GREEN HYDROGEN PRODUCTION FROM SOLAR-POWERED ELECTROLYSIS: TECHNO-ECONOMIC FEASIBILITY

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Abstract
The transition from fossil fuels has placed green hydrogen at the center of sustainable energy strategies. Produced via water electrolysis powered by renewable, it provides a zero-emission fuel for industry, transport, and energy storage. Among renewable pathways, solar-powered electrolysis is particularly promising in high-irradiance regions like Rajasthan, India. This study evaluates the techno-economic feasibility of an integrated photovoltaic (PV)-electrolyzer system by analyzing climatic data, technical specifications, and economic parameters such as capital expenditure (CAPEX) and operating costs. The primary challenge lies in balancing intermittent solar supply with continuous hydrogen demand while maintaining cost competitiveness. Modeling different configurations, we estimated hydrogen yield, system efficiencies, and Levelized Cost of Hydrogen (LCOH). Results show that a 100 MWp PV plant can produce 2,850–3,600 tons of hydrogen annually at ~12% efficiency, with an LCOH of USD 3.4–4.2/kg. Findings confirm technical feasibility and highlight cost reductions in PV and electrolyzers as critical for large-scale adoption.

Keywords: Green Hydrogen, Solar Energy, Electrolysis, Techno-Economic Feasibility, LCOH

1. Introduction

The global energy system is undergoing a profound transition to address the dual challenge of mitigating climate change and meeting rising energy demand. Fossil fuels, long the foundation of industrial growth, are now recognized as the primary drivers of “Greenhouse Gas (GHG)” emissions, environmental degradation, and resource depletion [1]. This has prompted policymakers, industries, and researchers to accelerate the shift toward renewable energy and carbon-neutral fuels [2]. Among these, hydrogen has emerged as a versatile energy carrier with applications in power generation, transportation, chemical industries, and energy storage [3, 4]. Unlike fossil fuels, hydrogen emits no carbon dioxide at the point of use, offering a sustainable alternative. However, the environmental impact of hydrogen depends largely on its production pathway [5].

Hydrogen production is commonly classified as grey, blue, or green. Grey hydrogen, produced mainly via “Steam Methane Reforming (SMR)”, dominates global supply but carries high CO_2 emissions [6]. Blue hydrogen couples SMR with “Carbon Capture and Storage (CCS)”, reducing emissions but still relying on fossil fuels and raising efficiency concerns [7, 8]. Green hydrogen, generated by splitting water through electrolysis powered by renewable electricity, represents the most sustainable option. Despite its promise, large-scale adoption of green hydrogen faces barriers in terms of cost, infrastructure, and efficiency [9].

Solar energy, abundant and increasingly cost-competitive, offers a strong basis for sustainable hydrogen production. Advances in PV technologies and supportive policies have spurred rapid growth in solar deployment worldwide [10]. Integrating solar power with electrolysis enables not only large-scale green hydrogen production but also effective storage of intermittent solar energy, enhancing grid stability and decarbonizing hard-to-abate sectors [11,12].

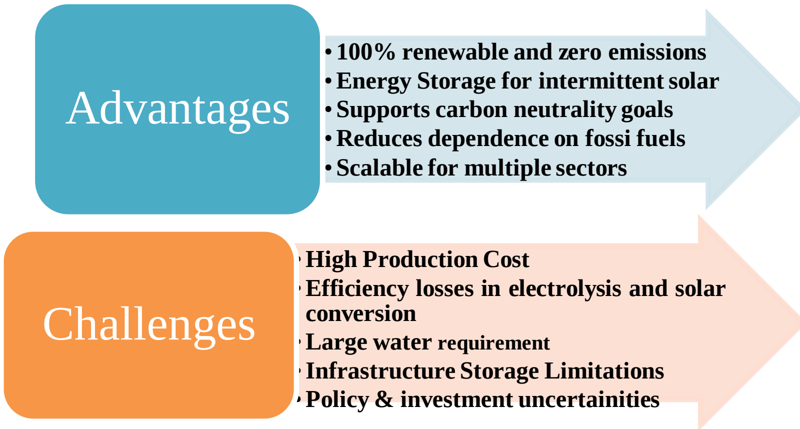

Figure 1: Advantages and challenges of solar-powered green hydrogen

The techno-economic feasibility of solar-powered electrolysis is vital for determining the competitiveness of green hydrogen against conventional hydrogen and fossil fuels. Technologically, the efficiency of photovoltaic systems, electrolyzer performance, and system integration must be assessed [13]. Electrolyzer types—“Proton Exchange Membrane (PEM)”, alkaline, and solid oxide—offer varying efficiencies, costs, and operational constraints, requiring careful evaluation for solar-driven applications [14, 15]. Economically, capital costs of electrolyzers, balance-of-plant systems, solar infrastructure, and storage strongly influence the LCOH [16]. Furthermore, policy incentives, carbon pricing, and economies of scale significantly shape the financial viability of green hydrogen projects.

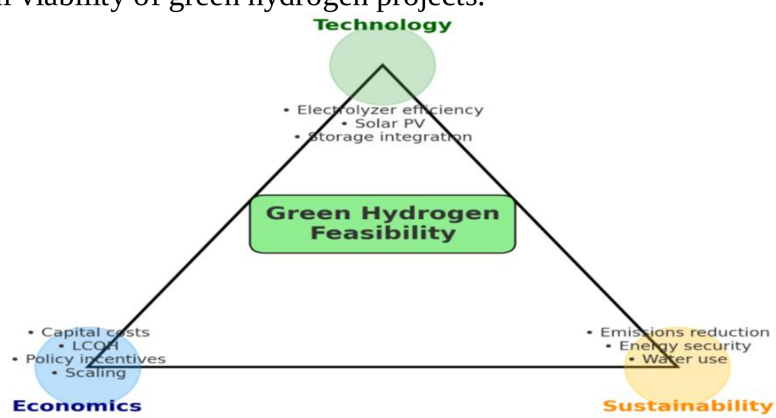

Figure 2: Techno-Economic Feasibility Triangle for Solar-Powered Electrolysis

Several studies indicate that green hydrogen production costs remain higher than grey or blue hydrogen, with current estimates of USD 4–6/kg compared to USD 1–2/kg for grey hydrogen [17]. However, falling solar PV costs, advances in electrolyzer technology, and economies of scale create optimism that green hydrogen could achieve cost parity within the next decade [18]. In addition, global energy security concerns, decarbonization goals under the Paris Agreement, and national hydrogen strategies in countries such as Germany, Japan, India, and Australia provide strong momentum for investment and research in this area [19]. Green hydrogen is expected to play a central role in achieving carbon neutrality by 2050, particularly when produced through solar-powered electrolysis. Realizing this potential requires a thorough understanding of its technical, economic, and policy dimensions [20].

Techno-economic feasibility studies are essential in this context as they help identify cost drivers, efficiency bottlenecks, and opportunities for optimization. Such analyses also inform innovation pathways and guide supportive policy frameworks [21, 22]. The purpose of this paper is to evaluate the techno-economic feasibility of solar-powered green hydrogen, focusing on photovoltaic performance, electrolyzer technologies, system integration, and economic assessment, while outlining opportunities for cost reduction and large-scale deployment.

2. Literature Review

The increasing global demand for sustainable energy solutions has positioned green hydrogen as a crucial player in the transition from fossil fuels to renewable energy systems. Produced via electrolysis using renewable electricity, green hydrogen offers a zero-emission fuel alternative capable of storing and transporting energy efficiently. Among the renewable pathways, solar-powered electrolysis has gained significant attention due to the abundant availability of solar resources in many regions, its scalability, and the potential to integrate with existing energy infrastructures. Understanding the techno-economic feasibility of such systems is essential for guiding investments, policymaking, and the broader adoption of green hydrogen technologies. Recent research has explored diverse strategies and system configurations for producing green hydrogen from solar energy while evaluating their economic viability. **Al Makky et al. (2025) [23]** demonstrated the potential of hybrid renewable energy systems in Oman, combining photovoltaic panels, wind turbines, battery storage, and fuel cells, producing 1544 kg of hydrogen annually at a LCOH of $5.67/kg. Similarly, **Lebepe et al. (2025) [24]** focused on rural South Africa, analyzing four photovoltaic-electrolyser configurations using HOMER software, and highlighted that improving electrolyser efficiency and reducing solar panel costs could lower LCOH by almost 50%, showing the impact of techno-economic optimization on affordability. **Barigozzi et al. (2024) [25]** addressed the challenge of intermittent solar energy for continuous industrial hydrogen supply, using TRNSYS-based dynamic modeling and optimization to minimize either LCOH or primary energy needs, with predicted costs ranging from $10 to $11.5/kg depending on renewable energy contribution. Complementing these studies, **Yilmaz et al. (2025) [26]**developed experimental and computational models in EES and Aspen Plus, achieving an LCOH of $5.84/kg while validating the energy and energy efficiency of solar-assisted electrolysis. **Park et al. (2024) [27]** further emphasized multi-objective optimization to balance hydrogen productivity and economic cost across countries, revealing that optimal electrolyser sizing and strategic battery integration could enhance system performance and economic viability.

Several studies have also focused on regional case studies and infrastructure design to evaluate real-world feasibility. **Srettiwat et al. (2023) [28]** compared domestic versus imported hydrogen costs in Belgium, indicating that importing green hydrogen from Namibia could achieve an LCOH as low as €3/kg under certain cost-reduction scenarios. **Muthia et al. (2024) [29]**proposed floating solar photovoltaic systems to meet industrial hydrogen demand, highlighting the potential of blending hydrogen with natural gas to support industrial decarbonization, although the current production cost remains high at $26.95/kg. In Italy, **Massaro et al. (2024) [30]**analyzed centralized versus on-site production in Sicily, showing that centralized production could significantly reduce costs due to economies of scale. Similarly, **Hassan et al. (2023) [31]** optimized off-grid PV-electrolyzer systems in Iraq, finding an optimal electrolyzer size of 8 kW paired with a 12 kWp PV array, producing hydrogen at $3.23/kg. **León**

et al. (2023) [32] and **Ibagon et al. (2023) [33]**developed techno-economic models in Chile and Uruguay, respectively, revealing that optimal system sizing, transport, and storage strategies are critical to minimizing LCOH while addressing renewable intermittency and scaling issues. **Loh et al. (2025) [34] and Muhammad et al. (2024) [35]** focused on optimization models for clean hydrogen production, assessing energy consumption, storage, and system yield, demonstrating the integration of high-temperature electrolysis with concentrated solar power to achieve an LCOH of $8.87/kg, reducible to $8.07/kg via cogeneration strategies. Despite progress in solar-powered green hydrogen production, critical research gaps persist. Most studies are region-specific and lack integration of large-scale operational data with dynamic modeling to address solar intermittency and seasonal variations. Long-term electrolyzer degradation, maintenance, and hybrid integration with wind or storage are seldom explored. Environmental impacts and lifecycle costs across deployment scales remain under-researched. Addressing these gaps is essential for a holistic understanding of technical, economic, and environmental feasibility, enabling wider adoption and stronger policy support.

3. Problem Formulation

Green hydrogen production through solar-powered electrolysis offers a sustainable energy pathway but faces key challenges. Intermittent solar supply versus continuous hydrogen demand requires optimized electrolyzer sizing, efficient system design, and storage integration. High capital costs, efficiency variability, and dependence on local solar resources further hinder feasibility. Limited studies integrate techno-economic modeling with real-world performance across scales. The core problem is to identify cost-effective, scalable configurations that maximize efficiency, reduce LCOH, and ensure reliability, guiding policymakers and stakeholders toward viable green hydrogen adoption.

4. Research Methodology

4.1 Research objectives

Here are four objectives for the study:

- To evaluate the techno-economic feasibility of producing green hydrogen using solar-powered electrolysis.
- To calculate the Levelized Cost of Hydrogen (LCOH) and assess overall system performance.
- To analyze the impact of key cost drivers such as capital expenditure, efficiency, and solar resource variability.
- To provide recommendations for optimization of system design and large-scale deployment.

4.2 Study Area

The research area for this study is Rajasthan, India, one of the most suitable regions for large-scale solar energy projects. Located in northwestern India, Rajasthan receives some of the country's highest solar irradiation, averaging 5.5–6.5 kWh/m²/day, with vast arid and semi-arid land, low population density, minimal agricultural use, and abundant space for PV installations. The state's clear skies and low annual rainfall enable consistent solar energy harvesting. Beyond natural advantages, the Rajasthan Solar Energy Policy 2019 promotes investment in solar and hydrogen projects, supported by strong transmission infrastructure and proximity to industrial hubs. These factors collectively make Rajasthan an ideal case study for assessing the techno-economic feasibility of solar-powered green hydrogen production.

4.3 Data Collection and Input Parameters

The **"**Renewable Hydrogen Production Dataset**"** provides data for 2,535 cities on hydrogen production from renewable energy, including PV and electrolyzer performance, solar irradiation, temperature, module efficiency, electrolyzer capacity, hydrogen output, CAPEX, O&M costs, and LCOH. It supports techno-economic feasibility and performance modeling.

- **Climatic Data:** For Rajasthan, key variables include solar irradiation, ambient temperature, and seasonal distribution, sourced from NASA SSE, NREL, and IMD, informing PV and electrolyzer performance.
- **Technical Specifications:** Include PV modules, PEM and Alkaline electrolyzers, inverters, compressors, and storage systems. Parameters such as efficiency, degradation, flexibility, and storage capacity are based on manufacturer datasheets and literature.
- **Economic Parameters:** Cover CAPEX, O&M, discount rates, project lifetime, tariffs, and hydrogen prices, sourced from industry reports, India's National Green Hydrogen Mission, and academic studies, enabling LCOH and financial feasibility analysis.

4.4 Data Preprocessing

The Renewable Hydrogen Production Dataset was preprocessed to ensure accuracy and uniformity. Missing irradiation or temperature values were filled using linear interpolation:

$$X_t = X_{t-1} + \frac{(X_{t+1} - X_{t-1})}{2}$$

Outliers were detected using the z-score method ($|z| > 3$) and corrected or removed. All parameters were standardized into common units (kWh/m²/day, °C, USD). Key modeling assumptions include a constant PV efficiency with 0.5% annual degradation, fixed electrolyzer efficiency with end-of-life replacements, an 8% discount rate over a 20-year project lifetime, and O&M costs escalating with uniform annual inflation. These assumptions ensure a transparent, reproducible, and comparable techno-economic analysis.

4.5 System Configuration and Design

The system design for solar-powered hydrogen production involves the integration of three main components: the PV system, electrolyzer, and hydrogen storage along with the "Balance of System (BOS)" components. The configuration is optimized to ensure maximum efficiency, reliability, and cost-effectiveness.

- **Photovoltaic (PV) System**: The PV system converts solar irradiation into electricity. Key design considerations include module type, capacity, efficiency, degradation, and array configuration, sized to meet the electrolyzer's annual demand.
- **Electrolyzer Selection**: Both PEM and alkaline electrolyzers are evaluated for efficiency, flexibility, lifetime, and cost, ensuring compatibility with variable solar input and high hydrogen production.

Figure 3: Designing of proposed system

- **Hydrogen Storage and Balance of System**: Hydrogen storage buffers intermittent solar supply against continuous demand, considering pressure, capacity, and efficiency losses. BOS components—such as inverters, controllers, pumps, and safety devices—are selected based on manufacturer specifications to ensure safe, stable, and well-integrated operation.

4.6 Techno-Economic Assessment

Both the techno-economic assessment examines the economic viability and energy operation of the proposed solar powered hydrogen production system, which involves estimating the NPC, LCOH, and efficiency metrics. The assessment provides these indicators for comparing system configuration, optimally design, and enabling economic viability.

- **Net Present Cost (NPC)**

The NPC is the total life-cycle cost of the system across its operational lifetime. It includes capital cost (CAPEX), O&M costs, replacement costs, and is discounted to present value:

$$\mathrm{NPC} = \mathrm{CAPEX} + \sum_{i=1}^{n} \frac{\mathrm{O\&M_t} + \mathrm{Replacement_t}}{(1+\mathrm{r})^{\mathrm{t}}}$$

Where CAPEX is initial capital cost (USD), O&M_t is operational and maintenance cost at year t (USD/year), $Replacement_t$ is cost of component replacements at year t (USD/year), r is discount rate, n is Project lifetime.

- **Levelized Cost of Hydrogen (LCOH)**

The LCOH represents the average cost per kilogram of hydrogen produced over the system lifetime, taking into account all costs and energy production:

$$\mathrm{LCOH} = \frac{\mathrm{NPC}}{\sum_{t=1}^{n} \frac{\mathrm{H_{2-t}}}{(1+\mathrm{r})^{\mathrm{t}}}}$$

Where H_{2-t} is Hydrogen produced in year t (kg), r is discount rate and n is Project lifetime (years). This metric is critical for comparing renewable hydrogen with fossil-fuel-based hydrogen production.

4.6.1 Efficiency Metrics

Efficiency metrics quantify the conversion of solar energy into hydrogen and system performance:

- **PV-to-Electricity Efficiency ($\boldsymbol{\eta_{PV}}$)**

$$\boldsymbol{\eta_{PV} = \frac{E_{el}}{E_{solar}} \times 100}$$

Where $\mathbf{E_{el}}$ is Electrical energy generated by PV (kWh), $\mathbf{E_{solar}}$ is Solar energy incident on PV array (kWh)

- **Electrolyzer Efficiency ($\boldsymbol{\eta_{EL}}$)**

$$\boldsymbol{\eta_{EL} = \frac{E_{H2}}{E_{el}} \times 100}$$

Where $\mathbf{E_{H2}}$ is Energy content of hydrogen produced (kWh or MJ), $\mathbf{E_{el}}$ is Electrical energy consumed by electrolyzer (kWh)

- **Overall System Efficiency ($\boldsymbol{\eta_{sys}}$)**

$$\boldsymbol{\eta_{sys} = \eta_{PV} \times \eta_{EL} \div 100}$$

Where $\boldsymbol{\eta_{sys}}$isrepresents total energy conversion efficiency from sunlight to stored hydrogen

To enhance techno-economic modeling, the following metrics can be included:

- **Capacity Factor (CF):** Ratio of actual hydrogen production to maximum possible production.

$$\mathrm{CF} = \frac{\mathrm{H_{2\ actual}}}{\mathrm{H_{2\ max}}} \times 100$$

- **Payback Period (PBP):** Time required recovering initial investment.

$$PBP = \frac{CAPEX}{\text{Annual net revenue from H2 sale}}$$

4.7 Optimization and Scenario Analysis

To enhance system performance and economic viability, optimization and scenario analysis were conducted on the proposed solar-powered hydrogen production system. This approach helps identify the most cost-effective and efficient configuration under varying conditions. The system's performance and economics are sensitive to key parameters, including solar resource availability, which affects PV energy output and hydrogen production; CAPEX, impacting NPC and LCOH; and system efficiency, influencing overall hydrogen yield and energy conversion. Sensitivity analysis was performed by systematically varying these parameters to quantify their effects and identify the most influential factors, providing guidance for system design and investment decisions. Multiple configurations were evaluated, including PV array size and technology, electrolyzer type and capacity, hydrogen storage alternatives, and hybrid setups with grid or battery support. Each scenario was assessed based on techno-economic metrics and efficiency, enabling identification of configurations that maximize hydrogen production while minimizing costs.

5. Result and Analysis

5.1 Solar Resource Assessment

Rajasthan shows a mean "Global Horizontal Irradiation (GHI)" of 5.8 kWh/m²/day and more than 300 clear-sky days annually, demonstrating solid solar potential. The monthly solar irradiation profile Figure 4 shows that summer month's peak above 6.5 kWh/m²/day while monsoon months bottom out at around 4.5 kWh/m²/day, showing the availability of solar energy varies seasonally.

Table 1: Monthly Average Solar Irradiation in Rajasthan

Month	**Solar Irradiation (kWh/m²/day)**
Jan	5.2
Feb	5.6
Mar	6.2
Apr	6.5
May	6.8
Jun	6.6
Jul	4.8
Aug	4.5
Sep	4.7
Oct	5.4
Nov	5.6
Dec	5.9

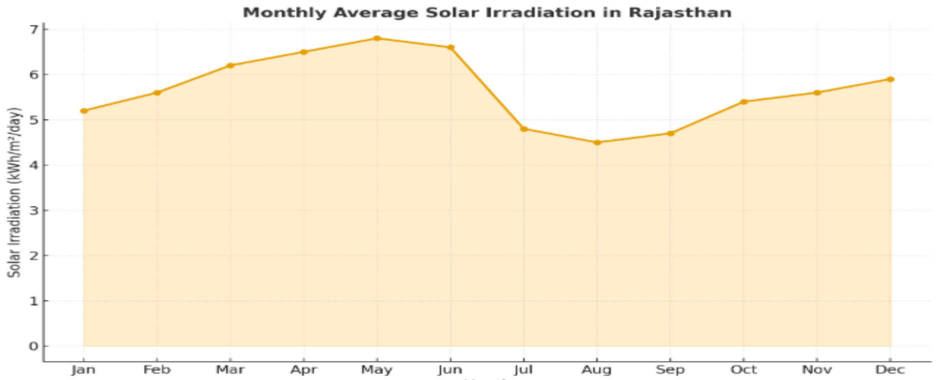

Figure 4: Monthly Average Solar Irradiation in Rajasthan

5.2 PV System Output

The energy supply is provided by a 100 MWp PV system in Rajasthan, delivering high solar irradiation year-round. In the first year, it produces ~170 GWh of electricity with a capacity factor of 19.4%, consistent with regional solar potential and expected conversion efficiencies. An annual PV degradation of 0.5 % over a 20-year project reduces cumulative energy yield by ~9–10%. The system primarily powers the electrolyzer, with excess electricity during peak hours stored as hydrogen. The PV array is sized to meet most of the electrolyzer's demand while minimizing underutilization of stored energy.

Table 2: PV System Performance Metrics

Parameter	Value	Unit
Installed Capacity	100	MWp
Annual Output (Year 1)	170	GWh
Capacity Factor	19.4	%
PV Module Efficiency (ηPV)	17.8	%
Annual Degradation Rate	0.5	%/yr
Lifetime Output (20 years)	~3,100	GWh

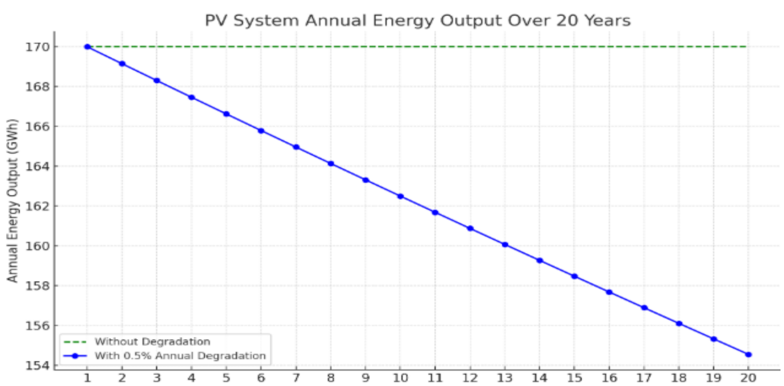

Figure 5: PV System Annual Energy Output Over 20 Years

5.3 Electrolyzer Performance

A performance comparison of PV-driven PEM and Alkaline electrolyzers shows a trade-off between efficiency and flexibility. The PEM electrolyzer produces 2,850 t/year of hydrogen at 65% efficiency, offering rapid response and better adaptability to variable solar input. The Alkaline electrolyzer yields 3,050 t/year at 70% efficiency, consuming less energy per unit of hydrogen but with limited flexibility, making it better suited for stable solar conditions or systems with storage. Overall, PEM is more adaptable for intermittent PV supply, while Alkaline achieves higher annual output and energy efficiency under consistent conditions.

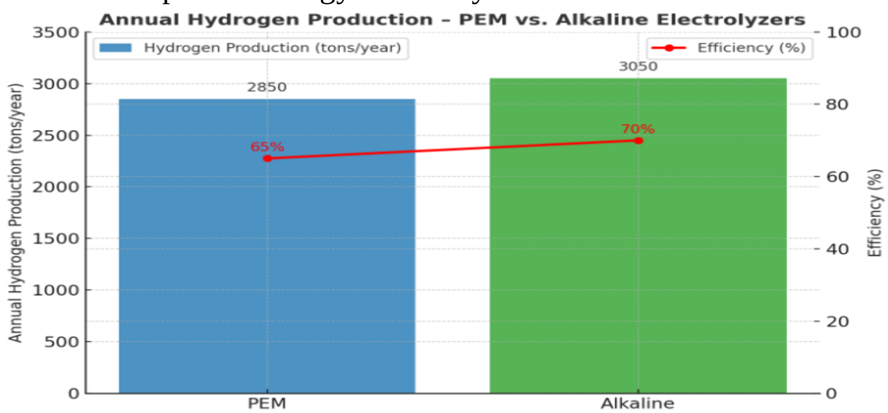

Figure 6: Annual Hydrogen Production and Efficiency – PEM vs. Alkaline Electrolyzers

The comparison in Figure 6 demonstrates that the Alkaline electrolyzer produced hydrogen at 3,050 tons/year at 70% efficiency, while the PEM electrolyzer produced 2,850 tons/year at 65% efficiency. The Alkaline technology is therefore more efficient and better both in terms of overall hydrogen output. PEM technology produces slightly less hydrogen, yet provides comparable performance and the flexibility to deal with a variable solar input, as it is capable of quickly responding to changes in operating conditions.

5.4 Techno-Economic Assessment

- ***Net Present Cost (NPC)***

The baseline system—100 MWp PV, 50 MW electrolyzer, and hydrogen storage—has a Net Present Cost (NPC) of USD 285 million over 20 years, including capital, O&M, and replacements. The PV system accounts for the largest share, followed by the electrolyzer with periodic stack replacements. Hydrogen storage supports supply-demand balance, while O&M costs contribute the least to total expenses.

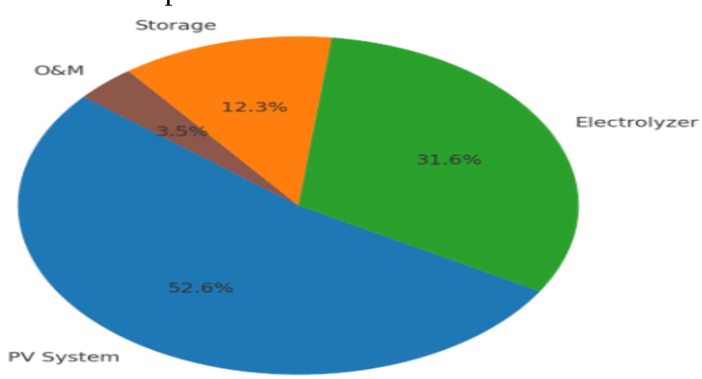

Figure 7: NPC Breakdown of PV-Electrolyzer-Storage System

Figure 7 represents the breakdown of cost for the baseline system. The data shows the PV system represents the most substantial portion of the Net Present Cost at USD 150 million (~53%), followed by the electrolyzer USD 90 million (~32%), then storage costs of USD 35 million (~12%) and finally O&M costs at USD 10 million (~3%). It can be observed that the majority investment is from the PV and electrolyzer, which reflects the significant harmalk impacts to overall system economics, and therefore warrants cost reduction consideration.

- **Levelized Cost of Hydrogen (LCOH)**

For the baseline system, they estimate LCOH in the USD 3.6–4.2/kg H_2 range, depending upon which electrolyzer technology and solar PV configuration is implemented. Table 4 summarizes the LCOH, NPC, and annual hydrogen production for different system scenarios.

- **PV + PEM (50 MW):** LCOH USD 4.2/kg H_2, NPC USD 285 M, hydrogen output 2,850 t/year; higher cost due to lower efficiency but flexible with variable PV.
- **PV + Alkaline (50 MW):** LCOH USD 3.9/kg H_2, NPC USD 280 M, hydrogen output 3,050 t/year; lower cost under stable solar conditions.
- **Oversized PV (120 MW + 50 MW electrolyzer):** LCOH USD 3.4/kg H_2, NPC USD 320 M, hydrogen output 3,600 t/year; higher yield and improved cost efficiency.

Table 3: LCOH Results under Different Scenarios

Configuration	**LCOH (USD/kg)**	**NPC (M USD)**	**H_2 Output (tons/year)**
PV + PEM (50 MW)	4.2	285	2,850
PV + Alkaline (50 MW)	3.9	280	3,050
PV Oversized (120 MW + 50 MW)	3.4	320	3,600

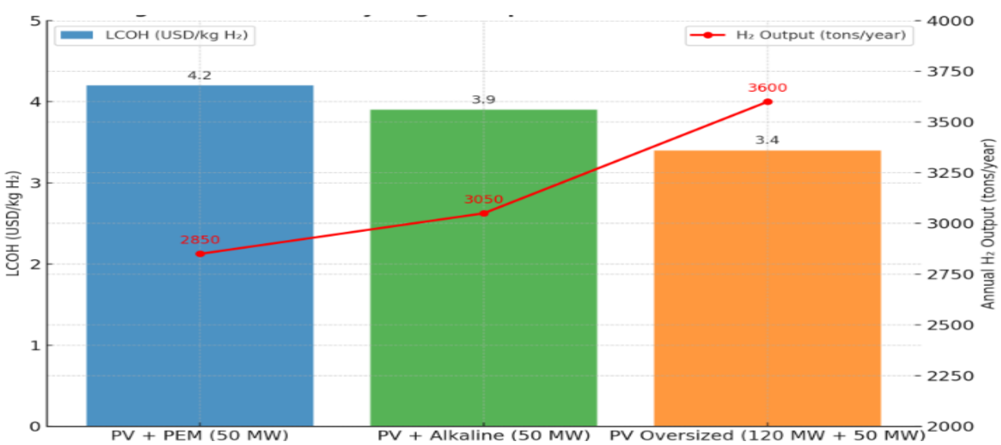

Figure 8: LCOH and Hydrogen Output under Different Scenarios

Figure 8 shows that the oversized PV configuration achieves thelowest LCOH (USD 3.4/kg H_2) while delivering the highest hydrogen output (3,600 tons/year)**,** despite a higher NPC of USD 320 million. In comparison, the Alkaline system provides a balanced outcome with an LCOH of USD 3.9/kg H_2 and production of 3,050 tons/year**,** whereas the PEM system records the highest LCOH (USD 4.2/kg H_2) and the lowest output **(**2,850 tons/year**).** This highlights the trade-off between capital investment and cost efficiency, with PV oversizing improving utilization and reducing hydrogen costs.

5.5 Efficiency Metrics

The overall energy conversion efficiency of the solar-powered hydrogen system was assessed in three stages: PV conversion, electrolyzer performance, and combined system efficiency**.** PV modules achieved an average efficiency of 17.8%**,** while electrolyzers operated between 65–70%**,** with alkaline types performing better under stable conditions. The integrated system efficiency, representing solar-to-hydrogen conversion, was about 12%. Although conversion losses occur at each stage, the results confirm the technical feasibility of solar-powered electrolysis for green hydrogen production in high-irradiance regions such as Rajasthan.

Table 4: Efficiency Metrics of the System

Metric	Value	Unit
PV Efficiency (ηPV)	17.8	%
Electrolyzer Efficiency (ηEL)	65–70	%
Overall System Efficiency (ηsys)	~12	%

5.6 Sensitivity Analysis

Sensitivity analysis shows that LCOH is highly influenced by CAPEX, electrolyzer efficiency, and solar variability. A 20% CAPEX reduction lowers LCOH by ~15%, a 5% efficiency gain reduces it by ~USD 0.3/kg H_2, and a ±10% change in solar irradiation alters LCOH by ±USD 0.25/kg, emphasizing the impact of costs, technology, and site selection.

Figure 9: Sensitivity of LCOH to CAPEX, Efficiency, and Solar Irradiation

Figure 9 indicates that a 20% reduction in CAPEX has the strongest impact, lowering the LCOH by about USD 0.57/kg H_2. A5% increase in electrolyzer efficiency reduces the LCOH by approximately USD 0.30/kg H_2, while a±10% variation in solar irradiation results in a moderate LCOH fluctuation of ±0.25 USD/kg H_2. These results suggest that capital cost reductions provide the greatest leverage in achieving cost-competitive green hydrogen, followed by efficiency improvements, whereas solar variability exerts a comparatively smaller but notable effect.

6. Conclusion

This study demonstrates the technical and economic viability of solar-powered green hydrogen production in Rajasthan, thanks to its high solar irradiance. A 100 MWp PV system with PEM or Alkaline electrolyzers can produce 2,850–3,050 tons of hydrogen annually, with system efficiency around 12%. Alkaline electrolyzers yield higher output under stable sun conditions, while PEM offers better flexibility with variable generation. Investment in PV and electrolyzers dominates system costs, with levelized hydrogen costs (LCOH) estimated at USD 3.4–4.2/kg. Sensitivity analysis shows that reducing capital costs and improving efficiencies can further lower costs. Overall, optimized PV-electrolyzer configurations in high-irradiance regions can produce sustainable and cost-effective green hydrogen.

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