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Optimizing Offshore Green Hydrogen Systems via Modular Simulation

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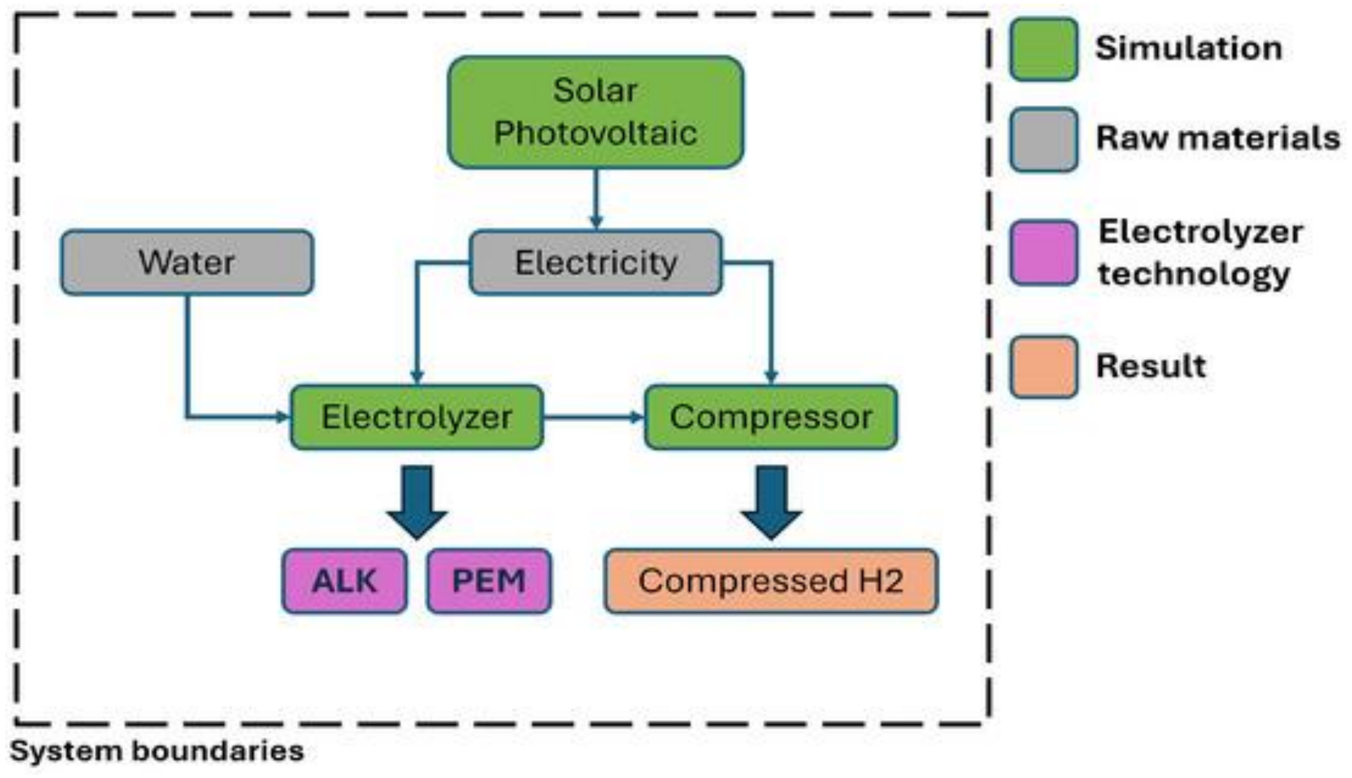
INTRODUCTION & AIM

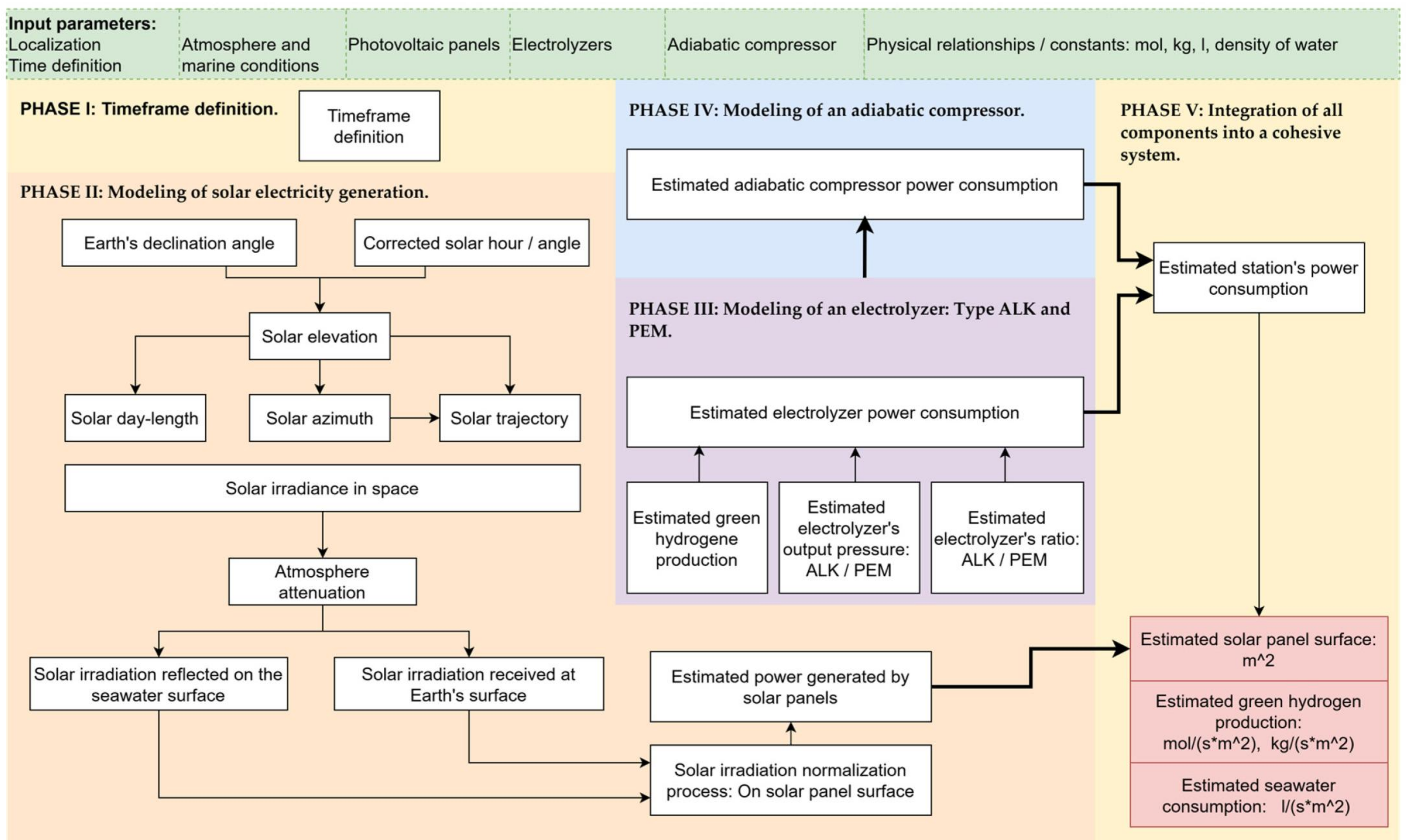
Offshore solar-powered hydrogen production is a promising solution to meet global decarbonization goals. **Marine environments offer significant advantages, such as higher solar irradiance, natural cooling, and lower land-use impact.** However, the complex interaction of environmental and technological factors requires robust tools for system design and optimization.



This work presents a **Python-based modular simulation model** to design, analyze, and optimize offshore hydrogen stations, integrating photovoltaic generation, water electrolysis, and hydrogen compression.

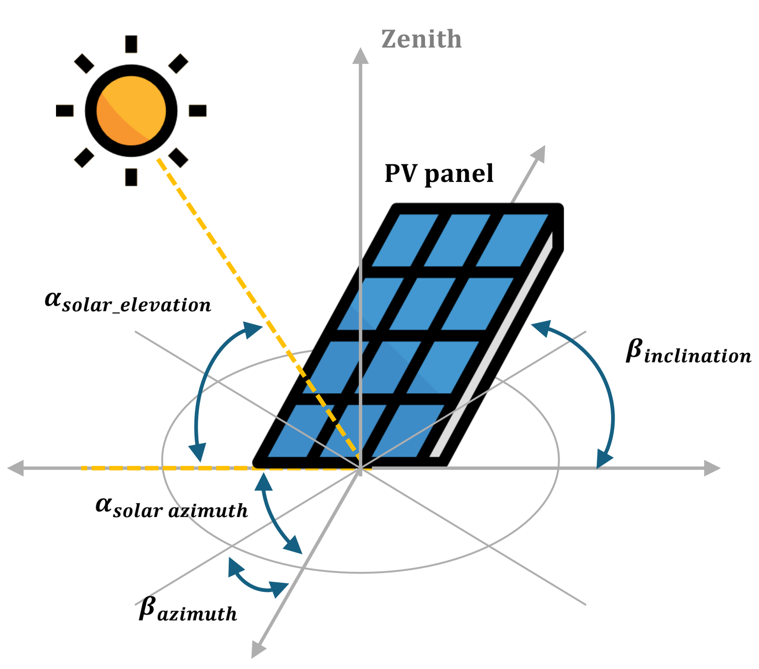
METHODS

The simulation follows a **five-phase modular structure**, enabling flexibility and reuse across geographical scenarios. Each module incorporates real-world physics and technical data:



To simulate real offshore behavior, the model incorporates:

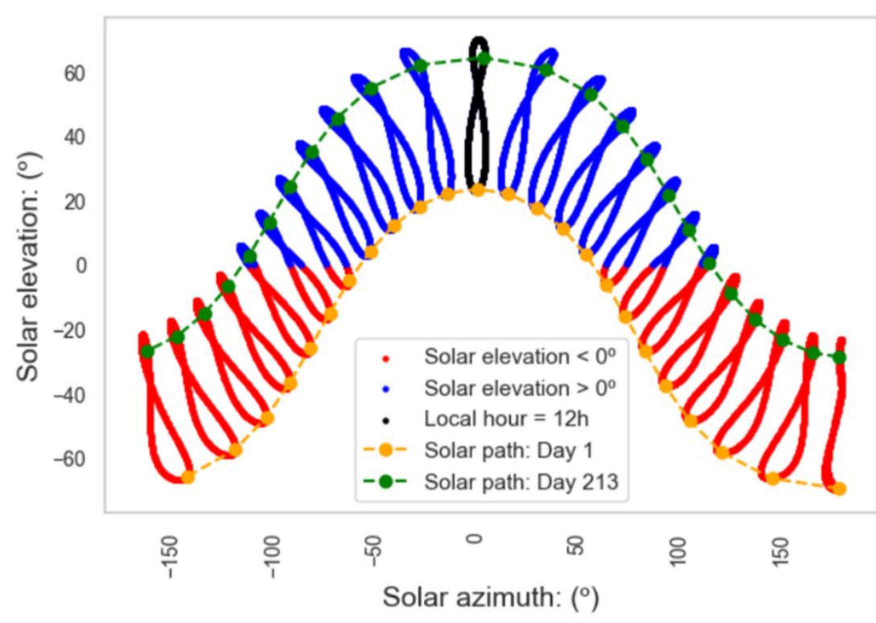
- **Solar Irradiance Estimation:** based on solar trajectory, photovoltaic panels' position and localization.
- **Sea Surface Reflectivity (SSR):** modeled as a function of surface flatness.
- **Air Pollution Impact:** estimated as a daily gain of +25.25% in irradiance normal vs dirty atmospheres.
- **Electrolyzer Parameters:** including type of technology, Hydrogen heating constant and efficiency.
- **Compressor Parameters:** pressure ratio, and compression efficiency.



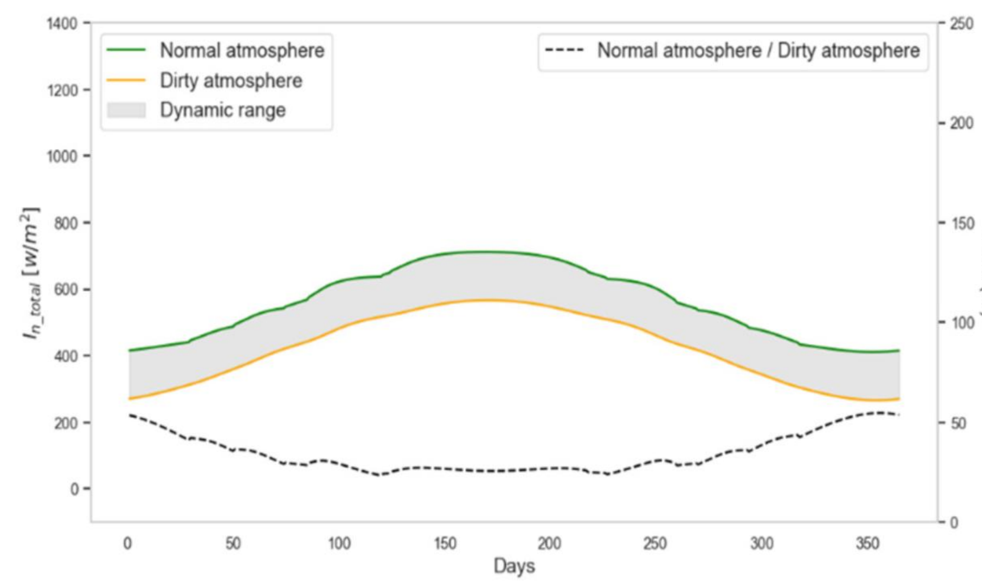
RESULTS & DISCUSSION

A simulation scenario is applied to **Santoña, Spain**, a coastal location with high potential for offshore solar deployment. The case study evaluates daily H_2 production from ALK and PEM electrolyzers, energy losses in compression, influence of environmental conditions on output, sensitivity to storage pressure (200–1000 bar) and effect of efficiency improvements.

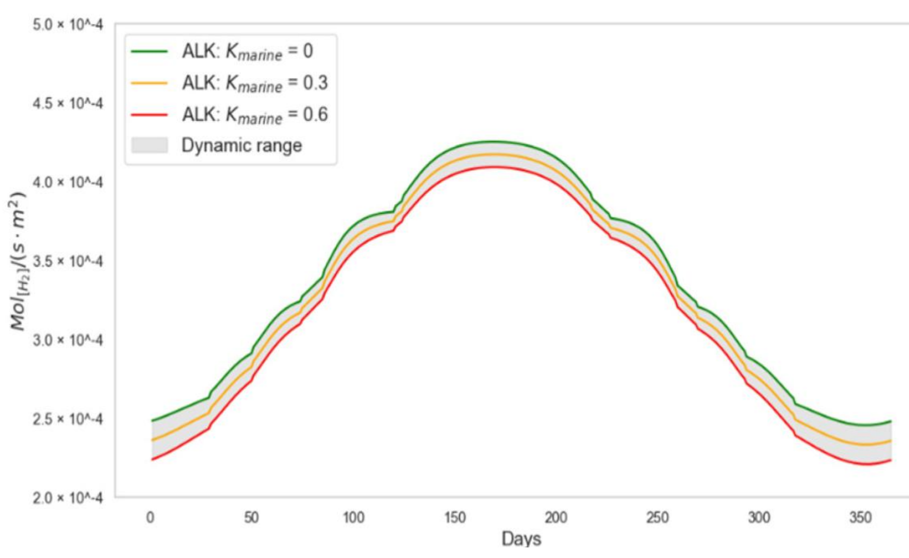
1) Solar analemmas



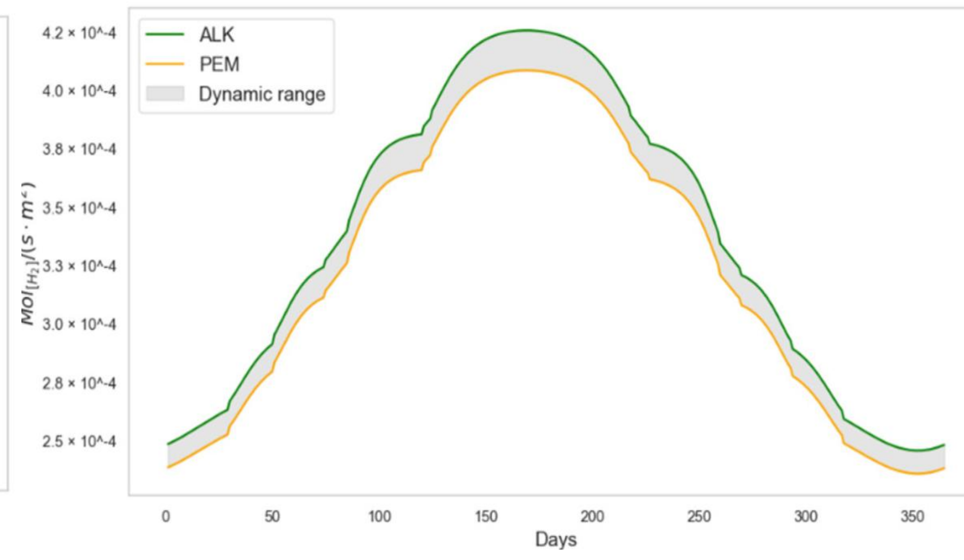
2) Contribution of air quality levels due to the atmospheric attenuation



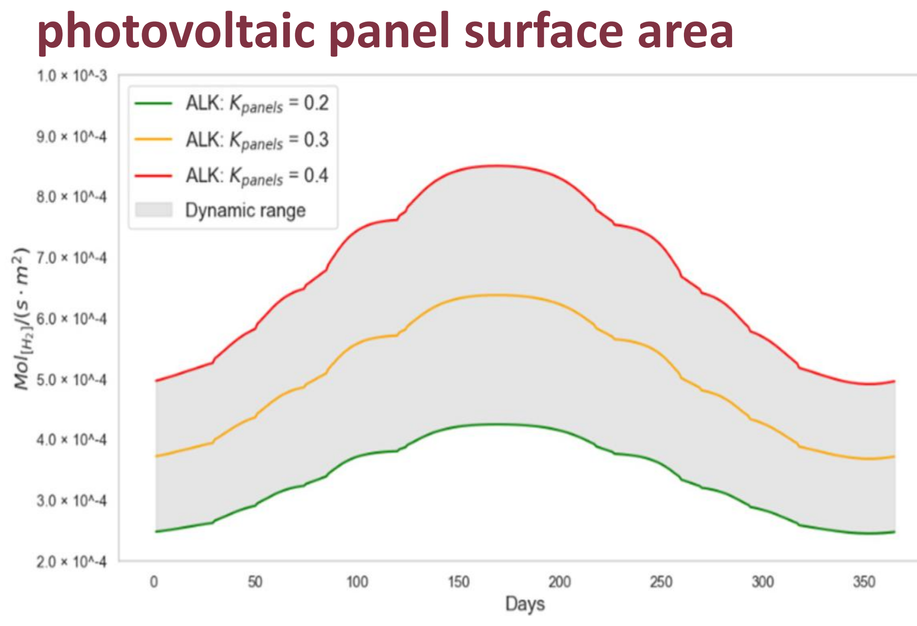
3) Contribution of air quality levels due to the atmospheric attenuation



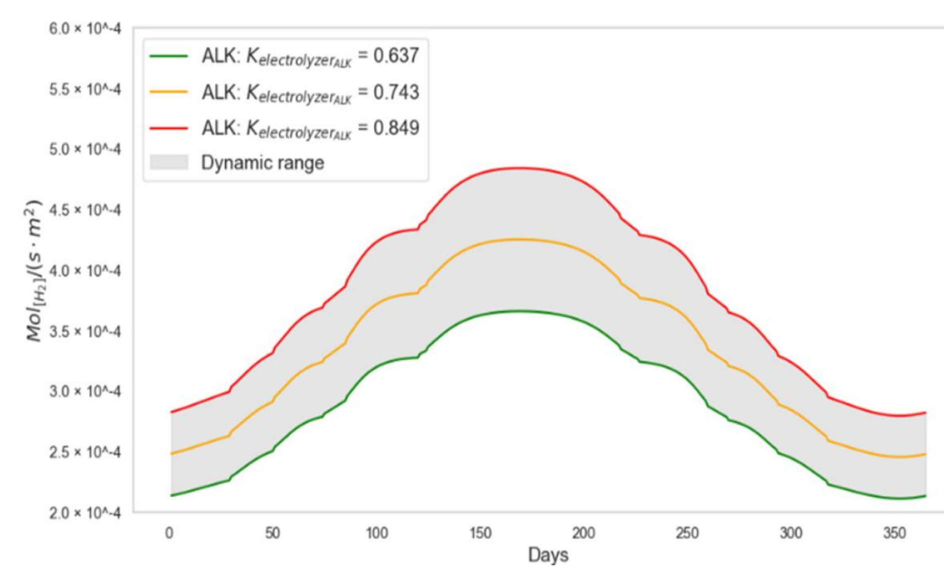
4) Hydrogen production



5) Contribution of photovoltaic efficiency to system performance and photovoltaic panel surface area



6) Contribution of electrolyzer efficiency



This modular approach supports **decision-making** in early-stage design of hydrogen infrastructure. By analyzing parameter sensitivities, the model enables:

- **Reduced surface area of PV panels due to higher system efficiency**
- **Optimized component sizing** (compressor, storage tank, electrolyzers)
- **Structural and anchoring requirements**
- **Lower Levelized Cost of Electricity (LCOE)** through efficiency gains
- **Smart Grid Integration**

CONCLUSIONS / FUTURE WORK

- Offshore solar hydrogen systems can be optimized using **modular, mathematics-driven simulations.**
- Environmental effects like sea reflectivity and pollution levels are **critical drivers** of performance.
- **Design parameters** such as storage pressure and efficiency **directly translate** into system-scale benefits.
- Future work will include dynamic load scenarios, cost modeling, and multi-source (wind + solar) integration.