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Techno-Economic and Policy Analysis of Ocean Current Energy for Hydrogen Storage and Grid Resiliency in Florida

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Abstract

This paper explores the techno-economic and policy potential of ocean current energy as a driver of hydrogen production and grid resiliency in Florida. Given the state's exposure to increasingly severe hurricanes and its reliance on imported hydrogen, there is a growing need to establish localized, resilient, and baseload-capable renewable energy systems. Ocean current resources, particularly in the Florida Straits, offer a promising yet underutilized solution. To align with the U.S. Department of Energy (DOE) cost targets for ocean current technologies, we evaluate the capital and operational cost thresholds necessary to achieve future benchmarks for the levelized cost of energy (LCOE) and hydrogen (LCOH). We simulate a range of hydrogen production system configurations, integrating ocean current turbines, solar PV, and grid interaction, and conduct sensitivity analyses on the capital and O&M costs of ocean current devices. Results highlight that optimized hybrid systems leveraging local renewables and strategic grid integration can significantly enhance hydrogen affordability, resilience, and energy independence. The findings position ocean current energy not only as a viable pathway toward achieving DOE cost goals but also as a catalyst for advancing Florida's hydrogen energy dominance and coastal energy security.

Keywords: Techno-Economic; Ocean Current Turbine; Hydrogen Storage; Homer

1 Introduction

The global shift to a low-carbon energy future has amplified interest in marine renewable resources—particularly ocean current, tidal, and wave energy—due to their predictability and site-specific reliability. Fraenkel et al. [1] introduced one of the first techno-economic evaluations of Gulf Stream-based underwater turbines, highlighting key parameters such as capital cost thresholds and load factor sensitivity. Subsequent work by Bahaj and Myers [2] emphasized design challenges of marine current turbines (MCTs), including blade durability and wake effects. Coles et al. [3] broadened this view by identifying high capital costs and lack of operational maturity as persistent barriers, underscoring the need for supportive infrastructure and policies.

Recent studies have shown increasing feasibility for ocean current systems in selected geographies. Sockeel et al. [4] projected competitive LCOE values in Florida (76% capacity factor) if capital and O&M costs decline. In Indonesia, Rumaherang et al. [5] found optimized Floating Ocean Current Power Plants (FOCPPs) could achieve payback in 6.4 years. Gaamouche et al. [6] demonstrated tidal energy's superior stability and cost-effectiveness over wind in hybrid systems for Moroccan villages. Collectively, these works highlight the growing viability of marine renewables for grid and off-grid applications.

In parallel, green hydrogen is emerging as a key decarbonization vector for sectors like shipping and heavy industry. Electrolytic hydrogen enables long-duration storage and clean fuel export. Jang et al. [7] evaluated a 500 MW offshore wind-to-hydrogen system, showing LCOH could drop from \$6.72/kg to \$2.82/kg through improved efficiency and lower CAPEX. Temiz and Dincer [8] proposed hydrogen ferries powered by floating PV stations, estimating LCOH at \$6.83/kg—a promising solution for coastal transport.

Florida provides a compelling case for marine renewables and hydrogen integration. Facing aging infrastructure, urbanization, and extreme weather, the state has experienced severe disruptions—e.g., Hurricanes Irma (2017) and Ian (2022) [9, 10, 11]. To build resilience, over \$100 million has been directed to clean hydrogen projects such as the Mulberry Clean Hydrogen Plant—developed by LowCarbon Hydrogen Corp., Ocean Green Hydrogen, and Space Florida [12, 13, 14]. Hydrogen is increasingly viewed as a dispatchable energy carrier, enhancing grid flexibility and decarbonizing hard-to-electrify sectors [15, 16]. With Florida's high ocean current potential, these integrated technologies offer a robust path toward a resilient, low-carbon energy system [17, 18].

2 Capital Cost Estimation Based on DOE Targets and LCOE Formula

To evaluate the required capital cost (CapEx) for marine hydrokinetic (MHK) systems, we apply the Levelized Cost of Energy (LCOE) formulation used in previous techno-economic assessments, such as the one presented by [4].
The Levelized Cost of Energy (LCOE) and the Capital Recovery Factor (CRF) are computed as shown in Equations 1 and 2, respectively:

$$\text{LCOE} = \frac{(CRF \cdot OC + FOM) \cdot 1000}{8760 \cdot CF} \quad (1)$$

$$\text{CRF} = \frac{r(1+r)^t}{(1+r)^t - 1} \quad (2)$$

where OC is the overnight capital cost (in \$/kW), FOM is the fixed operation and maintenance cost (in \$/kW/year), CF is the capacity factor, r is the discount rate, and t is the project lifetime (in years). For this study, we consider the following baseline parameters based on the DOE Water Power Technologies Office and literature [19]: the fixed operation and maintenance cost (FOM) is set to \$300/kW/year, the capacity factor (CF) is assumed to be 0.76 based on predicted Florida ocean current performance, the project lifetime t is 20 years, and the discount rates r are evaluated at 2.5%, 5%, and 7.5%. To support DOE's 2035 cost target for ocean current energy (\$0.11/kWh), we reverse-engineer the required capital cost using Equation (1). The results for different discount rates are plotted in Fig. 1. For example, at a discount rate of 2.5%, achieving an LCOE of \$0.11/kWh requires a capital cost of approximately \$3750/kW. Conversely, DOE's 2015 baseline (LCOE = 0.56/kWh) implies a required capital cost over \$26,000/kW, which reflects the cost-reduction challenge.
These findings highlight the sensitivity of required capital investment to financing conditions and policy support. Lower discount rates — representative of public financing or subsidies — significantly reduce the CapEx needed to meet LCOE targets. These insights can guide both private developers and policymakers when assessing the cost-competitiveness and investment conditions for ocean current energy systems.
To assess the sensitivity of the levelized cost of energy (LCOE) to variations in fixed operation and maintenance (FOM) cost, we consider a representative case with the following assumptions: a capital cost (CapEx) of \$3000/kW, a capacity factor (CF) of 0.76, a system lifetime of 20 years, and a discount rate of 2.5%. Using the standard LCOE formulation in (1), we calculate the LCOE for three FOM values: \$300, \$200, and \$100 per kW per year. The results

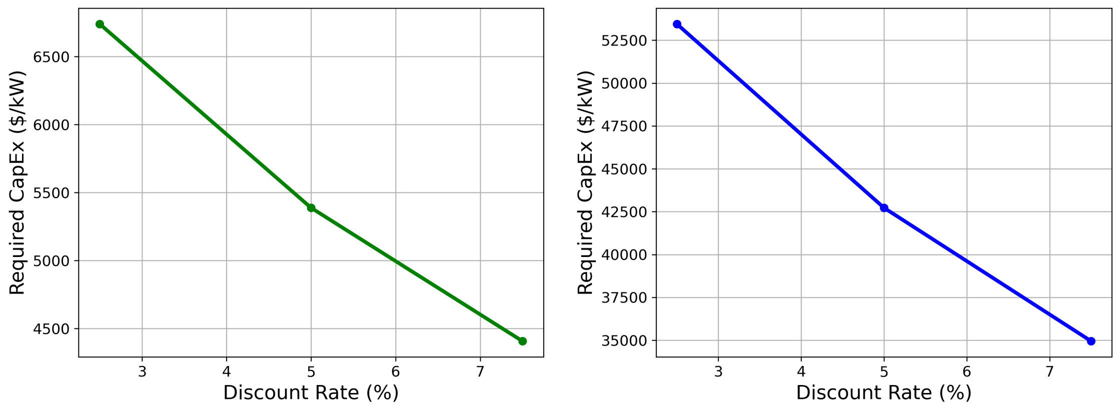

Figure 1: Required CapEx for achieving LCOE targets of $0.11/kWh (left) and $0.56/kWh (right) under different discount rates.

are shown in Table 1. These results show that lowering FOM has a significant effect on reducing LCOE. Specifically, reducing FOM from $300 to $100 per kW-year leads to a decrease in LCOE from 7.4 to 4.4 cents/kWh, demonstrating the importance of low-maintenance designs in marine energy systems.

3 Simulation Setup

To evaluate the techno-economic potential of ocean current energy for hydrogen production and grid resiliency in Florida, we performed comprehensive simulations using *HOMER Pro*. The objective is to explore how different configurations and cost assumptions affect both the levelized cost of energy (LCOE) and the levelized cost of hydrogen (LCOH). We designed five scenarios, each based on one of four distinct system configurations, as shown in Fig. 2. These configurations include: ocean current only (Configuration a), ocean current combined with solar PV (Configuration b), ocean current integrated with the grid (Configuration c), and a fully hybridized system incorporating ocean current, PV, and grid connection (Configuration d).

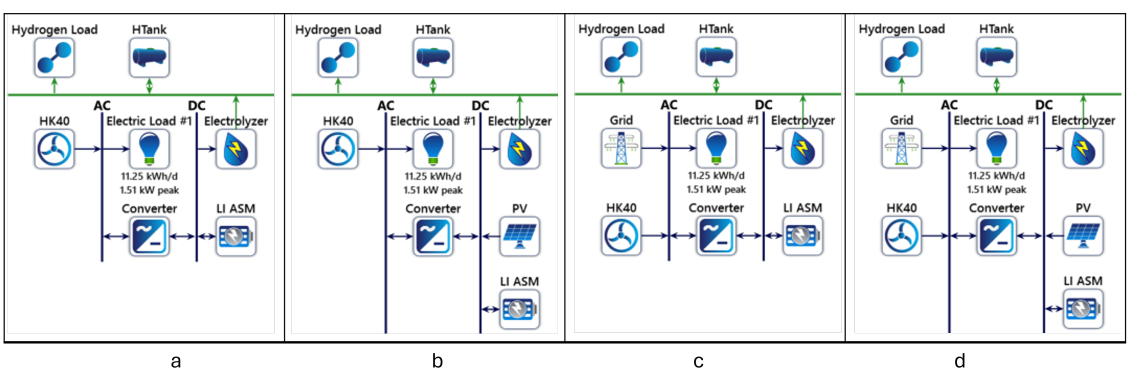

Figure 2: System configurations used in this study, including ocean current only, hybrid combinations with solar PV and/or grid connection, and full integration for resilient hydrogen production.

Scenario 1 and Scenario 2 are based on Configuration a, representing a stand-alone ocean current system under two different capital and O&M cost assumptions. Scenario 3 reflects Configuration c, which integrates the ocean current with the utility grid to support continuous electrolyzer operation. Scenario 4 corresponds to Configuration b, combining the ocean current with solar PV. Finally, Scenario 5 represents Configuration d, where all three sources—ocean current, solar PV, and grid power—are integrated to ensure reliable and cost-effective hydrogen production. Each configuration includes a 40 kW hydrokinetic turbine (HK40) to represent the ocean current resource, a DC-powered electrolyzer for hydrogen generation, a lithium-ion battery storage system (LI ASM), and an AC-DC converter. When applicable, the configurations also include solar PV modules and grid interconnection. A fixed electric load of 11.25 kWh/day with a 1.51 kW peak demand was assumed in all scenarios. The model also includes a hydrogen storage tank and assumes weekly hydrogen shipment, mimicking an industrial delivery schedule. Sensitivity analyses were conducted across scenarios by varying the capital cost and O&M cost of the ocean current system to assess their impacts on LCOE and LCOH, and to determine which configuration offers the most resilient and economically viable pathway for hydrogen production in Florida. The main cost assumptions for key system components are summarized in Table 2.

Table 1: Fixed O&M Impact on LCOE

Fixed O&M ($ /kW/yr)	LCOE ($ /kWh)
100	0.044
200	0.059
300	0.074

Table 2: Unit Cost Assumptions

Component	Cost
HK Turbine (HK40)	$3,000–$6,250/kW
Electrolyzer	$1,080/kW
H_2 Tank	$1,200/kg
Converter	$300/kW
Solar PV	$2,500/kW

4 Simulation Results

Figure 3 illustrates the comparative performance of five energy scenarios in terms of Levelized Cost of Energy (LCOE), Levelized Cost of Hydrogen (LCOH), and Net Present Cost (NPC). Scenario 1, with the highest ocean current capital cost, shows the highest LCOE, LCOH, and NPC, indicating limited economic viability. As capital costs decrease (Scenario 2) or grid integration is introduced (Scenarios 3 and 5), both LCOE and LCOH decline significantly. Scenario 5 (OC+PV+Grid) achieves the lowest overall cost, highlighting the value of hybrid configurations in reducing both energy and hydrogen production costs while minimizing long-term investment. Based on the comparative results, Scenario 5 (OC+PV+Grid) emerged as the most cost-effective configuration, achieving the lowest Net Present Cost (NPC) and Levelized Cost of Energy (LCOE). To further explore the economic viability of this optimal configuration, a sensitivity analysis was conducted on electrolyzer capital cost.

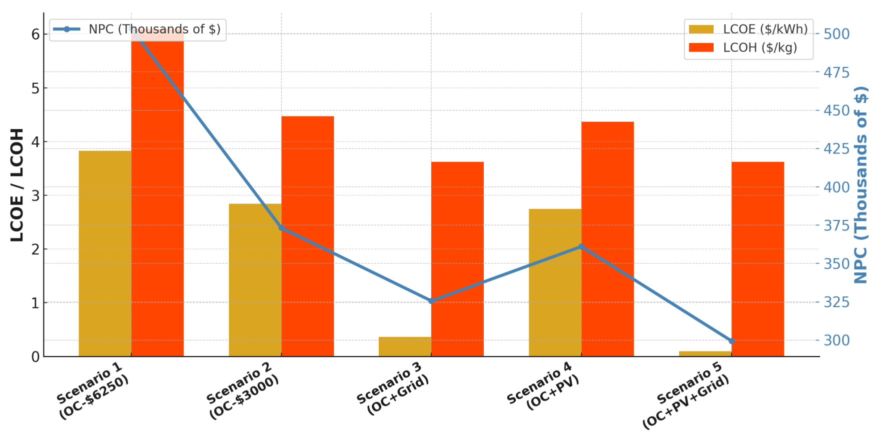

Figure 3: Comparison of LCOE, LCOH, and NPC across five scenarios.

Figure 4 illustrates the impact of varying the electrolyzer capital cost multiplier (from 1.0 to 0.1) on both LCOE and the Levelized Cost of Hydrogen (LCOH). The analysis reveals that while the LCOE exhibits a slight decline from $2.75/kWh$ to $2.62/kWh$, the LCOH shows a more noticeable drop from $4.32/kg$ to $4.11/kg$. This suggests that hydrogen production cost is more sensitive to electrolyzer investment than electricity cost, underscoring the importance of capital efficiency in hydrogen system design. Following this sensitivity evaluation, the study compares five different configurations for ocean current-based hydrogen production. These configurations reflect a range of design pathways, from high-cost stand-alone systems to hybrid systems with solar and grid integration.

Scenario 1: A stand-alone ocean current (OC) system with high capital and O&M costs resulted in the **highest LCOE**

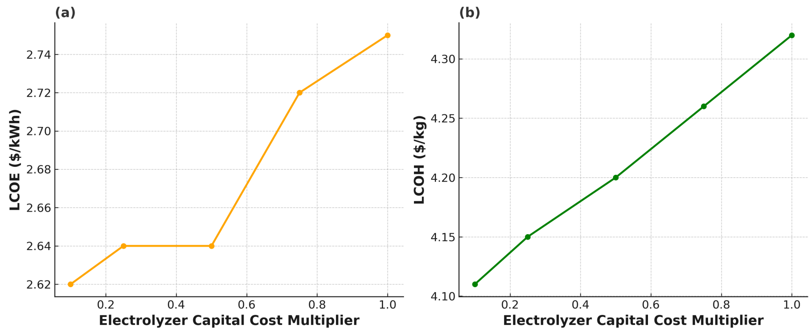

Figure 4: Sensitivity of LCOE and LCOH to variations in electrolyzer capital cost.

($ 3.87/kWh) and **LCOH ($ 6.05/kg)**, making it technically feasible but economically unviable due to high capital recovery and poor system flexibility.
Scenario 2: Lowering the capital cost to $3,000/kW and O&M to $100/kW/year improved the economics, reducing **LCOE to $ 2.80/kWh** and **LCOH to $ 4.62/kg**, but electrolyzer performance remained limited due to single-source intermittency.
Scenario 3: Introducing grid integration significantly enhanced stability and electrolyzer utilization. This led to a sharp drop in **LCOE ($ 0.30/kWh)** and **LCOH ($ 3.75/kg)**, making it one of the most cost-effective configurations, though with increased reliance on non-renewable grid electricity.
Scenario 4: Combining OC with solar PV improved renewable penetration and electrolyzer uptime. However, dual-source variability and limited grid support caused LCOE and LCOH to rise slightly to **$ 2.70/kWh** and **$ 4.47/kg**, respectively.
Scenario 5: The most effective configuration integrated OC, PV, and the grid, achieving the **lowest LCOE ($ 0.20/kWh)** and **LCOH ($ 3.60/kg)**, along with the lowest net present cost and highest electrolyzer utilization. This hybrid setup offered the best balance of cost, performance, and resilience.

Overall, these results confirm that *hybrid energy systems*, especially those combining renewable resources with grid support, can substantially improve both LCOE and LCOH. The sensitivity analysis also highlighted that **capital and O&M costs of the ocean current turbine** had the greatest influence on economic viability, reinforcing the importance of technological progress and enabling financial policies.

5 Conclusion

This study assessed the techno-economic potential of ocean current energy for hydrogen production and grid resilience in Florida, using DOE's 2035 targets as benchmarks. Achieving an LCOE of $0.11/kWh requires a capital cost of $3,750/kW under a 7.5% discount rate. Policy tools such as public-private partnerships and sovereign-backed financing can achieve this rate, improving project viability. Simulations using *HOMER Pro* show that reducing capital costs to $3,000/kW and O&M to $100/kW/year drops the LCOE below $0.12/kWh and the LCOH to $3.62/kg—progressing toward the DOE Hydrogen Shot goal. These results were achieved in a hybrid system combining ocean current, solar PV, and grid access, enabling continuous electrolyzer operation (82% utilization), net-negative CO_2 emissions, and surplus electricity export. Overall, ocean current energy—when hybridized and supported by favorable policy—can become a resilient, zero-carbon hydrogen source, strengthening Florida's energy independence and positioning the state as a leader in marine hydrogen innovation.

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