Techno-Economic Assessment of Green Hydrogen Production in Tunisia

Yassine Bensalem*[1], Rochdy Belhassen[1] and Nihel Chekir[1]

[1] University of Gabes, National engineering school of Gabes

*Corresponding Author: yassine.bensalem@univgb.tn

ABSTRACT – The global shift toward clean energy has strengthened interest in green hydrogen as a sustainable and carbon-free energy carrier. Tunisia possesses significant solar irradiation and considerable wind potential, making it a promising candidate for competitive hydrogen production. This study presents a techno-economic analysis of green hydrogen production using photovoltaic (PV) and wind energy under three operational scenarios: off-grid, grid-connected, and hybrid PV-grid systems. Additionally, wind-based hydrogen production is evaluated using regional wind power density data. The Levelized Cost of Hydrogen (LCOH) is computed for all Tunisian regions, and water availability is assessed as a limiting factor for large-scale electrolysis. Results show that hybrid PV-grid systems provide the best techno-economic performance, with LCOH values as low as €4.68/kg in high-irradiance regions such as Tataouine and Gabès. Wind-based production is competitive only in regions with strong wind potential, producing LCOH as low as €3.35/kg. Comparative analysis with international benchmarks indicates that Tunisia holds significant potential to become a competitive producer of green hydrogen in the Mediterranean region.

Keywords: Green hydrogen, techno-economic analysis, LCOH, photovoltaic systems, wind energy, Tunisia, renewable hydrogen.

1. INTRODUCTION

Green hydrogen, produced via renewable-powered electrolysis, is gaining global traction as a solution for decarbonizing hard-to-abate sectors and supporting long-term energy security. Countries with high renewable energy potential are increasingly investing in hydrogen infrastructure to meet growing global demand. Tunisia benefits from exceptionally high solar resources and favorable wind conditions, especially in the southern regions, positioning it as a strategic candidate for green hydrogen development and potential export to Europe.

Despite these advantages, the feasibility of green hydrogen production depends strongly on techno-economic parameters such as renewable production profiles, electrolyzer efficiency, capital and operational expenditures, and resource availability (notably water). This study evaluates the LCOH for multiple production scenarios in Tunisia, considering regional renewable resources and water constraints, and compares the results with global benchmarks[1].

2. METHODOLOGY

The methodology integrates renewable resource assessment, electrolyzer performance modeling, and techno-economic evaluation across all Tunisian regions.

2.1 Renewable Energy Data

- **PV potential** obtained from Global Solar Atlas (GHI, optimal tilt, derating factors)[1].
- **Wind power density** extracted from the Global Wind Atlas (100 m height)[6].
- **Regional** datasets compiled for energy yield and LCOH calculations [3].

2.2 *Electrolysis Modeling*

Both PEM and alkaline electrolyzers were analyzed based on:

- energy consumption (50–55 kWh/kg H_2),
- efficiency (60–70%),
- water requirements (9 kg H_2O/kg H_2),
- impact of intermittent operation.

2.3 Scenarios Assessed

1. **Off-grid PV systems**
   Fully dependent on renewable output; high intermittency and reduced electrolyzer utilization.
2. **Grid-connected PV systems**
   Stable operation using both PV and the national grid; lower CAPEX; influenced by grid tariffs.
3. **Hybrid PV-grid systems**
   Combines renewable production with the grid, maximizing electrolyzer efficiency.
4. **Wind-powered systems**
   LCOH computed for 1 MW turbines across all regions.

2.4 Economic Modeling

The Levelized Cost of Hydrogen LCOH is computed as:

$$LCOH = \frac{I + \sum_{i=1}^{n} \frac{M_i}{(1+r)^i}}{\sum_{i=1}^{n} \frac{H_i}{(1+r)^i}}$$

Where:

I: Initial investment cost (CAPEX)

M_i : Operating and maintenance costs (OPEX) in year i

H_i : Amount of hydrogen produced in year i, expressed in kilograms (kg)

r: Discount rate (expressed as a decimal)

n: the number of years over which the investment and outputs are considered

2.5 Water Availability Assessment

Regional water resources were analyzed, allocating 5–7% for hydrogen production, and estimating hydrogen production potential accordingly [5,6].

3. RESULTS AND DISCUSSION

The techno-economic assessment of PV-powered hydrogen production reveals significant regional variability across Tunisia.

3.1 PV-Based Hydrogen Production

- **Off-grid systems**: LCOH **6.75–10.02 €/kg**, the highest cost due to intermittency.
- **Grid-connected systems**: LCOH **5.08–7.55 €/kg**, with better reliability.
- **Hybrid PV-grid systems**: **lowest LCOH**, reaching **4.68 €/kg** in optimal regions.

Regions with high irradiation (Tataouine, Kebili, Gabès) consistently show the lowest costs.

3.2 Wind-Based Production

- Lowest LCOH in **Tataouine, Tozeur, Kebili**: **3.35–4.50 €/kg**
- Northern/coastal regions show poor wind potential: LCOH > €5.5/kg

3.3 Cross-Technology Comparison

- Southern Tunisia is the optimal zone for both PV and wind hydrogen.
- Hybrid PV-grid systems show overall best performance due to reliability + low cost.
- Economies of scale can dramatically reduce LCOH, especially for wind energy.

3.4 Water Constraints

Regions like Gabès and Kebili can support large-scale electrolysis due to relatively higher water availability. Predictive water management is essential to ensure sustainable, long-term hydrogen production.

3.5 Global Benchmarking

Compared to other countries, Tunisia is competitive with:

- **LCOH Morocco** (€2.5–3/kg)[13],
- **LCOH Germany** (€3.5–8/kg))[13],
- **LCOH Saudi Arabia / Chile / Australia** (€1.5–2.5/kg))[13].

Figures 1 and 2 summarize the spatial variation of LCOH and hydrogen production costs across Tunisian regions.

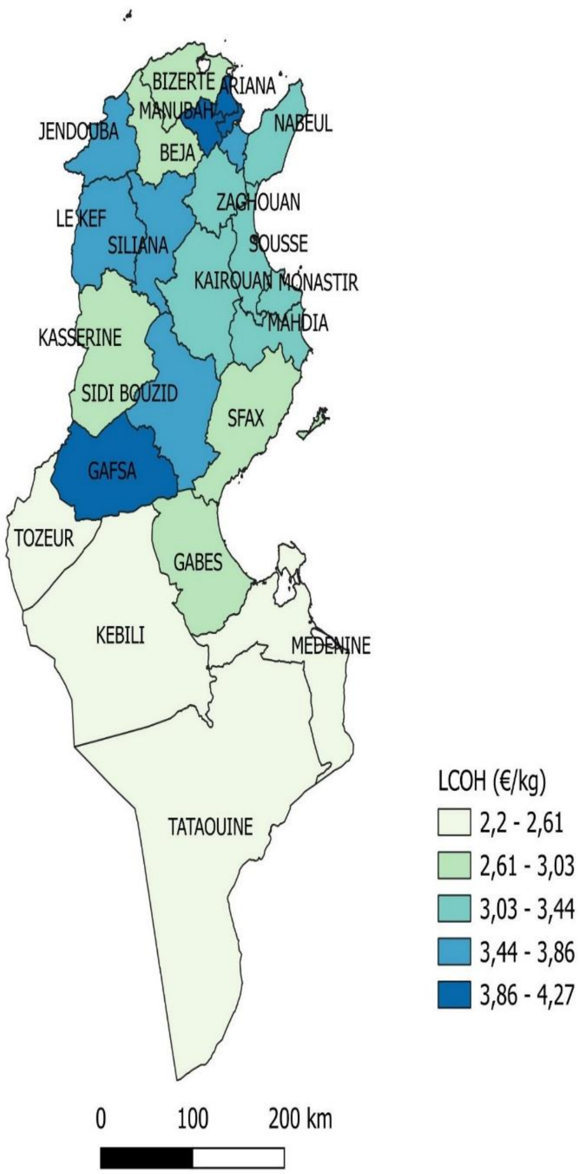

Figure 1: Spatial distribution of LCOH for PV and wind-based hydrogen production across Tunisia.

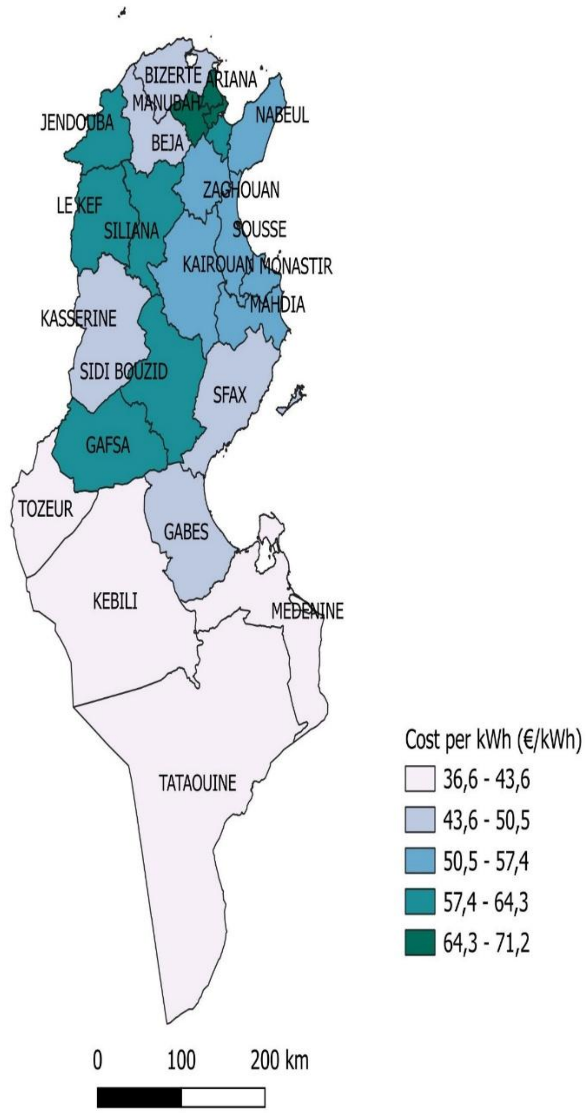

Figure 2: Regional variability of hydrogen production costs under different energy scenarios.

5. CONCLUSION

This study demonstrates that Tunisia holds strong potential for cost-competitive green hydrogen production. Hybrid PV-grid systems emerged as the most efficient configuration, achieving LCOH values between **€4.68 and €6.50/kg**, while wind-based systems can achieve **€3.35/kg** in optimal regions. However, regions with weak wind or low solar productivity exhibit significantly higher costs. Water availability and infrastructure remain key constraints that must be addressed. With strategic investments, Tunisia could position itself as a major hydrogen producer and exporter within the Mediterranean region.

Future work will include larger-scale simulations, integration with hydrogen storage systems, and the assessment of export pathways toward the European market.

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