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# Julia-Based Modelling and Optimization of Renewable Hydrogen Production from PV and Wind: Case Study of Algeria

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**Motivation:**
Renewable hydrogen is increasingly recognized as a key enabler for decarbonizing hard-to-abate sectors and for supporting large-scale integration of variable renewable energy sources. Countries with abundant solar and wind resources and existing energy export infrastructure are particularly well positioned to benefit from this transition. Algeria (North Africa) combines exceptional renewable energy potential with strategic proximity to European hydrogen demand, yet large-scale renewable hydrogen deployment faces two critical challenges: the intermittency of renewable electricity generation and the scarcity of freshwater resources. Addressing these challenges requires integrated energy–water system analyses that go beyond conventional power-only modeling approaches.

**Methodology:**
This study develops an hourly, techno-economic optimization model implemented in the Julia programming language using the JuMP optimization framework. The model represents an integrated energy–water–hydrogen system and is applied to two geographically distinct regions in Algeria: Ain Temouchent (coastal region) and Laghouat (Saharan region). The system includes solar photovoltaic and wind power generation, battery storage, water supply via seawater desalination and treated wastewater reuse, electrolysis for hydrogen production, hydrogen storage, and optional hydrogen-to-power reconversion using fuel cells. The optimization problem is formulated as a linear program that maximizes total system profit, accounting for revenues from hydrogen exports and regional electricity supply while considering capital and operational expenditures of all system components. Hourly solar and wind availability data are sourced from the Global Solar Atlas and Global Wind Atlas. All economic parameters are expressed using ISO-compliant currency codes (USD). Technical constraints such as minimum electrolyser load, storage losses, and capacity limits are explicitly modeled to ensure operational realism.

**Results:**
The results reveal pronounced spatial and temporal differences between the coastal and Saharan regions. Laghouat benefits from strong solar–wind complementarity, enabling high electrolyser utilization and reduced reliance on short-term battery storage. Ain Temouchent shows increased system flexibility due to reliable water availability from desalination and wastewater treatment. Across both regions, hybrid PV–wind configurations significantly enhance hydrogen production stability compared to single-technology systems. The inclusion of treated wastewater as an electrolysis feedstock proves to be technically viable and substantially reduces dependence on freshwater resources, an important advantage for arid regions. Hydrogen-to-power reconversion is activated only during limited periods of supply scarcity, confirming its role as a backup flexibility option rather than a dominant operational pathway. Economic results indicate stable hydrogen export revenues in USD with limited short-term variability, primarily driven by operational constraints rather than renewable resource availability.

**Conclusion**:
The study demonstrates that renewable hydrogen production in Algeria can be both economically attractive and resource-efficient when supported by integrated energy–water system design and hybrid renewable generation. Beyond the Algerian case, the proposed Julia-based modeling framework offers a transferable and scalable approach for analyzing renewable hydrogen systems in other water-scarce, renewable-rich regions.

**Author:** AGADI, Nadji

**Co-authors:** Dr DIETRICH, Kristin; Prof. VON HIRSCHHAUSEN„ Prof. Dr.Christian

**Presenter:** AGADI, Nadji

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