

Hydrogen Integration in Commercial Aviation: Technical and Operational Analysis at Malpensa Airport

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Abstract

The decarbonization of the aviation sector has become a central objective within global climate policies. Among the alternative energy carriers under evaluation, liquid hydrogen stands out as a promising solution for enabling zero-emission flight, particularly in short and medium-haul operations. This study provides a preliminary evaluation of hydrogen integration at one of Europe’s busiest airports, that is Milano Malpensa airport. A dedicated simulation tool is developed for estimating liquid hydrogen requirements across different flight categories, taking into account the airport-level traffic data. A case study, referred to a short haul route is considered. Results addressing key aspects such as the operational feasibility and overall hydrogen demand, emphasizing the opportunities with the introduction of hydrogen-powered aviation in real operational settings.

Introduction

The aviation sector is under increasing pressure to transition toward sustainable energy carriers. Among the viable alternatives, liquid hydrogen has attracted growing interest due to its high energy content per unit mass and carbon-free combustion. However, the shift to hydrogen requires not only technological adaptation at the aircraft level but also robust planning at the airport infrastructure scale [1]. Milan Malpensa Airport has been identified as a relevant case study for evaluating hydrogen integration scenarios. Its diverse network of domestic, regional, and intercontinental routes enables detailed hydrogen demand estimates by flight segment: short, medium, and long-haul, supporting infrastructure design and strategic planning.

Objectives

This study aims at evaluating the operational feasibility of using liquid hydrogen as an alternative fuel for commercial aviation, focusing on short-haul operations. A representative flight of a conventional narrow-body aircraft is analysed to assess the impact of replacing kerosene with liquid hydrogen. In this purpose, a computational tool developed within the ALRIGH2T project is presented [2]. It is devoted at characterizing the Milano Malpensa traffic data in terms of number of most common operating aircrafts and of most common performed routes, with the aim of calculating for each of them the amount of hydrogen needed for replacing the kerosene.

Materials and Methods

To estimate the hydrogen amount needed to support all commercial departures, a structured algorithmic framework was developed.

This framework integrates detailed operational data and performs energy balance calculations to quantify hydrogen demand with high accuracy. Core variables include route distance, aircraft type, flight frequency, and passenger load, enabling a refined classification of hydrogen needs across short, medium, and long-haul operations. The process starts with the selection of representative aircraft models; each associated with specific fuel types and performance characteristics.

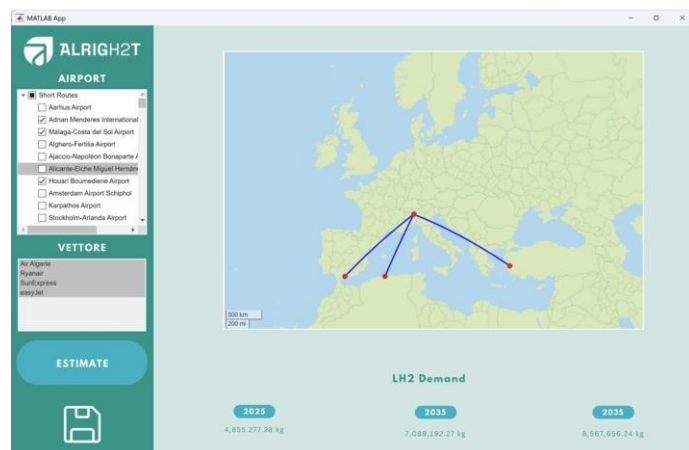


Figure 1: Developed Tool

Based on flight duration and distance, the algorithm calculates fuel consumption per segment. This data-driven, multi-variable methodology ensures a comprehensive and precise estimation of airport-wide liquid hydrogen demand, supporting strategic infrastructure design and optimal resource planning. Fig.1 shows an overview of the developed tool.

Results

Considering the potentiality of the developed tool, a specific case study has been selected. Table 1 summarized the aircraft type and the characteristics of its travelled common route.

Data	Value
Type of aircraft	Boeing 737-800
Rout Category	Short Houl
Distance [km]	1151

Distance [nm]	622
Travel Duration [hours]	1.51
Kerosene specific consumption [kg/km]	3.45
Kerosene total consumption [tons]	3.97

Table 1: Milano Malpensa - Madrid route Details

For the selected route, it is calculated a consumption of about 3.97 tons of Jet A1 fuel per flight, corresponding to an energy use of roughly 170.000 MJ. In the hypothesis of covering this energy requirement with hydrogen, about 1.41 tons of H₂ are needed. This represents a substantial reduction in fuel mass compared to kerosene, which has important implications for aircraft weight and fuel storage design. For context, similar calculations for other aircraft in the regional fleet, such as the Airbus A320 and the Airbus A321 neo, yield fuel consumption rates of 2.91 kg/km and 3.47 kg/km respectively, reinforcing the variability in demand depending on aircraft type and efficiency. However, the characteristics of the hydrogen storage technologies are fundamental issues to be taken into account since they can affect significantly the weigh and the volume of the hydrogen to be stored on board.

Conclusions

Aligning factors such as route types, flight frequency, and operational logistics to enable large-scale are fundamental parameters to consider for the adoption of hydrogen propulsion in airway sector. The developed analysis demonstrates the feasibility and benefits of hydrogen as an alternative fuel, while highlighting the need to address challenges related to liquid hydrogen storage and integration in existing aircraft configurations.

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