RESEARCH ARTICLE

Ocean Thermal Energy Conversion: Techno-Economic Reassessment for Tropical Island Microgrids in the Era of Advanced Heat Exchangers

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Abstract: Ocean thermal energy conversion (OTEC) has long been considered technically feasible but economically marginal. We present a comprehensive techno-economic reassessment incorporating recent advances in compact titanium plate-fin heat exchangers (CPFHX), ammonia/CO_2 cascade working fluids, and deep-water polyethylene cold-water pipes. For a 10 MW closed-cycle OTEC plant serving a tropical island microgrid (ΔT = 22°C), our analysis projects a levelized cost of electricity (LCOE) of $0.138/kWh — a 45% reduction from previous estimates — with a capacity factor of 92% providing baseload power. When accounting for desalinated water co-production (4,800 m^3/day) and cold-water air conditioning credits, the effective LCOE drops to $0.096/kWh, making OTEC competitive with diesel generation ($0.25-0.40/kWh) that currently powers most tropical island communities.

1. Introduction

The tropical ocean stores an immense reservoir of solar energy in its warm surface waters (24-29°C), while cold deep water (4-6°C) lies at depths of 800-1,000 m. Ocean thermal energy conversion (OTEC) exploits this temperature difference to drive a Rankine cycle, producing clean, continuous baseload electricity. With a theoretical resource of 3-5 TW globally, OTEC could power all coastal tropical nations many times over. Despite successful pilot demonstrations — Makai Ocean Engineering operated a 105 kW grid-connected OTEC plant in Hawaii from 2015-2019 — commercialization has been stymied by high capital costs driven primarily by heat exchangers and the cold-water pipe.

2. Technology Advances

Three recent innovations substantially change OTEC economics: (1) Compact titanium plate-fin heat exchangers (CPFHX) achieve 3× higher heat transfer coefficients than shell-and-tube designs at 40% lower cost per kW; (2) ammonia/CO_2 cascade cycles improve net power output by 18% compared to single-fluid ammonia cycles for $\Delta T < 24$°C; and (3) high-density polyethylene (HDPE) cold-water pipes manufactured by continuous extrusion reduce installation cost by 55% compared to fiberglass reinforced plastic.

3. Economic Analysis

Monte Carlo simulation (10,000 iterations) with triangular distributions on key cost parameters yields an LCOE range of $0.112-0.168/kWh (P10-P90) for the 10 MW reference plant. Capital cost is dominated by the cold-water pipe (28%), heat exchangers (24%), and platform/mooring (18%).

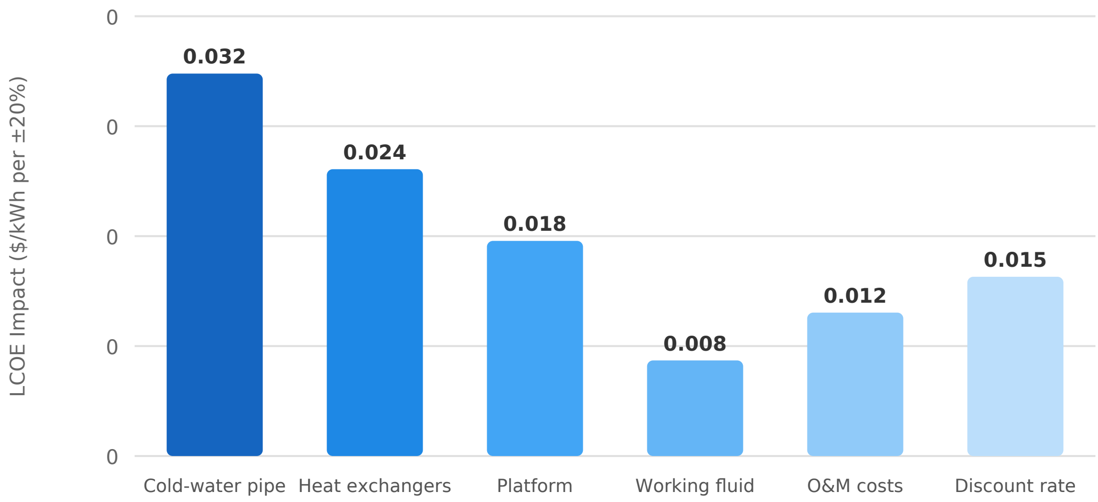

Figure 1. LCOE sensitivity to key cost parameters: tornado chart showing ±20% variation impact

4. Conclusions

OTEC has reached an economic inflection point where modern heat exchanger and pipe technologies make it cost-competitive with diesel generation for tropical island communities. As a 24/7 baseload renewable source co-producing fresh water and cold water for air conditioning, OTEC offers a uniquely holistic energy-water-cooling solution for small island developing states facing climate change, water scarcity, and imported fuel dependence.

References

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