Purpose

The purpose of this report is to outline team Aria Mavens analysis of the uptake of sustainable aviation fuel in commercial airlines throughout the EU27 countries as a part of their goal to achieve net-zero carbon emissions by 2050.

Abstract

This report analyses the patterns of air-travel growth, the amount of fuel consumed, the total carbon emissions, and the total costs of fuels for airlines. Afterwards, the report discusses the presence of SAFs in the picture and how their implementation will affect the industry. The report accounts for two major scenarios of SAF implementation growth: (S0) business-as-usual growth of SAFs based on industry drivers, which are assumed to be a linear growth due to various factors discussed below, and (S1) SAF uptake based on strict minimum thresholds outlined in the ReFuelEU Aviation Regulation (European Union, 2023). Furthermore, once the scenarios are accounted for, the report will forecast the total fuel consumption, total costs, and total CO2 emissions for each scenario. Necessary terminology for understanding this report is as follows:

(1) **Sustainable Aviation Fuels (SAF):** An alternative fuel made from non-petroleum feedstocks that reduces emissions from air transportation, which can be produced from feedstocks including, but not limited to, the food and yard waste portion of municipal solid waste, woody biomass, fats/greases/oils, and more (U.S. Department of Energy, n.d).
(2) **ReFuelEU:** An EU aviation regulation that aims to decarbonize the aviation sector by mandating an increase in the use of SAF. It mandates airlines to maintain strict quotas of SAF blends in their Jet fuels at the following levels: 2% by 2025, 6% by 2030, 20% by 2035, 34% by 2040, 42% by 2045, and 70% by 2050 (EASA, 2025).

The key takeaway from this report is that SAF is the most impactful lever for aviation decarbonization, but not yet the most economically accessible one. Its success depends on coordinated long-term policy support, technological innovation, and EU-wide collaboration. Please visit the following Github link to view the entire project and all inputs and outputs. https://github.com/vik01/datathon-2025.

Understanding Data

To understand the future, the team took a look at the past. Specifically searching for EU-based flight data from various sources, like Eurocontrol, the European Union Aviation Safety Agency (EASA), the Publication office of the European Union, the official Eurostat website for complete energy balances, the European Environmental Agency (EEA) for passenger transport activity, and more. All of these sources were scoured to find data relating to the CO2 emissions, flight traffic, and fuel usage over the years, as well as sources on SAF, such as the EU SAF blending mandate, the SAF types, SAF production costs, and more. The tables containing the data are all outlined here.

The initial data that was collected was very different across forms and types. Multiple data points were granular to the level of daily traffic or broken down per EU country. Countries not present in the EU27 were also part of the data; hence, there was a need to clean and present it. Additionally, as part of our storage solution, we used Google Cloud SQL to host a database to query the information required. Then we used Tableau to visualize the data to gain insights into the trends.

Modeling Assumptions and Framework

The forecasting and scenario analysis rely on a consistent set of numeric assumptions aligned with IE–IATA Sustainability Datathon guidelines. Aviation fuel demand begins at 39 million tonnes in 2025, with a long-run assumption of 1.8% annual exponential growth rate based on lower estimates from environmental estimates (ICAO, LTAG Supplement, 2022). Three models were applied to the 2025–2050 demand projection: ARIMA (primary), Holt's Linear Trend (comparison), and ETS-Growth (reference, not fitted). SAF scenarios incorporate two adoption pathways: S0, assuming a linear, slower adoption, starting at 1% and merely reaching 20% in 2050 which is a more optimistic SAF penetration value than IEA's Net Zero by 2050 report. (International Energy Agency, 2021), and S1 in accordance with the SAF mandates given by the ReFuelEU.

The SAF Scenario Construction and Emissions Modeling Framework establishes the mathematical structure used to quantify decarbonization impacts. The framework embeds a physics-based fuel-burn penalty accounting for reduced energy density, modeled as Fuel Penalty = 0.10 × SAF Share, meaning every 1% SAF increases fuel consumption by 0.1% on top of the growth rate. Emissions use standard factors: 3.16 tCO_2/tonne for fossil jet fuel and 0.63 tCO_2/tonne for SAF, assuming an 80% lifecycle reduction (IATA, Net Zero Roadmap, 2023). Total emissions follow a Tier-1 ICAO/IPCC formulation: Emissions = Fossil×3.16 + SAF×0.63, while avoided emissions equal the gap between fossil-only emissions and blended-fuel emissions (CO_2_baseline − CO_2). Finally, the costs are also averaged values based on real-world trends. Table 1 below outlines all the mathematical modeling frameworks used, as well as the assumptions for each value.

Forecast evaluation uses MAE, RMSE, and MAPE against the ETS-Growth truth benchmark, confirming ARIMA as the most accurate and stable model for long-horizon projections. These assumptions and framework structure ensure mathematical consistency across fuel demand, SAF blending, energy-penalty adjustments, and CO_2 calculations. The framework aligns with datathon objectives by enabling scenario comparison, quantifying long-term avoided CO_2, and demonstrating how differentiated SAF trajectories bend the emissions curve toward 2050.

Table 1 - Assumptions and Frameworks Definitions for fuels, emissions, and costs

Assumptions	**Calculations / Values**
Baseline Fuel Demand (2025)	$BL_F = 39\ Million\ tonnes\ (Mt)$
Aviation fuel growth rate	$GR_F = 1.8\ \%\ /\ year$
Aviation fuel demand (2026-2050)	$D_{F,year} = BL_F * (1 + GR_F)^{(year - 2025)}\ \forall\ years \in [2026,\ 2050]$
S0 SAF percentage uptake	$i = [0.01, \ldots, 0.20]\ linearly\ over\ 2026\ to\ 2050$
S0 SAF Fuel Demand (2026-2050)	$SAF_{Fi} = i * D_f + (0.01 * i * D_f)\ \forall\ j \in [2026,\ 2050]$
S0 Jet Fuel Demand (2026-2030)	$JF_{Fi} = (1 - i) * D_F\ \forall\ i \in [2026,\ 2050]$
S1 SAF percentage uptake	$j = [0.02, \ldots, 0.70]\ based\ on\ ReFuelEU\ 2026\ to\ 2050$
S1 SAF Fuel Demand (2026-2050)	$SAF_{Fj} = j * D_F + (0.01 * j * D_F)\ \forall\ j \in [2026,\ 2050]$
S1 Jet Fuel Demand (2026-2030)	$JF_{Fj} = (1 - j) * D_F\ \forall\ j \in [2026,\ 2050]$
Emission Factors (Fossil Jet Fuel)	$EF_{JET} = 3.16\ tonnes\ of\ CO_2\ /\ 1\ tonne\ of\ fuel$
Emission Factors (SAF Fuel)	$EF_{SAF} = 0.632\ tonnes\ of\ CO_2\ /\ 1\ tonne\ of\ fuel$
Total CO_2 Emissions per year (S0)	$EM_{S0} = EF_{JETi}JF_{Fi} + EF_{SAFi}SAF_{Fi}\ \forall\ i \in [2026,\ 2050]$
Total CO_2 Emissions per year (S1)	$EM_{S1} = EF_{JETj}JF_{Fj} + EF_{SAFj}SAF_{Fj}\ \forall\ j \in [2026,\ 2050]$
Total CO_2 Emissions gap per year	$GEM_{i,j} = EM_{S1j} - EM_{S0i}\ \forall\ i = j \in [2026,\ 2050]$
Costs (Fossil Jet Fuel) per tonne	$P_{FOSSIL} = 700\ EUR/tonne$ *(based on historical range of 650-700)*

Costs (SAF Fuel) per tonne	$P_{SAF} = 2400\ EUR/tonne$ *(averaged over different SAF pathways ranging 2000-3000 EUR/tonne)*
Cost of fuel (for both scenarios)	$C_{S0i} = (P_{Fossil} JF_{Fi} + P_{SAF} SAF_{Fi}) / 1000\ \forall\ i \in [2026,\ 2050]$ $C_{S1j} = (P_{Fossil} JF_{Fj} + P_{SAF} SAF_{Fj}) / 1000\ \forall\ j \in [2026,\ 2050]$

Modeling Justifications

Model selection was driven by the characteristics of the historical aviation fuel dataset, which is short, smooth, nearly linear, and lacks noise or structural breaks - making classical statistical models more suitable than machine-learning methods. ARIMA emerged as the preferred model because it handles limited time series effectively, captures the exponential curvature expected in long-term aviation demand, and produced the lowest forecast errors when evaluated against the ETS-Growth benchmark (MAE = 0.0172, RMSE = 0.1330, MAPE = 0.034%; full results in Appendix A). In contrast, Holt's Linear Trend was retained only as a comparison model: Although stable and appropriate for approximately linear patterns, it systematically underestimates nonlinear growth and exhibited errors roughly two orders of magnitude higher. ETS-Growth, while included, was not treated as a forecasting model since its near-zero error reflects the fact that it is a constructed industry-aligned reference curve rather than an empirically fitted algorithm. Machine-learning approaches - including Random Forest, Decision Trees, and Gradient Boosting - were also tested but rejected due to the dataset's lack of variability, which led to severe overfitting, step-function forecasts, near-constant predictions, and an inability to extrapolate smoothly to 2050. Because these models are not inherently time-aware, they cannot reproduce the smooth exponential trajectories characteristic of aviation demand. Overall, ARIMA provides the most accurate, stable, and interpretable long-run projections, supporting defensible scenario modeling and emissions analysis, while Holt serves as a secondary benchmark, and ETS-Growth remains the underlying baseline trajectory for scenario design.

ARIMA Model Results

Fuel demand is higher for S1-SAF uptake

The output of total fuel demand for both scenarios is displayed in Figure 1. Although they share the same underlying demand growth predicted by ARIMA, the energy-density penalty associated with SAF leads S1 to require more total fuel. This divergence is intentional and consistent with real-world SAF characteristics (World Economic Forum, 2023). The resulting forecast forms the basis for evaluating the emissions implications of each scenario in subsequent sections.

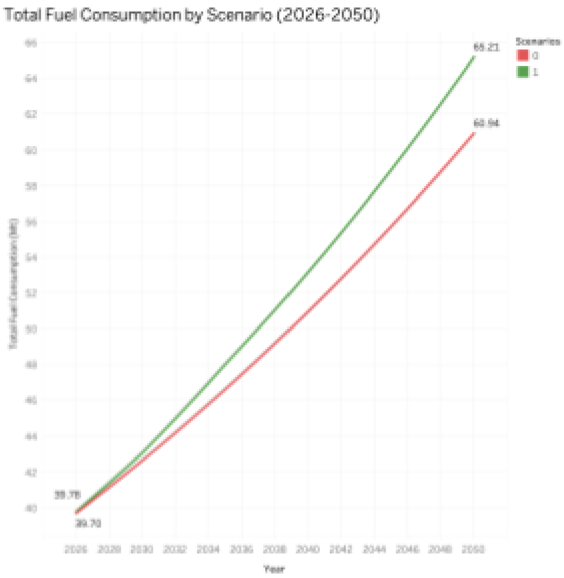

Figure 1 - Fuel demand growth for each scenario. Accounting for the fuel penalty for SAFs.

CO_2 emissions are much lower in S1-SAF uptake

Both scenario emissions are shown in Figure 2. In S0, emissions start at around the same 124 Mt in 2025 and steadily grow to ~162 Mt in 2050. In contrast, S1 rapidly scales SAF, and so while the emissions are ~ 123 Mt in 2025, the effective carbon intensity of the fuel mix drops sharply to ~90 Mt by 2050.

After about 2030, the emissions avoided through high SAF blending outweigh the additional demand growth, producing a downward-sloping emissions curve. This pattern aligns with major aviation decarbonization roadmaps. Similar to ICAO's 55% emission reduction estimates of IATA's estimates of cutting 125-140 Mt of emissions by 2050 (ICAO, n.d.; IATA, 2024), all of which show that aggressive SAF deployment can reduce emissions even as traffic continues to grow.

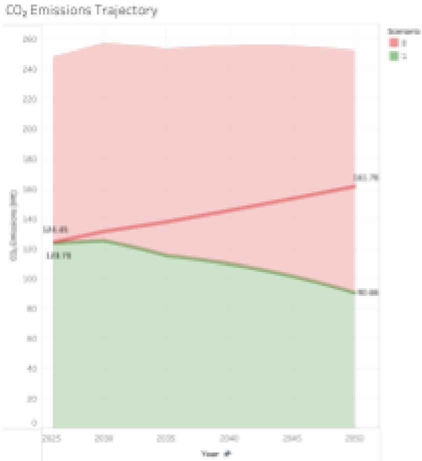

Figure 2 - Scenario 0 and 1 CO_2 emission forecast 2025-2050.

Cumulative 1033 Mt of avoided CO_2 over 25 years

Furthermore, Figure 3 shows the cumulative emission avoided. In S0, emissions savings reach just 30.8 Mt of avoided CO_2 by 2050. In contrast, for S1, as both SAF share and total fuel demand grow, the volume of fossil fuel displaced rises non-linearly, causing avoided CO_2 to accelerate over time and reach 115.4 Mt by 2050. Overall, leading to a cumulative 1033 Mt of avoided CO_2 over 25 years.

Now that we have classified the overall demand and emission forecasts of both scenarios, let's analyse the cost and understand if the picture is as rosy as it seems.

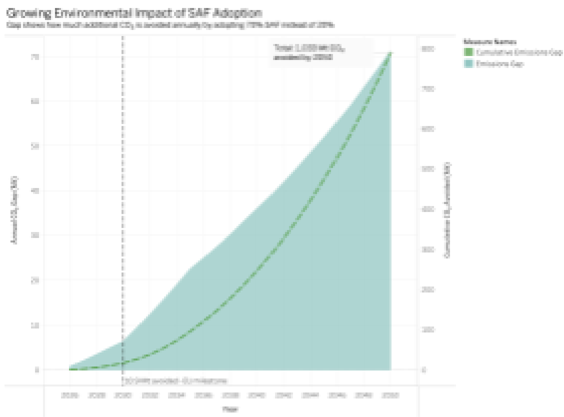

Figure 3 - Cumulative avoided CO_2 over 25 years

Cost Model Both Scenarios

Increasing price pressure due to the high cost of SAF

Figure 4 shows fuel costs rising sharply as SAF uptake increases, from about €30 million in 2025 to €123 million in 2050, with the SAF premium alone reaching €60 million and representing nearly half of total costs. This upward trend results from mandates driving demand while supply remains limited and unsubsidized, keeping SAF prices high (ICCT, 2025). Constrained production capacity and slow scaling of advanced and synthetic fuels reinforce this price pressure, making SAF the main driver of future fuel expenditures (IATA, 2024). For the industry, this signals persistently higher operating costs and reduced price stability unless additional policy support, such as production incentives or price-stabilisation measures, is introduced to ease the long-term cost trajectory (Climate Catalyst, 2025; ICCT, 2025).

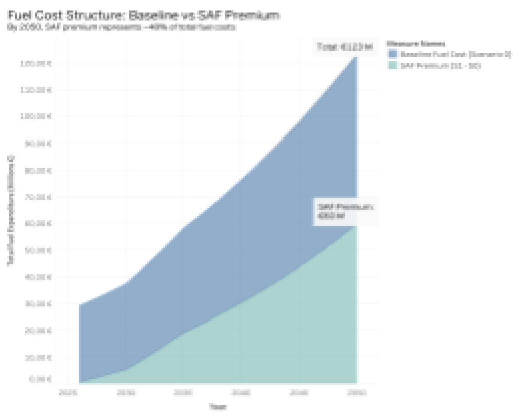

Figure 4 - S1 projects higher costs

Mandates, incentives, and carbon pricing for SAF deployment

A range of policy mechanisms can accelerate the adoption of SAF, with mandates, incentives, and carbon-pricing measures forming a complementary mix. Mandates are central, with blending quotas rising from 2% in 2025 to 70% by 2050, creating predictable demand and guiding investment (European Union, 2023; European Commission, 2024). These regulatory measures also discourage practices such as tankering to ensure fair competition (European Union, 2023). Economic incentives remain essential because SAF is far more expensive than conventional fuel; targeted support through subsidies, R&D funding, and feedstock programmes can reduce costs and enable supply-chain expansion (Climate Catalyst, 2025; IATA, 2024). Carbon-pricing instruments can strengthen SAF's competitiveness by increasing the relative cost of fossil fuels (IATA, 2024). Infrastructure and certification systems also require investment to support storage, blending, and distribution at scale (European Commission, 2024; now GmbH). Underpinning all these measures is the need for long-term regulatory stability to attract sustained investment and enable production growth (Synhelion, 2024; Climate Catalyst, 2025). Together, mandates, incentives, carbon-pricing tools, and infrastructure development form a coherent policy framework capable of accelerating SAF deployment and supporting aviation decarbonization.

Barriers and Restrictions to SAF deployment

Limited feedstocks and competing demand restrict SAF availability

Major barriers to the widespread adoption of SAF stem from constraints in feedstock supply, production capacity, economic viability, and infrastructure readiness. Sustainable feedstocks are limited: advanced biofuels rely on finite waste and residue streams, while synthetic fuels require large amounts of renewable electricity and captured CO_2, both of which must scale substantially (European Commission, 2024; Climate Catalyst, 2025). Competition from other sectors heightens the risk of shortages and price pressures (ICCT, 2025).

High costs and slow plant development constrain SAF production growth

Production capacity is another key constraint. SAF plants are costly and slow to develop, and current output remains far below future needs, raising doubts about whether supply can expand quickly enough (IATA, 2024). High production costs further challenge adoption, as SAF remains significantly more expensive than conventional jet fuel, and the lack of strong financial support mechanisms keeps the price premium high (ICCT, 2025; IATA, 2024).

Inadequate airport infrastructure and complex certification processes slow SAF deployment

Infrastructure limitations also hinder progress: many airports lack sufficient storage, blending, and refuelling systems, requiring major investment and coordination (European Commission, 2024; now GmbH). Certification and lifecycle monitoring add administrative burdens, while limited competition among producers may keep prices elevated as demand grows (Climate Catalyst, 2025; Carbon Gap, 2024).

Concluding vision for sustainable aviation grounded in evidence and feasibility

Taken together, the rising costs, infrastructure constraints, and supply limitations highlight that no single measure can deliver a successful SAF transition. A strong long-term solution will require a balanced mix of policy mandates, targeted incentives, and steady organic market growth to expand supply while reducing costs. Public awareness will also play a pivotal role: as passengers increasingly understand the environmental benefits of SAF, social pressure will encourage airlines to adopt cleaner fuels even when they carry a temporary price premium. Over time, technological innovation and scaling of advanced and synthetic fuels are expected to ease production bottlenecks and narrow the price gap, much as conventional jet fuel has seen cost convergence through decades of efficiency gains. Above all, sustained momentum is essential. The global aviation sector - and organizations like IATA in particular - must remain committed to advocating for supportive regulation, market transparency, and accountable climate action so that SAF deployment continues to accelerate, ensuring a lower-carbon future for aviation and society as a whole.

Appendix

Appendix A - Error calculations of the model outputs.

Models	Mean Absolute Error (MAE)	Root Mean Squared Error (RMSE)	Mean Absolute Percentage Error (MAPE)
ARIMA	0.0172	0.1330	0.034%
Holt	2.9822	3.6137	5.58%
ETS-Growth	0.0002	0.0003	0.0004%

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