Exploring techno-economically viable markets for wave energy harnessing in arid coastal regions of Latin America.

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The disjunction created by limited onshore land availability and the increasing efficiency of marine renewable energies (MRE) is driving an accelerated shift towards an offshore energy transition. However, the emerging MRE sector still faces diverse challenges associated with unrepresentative financial models and supply chain considerations constraining their commercial deployment. In this study, the techno-economic feasibility based on the bottom-up parametric optimization approach for marine hybrid clusters (MHCs) powered by Wave Energy Converters (WECs) and Offshore Wind Turbines (OWTs) is proposed. The analysis focuses on electricity supply for households and seaweed aquaculture, considering surplus storage via lithium-ion batteries and green hydrogen production at two potential arid coastal regions: La Serena, Chile, and Ensenada, Mexico (Fig. 1).

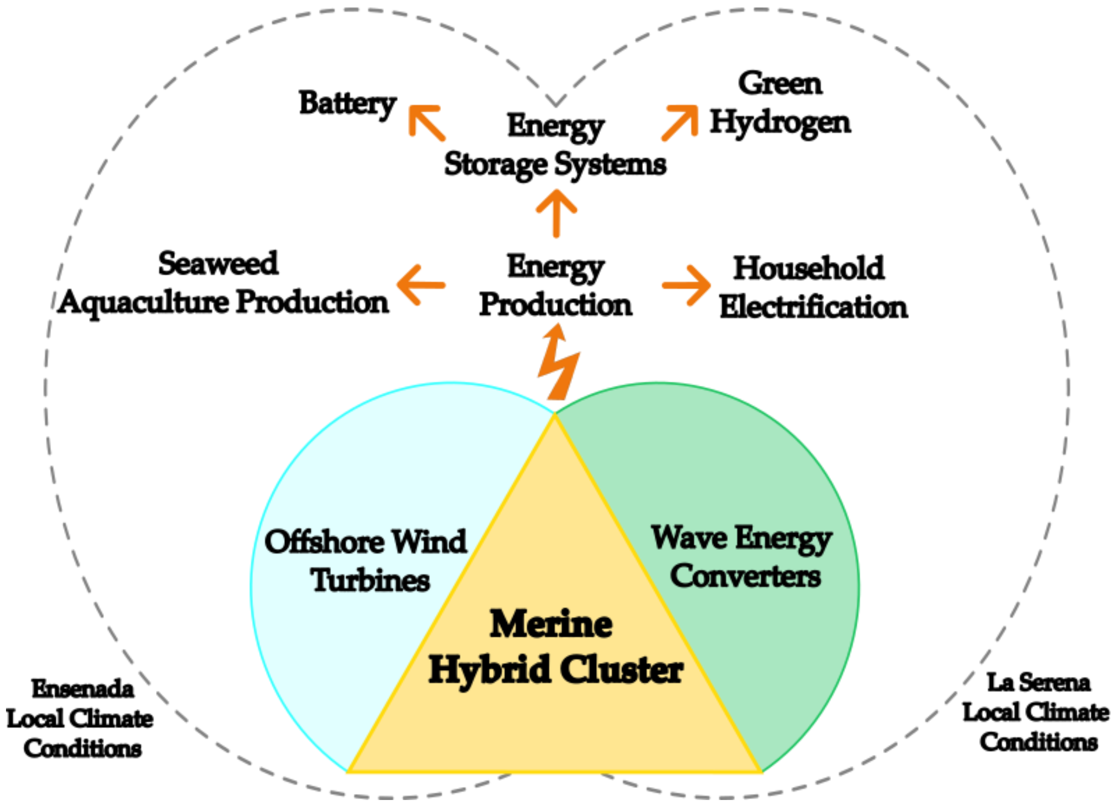

Fig. 1. Marine hybrid cluster components and by-products.

High-resolution wave-wind hindcasts were conducted using the SWAN and ERA-5 models to characterize the wave and offshore wind energy availabilities and the theoretical potential production from advanced WECs and OWT. Cost functions for multiple WEC-TEC components were retrieved from the literature and adapted for the analysis. La Serena, with higher wave power (26.05 kW/m) and lower variability, requires less hybridization than Ensenada (13.88 kW/m) (Fig. 2).

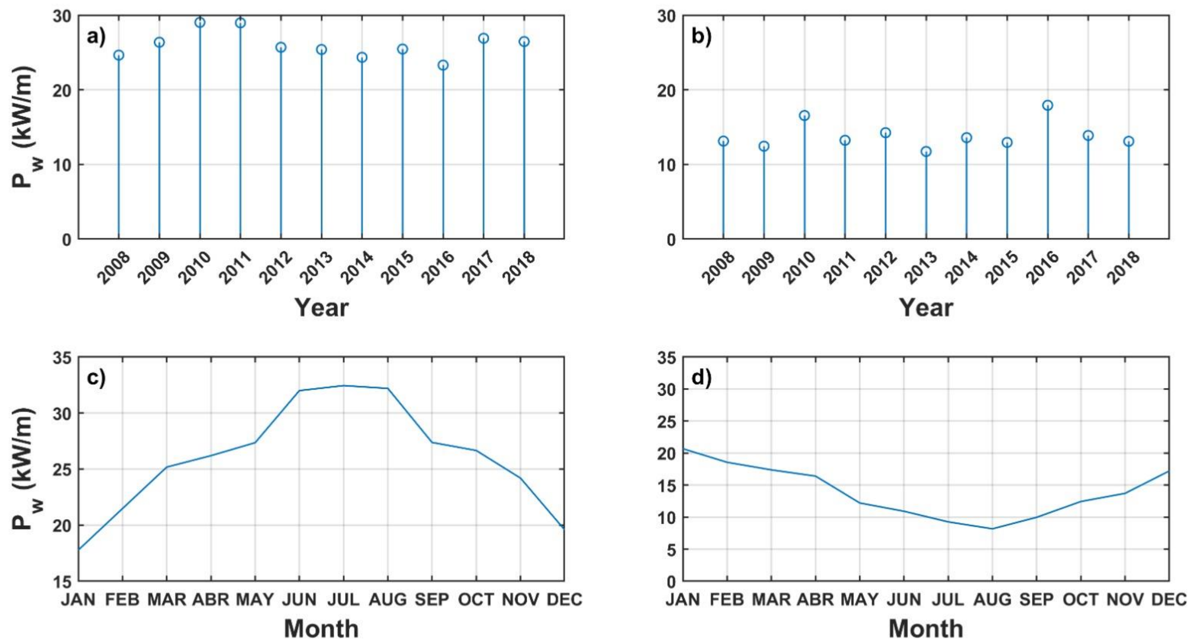

Fig. 2. Mean annual and monthly availability of wave power at La Serena, Chile (panels (a) and (c)) and Ensenada, México (panels (b) and (d)) over the full hindcast period.

The WEC in La Serena achieves the highest mean energy production (875 MWh/month), while Ensenada reaches up to 1,400 MWh/month for aquaculture. Household energy scenarios yield lower production across both locations. The WEC-OWT cluster is the most cost-effective in Ensenada (LCoE of 390 USD/MWh) but less profitable in La Serena (420 USD/MWh). Conversely, WEC-OWT performs better in La Serena (400 USD/MWh) than in Ensenada (1,100 USD/MWh) (Fig. 3).

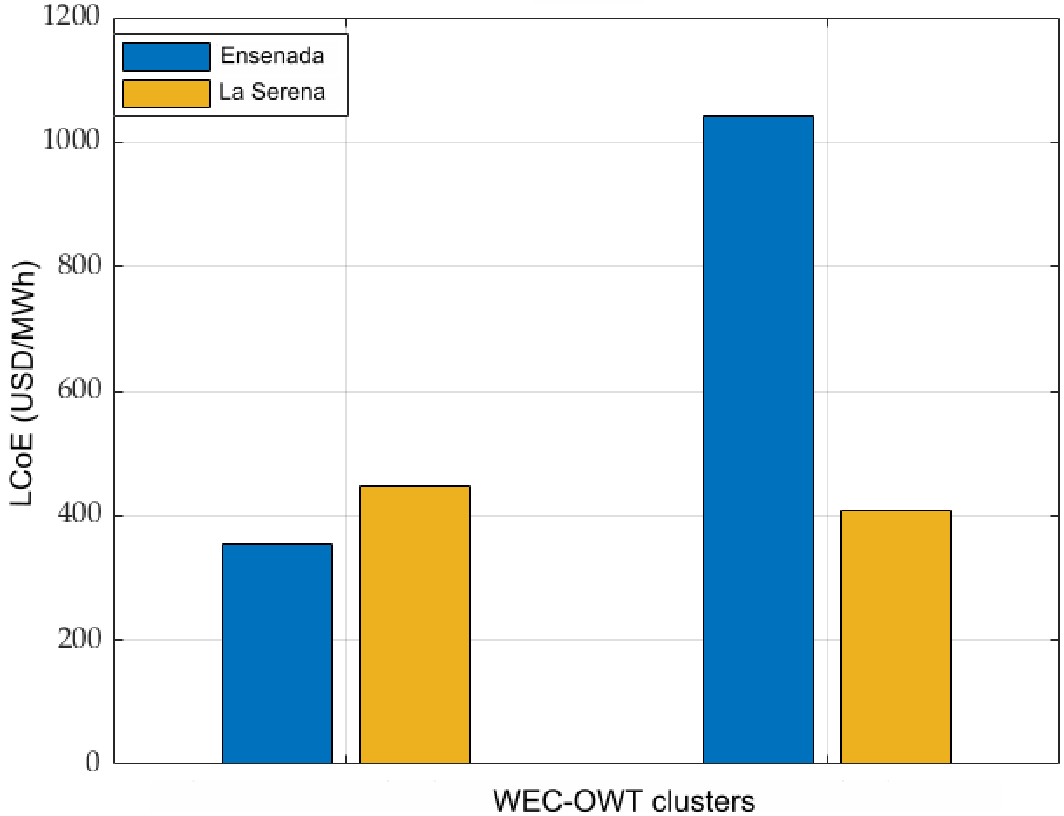

Fig. 3. Levelized cost of energy of the WEC-OWT clusters in La Serena and Ensenada.

Supplying electricity to seaweed aquaculture, particularly in La Serena, proves more profitable than household supply. Ensenada clusters generate more surplus electricity, better utilized in the electricity market, or converted to hydrogen during high-energy winter months. This research highlights the importance of tailoring emerging WEC systems to local conditions, optimizing hybridization strategies with OWTs, and integrating complementary consolidated industries such as aquaculture to improve economic and environmental outcomes. This evaluation aims to enhance the understanding of the feasibility and benefits of coupling multi-source WEC-OWT technologies, paving the way for future advancements in renewable energy in Latin America.