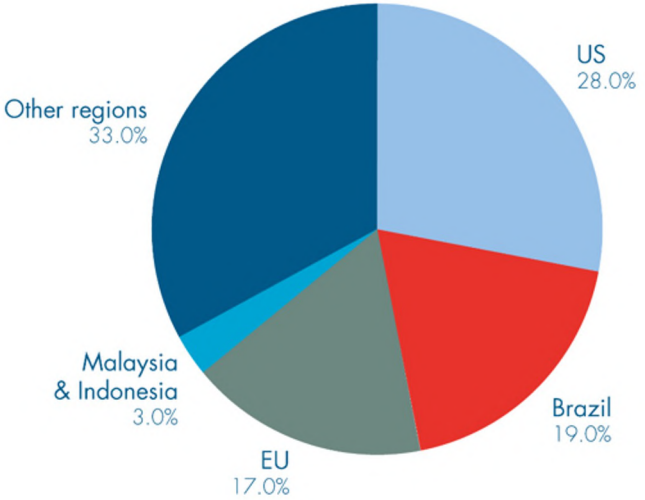
"The EU mandate on SAF and coalitions such as Clean Skies for Tomorrow will break the chicken and egg problem, boosting production and supply of SAF in the market, which makes us confident to reach our objective of 10% of SAF incorporated on all our flights by 2030."

Fatima da Gloria de Sousa
VP Sustainability, Air France-KLM

"The momentum around SAF will continue to grow. TotalEnergies is already investing a lot to increase its SAF production. This is completely in line with TotalEnergies' ambition to achieve carbon neutrality by 2050, together with the society."

Joël Navaron
President, TotalEnergies Aviation

2035 SAF production per region.



Sources: CORSIA

Efficiency improvements on aircraft technology will have the second most important impact for reaching net-zero

Although aircraft **efficiency is known to have improved by 85% over the last 70 years**, there is still room to improve engine and airframe performance, directly impacting carbon emissions. This lever is estimated to account for **34% of the sector's decarbonization by 2050**, and is expected to be derived from two different pathways:

The deployment of mature and available technology solutions.
Over the past decade, innovations in the use of composite materials to reduce the weight of aircraft structures, as well as engine improvements and airframe optimization, have enabled better aerodynamics and therefore reduced drag.

It is estimated that latest generation of aircraft having entered the market, such as the NEO series by Airbus, emit about 20 to 25% less CO2 than their predecessors.

"As of today, around 80% of the current fleet in service is not the latest standard of Airbus product line. The aircraft fleet replacement could thus yield a 20 to 30% of CO2 savings."

Karine Guenan
Vice President ZEROe H2 Ecosystem, Airbus

Anticipated future breakthroughs in innovation.
Jet engine OEMs are working on various disruptive innovations such as Open Fan architecture, next-gen turbine materials, hybrid electric or reduction gearbox, that have the potential to result in a further 20% saving in fuel consumption compared to today's most recent engines. Up to 10% additional gain could also come from lighter materials (composites, use of additive manufacturing), more electric aircraft, progress in aerodynamics, etc.

OEMs target 100% SAF compatibility before 2030, for any new aircraft/engines produced, and next-generation engines will be compatible with Hydrogen.

"Safran is already working on the next generation of engine and aircraft systems, with the aim of bringing up to 30% less fuel consumption than today's latest planes, by 2035."

Thibaud Normand
Climate Director, Safran Group

What we can expect from the hydrogen plane

While both are carbon neutral from a life cycle point of view, clean hydrogen (that is to say, produced from renewable energy) is actually the only latest generation of aircraft fuels whose **combustion carbon footprint is neutral**, as SAF are known to emit as much CO2 as kerosene in the combustion phase. Two hydrogen-propelled aircraft technologies are currently being developed:

- A hydrogen **internal combustion engine** which uses liquid hydrogen, and;
- **Hydrogen-powered fuel cell** which converts the chemical energy of gaseous hydrogen into electricity and water.

For the hydrogen plane to become a reality, several challenges need to be overcome such as the development of a dedicated **supply chain**, and heavy investments into **renewable energy production assets**, in order to produce **green hydrogen** at the scale required.

Given the volume and the weight of the hydrogen tanks needed for both technologies, hydrogen is for the moment only considered feasible for **regional and short-haul** flights which combined account today for about 28% of the sector's emissions, according to ATAG.

"Airbus ZEROe is exploring aircraft platforms powered with H2 combustion thrust or H2 fuel cells on the major aircraft concepts we revealed back in 2022, as well as the H2 ecosystem towards our ambition to commercialize the world's first hydrogen-powered aircraft for an entry into service by 2035."

Karine Guenan
Vice President ZEROe H2 Ecosystem, Airbus

"To achieve a decarbonized aviation, massive investments of more than 1.5 trillion euros[1] will be required until 2050. Airports and regulators will have to quickly start preparing regulation and standards for the handling – and possibly the production – of hydrogen at airports, ensuring a large network of airports worldwide could already supply liquid hydrogen at scale by 2035."

Laurent Fayollas
Deputy Head of Infrastructure, Ardian
President of the Supervisory Board, Hy24

(1) IATA, Fly Net Zero

Improvements to flight and ground operations will also contribute to the sector's decarbonization

Another way to decarbonize aviation is **to improve the efficiency of flight and ground operations** which could enable emission reductions by c. **7% of the net-zero 2050 path** according to ATAG's scenario 3. Three sub-levers have been identified:

Routes and flights optimization

Flight management systems, using real time data such as speed, live traffic and weather conditions enable aircraft "eco-pilotage", which has the potential to save up to **4% of fuel consumed in flight.**

To enable further routes optimization, **airspace harmonization** such as the Single European Sky initiative can also be a great lever to allow more efficiency in aircraft trajectories beyond constraints of national airspaces.

Last, the improvement of **plane load factors**, which were known to be around 82% globally, could also have a significant impact on carbon emissions reduction.

"The European Commission initiative for a Single European Sky, would cut aviation's carbon footprint over the EU territory by up to 10%."

Fatima da Gloria de Sousa
VP Sustainability, Air France-KLM

"The convergence towards the Single European Sky should be a priority for the European Union. There is a strong efficiency potential on operations which is impossible to unlock today."

Grégoire Carpentier
Co-Founder, Aéro-Décarbo - Project Leader for the Aviation Sector, The Shift Project

Optimization of aircraft ground operations

During parking time, the use of decarbonized Auxiliary Power Units (APU) for heating/cooling or the use of green vehicles for taxiing are examples of potential improvements.
For example, the company **FlightWatching** developed a platform to provide real-time monitoring of engine health using aircraft's data. It is a predictive analytics solution that empowers airlines to optimize fuel consumption, reduce asset failures and enhance safety.

Besides, it is estimated that the usage of electrical operational taxiing and electrical ground power can cut CO2 emissions by up to **3% per flight.**

Sources: IATA, ATAG, Destination2050, Shift Project, European Commission

Players such as Aéro-Décarbo are also calling for a coordinated action from international organizations and public authorities at the different decision levels

Facing a global issue such as decarbonization, the aviation industry can rely on its existing international organizations (such as the ICAO), whose role could become even more crucial.

One topic on the agenda is the harmonization of carbon reporting across countries, which would already help having a more faithful representation of the distribution of emissions worldwide.

Benefitting from their international reach, such organizations could also structure growth scenarios for the industry at a global level, taking into account the specificities and needs of each region.

When it comes to SAFs, an accurate and common definition to respect the same rules across the world is crucial.

Transitioning to a net-zero industry will mechanically generate additional costs, for which regional and national entities' role will be key in ensuring the viability and competitiveness of the industry.

Viability and resilience of the transition would first rely in the ability of the regional and national entities to develop a fully integrated local value chain.

Conditional financing as well as incentive mechanisms, depending on environmental and social impacts, granted by the States (such as higher tax amortization for new-generation aircraft investments, or buyback of loyalty programs in exchange of a possibility for the passenger of using miles to have a positive impact on the transition) is one form of supporting the viability.

As major technological breakthroughs are set to represent a key lever for reaching net-zero, public authorities' responsibility in improving the efficiency of certification processes will be paramount to meet the timeline.

The implication of local authorities and citizens should help steering the debate towards rational and concrete solutions.

Before deploying new capital expenditures, an analysis should be carried out regarding the coherence and essential nature of the project (versus the opportunity of a better usage of existing infrastructure) , encompassing both economic, social and environmental aspects.

"At local levels, an assessment around connectivity should drive a prioritization of areas to open up in relation with their ecological and energy constraints."

Grégoire Carpentier
Co-Founder, Aéro-Décarbo
Project Leader for the Aviation Sector, The Shift Project

Sources: Aéro-Décarbo.

In addition to decarbonization measures, carbon removal should be considered to reach net-zero target

To reach net-zero the sector will have to support carbon removals to neutralize residual emissions that cannot yet be eliminated by 2050, which is known to represent 6% of the overall effort in the ATAG scenario 3:

- Outside of the sector value chain, by providing financial support to **certified carbon sequestration projects** (e.g. agroforestry, mangrove restoration, reforestation, …).
- Inside the sector value chain by investing in **carbon capture usage and storage (CCUS) solutions.** These solutions could be deployed across the sector to help some airports effectively become green energy 'power stations' to fuel the aircraft they serve for achieving the true net-zero target.

In addition, **voluntary market-based mechanisms** and voluntary offsetting commitments (in addition to direct emissions reduction) will contribute to finance climate change mitigation projects outside of the sector value chain before 2050.

Finally, regulatory mechanism will provide further support decarbonization by providing financial incentive to reduce emissions, in particular :

- The EU Emissions Trading Schemes **(ETS)** sets a limit to carbon emissions from flights within the European Economic Area as well as flights to Switzerland and the UK through a Cap-and-Trade mechanism.
- The **UN-lead CORSIA*** program launched in 2021 whereby over 100 states voluntarily participating in the program commit to neutral growth for international aviation. Airlines with activities in these countries will have to offset their emissions above 2019 levels, by purchasing carbon credits generated by eligible projects.

"Increasing carbon sinks must always come in parallel to carbon reduction measures targeting scope 1, 2 and 3, and not in replacement. This is the only way to reach the Paris Agreement targets."

Raphaëlle Muhlmann-Eytan
Managing Director, Infrastructure, Ardian
Head of Investor Relations, Hy24

*Carbon Offsetting and Reduction Scheme for International Aviation

4.

The Strategic Vision
The augmented airport, a key catalyst for the industry decarbonization

Airports are the beating heart of the aviation sector...

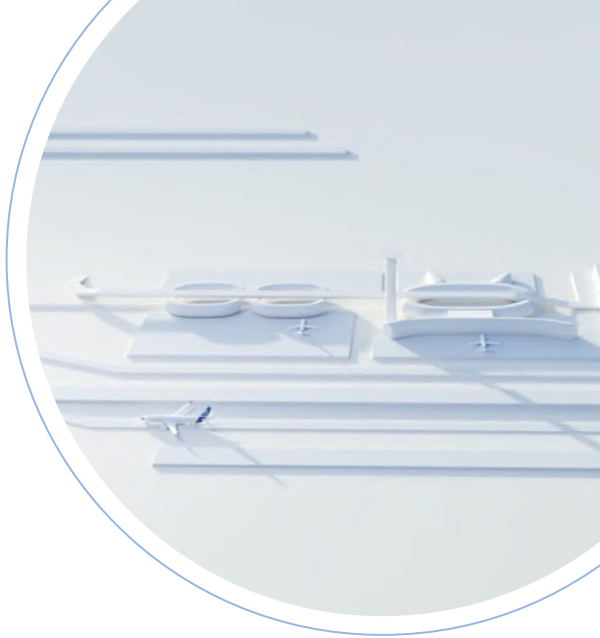
Airports stand at the center of the whole aviation value chain.
They are the natural link between passengers, airlines, air traffic controllers, energy suppliers and other stakeholders from the local region (public transport operator, government authorities, local communities, etc.).

Since airport areas are the locations where decarbonization solutions are deployed, they can be understood as the **natural and unique platform** gathering all the stakeholders, and have the potential to knock down existing silos.

"Airports are the place where the aircraft is based and refueled, and also where passengers board. They have a central role to play in decarbonizing the sector, especially when adopting a systemic approach to the question, which we truly believe in at Ardian."

Juan Angoitia
Co-Head of Infrastructure in Europe, Ardian

... and can have a structuring impact on the sector by focusing on their scope 3 emissions



Following the GHG protocol standards, airports emissions are categorized into three scopes. While scope 1 corresponds to their direct and internal emissions, and scope 2 to the emissions from purchased electricity, scope 3 relates to all the emissions they generate indirectly, which notably encompasses aircraft movements, which generally estimated to contribute to 99% of the emission of the sector.

According to Airport Carbon Accreditation's (ACA) standards, scope 3 encompasses at least emissions generated by aircraft landing and take-off (that is to say below an altitude of 3,000 feet), and goes up to including the halfway cruise for the airport to reach a higher level of ACA certification.

Scope 1
Emissions from airport controlled sources.
1 Vehicles/ground support equipment belonging to the airport.
2 On-site waste management.
3 On-site waste water management.
4 On-site power generation.
5 Firefighting exercices.
6 Boilers, furnaces.
7 De-icing substances.
8 Refrigerant losses.

Scope 2
Emissions from purchased electricity.
9 Off-site electricity generation.
A Heating.
B Cooling.
C Lighting.

Scope 3
Emissions from other sources related to the activities of an airport.
10 Flights.
11 Aircraft ground movements.
12 Auxiliary Power Unit.
13 3rd party vehicles/ground support eqpt.
14 Passenger travel to the airport.
15 Staff commute.
16 Off-site waste management.
17 Off-site water management.
18 Staff business travel.
19 Non-road construction vehicles and eqpt.
20 De-icing substances.
21 Refrigerant losses.

"Curbing internal and external carbon emissions for airports today is our license to operate."

Armando Brunini
CEO, SEA Milan Airports

Sources: AD, McKinsey, ACI

Air Carbon is a new-generation tool to help airports address their scope 3 emissions

In order to adopt a sustainable and realistic decarbonization approach, airports need to **have accurate data** on their direct and indirect emissions.

To enable portfolio assets to do so, Ardian has been developing a tool to help airport management teams **measure efficiently, and in real-time,** the majority of their scope 3 **carbon emissions**, using highly granular operational data.

The objective of the tool, created in 2019, is to be able to integrate more and more sources of emissions (including scopes 1 & 2), both in monitoring and also in simulating the impact of potential carbon reduction initiatives going forward.

ACA is in the process of approving the use of Air Carbon for Torino Airport to automatically report the landing and take-off component of their scope 3 emissions in the framework of their Level 3 accreditation. Depending on the results of this trial, Air Carbon could become the **reference carbon tracking tool for all airports** interested in using a **data-driven supporting tool** to meet their climate objectives.

"There is a lot to be done to reach ACA Level4+, and Air Carbon is a great tool to get there, because it enables to really focus on scope 3 emissions."

Michele Miedico
Head of Sustainability, Naples Airport

"We have just implemented real-time data feed in the Air Carbon tool, which will help us being more reactive on our carbon reduction pathway."

Lorenzo Gusman
COO, Torino Airport

To reach net-zero, airports have to accelerate their transformation into “augmented” airports

“When we designed the Augmented Infrastructure framework in 2018, we were convinced that it was our responsibility as long-term investors to create a strategic framework for technological innovation and data intelligence to enable the transition from traditional infrastructures to augmented ones, fully prepared to serve the needs of tomorrow. For airports, that means working on operational and financial performance together with carbon reduction targets and driving the transition of the sector. ”

Pauline Thomson
Director and Head of Digital Innovation, Infrastructure, Ardian

Open

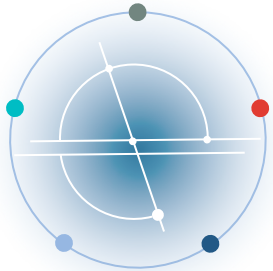
Interfacing and partnering with external stakeholders

The augmented airport is open to all kind of technologies, and to its local and global ecosystem, which enables it to accelerate the reduction of its emissions.

Prolific

Creating new revenue sources

The augmented airport has started to explore new opportunities to create sustainable value, that are not anymore based on passenger traffic growth only.



Intelligent

Leveraging data to improve performance

The augmented airport leverages the full power of data to create efficiency gains, improve customer satisfaction and reduce its emissions.

Impactful

Creating local and global impact

The airport is able to create an impact, both at the local and global levels by incentivizing third parties to improve or limit its negative impact on its surrounding environment.

Resilient

Withstanding shocks

The augmented airport is more independent. By having gained in autonomy, it is less vulnerable to unplanned events potentially leading to uncontrolled CO2 emissions.

Open

Because decarbonization of aviation will come from a combination of solutions rather than a single technological way out, the augmented airport is **open to multiple technologies**.

In that sense, the augmented airport is first and foremost technology-agnostic when it comes to aircraft energy supply.

As new fuel use will greatly depend on distances and routes (pipelines, roads, boats, …), airports of tomorrow are able to **guarantee supply of all kinds of fuels**, to enable decarbonization of air traffic.

As a means to decrease the part of scope 3 emissions related to customer and staff access to the airport, the augmented airport is **open to all kinds of shared transportation connections to the surrounding area/city.**

This includes traditional public transport connections, but also newer ICT-supported* shared mobility modes to rationalize private vehicle access to the airport.

"Hydrogen, SAF, electricity... At the end of the day, the decarbonization of aviation will need all those different new fuel propulsion technologies, and airports will have to be technology agnostic to position themselves as true enablers."

Pierre-Etienne Franc
CEO, Hy24

"Airports can be a decisive catalyst in the hydrogen value chain as they need to facilitate decarbonized logistics and systems. Ground transportation companies for example could be supplied from there."

Amir Sharifi
Senior Managing Director, Ardian
Chief Investment Officer, Hy24

* Supported by Information and Communication Technologies.

SEA (Milan Airports) is collaborating with ENI to improve the availability of SAF in Milan airports

As seen previously, SAF have the highest potential in decarbonizing the aviation sector in the medium term, potentially contributing **to the sector's total emissions decrease by 53%.**

With this in mind, SEA (Milan Airports) has been collaborating with the Italian energy provider ENI to support the development of SAF for aircraft, to reduce part of its **scope 3 emissions.**

Through the partnership, ENI is expected to provide SEA (Milan Airports) with ENI "Biojet" soon, a Bio Fuel which will be made exclusively from waste materials such as used cooking oil (UCO) or animal fats, to be blended with conventional jet fuel up to 50%.

ENI plans to produce c.150,000 tons/year of Biojet by 2024, which will meet the Italian market's potential requirements by 2025. Eni plans to reach a production capacity of at least 500,000 tons/year of Biojet by 2030.

According to the Renewable Energy Directive (RED) II, the bio-component in the final blended fuel (waste materials like UCO and Animal Fats) will ensure a reduction in greenhouse gas emissions of up to 80% over the entire life cycle compared to the fossil equivalent.

"In the medium term, we want to position ourselves as SAF enablers, which could have consequent impact on our scope 3 emissions."

Giorgio Medici
Environment Director,
SEA Milan Airports

Air Liquide and Groupe ADP work together to help airports preparing the transition to hydrogen

Air Liquide and Groupe ADP are already partnering to prepare airports for a hydrogen future. The parties launched in 2021, in collaboration with Airbus, a study to assess potential configurations for liquid hydrogen production, supply and distribution in airports for airlines.
Air Liquide and Groupe ADP intend to create a 50:50 venture early 2023 aimed at providing airports with the engineering and services they will need in their transition to hydrogen.

"Once the hydrogen plane has been built and the flight tests are validated, the supporting infrastructure should be ready. Airports must thus already plan for it."

Pierre Crespi
Director of Innovation, Air Liquide Advanced Technologies

ZeroAvia is working with Edmonton airport to make the hydrogen aircraft a reality

Although it only represents less than **4% of the total sector's emission**, regional travel accounts for **17% of the total global fleet** and is not to be neglected when thinking about aviation decarbonization.

To tackle this challenge, ZeroAvia has been working since 2017 on the development of a hydrogen-fuel cell powered aircraft.

After having **successfully demonstrated the maturity of its technology on a 6-seater aircraft in 2019**, ZeroAvia is now working on testing its propulsion system on a 19-seaters plane with the objective to sell its first units as early as 2024.

In parallel, ZeroAvia set up in 2022 an agreement with Edmonton International Airport in Canada to locally develop the required hydrogen infrastructure.

SEA is supporting Milan airports' access travel decarbonization through modal shift and electro mobility

SEA (Milan airports) has been undertaking tremendous efforts to connect better its airports to the local community in an attempt to reduce scope 3 emissions related to passengers and staff travelling to and from the city. At Malpensa, SEA (Milan airports) has been working closely with railway companies to improve train services to the city center. In Linate, SEA (Milan airports) has been collaborating with the city of Milan and partners to develop the Linate Airport metro station that will connect into the wider Milan network, and will open in Autumn 2022.

According to SEA (Milan airports), coordinated actions between the airport and railway companies, such as the pass-through connection of Malpensa airport with the national railway network, will lead to an **increase in the share of passengers using the train from 15% up to 20% by 2030**. The Linate Airport metro station opening this year is expected to increase the **modal share of public transportation used to reach the airport from 41% (bus only) to 57% (bus + metro) by 2025.**

Last but not least, both Linate and Malpensa have been implementing **EV fast-charging stations powered by renewable energy** to support the development of electro mobility and continue decreasing scope 3 emissions related to airport access travel.

"We are working hard with railway companies to improve even more the connectivity of our airports, and better connect them to other towns in the region, and not only Milan."

Claudia Carrà
Airport Accessibility Planning Manager, SEA Milan Airports

Skyports is working with airports to decarbonize first and last mile travel

To decrease emissions related to passenger and staff travel from the surrounding environment, pertaining to scope 3, a number of airports are also partnering with innovative enterprises for **first and last mile decarbonization** solutions.

Out of these, Urban Air Mobility (UAM) is expected to make up to **4% of the total mobility mix** in the future, with commercial services provided by **electric vertical take-off and landing aircraft (EVTOL),** which do not emit CO2 during operations because of their use of renewable electricity.

To really take off, UAM will require dedicated infrastructure to link airports to the surrounding area. This is specifically what Skyports is doing, through the development of an **end-to-end solution to deliver and operate an EVTOL-agnostic efficient and safe Advanced air mobility (AAM) infrastructure network.**

Skyports is working cojointly with Groupe ADP to enable first demonstration flights in the Paris Metropolitan Region as early as for the **2024 Olympics**, and commercial services in collaboration with Milan Airports for the **2026 Winter Olympics**.

"Skyports' ambition is to better connect airports and their surrounding territories by enabling decarbonized first and last mile travel through EVTOLs".

Duncan Walker
CEO, Skyports

"We believe that Skyports is a crucial player to accelerate the electrification of air transport, starting with the development of Advanced Air Mobility infrastructures."

Edouard Bertagna
Senior Investment Manager, Infrastructure, Ardian

Sources: Journal of Urban Mobility (Elsevier)

Intelligent

At the heart of the aviation sector, airports collect an **extensive amount of data** which offer a valuable resource to drive overall performance improvements. Data sharing between the different players of the industry, however, remains a challenge.

An intelligent airport **collects operational data in real-time from the facility** (such as passenger flows, energy consumption) but also directly **from ecosystem partners** (airlines, ground transport, public transport operators connecting the airport, roads network operators…) in order to monitor its scope 1, 2 and 3 emissions.

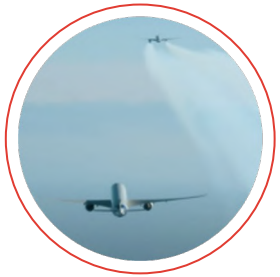
An intelligent airport is able to use this data for strategic purposes, to forecast and simulate potential future actions, take **data-driven decisions** to reach its operational and environmental objectives and follow its climate roadmap.

Lastly, the augmented airport is reciprocally **open with its operational data to third parties** in order to enable environmental synergies, breaking silos that today exist between the different stakeholders of the ecosystem.
The sharing of past air traffic data and forecasts can, for example, help mobility operators supply a well-dimensioned shared transportation offer to surrounding cities.

"The use of data-driven collaborative decision-making tools, such as Air Carbon, have the ability to break existing silos between aviation stakeholders and to enable collective actions to reduce carbon emissions."

Skander Kamoun
Data Scientist, Infrastructure, Ardian
Air Carbon Product Lead

Intelligent



Fello'Fly: decarbonization using biomimetics

Fello'Fly is a digital solution developed as part of Airbus' UpNext strategy to enable two aircraft that are in sequence on the same flight route to be paired through what is called a **"V-Flight".**

Inspired by **migration bird movements**, V-Flight pairing consists of **creating a flight "train"** in order to allow the follower aircraft to **use the uplift from the wake of the leader plane**. When positioned 3 km behind the leader plane, the follower aircraft is able to **decrease its carbon emission by 5% to 10%,** without compromising passenger comfort, and thus reducing airport's scope 3 emissions.

Wintics: make infrastructure smarter

Digitalization enables the collection of large amounts of data that can be used to **optimize passenger walking flows** within the airport to **avoid potential operational delays**, which can cause additional emissions.

Wintics is a French startup which uses existing cameras and **AI-supported video analytics** to **monitor passenger and vehicle movements** on a given perimeter, to identify **stress areas for improvement**. By streamlining passenger fluxes at the airport, Wintics helps to avoid flight delays, and minimize extended APU usage which is responsible for **6% of total emissions** in an airport and part of scope 3.

"Airports having access to incoming passenger fluxes data are able to work on their modal mix to try reducing part of their scope 3 emissions."

Matthias Houllier
Co-Founder, Wintics

Use case **Intelligent**

Safety Line leverages on big data to improve the energy efficiency of current fleets.

Extended flight trajectories due to congested runways can induce a **30% surplus of energy consumed**, and significant associated **scope 3 emissions**.

To avoid those and help optimize flight operations, big data-based solutions using machine learning and AI, such as **Safety Line**, can be of great help.

Airlines using the OptiFlight module from Safety Line receive real time route optimization guidance based on real time weather and traffic data analysis. This helps to optimize routes with more accuracy and more dynamically compared to traditional approaches; air traffic controllers traditionally compute and freeze routes several hours before departure based on weather forecasts.

It is for example estimated that airlines following Safety Line guidance for landing and take-off phases instead of traditional on-board computer guidance usually **save up to 6% of fuel during those phases, thus reducing consequently associated emissions.**

"Safety Line's solutions follow logics of cost reduction on fuels that will also be synonymous with decarbonization."

Pierre Jouniaux
President/CEO, Safety Line

Resilient

Given the immense challenges and level of uncertainty regarding the decarbonization of aviation, the augmented airport must be **resilient.**
The airport must thus be able to absorb shocks and changes to ensure long-term durability

Firstly, resilient from an **energy perspective**: by using its available land to also produce, store and use energy on-site, the augmented airport **reduces its dependency** on its external environment, and thus **decreases its vulnerability**.

A resilient airport **adopts and masters new technologies** to ensure that it is equipped to adapt quickly, safely and smoothly to sudden traffic peaks or drops.

Then, the augmented airport is resilient from an ecosystem perspective. At a global level, it is rooted in a **solid ecosystem of autonomous stakeholders**, sharing best practices, and collaborating to make **decarbonization of aviation a system-wide reality.**

Finally, the augmented airport is **cyber** resilient. Decarbonizing aviation requires to act on technological factors, which includes leveraging data, and therefore providing airports with a **secure working environment.**

"When we look forward, the first questions airports ask themselves relates to their climate change resilience."

Daniele Rizzolini
Managing Director, Infrastructure, Ardian
Member of the Board of Directors, GESAC (Naples and Salerno Airports)

Naples airport is becoming more energy independent through on-site solar energy generation

In order to decrease its energy dependency from outside the airport, Naples airport is planning the construction of an on-site solar plant. In total, approximately 3,600 photovoltaic (PV) panels will be installed on airport hangars, as well as a series of minor systems on the roofs of the freight terminal buildings, multi-storey car park and departures shelter. Final positioning of panels has been determined in order not to create reflections that might impact plane traffic.

In consideration of the climatic zone of Naples, the solar plant is expected to be able to deliver an instantaneous peak power of approximately 2,200kWp, and produce approximately 3.1GWh in a year, equal to approximately 15% of the entire annual electricity needs of the airport.

It is estimated that the solar plant should lead to electricity purchase savings of c.11% per year through the next 20 years.

"We are planning to be able to produce about 25% of our energy needs by 2025. The goal here is to increase our energy independency, to become more resilient."

Andrea Guglielmi
Head of Engineering, Naples Airport

Good decarbonization practices exchanged through the Ardian Transport Working Group (TWG)

All of the assets within Ardian's portfolio are subject to a quantitative sustainability strategy. To accelerate the implementation of those action plans, Ardian has established a Transport Working Group (TWG) aimed at exchanging the best decarbonization practices among its members.

While participants stay autonomous to make their climate strategy a reality, they can benefit from a solid network of partners to reach their climate and sustainability targets sooner.

The group held its first online meeting in July 2020, gathering operational leaders from 6 Ardian portfolio companies including the motorway operators Ascendi from Portugal, ASTM, based in Italy, and Vespucio Norte from Chile, along with SEA Milan airports, which operates the two airports in Milan, and Lisea, which manages the 300-km high-speed rail link between Tours and Bordeaux in France.

"The idea of the TWG is to give our assets means to accelerate their sustainability transition, while developing the resiliency of the sector as a whole."

Candice Brenet
Head of Sustainability, Ardian

Impactful

Being intelligent, open and resilient, the augmented airport is able to have real **impact** on its direct (scope 1 & scope 2) and indirect (scope 3) emissions, which results in both a **local and global impact simultaneously**.

An impactful airport **encourages airlines to reduce their scope 1 emissions** globally through the implementation of incentive schemes, which **directly reduces the airport's scope 3 emissions**, subject to the development of the right regulatory frameworks and associated level playing field.

An impactful airport works with innovative companies to **provide the infrastructure required to research and test** ground-breaking decarbonized technologies, such as for aircraft taxiing or propulsion systems.

Last but not least, once carbon reduction measures have been implemented, airports can have a global impact by engaging in **nature-based carbon offsetting projects**. Such projects have the ability to create significant environmental, social and economical impact on the local area where they are implemented, as well as globally.

"Given their position in the whole aviation ecosystem, and their strong territorial anchor, airports are among the only stakeholders of the sector that are able to have an impact both locally and globally."

Alexis Ballif
Managing Director, Transport, Infrastructure, Ardian

"Airports can use competition to create an impact and lead the decarbonization transition. The possibility for airports to incentivise cleaner aircraft based on CO2 emissions could be explored in the context of a revision of the EU's Airport Charges Directive and the Slot Regulation."

Matthias Finger
Professor, Florence School of Regulation, EUI

SEA uses competition mechanisms to help airlines at Milan airports create impact

In order to accelerate the sustainable transition of a given industry, and help partners to also generate an impact, **market mechanisms can be a powerful ally**. SEA (Milan airports) understands this and has created financial incentive schemes to help airlines reduce their scope 1 emissions, while directly reducing its scope 3 emissions.

SEA (Milan airports) has already started to **apply commercial policies** which incentivize traffic development by airlines with more modern aircraft, mainly focusing on airport **noise reduction** which can be a sensitive issue for local residents.

SEA (Milan airports) has also designed an **'airport green charges' framework** - under evaluation by the Italian Authority for Transport Regulations - to promote carriers operating at Milan Airports to deploy aircraft with better noise performance and reduced emission profiles. This framework would apply transparent, non-discriminatory dynamic criteria to **incentivize operations with reduced environmental impact.**

"SEA (Milan airports) already incentivizes airlines that use greener aircraft, to encourage them to decarbonize."

Rosario Mazza
Managing Director - Head of Infrastructure in Italy, Ardian
Member of the Board of Directors, SEA

Bangalore Airport is working with TaxiBot to decarbonize taxiing from the gate to the runway

Aircraft taxiing at airports represents c. 5% of the total CO2 emitted by an aircraft during its flight and creates excessive noise. At an airport level, it represents **about 28% of total airport emissions** which is equivalent to **a third of its scope 3 emissions*.**

TaxiBot has developed, in collaboration with IAI, Airbus and TLD (a subsidiary of Alvest), a semi-robotic electric dispatch towing system aimed at replacing aircraft engine use during taxi.

Overall the solution is supposed to **cut taxiing CO2 emissions by up to 85% while reducing noise pollution by 60%.** TaxiBot is currently being experimented in Bangalore airport showing encouraging results.

"TaxiBot services commenced in June 2022. TaxiBot is one of our many sustainability initiatives contributing towards our 2030 sustainability strategy."

Jayaraj Shanmugam
COO, Bangalore International Airport

* In this case, scope 3 emissions were calculated using previous ACA guidelines, which does not take into account half-cruise emissions.

aDryada, a biodiversity carbon fund

According to ATAG's third scenario, the air transport sector will have reduced its carbon emissions by 94% in 2050. The remaining 6% reduction to achieve net-zero by 2050 will need to come from carbon offsets. To meet such targets, it is imperative to invest today in projects capable of generating high quality removal carbon credits to be used towards air transport sector decarbonization.

For that matter, **nature-based solution** projects are expected to supply large volumes of removal carbon credits in a timely and cost-effective way. Such credits would also have compelling social and environmental co-benefits in particular in preserving and restoring biodiversity.

With this in mind, aDryada develops **nature-based removal projects** which would generate carbon credits aimed at helping all companies offset their emissions.

First of its kind, aDryada supports the **Karidja** project in Ivory Coast, aimed at restoring 70,000 hectares in the Haut Sassandra Forest which has lost over 80% of its original forest cover, in partnership with public authorities and local communities. The project is estimated to **sequester 20 million tons of CO2e over 40 years**, sold through dedicated carbon credits to interested companies.

"We are launching the first Karidja project with the objective of reforesting 70,000 hectares with a focus on biodiversity in Ivory Coast. We expect at least 20 million tons in carbon credits generated."

Fabio Ferrari
CEO, aDryada

1PointFive pushes for the standardization of Direct Air Capture plant deployment

As mentioned, carbon offsetting measures should account for about **6% of the sector's decarbonization** and must thus not be ignored to effectively meet the 2050 net-zero target.

In that regard, new carbon capture technologies are emerging such as Direct Air Capture technology **(DAC)** that captures carbon dioxide directly from the ambient air, and stores it underground. This technology is expected to capture CO2 much faster with significantly less land use than traditional tree planting.

One DAC initiative worth mentioning is 1PointFive, a subsidiary of Oxy Low Carbon Ventures, closely working with Canadian company Carbon Engineering, that has developed DAC plans close to carbon generation places such as large industrial facilities and can be of interest to airports interested to offset parts of their emissions.

Wright Electric is building an electric jet engine to make short haul flights zero-emissions

Airports have the ability to create a positive impact by enabling the development of cutting edge propulsion technologies.

Wright Electric has understood so and is working on an electric jet engine for a hundred-seats commercial narrow body aircraft that is expected to enter the market in 2026. Such equipment would help to **decarbonize short haul flights market**, especially in regions where there is no infrastructure to enable a shift to other means of transport.

Eventually, a main advantage of electric batteries is the possibility to quickly swap one for another between flights, as well as the safety of manipulating solid materials compared to the risks associated with liquified hydrogen.

Prolific

Today, airport revenues are based on passengers transported, hence **airport financial growth is very much linked to air traffic growth**. In a world where sobriety has become paramount, the augmented airport has found new opportunities for revenue generation.

Firstly, the augmented airport is an energy hub, potentially selling **energy produced** directly to nearby consumers.

The augmented airport is a **multi-modal transportation hub**. It does not only provide flight services, but also potentially train and public transport.

Lastly, the augmented airport is a key stakeholder in the development of the local community, enabling value creation through **urban regeneration projects.**

The transformation of a conventional airport into a **prolific** airport is made possible due to the development of the **right regulatory frameworks** at the national and pan-European levels and collaborative work conducted with other ecosystem stakeholders.

"The COVID19 gave us a hard lesson on our dependency to passenger traffic and we have to find new ways to generate opportunities."

Michele Miedico
Head of Sustainability, Naples Airport

Torino Airport is transforming into an energy hub to create new revenue sources

As part of the **TULIPS consortium**, Torino Airport is working with Politecnico di Torino to **develop an airport smart energy hub**, that will include the use of different energy sources, storage systems and smart grids.

Torino Airport has planned the development of a **hydrogen ready trigeneration system** based on MCFC fuel cell technology* as well as a large-scale **photovoltaic** plant (1,5 MWp). While the energy produced on site is expected to be consumed directly by the airport initially, Torino Airport is actively working with EU and Italian regulators to enable the sale of electricity and heat produced to external partners.

Torino Airport plans to take advantage of the important energy amounts that will be needed to produce green Hydrogen within the **Piemont Hydrogen Valley.**

"We plan to position ourselves as renewable energy producers and potentially generate revenues from supplying green electricity to nearby stakeholders."

Andrea Andorno
CEO, Torino Airport

*Molten-Carbonate fuel cells.

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Naples Airport is fostering the development of its local community through urban regeneration project

Given the social and economic importance of an airport on the local community, and their connection to other land-based transportation systems, airports have the ability to accelerate the transformation of the urban fabric and generate value.

GESAC is engaging in several urban regeneration projects like this.

Through the "Mille alberi per la citta project", Naples airport aims at conducting urban forestry program in a nearby neighborhood through the planting of tree species of esthetic value, effective at the same time in reducing climate-altering gases and enabling landscape enhancement.

Naples airport is also supporting the redevelopment of the Casalnuovo neighborhood through green infrastructure development in order to increase urban prosperity and quality of life.

"One way to do so could be to create value by engaging in urban regeneration projects, to transform the airport area in a dynamic zone for the territory."

Michele Miedico
Head of Sustainability, Naples Airport

Together with the Société du Grand Paris (SGP), Groupe ADP is redefining the local integration of its airports

Since 2014, the SGP is working hard with the RATP and Groupe ADP to improve accessibility of Orly airport. Through the construction of a dedicated new train station for the metro lines 14 and 18, the consortium aims to tackle private car usage, that today represents about 80% of the access to the airport, by consequently increasing the share of rail.

Groupe ADP is also involved in the regeneration of the urban fabric around the Bourget airport. While the whole territory is set to develop through mixes of real estate programs, it will also host two new train stations of lines 16 and 17, which themselves will contribute to reducing the airport external emissions, while contributing to local economic development.

"While we have to embrace sobriety one way or another, the augmented airport, and its train station, has evolved from a standard passage-way towards a true living space fully connected to local population and local economy through exchange channels."

Elizabeth de Portzamparc
Architect, winner of the Grand Paris "Le Bourget" station design

"We actively support the development of intermodality at our airports with our stakeholders."

Edward Arkwright
Deputy CEO, Groupe ADP

5. Conclusion

To reach net-zero by 2050, ecosystem stakeholders will need to act collectively, and start diversifying their activities

Through their position at the core of the whole aviation value chain, airports have the power and the duty to drive the sector's transition.

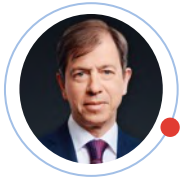
Achieving net-zero is the greatest challenge faced by air transport. The only way to succeed is therefore to agree on a globally-coordinated action plan involving all the industry stakeholders.

Acting collectively will be essential and necessary if we need to **reinvent air travel with more sustainability at a global scale**.
Airports, institutional and industry players will need to strengthen their collaboration to enable the transition of the sector.

Likewise, collective action will be needed to **make decarbonized fuels available at a global scale** and in a sustainable manner.

Finally, to overcome the upcoming transition of the sector, and cope with sobriety, airports will have to **diversify their activities**, and create new opportunities decorrelated from passengers' traffic growth.

We believe in a new paradigm where augmented airports emerge as **essential hubs for multimodal transport and renewable energy** while remaining key players in the **local economic development**.



"We believe it is our responsibility as long-term investors and shareholders of airports to ensure their resilience and transition to drive the sustainable aviation of tomorrow."

Mathias Burghardt
Head of Infrastructure and Member of the Executive Committee, Ardian

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