

ASSESSING AIRLINE PURCHASE MOTIVATION FOR HYDROGEN AIRCRAFT UNDER FUTURE CORSIA

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Abstract

The central question motivating this study is how regulatory frameworks may shape airline purchase motivation toward hydrogen aircraft. The International Civil Aviation Organization (ICAO) has committed international aviation to net-zero CO_2 by 2050 via the Long-Term Aspirational Goal (LTAG), primarily driven by four measures: scaling up Sustainable Aviation Fuels (SAF), introducing new aircraft technology, optimizing operational improvements, and utilizing market-based measures. The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which enters its mandatory Phase II in 2027 and shifts to an 85 % sector-growth / 15 % operator-growth allocation in 2033, will be the dominant global market-based instrument for net-zero during the time when the first hydrogen-powered regional aircraft are expected to enter service. Against this regulatory backdrop, this paper examines whether the offset-cost structure of future CORSIA, combined with SAF blending mandates, is sufficient to motivate airlines to purchase hydrogen aircraft. Using an ATR72-class regional mission as a reference, we quantify per-flight fuel demand, life-cycle CO_2 emissions, and CORSIA offset obligations for (i) a Jet-A baseline, (ii) a 2 % HEFA blend, (iii) a 20 % HEFA blend, and (iv) a liquid-hydrogen fuel-cell retrofit. We then map the parameter space of hydrogen price and credit price to identify break-even regions. Two findings stand out. First, on a per-passenger basis, a green-hydrogen regional aircraft is statistically tied with a 20 % SAF blend on a conventional ATR72, at approximately 43 kg of CO_2 per passenger; it could be said that hydrogen's strategic value rests on long-run SAF feedstock limits rather than on absolute emissions intensity. Second, airline purchase motivation for hydrogen aircraft could be contingent on the availability of alternatives — SAF blending in-sector and CORSIA credits out-of-sector. Although the finite supply of both is already well documented, both remain practically available and politically uncontested at present, and are therefore not reflected as binding constraints in the cost model used here, which weakens the present-day economic case for hydrogen aircraft in the result. Even at the optimistic Transformative bound (LH_2 at USD 6/kg, credit at USD 80/t), the per-flight fuel-and-offset bill rises to roughly 2.5× the present-day Jet-A cost before CAPEX is included. Decarbonizing aviation in-sector is therefore expensive. The aviation industry's task is therefore the dual one of pursuing in-sector reductions at a credible pace while preserving aviation as a mobility option for the populations who depend on it.

Keywords: hydrogen aircraft, CORSIA, sustainable aviation fuel, regional aviation, airline economics

1. Introduction

Commercial aviation currently accounts for around 2 % of global anthropogenic CO_2 emissions, and

this figure is expected to increase as demand for air travel is predicted to grow until 2050. At the 41st ICAO Assembly in 2022, member states formally endorsed the Long-Term Aspirational Goal (LTAG) of achieving net-zero CO_2 emissions from 2050. This target had been adopted by the International Air Transport Association (IATA) one year earlier. To achieve this, four measures must be combined: scaling up SAF, introducing new aircraft technology such as hydrogen and electric flight, optimising operational improvements, and utilising market-based measures principally CORSIA and regional emissions-trading schemes.

Among these measures, SAF is widely considered the near-term workhorse among these measures, but its long-term contribution is constrained by feedstock availability, production capacity and high production cost. Conversely, hydrogen-powered aircraft, particularly fuel-cell–based regional aircraft, are viewed as promising mid-to-long-term solutions among the decarbonized technologies under active development (Fig. 1). Hydrogen is the most abundant chemical element on Earth and can be produced from carbon-free electricity through water electrolysis. However, hydrogen aircraft face severe system-level penalties: cryogenic storage is bulky, tank mass reduces payload, and the price of green hydrogen in 2025 is an order of magnitude higher than Jet-A on a unit-energy basis.

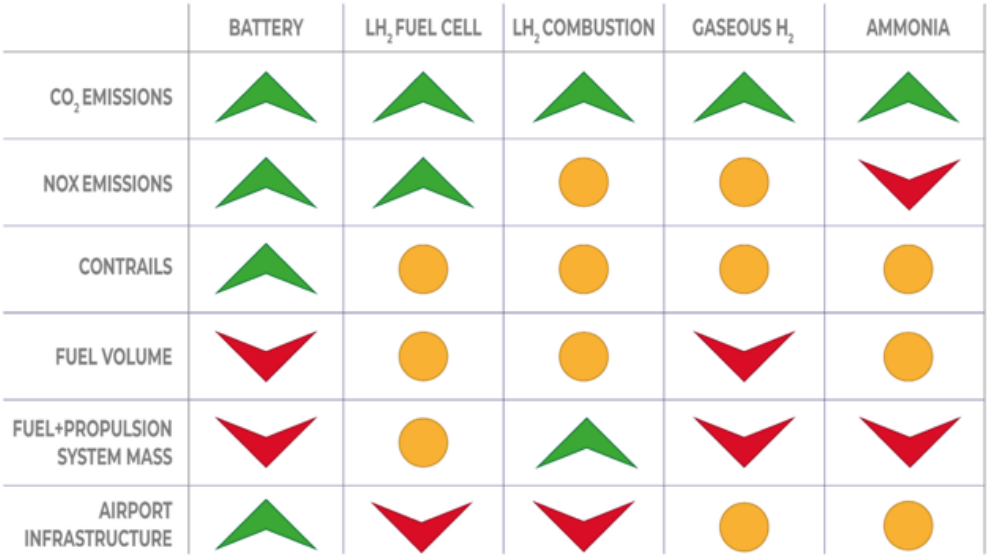


Figure 6 – Zero-carbon emission aviation fuels, initial assessments for FlyZero scope focus market.

Figure 1 –Zero-carbon emission aviation fuels, initial assessments for FlyZero scope focus market (adopted from [3])

The motivation for this study is one step removed from the airline operating decision. Aircraft manufacturers do not launch new programs unless they can see a market for the resulting aircraft. Hydrogen aviation is currently in a TRL-uplift phase, supported by national and supra-national programs that fund demonstrators and integrated ground tests. That phase cannot continue indefinitely; at some point an OEM has to take a launch decision and commit to type certification, which depends on confidence that airlines will see purchase motivation when the aircraft enters service. This paper therefore asks; under future CORSIA rules, and accounting for parallel SAF mandates, will an airline have an economic motivation to replace a conventional regional aircraft with a hydrogen-powered one? While prior research has compared the lifecycle environmental impacts and operational costs of hydrogen versus conventional aircraft (ex. [4-5]), few studies have examined the adoption feasibility from the perspective of airline purchase motivation under realistic policy environments. This study

addresses this gap by integrating previous research approaches with detailed modeling of future carbon-pricing schemes. I constructed a per-flight cost model for a representative ATR72-class regional mission, varying the key uncertain parameters (SAF blending ratio, credit price, hydrogen price, SAF price, sector-growth factor) and mapping the regions of parameter space in which hydrogen becomes cost-competitive. The analysis focuses on the late 2030' horizon because this is when the first certified hydrogen regional aircraft are expected to enter service.

The remainder of the paper is organized as follows. Section 2 summarizes the CORSIA architecture and the concurrent SAF and carbon-pricing instruments. Section 3 reviews current hydrogen-aircraft development. Section 4 describes the per-flight model and its assumptions. Section 5 presents CO_2 and offset results. Section 6 performs the break-even cost analysis. Section 7 examines per-passenger emissions and the link to the UK SAF-mandate carbon-value framework. ection 8 discusses the implications of these results for the OEM launch decision and for the dual industry task, and Section 9 concludes.

2. Policy Landscape Around 2035

2.1 The CORSIA architecture

CORSIA was agreed at the 39th ICAO Assembly in 2016 and is being implemented in three phases. The pilot phase (2021–2023) and Phase I (2024–2026) are voluntary, while Phase II (2027–2035) is mandatory for all ICAO member states[1] with the exception of routes serving the least-developed countries and a small set of humanitarian, medical, and fire-fighting operations. An airline's annual offset obligation OR_Y in year y is computed from measured, reported and verified (MRV) emissions after a three-year compliance cycle; the obligation must then be discharged using CORSIA-Eligible Emissions Units (EEUs). Here, EEUs are specific types of carbon credits that airlines buy and "cancel" to meet their carbon-neutral growth targets. The credits come from projects of other industries such as reforestation, renewable energy plants, or methane capture from landfills. There is a rigorous system to approve the credits as EEUs so it is said that there is not enough EEUs at the coming Phase II.

CORSIA-eligible SAF can be deducted from the obligation on a life-cycle basis, but it is not treated as zero emission.

Between 2033 and 2035 the obligation formula shifts to an 85 % sector-growth / 15 % operator-growth weighting:

$$OR_y = 0.85 \cdot OE_y \cdot SGF_y + 0.15 \cdot OE_y \cdot OGF_y \qquad (1)$$

where OE_Y is the operator's covered emissions in year y, SGF_Y is the sector-wide growth factor, and OGF_Y is the operator-specific growth factor. For 2033–2035, IATA currently anticipates SGF in the range 24.6 – 32.4 %(Fig. 2) [6]. According to ICAO's explanatory materials, the OGF is stated as 4.6%. An operator that adopts a effective decarbonization strategy may reduce its own growth in CO_2 emissions (OGF → 0) but still carries the sector-wide 85 % component [7].

[1] More precisely, countries with a certain level of involvement in international aviation activities are subject to mandatory requirements.

Figure 1: IATA CORSIA SGF Forecast (September 2024)

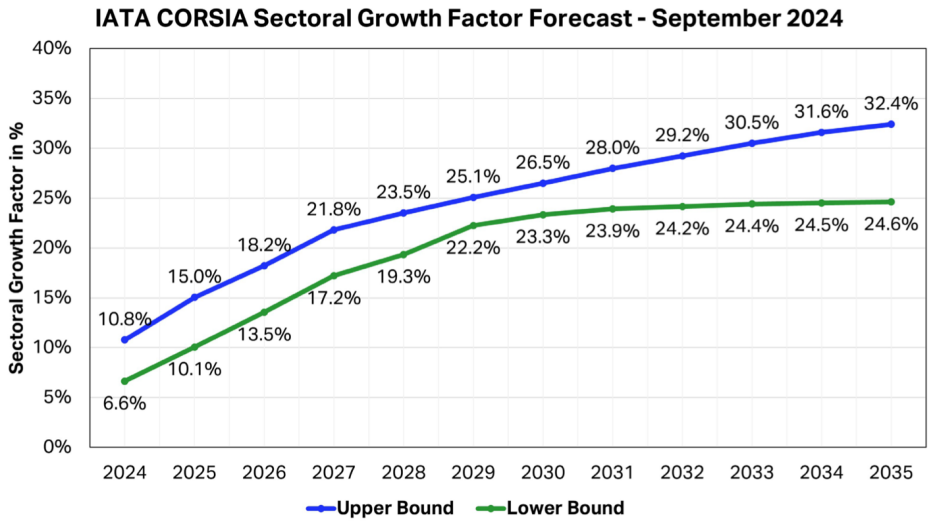


Figure 3 – IATA CORSIA SGF Forecast (as of 2024) [6]

2.2 SAF blending mandates

CORSIA does not operate in a vacuum. Another policy stream will simultaneously shape airline economics. It is SAF blending mandate. ReFuelEU Aviation mandates a minimum SAF blend at EU airports, ramping from 2 % in 2025 to 20 % by 2035 and beyond. Fuel suppliers who fail to meet the mandate pay a fine of at least twice the price gap between SAF and fossil kerosene per tonne of missing SAF. In parallel, the aviation EU ETS finishes the phase-out of free allowances by 2026, so from that year onwards every tonne of CO_2 on an intra-EEA flight is a direct cash cost at the prevailing ETS price. This mandate for SAF blending is expected to spread worldwide. It is considered crucial for increasing the availability of SAF—that is, for encouraging companies to invest in SAF production facilities. The United Kingdom's SAF mandate (2025–) uses a buyout mechanism set at roughly £4.70/L, equivalent to about £6.7/kg of SAF, calibrated so that real SAF supply remains cheaper than buyout.

For an airline evaluating hydrogen, these instruments matter in two ways. First, they raise the effective cost of conventional fuel — directly via ETS and indirectly via SAF-mandate pass-through. Second, they create a reference price for low-carbon energy: the UK buyout price of £6.7/kg SAF, or equivalently about €7.5/kg, is a floor below which a low-carbon fuel (including hydrogen, measured on an energy-equivalent basis) can in principle displace SAF in the supplier's compliance mix.

3. Hydrogen Aircraft: State of Development

Three zero-carbon energy vectors are currently assessed by OEMs and national programs: batteries, ammonia and hydrogen. The UK FlyZero study concluded that batteries are attractive on emissions grounds but suffer from low specific energy; gaseous hydrogen has an earlier route to market than liquid hydrogen but its heavy tanks confine it to short-range aircraft; ammonia is close at a fuel-production-infrastructure level but its payload/range is inadequate for mainline aviation. Green liquid hydrogen — used in fuel cells, gas turbines or hybrid architectures — emerges as the most plausible alternative fuel for regional and possibly short-haul single-aisle missions.

Several development programs are now past the early-concept stage. In the United States, ZeroAvia

received a signed FAA G-1 and, in August 2025, a P-1 issue paper for its 600 kW electric propulsion system, and in November 2025 obtained a UK CAA design-organization approval [8] (Fig. 4). Joby Aviation, with its subsidiary H2Fly, demonstrated a 523-mile hydrogen-electric concept flight in 2024 and is targeting in-service entry around 2030 [9] (Fig. 5). In Europe, Airbus's ZEROe program has been re-baselined to a late-2030s entry into service, with a revised configuration using four 2 MW electric-propulsion engines fed by two liquid-hydrogen tanks via four fuel-cell systems, and integrated ground testing planned for 2027 at Munich [10] (Fig. 6). Rolls-Royce has run Pearl 15 combustor tests on hydrogen and, with easyJet, Heathrow and UCL, published a December 2025 study arguing that concentrating hydrogen refueling at roughly 20 large European airports could unlock more than 80 % emissions reduction on European flows. Conscious Aerospace, with an €73.3 M grant under the Dutch Luchtvaart in transitie program, is retrofitting a De Havilland Canada Dash 8-300 with a 1.7 MW LH_2 fuel-cell powertrain.

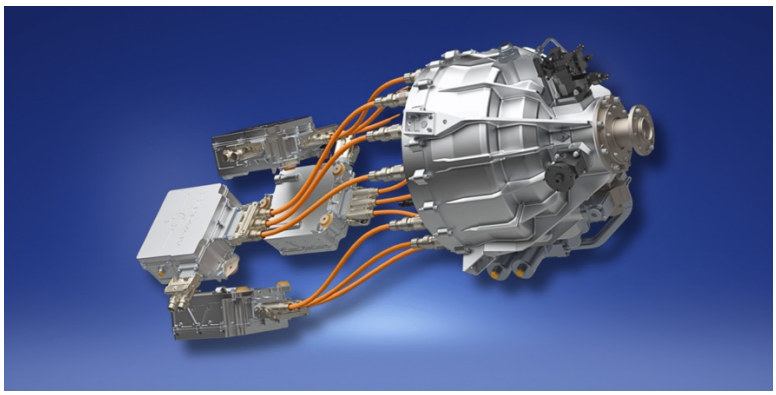


Figure 4 – ZeroAvia 600kW Electric Propulsions System with the P-1 issue paper [8]



Figure 5– Joby's hydrogen-electric technology demonstrator [9]



Figure 6 –Airbus ZEROe aircraft [10]

4. Per-Flight Model

4.1 Reference mission

I use a representative ATR72-600 regional mission, consistent with Airbus Japan public-domain data, as the baseline [11] (Fig. 7). The mission consumes 896 kg of Jet-A. Using a Jet-A energy density of 46.2 MJ/kg, this corresponds to a chemical-energy input of 41.4 GJ. Assuming a gas-turbine propulsive efficiency of 0.4, 16.6 GJ of propulsive work is required. We assume the same propulsive-energy requirement for the LH_2 fuel-cell aircraft and adopt a whole-system LH_2-to-propulsion efficiency of 0.4 (consistent with fuel-cell + motor + tank-to-prop losses), so total LH_2 chemical energy is 41.4 GJ. With an LH_2 lower heating value of 141.8 MJ/kg, this equals 292 kg of hydrogen per flight.

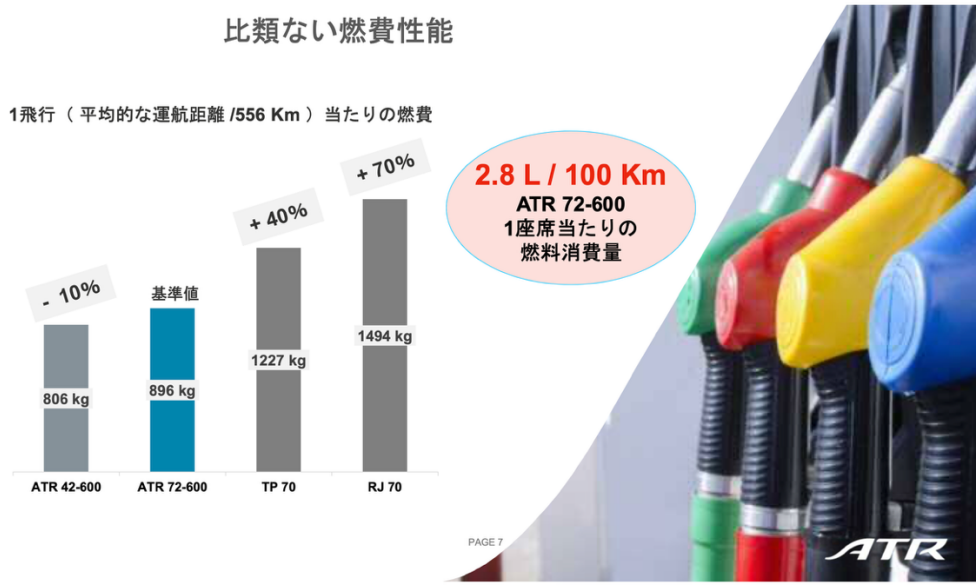


Figure 7-ATR 72-600 fuel consumption for a typical flight [11]

4.2 Emission factors

Following ICAO default values and [5], we adopt the well-to-wake factors shown in Table 1. Green hydrogen is taken at 41.3 gCO_2/MJ and grey hydrogen at 75.6 gCO_2/MJ [5].

Fuel	CO_2 intensity [g/MJ]	Source
Jet-A	89.0	ICAO default
HEFA SAF	13.9	ICAO default
Green H_2	41.3	[5]
Grey H_2	75.6	[5]

Table 1 – Well-to-wake CO_2 intensity of the fuels considered.

4.3 Cost inputs and scenarios

Fuel and credit prices are bundled into three scenarios intended to span the plausible 2035+ envelope. The “Current” scenario corresponds to 2025 reference prices. The “Moderate” scenario assumes that hydrogen production scales but SAF remains tight. The “Transformative” scenario assumes ambitious hydrogen deployment and sustained high carbon prices consistent with the UK carbon-value framework. Fuel masses in the Jet-A + HEFA blends are computed on an energy-equivalent basis to deliver the same 41.4 GJ mission energy (Table 2).

Scenario	Jet-A [USD/kg]	HEFA [USD/kg]	Green H_2 [USD/kg]	CORSIA Credit [USD/t]
Current (2025)	0.81[2]	2.29[2]	32.9 [3]	21.7[4]

[2] https://www.easa.europa.eu/en/document-library/general-publications/2024-aviation-fuels-reference-prices-refueleu-aviation
[3] https://stillwaterassociates.com/2025-cost-showdown-for-drivers-is-hydrogen-fuel-cheaper-than-gasoline/
[4] https://www.iata.org/en/pressroom/2025-releases/2025-01-22-01/

Moderate (2035)	0.81	1.74[5]	10.0 (original)	25.0 (original)
Transformative (2035+)	1.42[6]	3.00 (original)	6.0 (original)	80.0 (original)

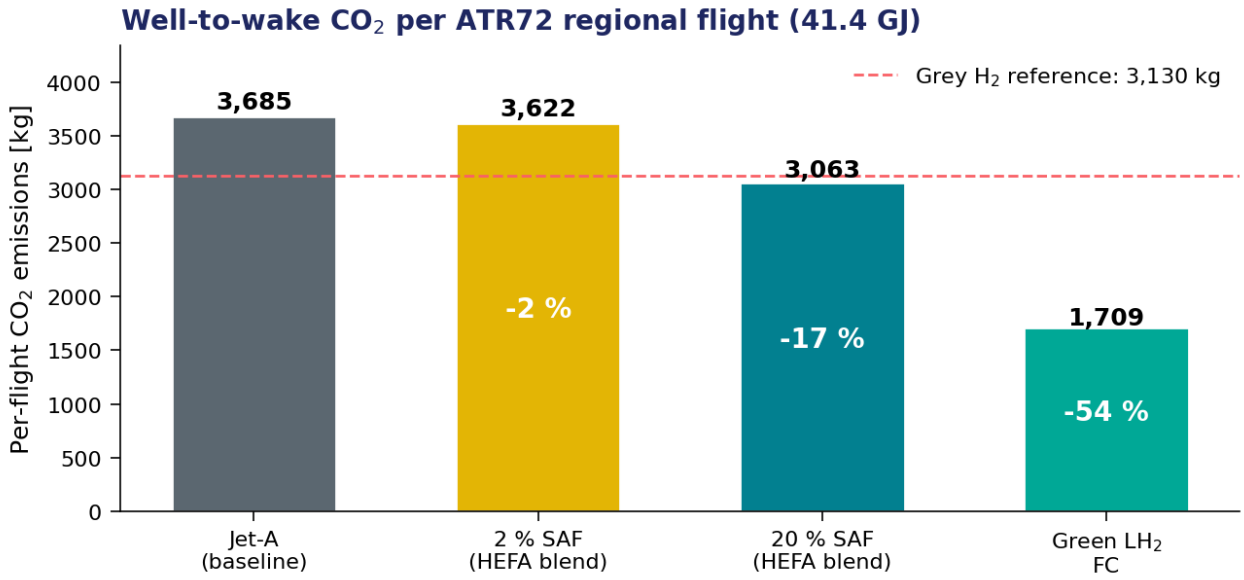
Table 2 – Fuel and credit-price scenarios used in the analysis.

4.4 How the regulatory framework enters the model

Each policy instrument introduced in Section 2 enters the per-flight cost model through one of two channels. CORSIA enters the *carbon-cost channel*: per-flight CO_2 emissions are multiplied by the offset ratio implied by Eq. (1) and by the prevailing CORSIA credit price to give an offset cost in USD per flight. ReFuelEU and the UK SAF mandate enter the *fuel-cost channel*: by mandating a minimum HEFA share in the conventional fuel mix, they raise the conventional fuel bill per flight, since HEFA is more expensive per kg than Jet-A. The aviation EU ETS, where applicable, would enter the carbon-cost channel as a second term alongside CORSIA, but is excluded from the present analysis to keep the focus on the global regulatory question. The break-even maps in Section 6 then treat the CORSIA credit price and the green-hydrogen price as the two free axes of the regulatory-cost space, with the SAF mandate fixed at either 2 % or 20 %.

5. Per-Flight CO_2 and Offset Results

Applying the emission factors to the per-flight energy of 41.4 GJ gives the CO_2 footprints plotted in Figure 8. The Jet-A baseline emits 3,685 kg of CO_2. A 2 % HEFA blend reduces this by about 1.7 % to 3,622 kg — a small decrement because only the SAF fraction benefits from the 13.9 g/MJ factor. A 20 % HEFA blend reduces emissions to 3,062 kg, a 17 % reduction relative to Jet-A. The green-hydrogen fuel-cell aircraft emits 1,709 kg, a 54 % reduction relative to Jet-A and a 44 % reduction relative to the 20 % SAF blend. If the hydrogen were grey (75.6 g/MJ), the saving would collapse to about 15 % relative to Jet-A — close to the 20 % SAF blend and insufficient to justify the capex jump.



[5] https://www.carbon-direct.com/insights/how-saf-mandates-in-the-eu-and-uk-are-reshaping-aviation-fuel-markets

[6] The most expensive fuel price record during 2010' according to https://www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet-fuel/

Figure 8 – Per-flight CO_2 emissions for the ATR72-class mission.

Figure 9 converts these emissions into CORSIA offset obligations under the 2033–2035 formula. CORSIA offset obligations do not apply to the total CO_2 emissions from a single flight. As discussed in Section 2.1, the variables are SGF and OGF. IATA expects SGF to range from 24.6% to 32.4% (Fig. 3). Regarding OGF, this study assumes a value of 4.6% for conventional operators, in accordance with ICAO guidance materials [7], and 0% for operators with ambitious decarbonization goals planning to introduce hydrogen-powered aircraft. Based on these assumptions, with the sector growth factor SGF in the range 24.6 – 32.4 %, a conventional operator with OGF = 4.6 % carries an offset obligation of 21.6 – 28.2 % of its covered emissions; the hydrogen operator, at OGF = 0 %, carries 20.9 – 27.5 %. Per flight, the offset obligation is thus 0.78 – 1.02 t for the 2 % SAF blend, 0.66 – 0.87 t for the 20 % SAF blend, and only 0.36 – 0.47 t for the LH_2 aircraft. The hydrogen case saves roughly 0.4 – 0.6 t of offset per flight relative to either SAF blend, equivalent to 40 – 55 % of the offset stream.

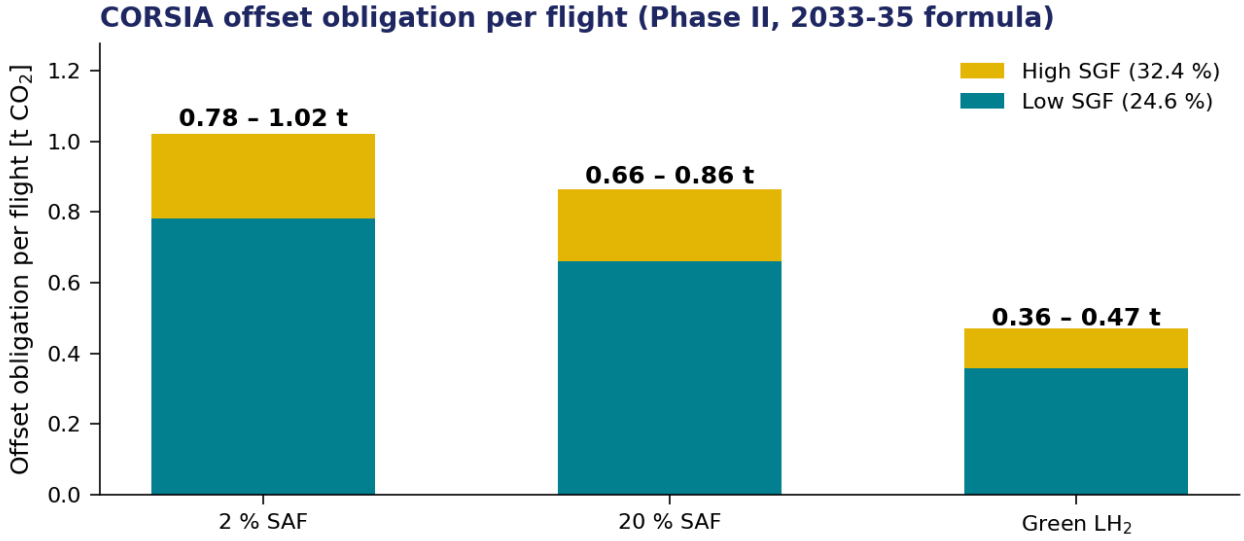


Figure 9 – CORSIA offset obligation per flight under the Phase II 85/15 formula.

6. Cost Analysis and Break-Even Regions

6.1 Total per-flight cost by scenario

Figure 10 combines fuel cost and CORSIA-offset cost for the three scenarios of Table 2. In the Current scenario, hydrogen is uncompetitive by a wide margin: at USD 32.9/kg, the fuel bill alone is USD 9,607 per flight, several times the conventional bill, and the offset saving is small because the credit price is low. The Moderate scenario is a closer race: hydrogen fuel at USD 10/kg drives the per-flight fuel bill to USD 2,920, while the 2 % SAF blend costs USD 752 in fuel and the 20 % SAF blend costs USD 891, but the offset gap partially compensates. In the Transformative scenario, hydrogen fuel at USD 6/kg costs USD 1,752 per flight, and the per-flight offset saving (about USD 35–50) at an USD 80/t credit price rises to USD 2.8–4.4 k, tipping the total-cost comparison in hydrogen's favour against the 2 % blend and bringing hydrogen to near-parity with the 20 % blend. It should be noted that while I arbitrarily set this figure at $80, it is not without basis. This is because, in discussions within the energy sector, there were concerns that if CORSIA Phase II were to begin while CORSIA credits were in short supply, credit prices would skyrocket compared to the current voluntary Phase I. As for the price of hydrogen, a figure of $6 per kilogram is not outlandish in the context of ambitious policy discussions.

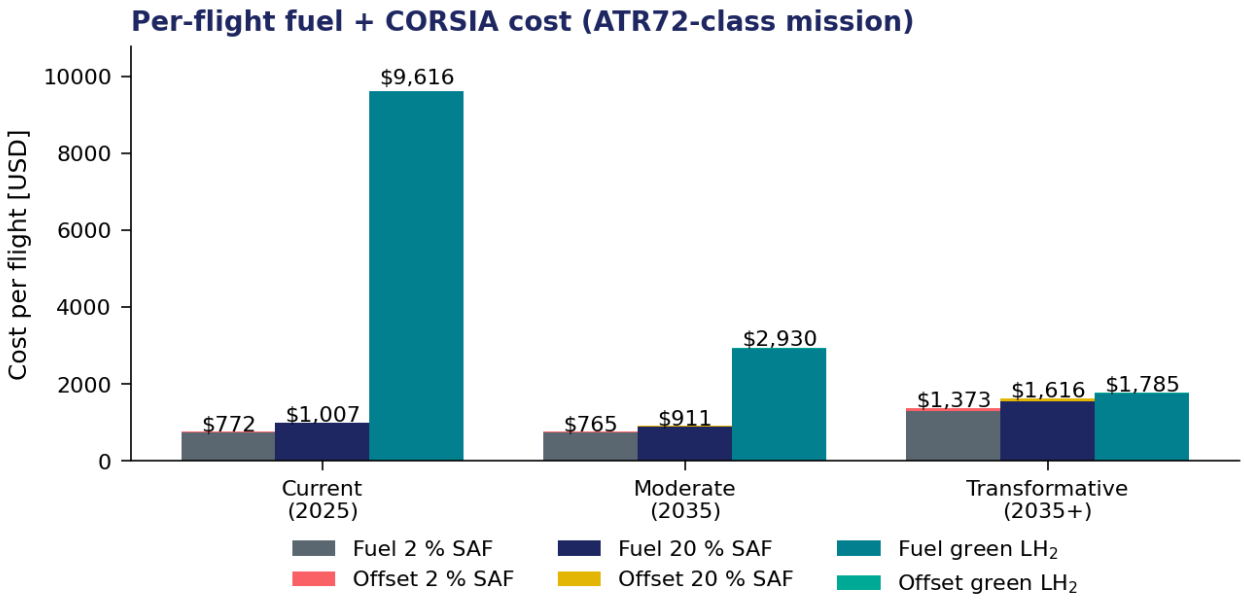


Figure 10 – Per-flight fuel + CORSIA cost for the three scenarios.

6.2 Break-even maps

To generalise beyond the three discrete scenarios, we hold the fossil prices fixed at Jet-A = USD 1.00/kg and HEFA = USD 2.50/kg, and sweep the green-hydrogen price from 3 to 15 USD/kg on the horizontal axis and the CORSIA credit price from 10 to 120 USD/t on the vertical axis. For each grid point we compute the per-flight cost difference between the LH_2 aircraft and the conventional aircraft, using exactly the same energy, mass and offset-ratio inputs as in Section 6.1. The black contour at zero is the break-even line; blue regions are where the hydrogen aircraft is cheaper per flight, red regions where it is more expensive. Figure 11 shows the comparison against a 2 % HEFA blend; Figure 12 shows it against a 20 % HEFA blend.

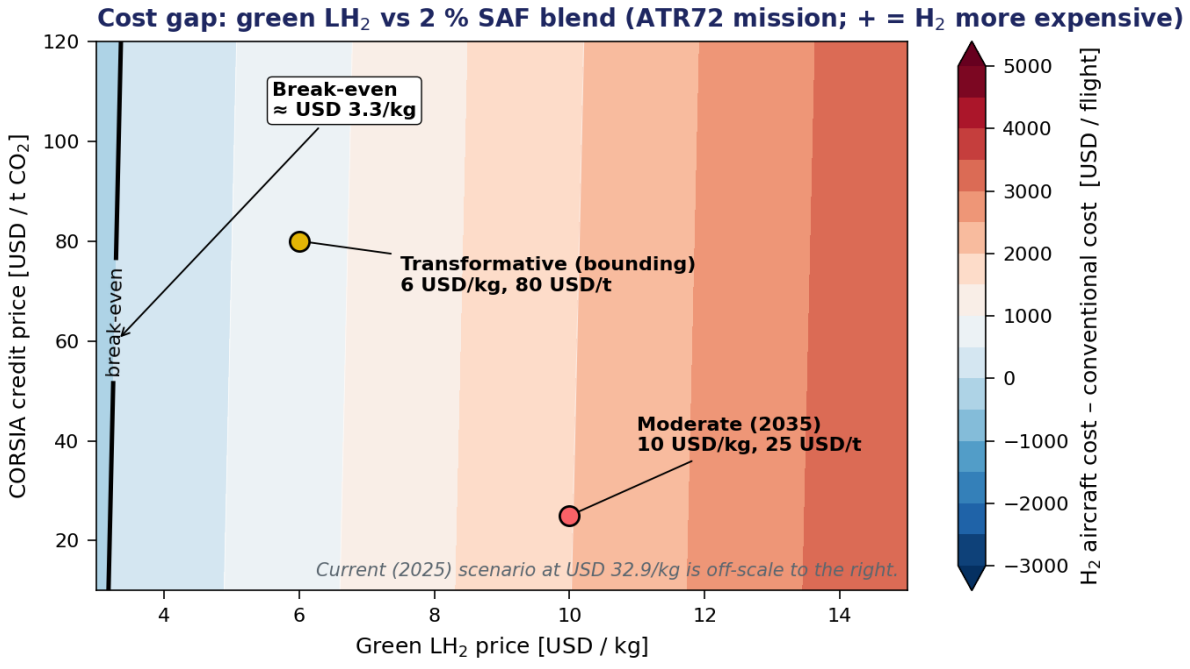


Figure 11 – Hydrogen vs 2 % SAF blend: per-flight cost gap (+ = hydrogen more expensive).

The first feature of both maps is that the break-even line is nearly vertical. Solving the equality of total costs analytically explains why. For the 2 % blend, the break-even hydrogen price as a function of the credit price C is $P_H_2^* = (922.95 + 0.4886 \cdot C)/292$, which moves from USD 3.20/kg at C = 25 USD/t to USD 3.30/kg at C = 80 USD/t and only USD 3.36/kg at C = 120 USD/t. For the 20 % blend, the analogous expression is $P_H_2^* = (1{,}164.50 + 0.3493 \cdot C)/292$, which moves from USD 4.02/kg at C = 25 USD/t to USD 4.08/kg at C = 80 USD/t. In both cases the entire 10–120 USD/t credit-price sweep shifts the break-even hydrogen price by less than USD 0.20/kg. Per-flight CORSIA offset costs are only of order USD 20–100, whereas a USD 1/kg change in the hydrogen price moves the per-flight fuel bill by USD 292. The fuel-price axis dominates; the credit-price axis is almost a shadow variable.

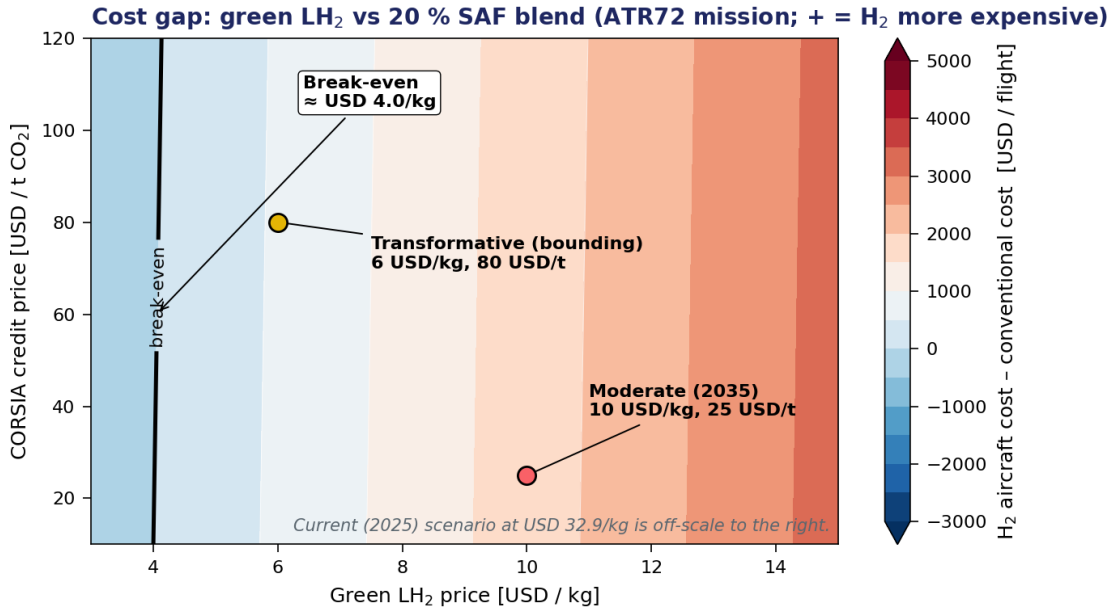


Figure 12 – Hydrogen vs 20 % SAF blend: per-flight cost gap (+ = hydrogen more expensive).

The second feature is that the 20 % blend pushes the break-even hydrogen price up by roughly USD 0.8/kg compared to the 2 % blend. This is not a carbon effect — the offset terms are nearly identical between the two cases. It is a fuel-cost effect: replacing 161 kg of Jet-A by 161 kg of HEFA at USD 2.50/kg versus USD 1.00/kg adds about USD 240 to the conventional flight's fuel bill, and hydrogen has to underprice that larger conventional bill, not the smaller one. Counter-intuitively, therefore, a stronger SAF mandate makes hydrogen easier to justify on a per-flight cost basis, but only because the SAF mandate raises the conventional fuel cost — not because it changes the carbon arithmetic.

The third feature concerns where the three scenarios of Section 6.1 sit on the maps. The Current scenario at USD 32.9/kg LH_2 lies far to the right of the plotted range and is omitted for clarity. The Moderate scenario at USD 10/kg, USD 25/t is plotted as the coral marker and sits deep in the red region — about USD 1,750 per flight in disfavour of hydrogen against a 2 % blend, and about USD 1,300 against a 20 % blend. The Transformative bounding scenario at USD 6/kg, USD 80/t is plotted as the gold marker. Even this optimistic bound does not reach break-even: the gap is still about USD 760–820 per flight against a 2 % blend, and about USD 555 against a 20 % blend. The implication is that the entire plausible 2035+ scenario envelope, including its optimistic extreme, lies on the unfavourable side of the break-even line. Reaching parity requires the hydrogen price to fall further still, into the USD 3–4/kg band, which is below even the Transformative bound.

Two implications follow for the regulatory question that frames this paper. First, the CORSIA credit price, taken alone, is a weak lever for inducing airlines to buy hydrogen aircraft on regional routes; even more than tripling the credit price from 25 to 80 USD/t shifts the break-even hydrogen price by less than USD 0.10/kg. Second, the SAF mandate is a more decisive lever, because it raises the conventional fuel cost that hydrogen must beat. The interaction of CORSIA credit pricing with SAF mandates therefore matters more than either instrument in isolation, but the dominant pathway is the fuel-cost channel through SAF, with CORSIA acting as a small additive nudge.

7. Per-Passenger Emissions and the Carbon-Value Test

Total-flight numbers understate one feature of hydrogen aircraft: the payload penalty. The reference LH_2 regional aircraft carries about 40 passengers against 72 for the ATR72, because cryogenic tanks displace both structural volume and mass. Figure 13 shows per-passenger CO_2: Jet-A sits at 51 kg, the 2 % SAF blend at 50 kg, the 20 % SAF blend at 43 kg, and green LH_2 at 43 kg. On this per-passenger metric, a 20 % SAF blend is indistinguishable from a green-hydrogen aircraft. The hydrogen flight's advantage is absolute — fewer total tonnes on the route — rather than specific.

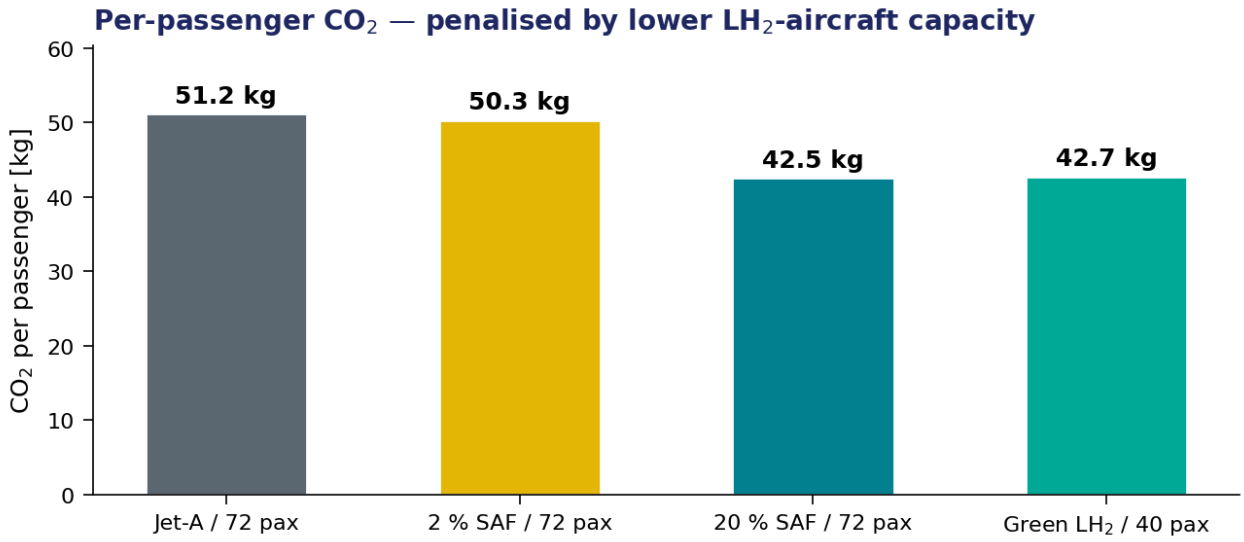


Figure 13 – Per-passenger CO_2 under the four cases.

The UK SAF-mandate impact assessment [12] frames this comparison from a different direction. It argues that a low-carbon technology is worth adopting if its cost of abatement per tonne of CO_2 is below the official carbon value. Taking the UK carbon-value band of roughly £159–506/tCO_2 as a reference, we compute, per flight, the carbon value captured by the low-carbon fuel as the per-flight CO_2 reduction relative to Jet-A multiplied by the carbon value, and then divide by the fuel mass to express the result on a per-kilogramme basis. For HEFA used inside a 20 % blend, the per-flight reduction is 621 kg and the in-blend HEFA mass is 179 kg, giving an implied premium of £0.55–1.76/kg of HEFA. For green hydrogen, the per-flight reduction is 1,975 kg and the LH_2 mass is 292 kg, giving an implied premium of £1.08–3.42/kg of LH_2 (Figure 14).

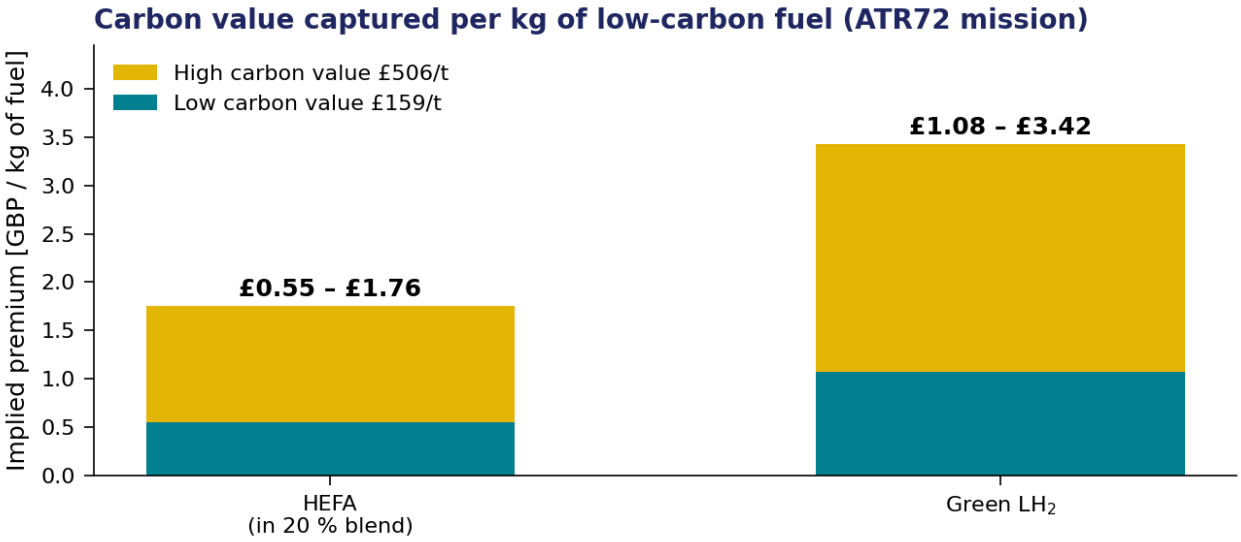


Figure 14 – Carbon value captured per kg of low-carbon fuel, ATR72 mission.

Two observations follow. First, on a per-kg-of-fuel basis the carbon-value premium of green hydrogen is roughly twice that of HEFA — primarily because LH_2's well-to-wake CO_2 intensity (41.3 g/MJ) is a larger reduction relative to Jet-A than HEFA's (13.9 g/MJ versus the 89 g/MJ baseline), and secondarily because hydrogen displaces a larger share of the per-flight energy demand. Second, at the upper end of the band (£506/t, ≈ USD 645/t at recent FX), the implied LH_2 premium of £3.42/kg corresponds to roughly USD 4.4/kg of LH_2, which sits inside the break-even band identified in Section 6.2. In other words, if the UK carbon-value framework — rather than the much lower CORSIA credit price — were the operative carbon signal facing airlines, hydrogen at a delivered price of about USD 4–5/kg would already pass the test on regional routes, provided its upstream CO_2 intensity is held at or below 20 gCO_2/MJ. Above that intensity, the implied premium collapses.

The gap between the UK carbon-value band and plausible CORSIA credit prices (10–80 USD/t in our scenarios) is therefore another quantitative expression of the same regulatory-framework point made in Section 6.2: the choice of carbon-pricing instrument, far more than the choice of aircraft technology, determines whether airlines will see purchase motivation for hydrogen.

8. Discussion

8.1 What the paper was set up to ask, and what it found

The motivation for this study is one step removed from the airline operating decision. Aircraft manufacturers do not launch new programs unless they can see a market for the resulting aircraft, and airlines do not introduce a new technology unless the operating economics support it. Hydrogen aviation is currently in a TRL-uplift phase, supported by a number of national and supra-national programs that subsidies demonstrators and integrated ground tests. That phase cannot continue indefinitely; at some point an OEM has to take a launch decision and commit to type certification, which in turn depends on confidence that airlines will see purchase motivation when the aircraft enters service. The question this paper asks is whether today's decarbonizing policy environment — CORSIA, the SAF blending mandates, and the carbon-value frameworks attached to them — is sufficient to generate that motivation, and therefore sufficient to underwrite an OEM launch decision in the late 2020s or early 2030s.

The answer the per-flight model produces is conditional, and the conditioning variable is the availability of alternatives to hydrogen for the airline. Two alternatives matter. The first is SAF blending: the higher the mandated blend, the higher the conventional fuel cost that hydrogen has to underprice. Section 6.2 shows that this fuel-cost channel moves the break-even green-hydrogen price by roughly USD 0.8/kg between a 2 % blend and a 20 % blend — a larger effect than any conceivable CORSIA price movement produces. The second alternative is the CORSIA credit itself, which lets the airline discharge its emission obligation by purchasing reductions made outside the aviation industry. The break-even maps show that the CORSIA price is a weak technology-choice lever — even the BloombergNEF EU-alignment scenario at USD 477/t in 2027 [13] only moves the break-even hydrogen price to roughly USD 4.0–4.6/kg, still short of the USD 6/kg Transformative bound — but its existence does much more analytical work than its level. CORSIA establishes that some of an airline's compliance cost can always be discharged elsewhere, which fundamentally weakens the cost case for buying a hydrogen aircraft.

This is the paper's main finding, and it is uncomfortable. On a per-passenger basis, the green-LH_2 regional aircraft is statistically tied with a 20 % HEFA blend on a conventional ATR72 (43 kg per passenger in either case). On a per-flight cost basis, even the optimistic Transformative bounding scenario — green hydrogen at USD 6/kg, CORSIA credit at USD 80/t — yields a fuel-and-offset bill of USD 1,785, against USD 726 for a present-day all-Jet-A flight, a 2.5× ratio before any CAPEX is included. In any worse scenario the LH_2 ratio rises to between 3× and 4× the Jet-A anchor. Decarbonizing aviation in-sector is expensive, and per-passenger-emissions-ineffective relative to a high-blend SAF alternative.

8.2 Why this makes CORSIA — and SAF availability — fortunate, but provisionally so

Read straightforwardly, this finding makes the existence of CORSIA fortunate from the aviation industry's standpoint. If decarbonising in-sector is expensive and per-seat-ineffective, then a market-based instrument that lets the sector account for cheaper reductions made elsewhere is doing genuine economic work: it allows aviation to discharge a Net-Zero obligation that would otherwise impose a fuel-cost shock of two to four times present-day levels on a sector whose demand is price-elastic. SAF mandates do similar work in a different way, by allowing partial in-sector decarbonisation at a smaller cost than full hydrogen substitution would require, while the upstream synthetic-fuel and electrolysis industries scale.

But this fortune is provisional in two specific ways. The first is feedstock. Both fortunate alternatives are bounded. The UK SAF-mandate impact assessment caps HEFA at 100 % of SAF demand in 2025–26, falling to 71 % by 2030 and 35 % by 2040 [12]; e-kerosene production cost converges on green hydrogen because both share the same upstream electrolysis bottleneck. CORSIA-eligible emission units are also a bounded supply, governed by the rate at which approved programmes issue corresponding-adjusted credits, with several Phase II analyses concluding that supply may lag demand for several years [13-15]. Beyond the mid-2030s, neither alternative scales costlessly with continued aviation traffic growth.

The second way fortune is provisional is social. Not all of society shares the framing that aviation is a sufficiently essential service to merit out-of-sector accounting of its emissions. Some commentators, civil-society organisations and national policy currents argue that the aviation sector should reduce its emissions inside the sector even if doing so is expensive, and even if it implies a smaller flying world. This view is not unanimous and not universal, but it is sufficiently widespread that an OEM

contemplating a launch decision in 2028 cannot rule out a tightening of the regulatory framework over the 20–25 year service life of the resulting aircraft. The Phase II eligibility, vintage and cancellation rules of CORSIA — which determine, in practice, how much out-of-sector substitution aviation is permitted — are themselves a policy decision, not a market parameter, and they are subject to revision.

8.3 The dual task for the aviation industry

The conclusion the model points to is therefore not "hydrogen aircraft will be uneconomic in 2035" or "CORSIA will rescue the sector from in-sector costs," but the more useful and harder one: that the aviation industry has a dual task. The first half of the task is to pursue genuine in-sector emission reductions — through the SAF pathways available now and through hydrogen aircraft when feedstock limits begin to bind — at a pace that gives society confidence the sector is doing its share. The second half is to preserve aviation as a viable mobility option for the populations who depend on it, including the regional connectivity that hydrogen aircraft are best-suited to in the late-2030s window.

These two halves are in tension. The fully in-sector pathway costs roughly two to four times present-day fuel cost per flight, before CAPEX, and produces decarbonization in part through demand destruction on price-elastic regional routes. The fully out-of-sector pathway is cheaper but rests on social acceptance of substitution that may not hold across the full LTAG horizon. Neither extreme is stable, and the framework that emerges will sit somewhere between them.

The OEM launch decision for hydrogen regional aircraft is, in this light, neither a slam-dunk nor a write-off. It is a decision under genuine policy uncertainty, in which the relevant uncertainty is not technical readiness but the future political settlement on out-of-sector substitution. The current TRL-uplift programmes are a way of buying time on that decision; the analysis here suggests that the decision itself, when it comes, is less about whether hydrogen is cheap enough than about whether the regulatory framework of the late 2030s will treat in-sector decarbonization as binding.

8.4 Limitation

The analysis is restricted to per-flight fuel and CORSIA-offset costs, holding aircraft-level CAPEX, maintenance, crew and airport-handling deltas constant; we adopt a whole-system LH_2 efficiency of 0.4 and a 40-vs-72-seat per-passenger comparison; the aviation EU ETS is excluded to keep the focus on the global CORSIA framework; and results are for a single regional mission, with network-level aggregation left to future work.

9. Conclusions

This paper has used a per-flight cost model for an ATR72-class regional mission to ask whether the offset-cost structure of future CORSIA, combined with parallel SAF blending mandates, is sufficient to motivate airlines to purchase hydrogen aircraft — and therefore sufficient to underwrite the OEM launch decision that hydrogen regional aircraft now require. Four findings follow.

First, on the per-passenger CO_2 metric, a green-LH_2 regional aircraft is statistically tied with a 20 % HEFA blend on a conventional ATR72, at 43 kg per passenger. The strategic case for hydrogen aviation is therefore a feedstock-availability case, binding only beyond the mid-2030s, not a per-passenger-emissions case in the present.

Second, the CORSIA credit price is a weak technology-choice lever. The break-even green-hydrogen price is essentially flat at USD 3.2–3.4/kg against a 2 % SAF baseline and USD 4.0–4.1/kg against a 20 % SAF baseline; even BloombergNEF's USD 477/t EU-alignment scenario only shifts these to USD 4.0–4.6/kg, still short of the USD 6/kg Transformative bound. The SAF mandate is the more decisive lever for purchase motivation, because it operates through the conventional fuel cost that hydrogen must beat.

Third, in the optimistic Transformative scenario the per-flight fuel-and-offset cost is USD 1,785 for green LH_2 against USD 726 for present-day Jet-A — a 2.5× ratio before any CAPEX, rising to 3–4× in any less optimistic scenario. Decarbonising aviation in-sector is expensive, and per-passenger-emissions-ineffective relative to a high-blend SAF alternative.

Fourth, and most fundamentally, airline purchase motivation for hydrogen aircraft — and therefore the OEM case for launching such aircraft — is contingent on the availability of alternatives. Where SAF blending and CORSIA credit substitution are both available and uncontested, the airline economic case for hydrogen does not close. Where one or both are constrained — by SAF feedstock limits binding, by CORSIA eligibility tightening, or by social and political pressure for in-sector reductions — the case strengthens, but at a fuel-cost ratio that depresses passenger demand on price-elastic regional routes.

The dual task for the aviation industry is therefore to pursue genuine in-sector emission reductions at a credible pace while preserving aviation as a mobility option. Whether airlines actually purchase the hydrogen regional aircraft now under development − when, and if, those aircraft enter service — depends on which side of this tension the regulatory framework of the late 2030s settles. The result presented here is that the framework, as currently designed, has not yet settled the question; the OEM launch decision must therefore be taken under genuine policy uncertainty rather than under a technical-readiness criterion alone.

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Acknowledgement

This research is based on results obtained from a project, JPNP21030 commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

References

[1] ICAO. “CORSIA implementation plan – Standards and Recommended Practices (Annex 16, Volume IV),” International Civil Aviation Organization, Montreal, 3rd edition, 2023.

[2] IATA. “Net zero 2050: resolution on net-zero carbon emissions,” International Air Transport Association, Boston, 2021.

[3] Aerospace Technology Institute. *Realizing Zero-carbon emission flight*. FZO-PPN-REP-0001, 2021.

[4] K. Alsamri, S. Rezaei, V. Chung, J. Huynh and J. Brouwer, "Methodology for Assessing Retrofitted Hydrogen Combustion and Fuel Cell Aircraft Environmental Impacts," Journal of Propulsion and Power, vol. 40, pp. 661–676, 2024, doi: 10.2514/1.B39405.

[5] T.A. Alothaim, B.M. Alrubayan, E. Pontika, and P. Pillidis, "Transition to Hydrogen Aviation: A 2030–2050 Scenario Performance Analysis for an Airline," Clean Energy and Sustainability, 2025. , 10011. https://doi.org/10.70322/ces.2025.10011

[6] IATA. "IATA's updated CORSIA Sectoral Growth Factor Forecast," https://www.barin.nl/wp-content/uploads/2024/10/IATA-SGF-Forecast_September2024_send.pdf

[7] C Mazhetese. "CORSIA Offsetting RequirementsA un specialized agency," JOINT ICAO/SADC SASO ENVIRONMENTAL WORKSHOP FOR SADC MEMBER STATES, Swakopmund Plaza, Namibia: 11-13 November 2025

[8] ZeroAvia. "ZeroAvia Receives Signed P-1 Issue Paper from Federal Aviation Administration for 600kW Electric Propulsion System," https://zeroavia.com/zeroavia-receives-signed-p-1-issue-paper-from-federal-aviation-administration-for-600kw-electric-propulsion-system/

[9] Joby, "Joby Demonstrates Potential for Emissions-Free Regional Journeys With Landmark 523-Mile Hydrogen-Electric Flight," https://ir.jobyaviation.com/news-events/press-releases/detail/101/joby-demonstrates-potential-for-emissions-free-regional

[10] Airbus, "Our hydrogen-powered aircraft," https://www.airbus.com/en/innovation/energy-transition/hydrogen/zeroe-our-hydrogen-powered-aircraft

[11] ATR Japan, "Future Air Travel Demand Globally and in Japan, and the Environmental Performance of Airbus/ATR Aircraft (in Japanese)," 2019, https://web.pref.hyogo.lg.jp/ks06/documents/e.pdf

[12] UK Department for Transport. "UK SAF mandate: final stage cost benefit analysis," 2024, https://assets.publishing.service.gov.uk/media/66601969dc15efdddf1a872d/uk-saf-mandate-final-stage-cost-benefit-analysis.pdf.

[13] BloombergNEF. "Aviation Credits Market Outlook: CORSIA Gets its Wings," BloombergNEF Insight Report, 18 June 2025. https://about.bnef.com/insights/clean-transport/aviation-credits-market-outlook-corsia-gets-its-wings/

[14] Sylvera. "CORSIA Phase 1 Pricing: What Airlines Need to Know About Costs," Sylvera Market Outlook, 25 July 2025. https://www.sylvera.com/blog/corsia-phase-1-pricing-what-airlines-need-to-know-about-costs

[15] Fastmarkets. "CORSIA outlook: demand tailwinds meet supply headwinds in carbon credits," 19 September 2025. https://www.fastmarkets.com/insights/demand-tailwinds-meet-supply-headwinds-forecasting-corsias-impact-on-carbon-credit-markets/