Aviation Intelligence Unit
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EUROCONTROL

The aviation network – Decarbonisation issues

Decarbonising aviation is arguably the greatest challenge facing the air transport industry.

Globally, aviation carried 4.4 billion passengers in 2018. The industry provides 65.5 million jobs, supports $2.7 trillion of the world's gross domestic product (3.6% of GDP) and carries over one third of traded goods by value. Aviation has invested over $1 trillion in new aircraft since 2009, and the global fleet of 32,000 aircraft connects the world's citizens on over 62,000 routes .

Environmental efficiency has continued to improve, with fuel burn per hundred passenger kilometres falling to 3.4 l/100 km in 2017, down 24% from 4.4 l/100km in 2005. The EU Emissions Trading System is estimated to save 193 million tonnes of CO_2 (for the years 2013-2020); the ICAO CORSIA scheme could potentially mitigate around 2.5 billion tonnes of CO_2 and could generate approximately $40 billion of climate financing by 2035.

Overall, the aviation industry has a proud record of achieving significant environmental improvements, as summarised below.

Reduction on CO_2 emissions per seat kilometre since first jets	-80%
Reduction in perceived noise since first jets	-75%
CO_2 emissions avoided since 1990	10 billion tonnes
Fuel burn per 100 passenger km flown (latest jets)	< 3 litres / 100 km
Fuel efficiency improvement 2009-2016	2.1% annual average

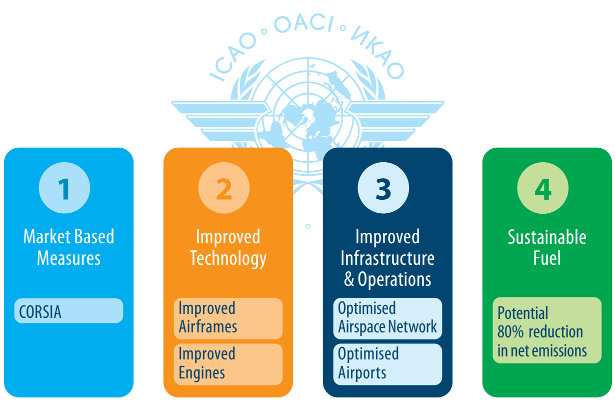
However, aviation did produce more than 900 million tonnes of carbon dioxide (CO_2) in 2018 . This is not going unnoticed. Greta Thunberg, School Strike for Climate, #flygskam and Extinction Rebellion have been the focus of mainstream and social media for months. There was a "green surge" in the European Parliamentary elections in many States; 36% of first-time voters in Germany voted green .

The UK's Climate Change Commission issued a report recently recommending that a national target of net-zero greenhouse gases be adopted for 2050, including aviation.

Aviation has also responded – ACI EUROPE's member airports have committed to a target of net zero-carbon by 2050 for all emissions fully under their control. KLM, under its "Flying Responsibly" initiative is even asking passengers to reconsider whether they really need to travel by air at all and several airlines, such as Lufthansa, offer passengers the opportunity to offset their emissions.

Aviation is clearly under increasing pressure to decarbonise. But, it is a very long-term industry, with returns on investment measured in decades, so it is really difficult to decarbonise quickly. Let's look at some facts.

AVIATION'S RESPONSE – ICAO 4 PILLARS



FOUNDING MEMBER SESAR JOINT UNDERTAKING

NETWORK MANAGER

Traffic and Emissions Growth

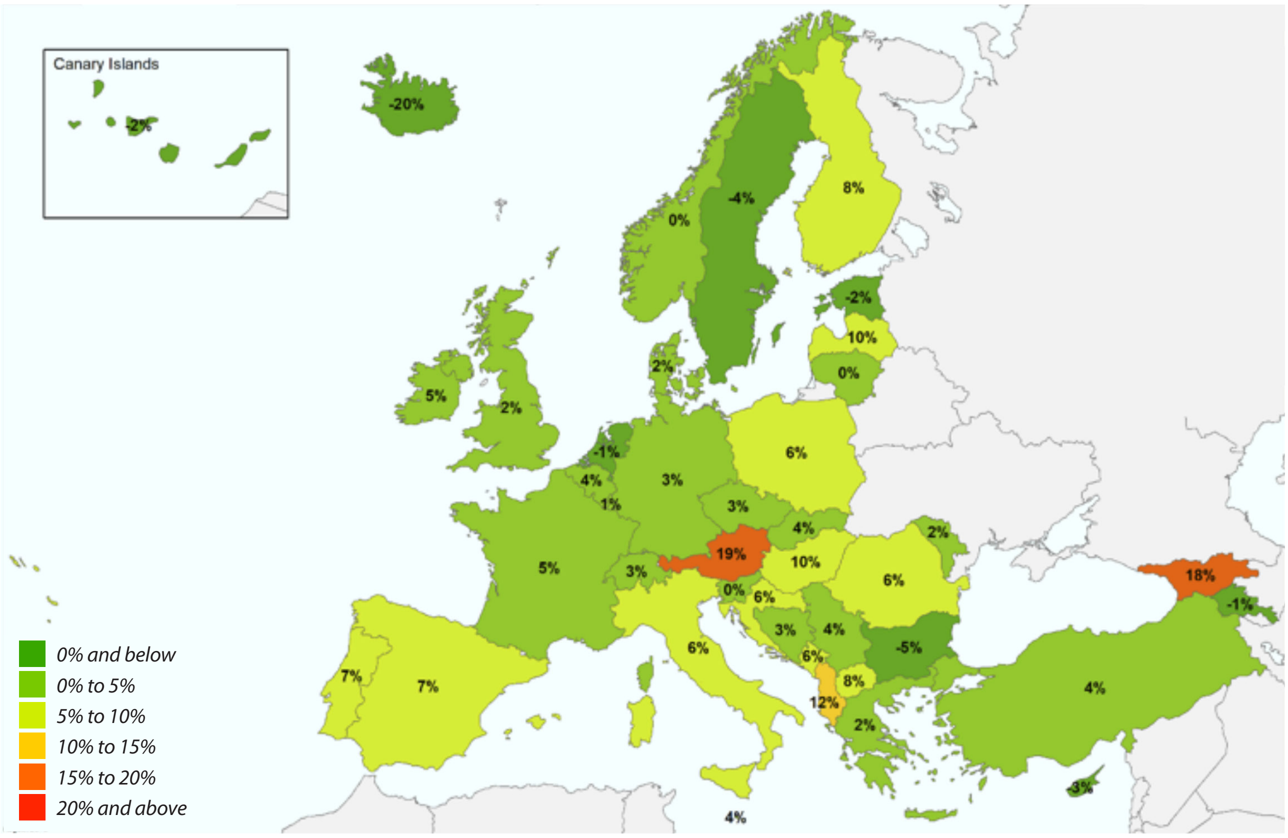
Air traffic growth just seems to be inexorable; it shrugs off economic downturns, terrorist attacks, extreme weather and even "great recessions" such as that of 2008-2009. Looked at over time, traffic growth is closely linked to GDP growth. As the world has become richer, the propensity to fly has grown. While average flights per head of population may be fairly steady in the developed world, a pool of untapped demand remains elsewhere. The traffic growth we have seen from Japan, South Korea, Singapore and most recently, China, points to what lies ahead. Moreover, business models have evolved. Who, twenty-five years ago, would have foreseen the rise of the Gulf Carriers as "super-connectors" or predicted that a small airline in Ireland would now be flying over 150 million passengers throughout Europe every year?

In the first six months of this year, flights departing airports in the countries on the map grew by 1.3% compared to 2018; but emissions increased by 3.4%. Swedish traffic dropped 6.1% and its emissions fell by 3.6%, influenced many believe by the "Flying shame" movement.

The chart on the next page shows the 44 ECAC States' CO_2 emissions from departing flights for the period 2005-2040, with historical values up to 2017 and three emissions forecasts covering 2017-2040.

Unless traffic characteristics change, improvements in technology to reduce emissions will not compensate for the emissions from the additional flights.

CO_2 EMISSIONS GROWTH IN JAN TO JUN 2019 DEPARTING FLIGHTS



"Air traffic growth is closely linked to economic growth"

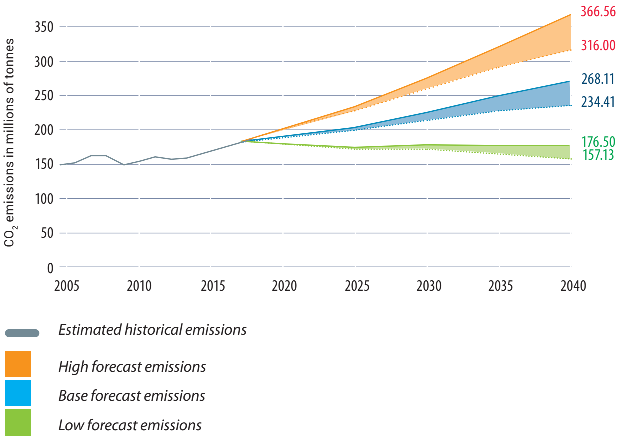
Comparison with other sectors

Aviation is not the biggest polluter in the transport sector. According to the latest figures from the International Energy Agency, transportation is responsible for 24% of direct CO_2 emissions from fuel combustion, with road vehicles accounting for almost 75% of that. Aviation and shipping emissions were very similar at about 11% of the transport total in 2018, but each less than one sixth the size of road transport overall.

External costs, such as climate change, are only partially covered by the transport sector, with aviation's average external costs in the EU28 slightly lower than those of a bus or coach, and over three times less than for a passenger car. Aviation also covers a far higher proportion of its infrastructure costs (82%) compared to the other sectors.

ECAC AREA - ESTIMATED CO_2 EMISSIONS BETWEEN 2005 AND 2040 (IMPACT)

IFR DEPARTURE FLIGHTS



Shaded areas show the emissions ranges between assuming technology remains frozen (upper solid lines) and assuming annual technology improvement of 1.16% incorporated into new aircraft deliveries (lower, dotted lines)

> *"Unless traffic characteristics change, improvements in technology to reduce emissions will not compensate for the emissions from the additional flights."*

TRANSPORT SECTOR CO_2 EMISSIONS BY MODE (BILLIONS OF TONNES (GT))

Sector / Year	2000	2005	2010	2015	2018
Passenger Road	2.5	2.9	3.1	3.5	3.6
Road Freight	1.7	1.9	2.1	2.3	2.4
Shipping	0.6	0.7	0.8	0.8	0.9
Aviation	0.67	0.73	0.74	0.87	0.93
Rail	0.1	0.1	0.1	0.1	0.1
Other	0.1	0.2	0.2	0.2	0.2
TOTAL	5.67	6.53	7.04	7.77	8.13

Source: International Energy Agency

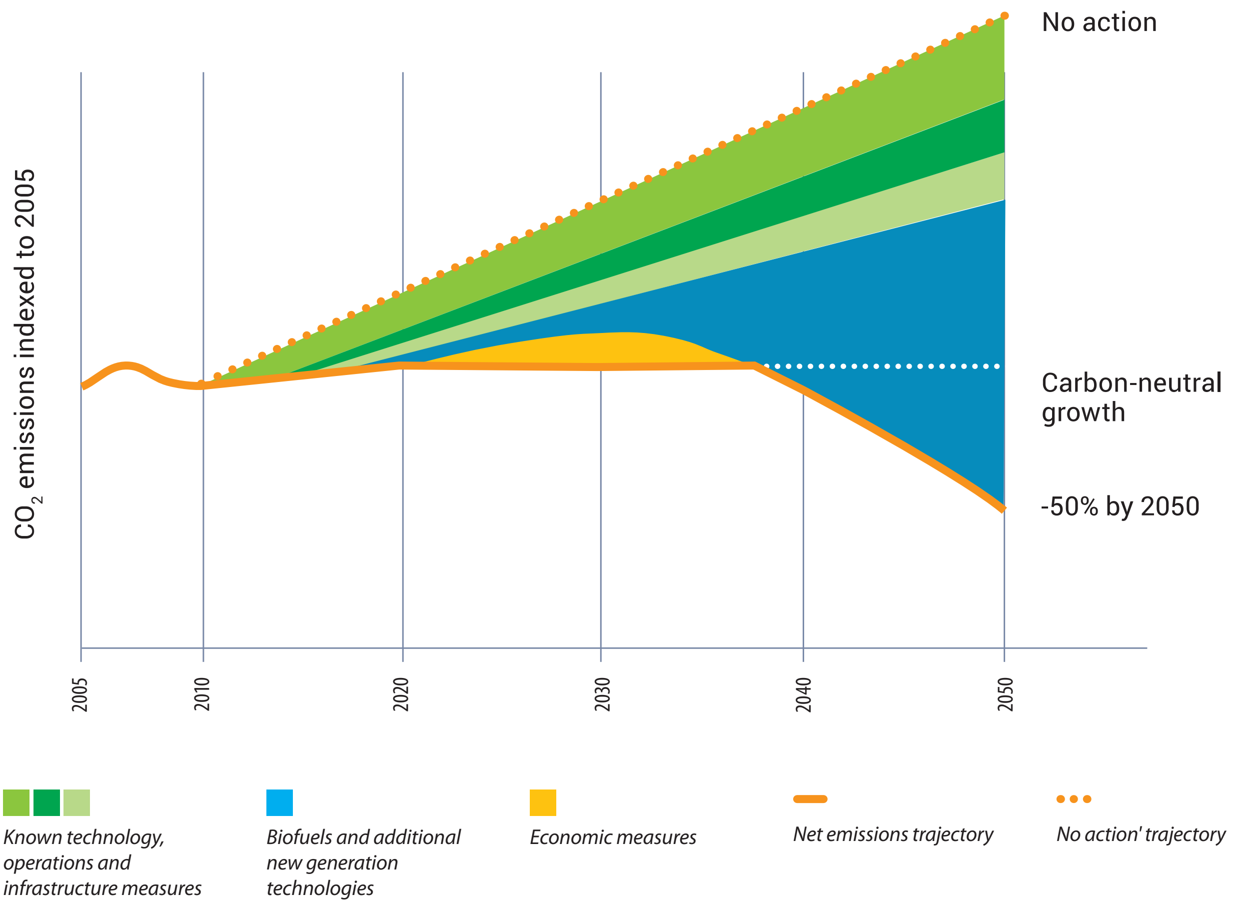
> *"Aviation covers 82% of its infrastructure costs – much more than other transport sectors"*

The “Basket of Measures” - Aviation’s Response

Aviation was the first industrial sector to set a target for CO_2 emissions reduction, pledging to introduce Carbon-Neutral Growth from 2020 (CNG2020) and aiming to achieve a 50% reduction of emissions by 2050 when compared to those emitted in 2005.

The aviation industry and its global regulator and standard setter, the United Nations’ International Civil Aviation Organisation (ICAO), have adopted a four-pillar approach to deliver on this. It is based on improvements in technology (airframes and engines), improvements to infrastructure and operations (so, make airport operations, air traffic control, airspace design and the way aircraft fly more efficient), market-based measures and the introduction of sustainable aviation fuels. This is known as the “basket of measures” and is shown below.

BASKET OF MEASURES



“The response to emissions needs to be global”

Technology

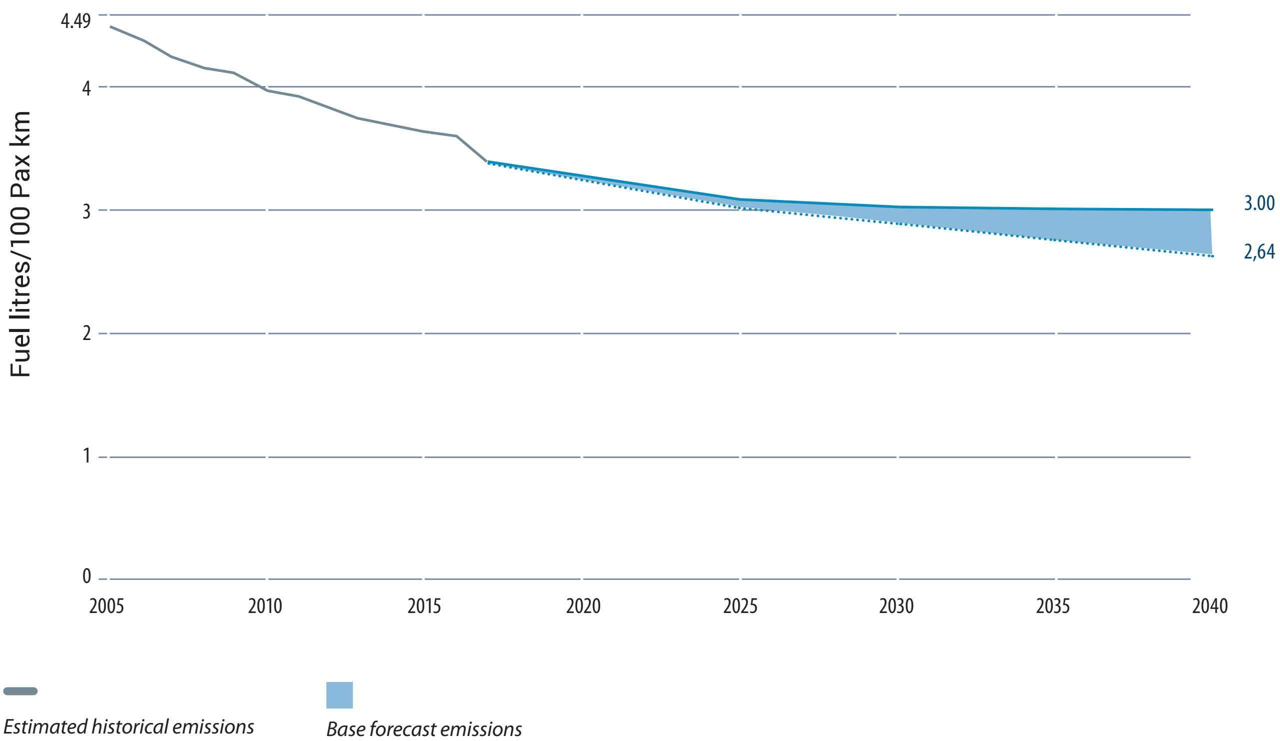
The drive to cut fuel burn and reduce emissions has been underway for many years. It has triggered massive investments by the industry and it is paying off. The latest generation of aircraft (e.g. A350, B787), powered by more efficient engines, burn about 15-20% less fuel than the aircraft they replace. This impact is seen in the graph below. Fuel burn per 100 passenger kilometres fell by 24% between 2005 and 2017, from 4.4 to 3.4 l/100km, and can be expected to improve further.

The last of the new generation of aircraft to enter into service will be the Boeing 777X early in the next decade. No firm plans have been announced for an airliner of the generation beyond, which would be expected to deliver a further 15-20% reduction in fuel burn and emissions. It is therefore difficult to predict what the efficiency of the fleet will be by 2040.

The new generation of aircraft will still be in production in 15-20 years' time. The last airframe off the production lines will be in service approximately 30 years after that, well into the second half of this century. So, there is built-in inertia to a radical "rollover" of the fleet. The introduction of substantially less polluting aircraft from, say 2030-2035, will have a gradual effect, unless there is a fleet replacement surge. This is one reason why the industry talks of a "basket of measures" - all of which are required to reduce net emissions.

ECAC AREA - FUEL EFFICIENCY BETWEEN 2005 AND 2040 (IMPACT)

IFR DEPARTURE FLIGHTS - BASELINE FORECAST



The shaded area show the possible range of emissions for the baseline forecast, assuming no technology improvements (upper line) and annual technology improvements of 1.16% incorporated into new aircraft deliveries (lower line)

"A system-wide sustainability approach is essential"

Operations

Average aircraft size is increasing, the proportion of seats filled per flight (load factor) is growing and the average distance flown is lengthening. These are all indicators of airline efficiency improvements.

Air Traffic Management can influence roughly 6% of aviation's emissions in Europe according to EUROCONTROL's latest Performance Review Report. Currently, the EUROCONTROL Network Manager is coordinating the introduction of "free route airspace" in the upper airspace, which it is estimated has already delivered 2.6 million tonnes of CO_2 emissions savings since 2014. EUROCONTROL is also developing a Joint Action Plan with the industry to encourage more continuous climb and decent operations. This could reduce CO_2 emissions by up to 1.1 million tonnes per year. The European Commission's Airspace Architecture Study, developed by the EUROCONTROL Network Manager and the SESAR Joint Undertaking, foresees a potential reduction of up to 13NM in distance flown per flight by 2035, translating into CO_2 savings of 30-60 million tonnes for the period 2019-2035.

Other operational improvements could eke out small savings here and there but once the vertical and horizontal profiles are optimised to the extent possible, the amount of emissions that ATM can influence will be small. Overall, the additional emissions generated by a few years of traffic growth could be equal to the savings delivered by ATM.

Market-Based Measures

The EU Emissions Trading System is applicable to flights in the European Economic Area, with a cap based on average emissions in 2004-2006. It has been estimated that the net reduction in aviation-related emissions for the years 2013-2020 will be approximately 193 million tonnes of CO_2.

ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) requires monitoring of fuel consumption on international flights starting on 1st January 2019. By 2027, CORSIA will be compulsory for all international flights between States not exempted from the scheme (small island developing nations and least-developed States principally). The CORSIA emissions baseline is the average of 2019-2020 emissions from international air traffic. Although the EU ETS baseline can be considered as more constraining as it was set when emissions were lower, CORSIA does have the advantage of being applied worldwide. CORSIA could potentially mitigate around 2.5 billion tonnes of CO_2 and could generate approximately $40 billion of climate financing by 2035.

EU CARBON PRICES
(EUROPEAN CO_2 EMISSIONS ALLOWANCES)

Sustainable Aviation Fuels (SAF)

There is pent-up demand for SAF but very limited supply at a price point that would attract buyers.

Nevertheless, progress is being made. Some EU States are starting to introduce targets for aviation biofuel use, with ambitions up to a 30% share by 2030. United Airlines, KLM and British Airways are investing in sustainable fuels production and are committed to purchasing SAF over the coming years, but this will only cover a small proportion of their flights.

Potential alternative power sources are hydrogen fuel cells and electrofuels, in which water is electrolysed to extract its hydrogen, which is then combined with CO_2 captured from the atmosphere to produce a drop-in liquid hydrocarbon fuel. But both require significant new infrastructure and, as their production processes are energy intensive, this would need to come from renewable sources to make sense. These are potential sustainable fuel sources from the 2030s at the earliest.

"Free Route Airspace has delivered 2.6 million tonnes of CO_2 savings since 2014"

Future Outlook

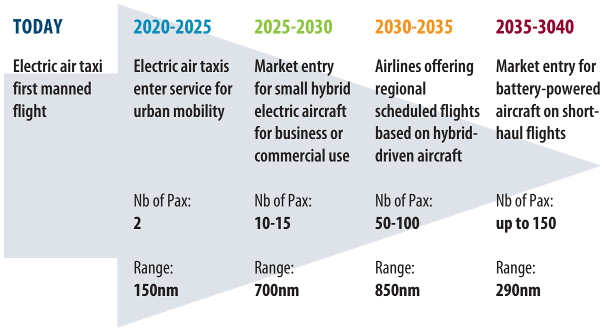
It will be challenging to reduce aviation emissions quickly with currently available technologies. While the ETS and CORSIA encourage airlines to reduce emissions, the offsetting process reduces emissions elsewhere rather than directly in the sector, but does count towards net reductions for aviation. Similarly, SAF based on biomass feedstock will also reduce aviation's net emissions. However, the move to SAF represents a major technological shift with considerable transition costs, and it is difficult to see how the industry can achieve a significant uptake of SAF without government support.

From the constructors' perspective, there is the challenge of developing new airframes that may look unfamiliar in the search for considerably improved efficiency. Examples of research include: a V-shaped variation on the flying wing; the transonic truss-based wing; laminar flow; boundary layer ingesting engines; bio-inspired wing design and even free-folding wingtips. But all of this will take time to test through to successful certification, probably not before 2030.

Engine and airframe manufacturers are deeply involved in researching the electrification of propulsion systems. New design and manufacturing possibilities could lead to improved propulsion/fuselage integration to meet both efficiency and noise reduction goals.

Small aircraft are already being flown under hybrid and battery power. Such pioneering initiatives will help build the critical experience and confidence to pursue a deeper penetration of electric flight.

The drone and Unmanned Aerial Vehicle industries can be expected to throw up innovations. Some start-ups, such as Lilium, have already received impressive seed funding. They are driving new concepts such as Urban Air Mobility and pursuing rapidly improved battery performance. Aviation should also benefit from the rapid electrification of the automobile industry in which improved battery energy density is the key to alleviating range anxiety. A possible technological path for the electrification of aviation is shown below.



Source: IATA

The question is whether progress on Sustainable Aviation Fuels, airframe and propulsion technologies can come quickly enough.

Outlook for ATM

The additional distance flown horizontally along a route in Europe was just 2.7%, despite the increase in traffic. Network improvements mentioned in this paper should further improve horizontal and vertical flight profiles. Realistically, ATM's "benefit pool" is finite and will eventually run dry, as efficiency improvements currently planned are delivered. Indeed, it may be challenging in itself to maintain efficiencies as traffic grows.

ATM's long-term contribution to decarbonising aviation will increasingly turn, therefore, to ensuring the safe introduction of new types of highly efficient aircraft into increasingly congested airspace and airports, so that neither a drop of SAF, nor a kilowatt-hour of electrical energy, is wasted.

In parallel, ATM may have a further role to play in reducing the "non-CO_2 impacts" of aviation, for which the scientific community is gathering evidence. However, in Europe, the "route charges" system, through which aircraft operators pay for air traffic control-related services, could be used to incentivise "cleaner, greener" flights. This is perhaps an underappreciated tool that ATM could use to support decarbonisation of our industry.

"Incentives to use sustainable aviation fuels are needed"

Five top things to do

Decarbonising aviation is arguably the greatest challenge facing the air transport industry. If decision-makers had to choose just five top things to do to achieve net zero carbon aviation by 2050, they should focus on the following:

1	Change the European Air Traffic Management network, and encourage environmental improvements through provision of shorter and better routes.
2	Support the rapid transition to the widespread use of Sustainable Aviation Fuels for long-haul flights in particular. SAF is too expensive and we must incentivise its production and use.
3	Develop highly-efficient, large-capacity, short-haul aircraft to handle passenger throughput.
4	Undertake a total fleet renewal by 2050 so that aircraft only fly if they are wholly or partly electric, or for long-haul flights only use SAF.
5	Bridge the gap to electrification of short-haul passenger aircraft through hybridisation and improving battery energy densities, while developing hydrogen fuel-cell and electrofuel technology and infrastructure.

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