Techno-Economic Evaluation of Sustainable Aviation Fuel Production via Power-to-Liquid Technologies in Tunisia

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Introduction

The present work examines the techno-economic feasibility of producing Sustainable Aviation Fuel (SAF) in Tunisia using Power-to-Liquid (PtL) technologies based on Fischer–Tropsch (FT) synthesis. The interest comes from the challenge of decarbonizing the aviation sector, a high-emitting industry responsible for about 2.4% of global CO_2 emissions and projected to grow significantly in coming decades. With expected increases in air traffic and global commitments to net-zero emissions—such as ATAG's goal to halve aviation emissions by 2050 relative to 2005—SAF appears as a necessary pillar for climate mitigation. Traditional aviation fuels remain carbon-intensive, and non-CO_2 effects, like NOx, water vapor and soot, amplify the sector's climatic impact. Thus, scalable alternatives like PtL-based e-kerosene are essential.

Despite growing international research on PtL systems, studies focusing specifically on Tunisia remain absent. The country, however, possesses exceptional renewable energy potential—particularly solar irradiation exceeding 2,000 kWh/m² in the south and significant wind resources—making it a promising candidate for SAF production. The study is intended to fill this gap by evaluating the techno-economic viability of producing 200,000 tons of SAF per year, a quantity aligned with Tunisia's historical aviation fuel consumption and projected to meet roughly half of its 2050 demand.

Methodology:

An iterative MATLAB model was developed to calculate the Levelized Cost of Fuel (LCOF) based on CAPEX, OPEX, process efficiencies, component lifetimes, and electricity prices. Five regions, namely Tozeur, Tataouine, Gafsa, Sidi Bouzid, and Kairouan, are evaluated, reflecting Tunisian geographic diversity in solar and wind resources. The study includes detailed modeling of three critical technologies: Direct Air Capture (DAC), water electrolysis for hydrogen production, and Fischer–Tropsch synthesis with downstream refining. A low-temperature FT configuration is chosen to maximize kerosene-range hydrocarbons, while alkaline electrolysis is selected for hydrogen production due to its maturity and cost-effectiveness.

Results:

A highlight of the obtained results is presented in this section. A key outcome of the analysis is the substantial variation in LCOF across Tunisian regions, driven primarily by differences in renewable electricity prices. In 2020, LCOF ranges between 1.81 and 1.89 USD/kg, but declines sharply to 0.65–0.67 USD/kg by 2050 as renewable energy costs decrease and PtL technologies mature.

Tataouine shows the lowest costs thanks to its high-quality solar resources, while Kairouan shows the highest. By 2050, however, regional cost differences narrow considerably, reflecting convergence in electricity costs and improved technological efficiencies.

The breakdown of LCOF components reveals that electricity is the dominant cost factor across all time horizons, representing roughly 35–44% of total cost. When electricity costs are allocated directly to each technological subsystem, water electrolysis emerges as the single largest contributor (47–50%), followed by the Fischer–Tropsch unit (21–30%). DAC contributes between 17–25%, with other balancing and storage components representing 5–6%. This structure underscores the energy-intensive nature of PtL synthesis and confirms that long-term cost reductions depend heavily on lowering electricity prices and CAPEX for electrolysis.

When benchmarked internationally, Tunisia shows a clear competitive advantage. In 2030, Tunisian SAF would cost about 1.22 USD/kg, compared with projected costs of 1.58 USD/kg in the EU-27 and 1.45 USD/kg in the US. By 2050, Tunisia remains approximately 20–25% cheaper than both regions—a result driven mostly by lower renewable electricity costs and favorable solar-wind complementarities. This suggests Tunisia could become a significant producer and exporter of SAF for Europe and other regions seeking low-carbon fuels. Nevertheless, SAF remains more expensive than fossil jet fuel, which has historically ranged from 0.26 to 0.68 USD/kg. Closing this gap will require technology improvements, reductions in capital costs, supportive regulatory frameworks, and possibly carbon pricing mechanisms.

The sensitivity analysis identifies three variables with strong influence on LCOF: the discount rate, CAPEX for DAC, and CAPEX for water electrolysis. A decrease in the discount rate from 13% to 5% increases LCOF by about 10%, illustrating the importance of financing conditions for large-scale PtL projects. DAC capital costs also strongly affect final fuel price: increasing DAC CAPEX from 100 to 1,100 €/ton CO_2 raises LCOF by almost 26%. Yet the most impactful factor is the CAPEX of water electrolysis. Varying it between 100 and 1,500 €/kW produces a 36% change in LCOF, reinforcing that electrolyser cost reductions—through scaling, technological innovation, and global market growth—are pivotal to making SAF economically competitive.

Conclusion:

Based on the present study, it can be concluded that Tunisia possesses the natural and economic conditions to become a regional hub for PtL-derived SAF production. Abundant solar and wind resources, declining renewable electricity prices, and geographic proximity to European markets provide strategic advantages. With SAF technologies approaching commercial maturity, especially in DAC and FT units, Tunisia could support both domestic aviation decarbonization and international supply chains. Tunisia can produce SAF at globally competitive costs by 2030–2050, However, realizing this potential requires supporting infrastructure, including hydrogen transport pipelines, CO_2 capture and distribution systems, refining units, storage facilities, and logistics networks linking production sites to airports and export terminals.

Further research on the full supply chain, including transportation, distribution, storage infrastructure, and integration with Tunisia's energy transition plans, is needed. The success of SAF production depends heavily on the policy frameworks, incentives, and international partnerships to stimulate investment and accelerate SAF deployment.