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Design and Assessment of SOFC-Photovoltaic Hybrid Energy System for Southeast Asian Communities

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Title
Design and Assessment of SOFC-Photovoltaic Hybrid Energy System for Southeast Asian Communities

Background
Southeast Asia faces unique energy challenges due to its tropical climate, rapid economic growth, and in some areas, unstable power grids [1]. This results in a significant and integrated demand for cooling, hot water, and electricity [2]. Fortunately, the region possesses abundant natural gas reserves and high solar radiation [3]. These resources create an excellent opportunity to deploy a hybrid system combining Solid Oxide Fuel Cell (SOFC), Battery Energy Storage (BESS) with Photovoltaics (PV) [4], [5].

Objectives
1. Optimal Configuration: To determine the optimal capacity mix of SOFC, PV, and BESS to minimize the annual cost.
2. Strategy Design: To propose an efficient energy system management and dispatch strategy.
3. Benefit Assessment: To quantitatively analyze the system's economic feasibility and environmental benefits in both grid-connected and off-grid modes.

Methodology
The study establishes a 24-hour model for the electricity, cooling, and heating loads of a typical 100-household community in Southeast Asia. Mathematical models are formulated for the key components including SOFC, PV, and BESS. A Mixed-Integer Linear Programming (MILP) Method is used to solve for the configuration with the lowest life-cycle cost. Finally, both comparative and sensitivity analysis are conducted for various operation scenarios (grid-connected or off-grid) and economic parameters (fuel price, electricity tariffs).

Results and Discussion
1. Economic & Environmental Benefits: In both grid-connected and off-grid modes, the hybrid system shows lower costs and less carbon emissions than traditional "grid/diesel-only" solutions. In the grid-connected mode, the system can save approximately 24.75% in annual costs and reduce carbon emissions by 72.68%.
2. Grid-Connected Mode: The system is configured with larger PV and BESS capacities to maximize the use of solar energy. This setup allows it to capitalize on peak/off-peak electricity price arbitrage for the greatest economic benefit.
3. Off-Grid Mode: The system relies on a larger-capacity SOFC as the core baseload power source to ensure stability and reliability, with the BESS mainly used for peak shaving.
4. Cost Sensitivities: The system's optimal configuration is highly sensitive to external prices. Natural gas price is the "make-or-break" factor for the SOFC's economic viability, while the peak-valley electricity price differ is the core driver for the deployment scale of the BESS.

Conclusions
The SOFC-PV hybrid combined cooling, heat, and power system is an effective solution for the integrated energy needs of Southeast Asian communities, offering both economic and environmental advantages. The optimal design depends on grid access: grid-connected systems are optimized for economic returns, whereas off-grid systems prioritize reliability.

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