TECHNO-ECONOMIC ANALYSIS OF A SOLAR THERMAL WATER PREHEATING SYSTEM FOR A 5 MW ELECTROLYZER IN PECÉM, BRAZIL

Summary

In this study, a techno-economic analysis is presented for a solar thermal system designed to preheat feedwater for a 5 MW hydrogen electrolyzer at the Pecém Industrial and Port Complex (Ceará, Brazil). The system uses 602 m² of solar collectors to heat 21.6 m³ of water per day from 30 °C to 90 °C. Annual solar heat supply (~0.55 GWh) yields approximately R$329,551 in electricity savings and excellent financial performance: net present value (NPV) ~R$1.27 million, internal rate of return (IRR) 24.46%, and discounted payback ~5 years. The levelized cost of heat (LCOH) is estimated at R$0.329/kWh, significantly below the local electricity tariff, confirming the economic viability of integrating solar thermal preheating into green hydrogen production.

Keywords: solar thermal, water preheating, electrolyzer, techno-economic analysis, green hydrogen

1. Introduction

Green hydrogen produced via water electrolysis is anticipated to play a key role in decarbonizing industries and energy systems. However, producing renewable hydrogen remains several times more expensive than conventional hydrogen, largely due to the high energy requirements of electrolysis (IEA, 2021). Reducing the electrical energy consumption for hydrogen production is therefore crucial to improve its economic viability. One approach is to utilize abundant renewable thermal energy resources to supply part of the energy required by the process. Solar thermal systems can provide heat at low-to-medium temperatures (≈60–100 °C) suitable for industrial processes, making them well-suited for preheating the feedwater of electrolyzers (Kalogirou, 2003). Ceará, in Northeast Brazil, has high solar irradiance and a strong potential for renewable energy, which makes it an attractive location for clean hydrogen production. In fact, a major green hydrogen hub is being developed at the Pecém Industrial and Port Complex. In this context, the present work evaluates the technical and economic feasibility of integrating a solar thermal water-heating system to preheat the input water for a 5 MW electrolyzer at Pecém.

2. Methodology

The study considers a solar thermal system sized to preheat 21.6 m³ per day of demineralized water (the feedwater for a 5 MW electrolyzer) from 30 °C (ambient supply temperature) to 90 °C. The system is composed of an array of solar collectors with a total aperture area of 602 m², a thermal storage tank, and the necessary pumps and controls to deliver hot water to the electrolyzer continuously. The solar collectors were assumed to be flat-plate or evacuated tube collectors capable of reaching 90 °C outlet temperature under the local climate conditions. A simulation of the system's thermal performance was carried out using typical meteorological year data for Pecém to estimate the hourly and seasonal variation of useful heat output over one year. This delivered solar thermal energy displaces an equivalent amount of electric heating that would otherwise be required to raise the water temperature to 90 °C.

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For the economic analysis, the capital and operating costs of the solar heating system were evaluated against the monetary savings from reduced electricity consumption. The total installed cost was estimated based on typical unit costs per square meter of collectors and balance-of-system components in Brazil, and an annual operation and maintenance cost of approximately 2% of the initial investment was assumed. The economic performance was assessed over the project lifetime (assumed 20 years) using standard cash-flow analysis. Key indicators calculated include the net present value (NPV), internal rate of return (IRR), discounted payback period, and levelized cost of heat (LCOH). The LCOH was computed analogously to a levelized cost of energy, by spreading all life-cycle costs of the solar thermal system over the total useful heat supplied (Louvet *et al.*, 2017). An electricity tariff of approximately R$0.60 per kWh was used for calculating the value of displaced electricity, representative of local industrial energy prices. All financial values are in Brazilian Real (R$) and were calculated in constant currency (real terms).

3. Results and Discussion

Simulation results indicate that the 602 m² solar collector field can supply on the order of 550 MWh of heat per year (≈1.98 TJ/year) under the solar irradiance conditions of Pecém. This solar output is sufficient to meet essentially 100% of the annual thermal energy demand for preheating the specified water flow from 30 °C to 90 °C. Minor shortfalls may occur during periods of low insolation, but these can be addressed by the thermal storage and, if necessary, a backup heater to ensure continuous operation of the electrolyzer. By offsetting electric heating, the solar system reduces the electrolyzer's electrical energy consumption by roughly 0.55 GWh per year.

Tab. 1: Key techno-economic results of the solar thermal preheating system.

Metric	Value
Annual electricity savings	R$ 329,551 per year
Net present value (NPV)	R$ 1,273,434
Internal rate of return (IRR)	24.46%
Discounted payback time	5 years
Levelized cost of heat (LCOH)	R$ 0.329 per kWh

As summarized in Table 1, the solar preheating system yields substantial financial benefits. With the given electricity tariff (~R$0.60/kWh), the annual electrical energy cost savings are about R$329,551. These savings drive a high NPV of approximately R$1.27 million (assuming a reasonable discount rate for industrial projects) and an impressive IRR of 24.46%. An IRR in this range is well above typical hurdle rates for energy projects, indicating that the investment is highly attractive from an economic standpoint. The discounted payback period is around 5 years, meaning that when accounting for the time value of money, the cumulative net savings by the fifth year equals the initial investment. This payback period is relatively short for an infrastructure project, further underscoring the economic feasibility of the system.

The calculated LCOH of the solar thermal system is R$0.329 per kWh of heat delivered. This is significantly lower than the cost of providing the same heat with grid electricity (which was assumed at ~R$0.60/kWh). In other words, each unit of thermal energy from the solar system costs roughly half as much as the equivalent unit of electric heating energy. This cost competitiveness demonstrates that solar process heat can economically replace a portion of electrical energy use in hydrogen production. In addition to the direct cost savings, the reduction in electricity consumption (approximately 550 MWh/year) can alleviate demand on the electrical grid. As a co-benefit, if the grid electricity has associated carbon emissions, using solar heat would avoid those emissions for the displaced electricity, improving the overall sustainability of the hydrogen production process. The successful integration of a solar thermal system in this case suggests that similar green hydrogen projects in sunny regions could benefit from coupling to solar heat, thereby lowering operational costs and improving environmental performance.

4. Conclusions

The proposed solar thermal water-heating system for preheating an electrolyzer feedwater stream has been shown to be both technically feasible and economically advantageous. A collector field of around 602 m² can supply the required thermal energy (heating 21.6 m³/day of water to 90 °C) on an annual basis, significantly reducing the electrical energy demand of a 5 MW water electrolyzer in a high-irradiation location like Pecém. The financial analysis, focusing on current Brazilian cost parameters, indicates a strong business case: the system achieves a short payback period (~5 years) and a high internal rate of return (~24%), along with a positive NPV exceeding R$1.2 million. The levelized cost of the delivered heat (R$0.329/kWh) is substantially lower than the prevailing cost of electric heat, confirming that the solar thermal solution can produce hot water more cost-effectively than using electricity.

In summary, integrating solar thermal preheating into the hydrogen production process can effectively lower operational costs and improve the sustainability of green hydrogen projects. This case study at the Pecém Industrial and Port Complex illustrates the viability of such integration in an emerging green hydrogen hub. It is a clear indication that solar heat can complement renewable electricity in powering electrolyzers, leveraging the region's abundant solar resource for additional economic and environmental gains. Future work may explore optimization of the system design (e.g., collector technology, storage capacity) and analyze sensitivities to factors such as solar resource variability, electricity price fluctuations, and potential incentives. Nevertheless, the results obtained provide confidence that solar-assisted hydrogen production is a promising strategy for reducing the energy costs and enhancing the competitiveness of green hydrogen, especially in sun-rich regions like Northeast Brazil.

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