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Aviation is an industry on the cusp of change. As a hard-to-abate sector, aviation is embarking upon a transition to non-fossil fuels to reach net-zero by 2050. According to IATA (2021a), the contribution to achieving net-zero carbon emissions by 2050, will come from

- use of SAF (65%)
- offsetting/carbon capture (19%)
- new technology including alternative aerodynamics & propulsion systems (13%)
- improved infrastructure with focus on air traffic management (ATM) (3%).

Of these, the top contributors to net-zero emissions, SAF and carbon markets are immediately actionable solutions – although in early stages of deployment.

The carbon market is seen as a transitional solution, while SAF is regarded as the long term path to carbon-neutrality.

NET-ZERO

IATA updated the industry-wide goal to reach net-zero by 2050 or sooner. While airlines and OEMs have always **aimed for efficiency** and **delivered on fuel reduction**, the industry now has unifying goals and mandates for carbon emissions and SAF. According to IATA, the first milestone to reach net-zero is the abatement of 381 megatonnes of CO_2 by 2025. This reduction is expected to come from offsets (97%), SAF (2%), and improvements above business as usual (1%). By 2050 offsets are expected to drop to 8% and SAF to increase to 65% (IATA, 2021a). More solutions (innovative technology reducing fuel burn, hydrogen aircraft, new infrastructure) will join the pathway to net-zero; the immediate focus is on **offsetting carbon** and **SAF**. This paper aims to **quantify the cost differences** between SAF and carbon offsets at an asset level.

CARBON OFFSETTING

The two central carbon offsetting programs in aviation are the EU Emissions Trading Scheme (EU ETS) and the UN Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). EU ETS covers flights landing and taking off in the European Economic Area (EEA). CORSIA covers international flights between member states. They are separate schemes.

EU ETS (revised regularly & now in phase 4: 2021-2030) is the world's largest carbon market, based on a **cap-and-trade** scheme. A cap is set on emissions, benchmarked on the verified tonne-kilometer data from 2010, and **emission allowances** are distributed for **free** and through **auction**. Airlines able to reduce emissions can trade unused allowances or buy additional emission units if they exceed their allowances. In 2021 82% of allowances were free, 15% were auctioned, and 3% were saved for new or fast-growing airlines. In the revised EU ETS directive, free allowances will be fully phased out before 2027. Furthermore, the cap will be reduced gradually by an annual rate of 4.2% (current 2.2%) so that even fewer allowances will be issued in the future. These actions will significantly increase the cost of carbon for EU airlines, which is expected to stimulate emissions reductions within the sector.

CORSIA was updated to cap emission at the 2019 international aviation level (~600million tonnes CO_2) starting in 2021. All emissions above this baseline are to be offset. Under CORSIA, offsetting obligations are voluntary until 2026 and mandatory from 2027. Airlines buy carbon credits from projects (wind farm, forestry) recognised by CORSIA and other international agencies. So far, evidence suggests an oversupply of carbon offset credits in CORSIA's pilot phase (2021-2023) which has been interpreted – together with the low cost of credits – as unlikely to lead to emissions reductions within the sector (Transport and Environment, 2021). The review of CORSIA in 2022 will examine the impact of COVID-19 on the scheme.

CARBON MARKET

The market dictates the pricing of carbon. One carbon credit gives the airlines the right to emit one tonne of CO_2 (tCO_2). In the EU carbon market, the CO_2 prices have hovered around €60 since September 2021. Projected carbon prices range between €85 to €120 by 2030 (EC, 2021; OECD, 2021) and are estimated to reach ~$300 by 2050 (World Bank, 2019).

Another suggestion is that reaching the Paris Agreement objective of keeping warming below 1.5°C require global carbon prices to rise at \$600-\$800/tCO_2 in 2010 US\$ (Oxford Economics, 2021).

SAF MARKET

Current SAF prices trade between 2x and 5x that of Jet A-1 fuel (World Economic Forum, 2021). The SAF price is projected to drop with the help of supportive policies, scaled-up production and increased market competition. There are multiple challenges regarding scalability, such as developing the production process and a blueprint for efficient factories. Several SAF mandates were issued globally, but not all regions benefit from supportive policies. Most supportive policies are in the US. Until the SAF market overcomes these obstacles, carbon offsetting is seen as a bridging solution.

SAF and carbon credits cost comparison for single-aisle aircraft – A320NEO

While SAF and carbon offsetting are being discussed at an absolute level for the whole industry, their costs are not easy to compare as they are applied differently. SAF cost is in USD per gallon; a carbon credit is priced per tonne CO_2. For simplicity, we assume a set of conditions: a single asset type (A320NEO) with an average annual utilisation rate at 9 flight hours per day or equivalently an average of 4.5 flight cycles per day, each cycle consisting of a two-hour flight. The aircraft is assumed to have full economy seating capacity and 80% load factors.

This simulation investigates the cost of reducing CO_2 emissions by 10% for an A320NEO aircraft. Two reduction scenarios are achieved via **SAF** or **carbon offsets**. Carbon is priced at three levels: average current values on the EU ETS market of ~€60 (2021), €100 in medium-term (2030) and €250 in long term values (2050), or equivalently, \$70, \$115, and \$290. For current values, SAF is estimated at ~\$4.00/gallon, and Jet A-1= \$76.6/bbl~\$1.80/gallon — its average price in 2021 (IATA, 2021b). By 2030, the difference between SAF and fossil fuel is assumed to drop by 40% — in line with the view on future SAF prices of the World Economic Forum (2021). By 2050, the difference between SAF and fossil fuel is assumed to drop by another 40% — a more conservative view than that of SAF producers who envisage equal prices for fossil fuel and SAF by 2050. SAF is assumed to contribute to 80% CO_2 emissions reduction in its lifecycle.

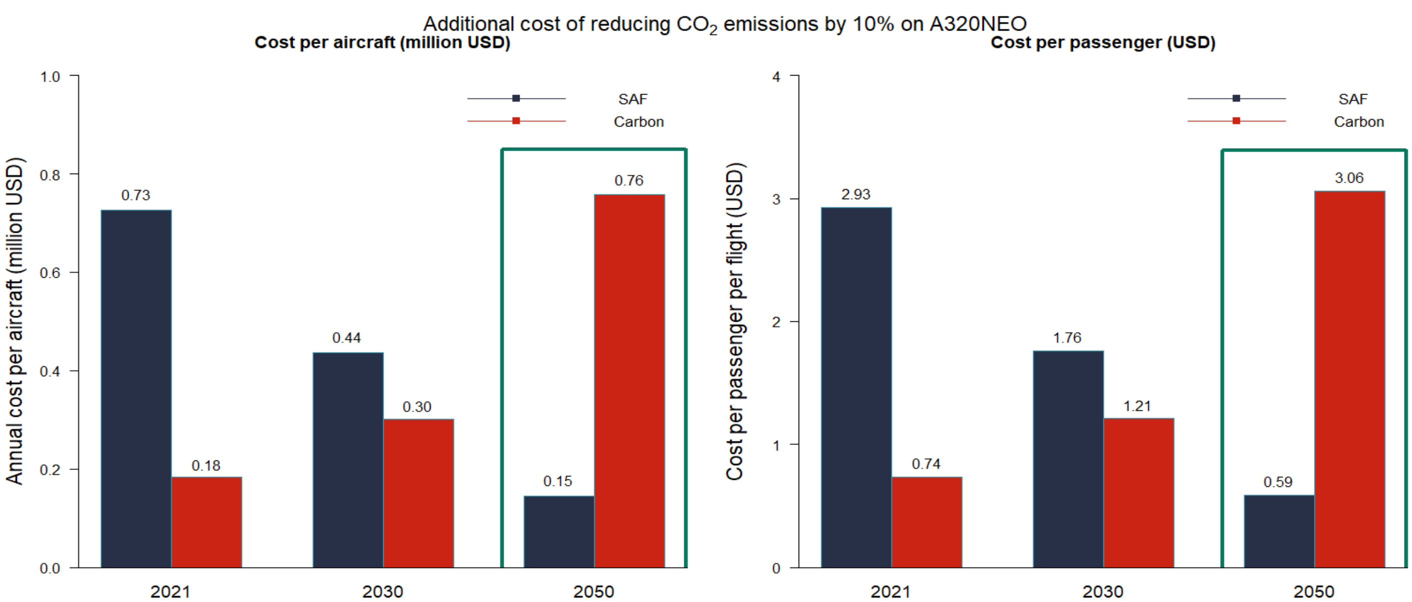

*Figure 1. The **additional cost** is estimated at three points: at present, when carbon trades at ~\$70, in 2030, when carbon is estimated to exceed \$100 per tonne CO_2 and in 2050 when carbon is assumed to be close to \$300 per tonne CO2. The additional cost of SAF for an A320NEO is ~\$750k per aircraft annually, or ~\$3 per passenger per flight. In contrast, the carbon offsetting costs \$0.18 million per aircraft or \$0.74 per passenger. **The current gap in scale is significant.** The two costs become similar after 2030, and by 2050 the cost of carbon offsetting may increase above that of SAF.*

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Conclusion

A successful solution requires the combined results of both carbon offsetting and the use of SAF.

Currently, the cost of SAF exceeds that of carbon pricing by a 4x factor. However, as SAF production scales up and the price gap between SAF and fossil fuel reduces, SAF will be a cheaper solution to CO_2 emission reduction in the long term.

This study proposes empirical evidence based on simplified assumptions. In reality, more factors will come to play a role in CO_2 emission reductions. This study **explores the contrast in magnitude** between the cost of SAF versus carbon offsets at an asset level. These results confirm the view that **carbon offsetting is a bridging solution until the SAF production scales up** and SAF becomes available in large quantities and at a price comparable to that of fossil fuel.

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