Techno-Economic Assessment of Large-Scale Green Ammonia Production in Tunisia

Ameni Trigui*[1], Oussema Ridanea[1], Maher Ben Chiekh[1], Thomas Nietsch[2]

[1] University of Monastir, ENIM, Laboratory for the Study of Thermal and Energy Systems, Monastir, Tunisia

[2]ABO Energy AG, Future Energy Department. Unter den Eichen 7, 65195 Wiesbaden, Germany

*Corresponding author: maher.benchiekh@enim.rnu.tn

ABSTRACT

This study presents a techno-economic assessment of large-scale green ammonia production in Tunisia, based on the integration of hybrid wind-photovoltaic electricity, water electrolysis, air separation, and Haber-Bosch synthesis. Optimal sites near Gabès are selected, and hour-by-hour modelling is performed for production profiles and mass and energy balances. Two hydrogen management strategies are compared: maximizing production and storage versus adjusting to storage capacity. Results show that the former strategy delivers superior cost-effectiveness by valorizing surplus H_2 and O_2, achieving a levelized cost of hydrogen of €2.63/kg and of ammonia of €750/t. The analysis demonstrates Tunisia's strong potential as a regional hub for green ammonia and its contribution to decarbonizing the domestic chemical industry.

Keywords: Green ammonia; Power-to-Ammonia (PtA); techno-economic assessment; renewable energy; wind-PV hybrid system; Levelized Cost of Ammonia (LCOA).

1- INTRODUCTION

Ammonia plays a crucial role at the intersection of global food security and the energy transition, serving both as a key fertilizer feedstock and an emerging carrier for green energy storage and transport. Figure 1 presents a simplified process flow diagram of an integrated green ammonia production system. Electricity generated by wind turbines and photovoltaic (PV) panels supplies power to the entire chain. The electrolyzer uses renewable electricity to split water into hydrogen and oxygen. An air separation unit, also powered by renewables, produces nitrogen from ambient air and stores it in a separate tank. Finally, hydrogen and nitrogen streams are fed to the Haber–Bosch reactor, where they react to form ammonia (NH_3), which exits as the main product of the system.

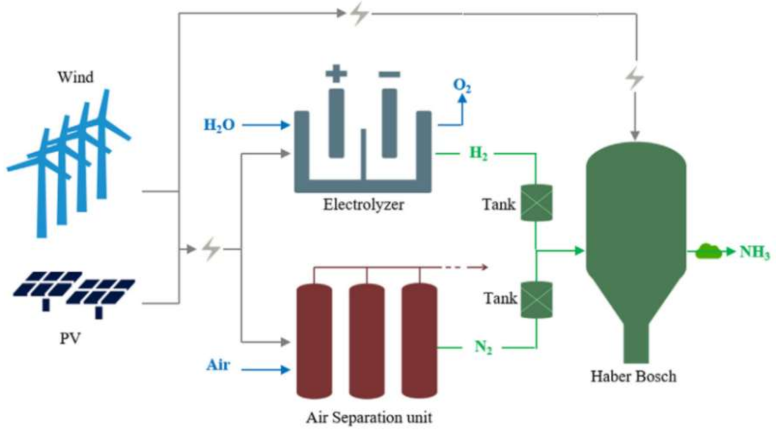
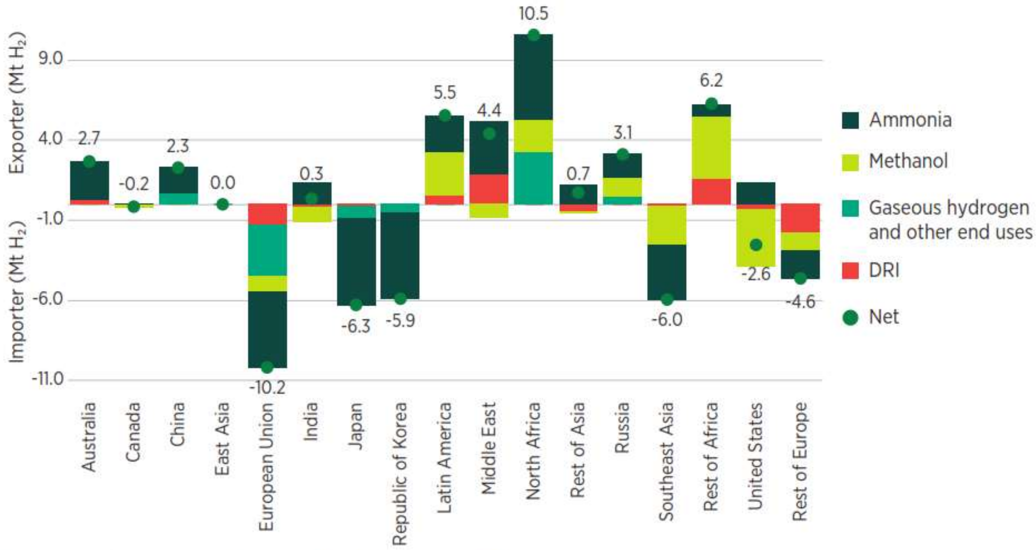


Figure 1- Model architecture of a Green Ammonia plant [1]

IRENA's scenario analysis (Fig. 2), which explores the techno-economic potential for trading green hydrogen and associated commodities such as ammonia, e-methanol and direct reduced iron (DRI) by 2050 using a cost-optimization approach, indicates that ammonia is expected to be the most traded commodity, with almost 30% of its demand met through international trade, significantly more than for the other green commodities considered in the study.



Notes: DRI = direct reduced iron; Mt H_2 = million tonnes of hydrogen.

Figure 2- Trading green hydrogen and associated commodities IRENA scenario for 2050 [2]

Tunisia has an established domestic ammonia industry, led by the Tunisian Chemical Group (GCT), which currently relies on imported ammonia to produce fertilizers for both domestic use and export. The national green hydrogen strategy [3] therefore places strong emphasis on developing green ammonia through the integration of green hydrogen with Haber–Bosch synthesis. Green ammonia holds a strategic position in Tunisia's green hydrogen roadmap. As a hydrogen derivative with high energy density and comparatively easier storage and transport, it is identified as a priority export product, particularly for European markets seeking low-carbon energy carriers. At the same time, domestic production of green ammonia would support the decarbonization of Tunisia's chemical and fertiliser industry, enabling GCT to gradually replace fossil-based ammonia imports with a competitively produced, low-carbon alternative.

A MoU between Amarenco, H2 Global Energy, and the Tunisian government has launched in 2024. The project plans to deploy 1.5-1.8 GW of electrolysers, enabling the production of 180,000 tonnes of green hydrogen per year. Construction is expected to begin in 2028, with commercial operations starting in 2031 [3].

This study presents a tailored techno-economic model for a green ammonia facility serving GCT, combining renewables, desalination, hydrogen storage, and grid integration.

2. SYSTEM DESIGN AND CONFIGURATION

Three optimal sites in Gabès, Tunisia, have been identified following regulatory criteria (minimum distance from residences, slope conditions, land use). The hybrid renewable system combines 1,116 MW wind and 1,040 MW photovoltaic (PV) capacity.

The modeled annual electricity output is 2.76 TWh from wind and 2.52 TWh from PV, with complementary generation profiles reducing storage needs and ensuring near-continuous electrolysis operation. Two wind farms hosting 95 and 85 Siemens Gamesa turbines deliver a combined capacity factor of 28%. The PV plant utilizes 230,094 JinkoSolar panels, yielding an annual energy production of ~2.52 TWh at a load factor of 27.7%.

A 750 MW PEM electrolyser system (75 units of 10 MW) is selected for its efficiency (66%) and operational flexibility. It consumes ~50 kWh/kg H_2 and produces ~83,856 tonnes H_2 annually. Water consumption is about 15 kg per kg H_2 produced, accounting for losses and system needs.

A dedicated seawater reverse osmosis plant supplies 360 m³/h of demineralized water, essential for reliable PEM electrolyser operation. Energy consumption for desalination is estimated at 4 kWh/m³.

Hydrogen is compressed and cooled to 25°C at 30 bars and stored in high-pressure tanks with a capacity of 550 tonnes, ensuring supply stability despite renewable intermittency.

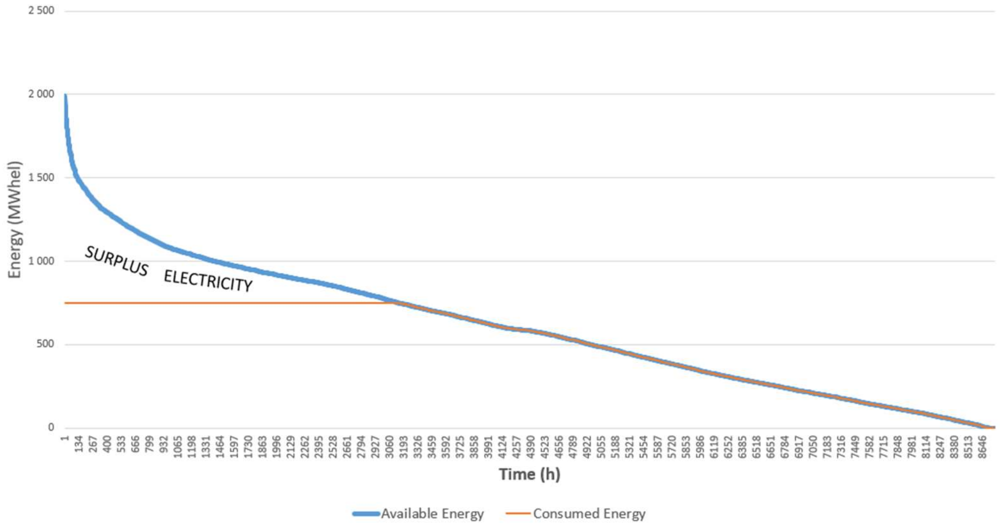


Figure 3- The electrolyser operation time.

3. RESULTS AND DISCUSSION

The technical and economic assessment compares two operational strategies for managing hydrogen production, storage, and energy integration within the proposed green ammonia system.

The first strategy consists of operating the electrolysers at maximum available renewable capacity throughout the year. In this case, hydrogen continues to be produced even when storage tanks are full, resulting in an annual overflow estimated at approximately 21,342 tonnes of hydrogen. Rather than being lost, this surplus can be valorised commercially. A realistic export pathway is the future SouthH_2 Corridor, a hydrogen pipeline intended to link southern Tunisia with El Haouaria and subsequently connect to Italy and European markets by 2030. Revenues generated from surplus hydrogen sales, combined with the commercialisation of by-product oxygen, significantly improve the economic performance of the plant. Under this scenario, the Levelized Cost of Hydrogen (LCOH) is calculated at €2.63/kgH_2, and the Levelized Cost of Ammonia (LCOA) reaches €750/tNH_3, making it the most economically favourable configuration.

The second strategy eliminates hydrogen overflow by curtailing electrolyser output once storage capacity is reached. While this approach prevents losses and simplifies storage management, it results in reduced annual hydrogen production, falling from 83,856 tonnes to approximately 65,700 tonnes. Consequently, the share of surplus renewable electricity exported to the grid rises from 19% to 37% of total annual generation. Although electricity exports provide an income stream, the associated revenues are considerably lower than those from hydrogen sales. This reduction in hydrogen output spreads the capital and operational expenditures over a smaller production volume, producing higher unit costs. Under this second strategy, the LCOH increases to €4.37/kgH_2, and the LCOA to €938/tNH_3.

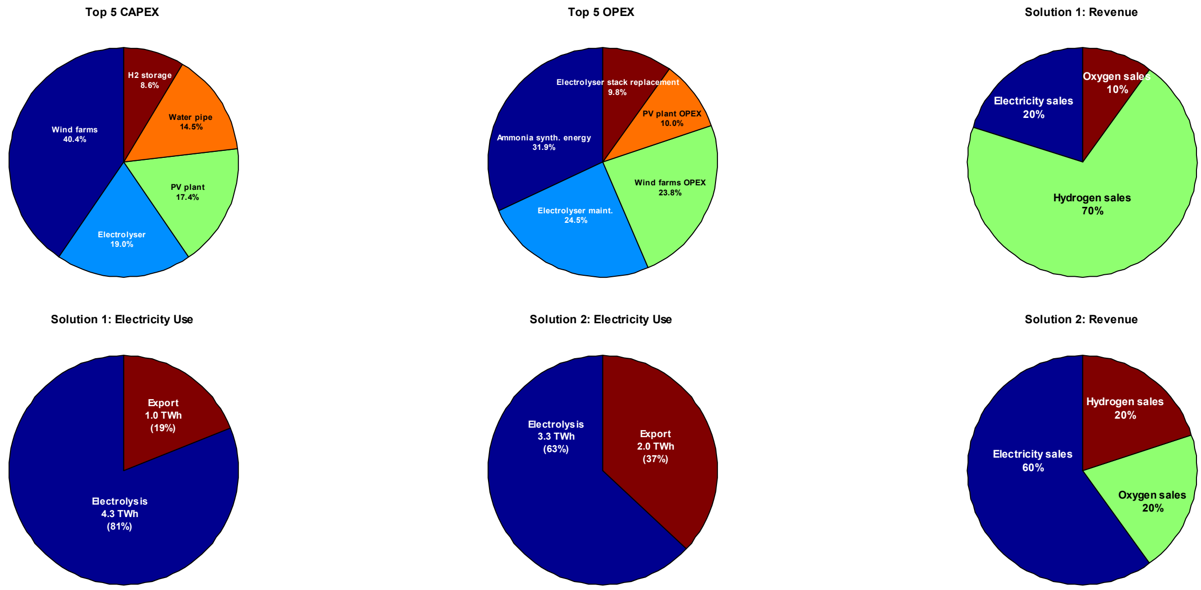


Figure 4- Comparison of the two operational strategies.

In both cases, three sources of revenue are taken into account: the sale of surplus electricity to the national grid (at €22–28/MWh), the sale of surplus hydrogen (assumed at €4.5/kgH_2), and the sale of high-purity oxygen generated during electrolysis (valued at €50/tO_2). The analysis demonstrates that economic competitiveness depends not only on reducing capital and operational costs but also on the capacity to valorise surplus energy streams. Overall, the first strategy proves superior because exporting surplus hydrogen provides high added value, thereby lowering the effective production costs of both hydrogen and ammonia. The study underscores the importance of integrated market and infrastructure strategies in green ammonia projects, particularly in regions where hydrogen export corridors are emerging.

4. CONCLUSION

this study confirms the strong techno-economic viability of green ammonia production in Tunisia using a hybrid wind-photovoltaic system, water electrolysis, air separation, and Haber–Bosch synthesis. The analysis demonstrates that maximized electrolyser operation and valorization of surplus hydrogen can bring the Levelized Cost of Hydrogen down to €2.63/kg and the Levelized Cost of Ammonia to €750/t. These results position Tunisia as a highly competitive regional supplier, supporting both domestic industry decarbonization and the growth of international low-carbon ammonia markets.

5. REFERENCES

[1] Bouaboula, H., Ouikhalfan, M., Saadoune, I., Chaouki, J., Zaabout, A., & Belmabkhout, Y. (2023). Addressing sustainable energy intermittence for green ammonia production. Energy Reports, 9, 4507-4517.

[2] IRENA, Analysis of the potential for green hydrogen and related commodities trade, 2025.

[3] MINE: National strategy for the development of green hydrogen and its derivatives in Tunisia, 2024.