

<https://doi.org/10.7250/CONNECT.2025.053>

TECHNO-ECONOMIC OPTIMIZATION OF SOLAR PANEL INSTALLATIONS: BALANCING THERMAL PERFORMANCE AND ECONOMIC VIABILITY

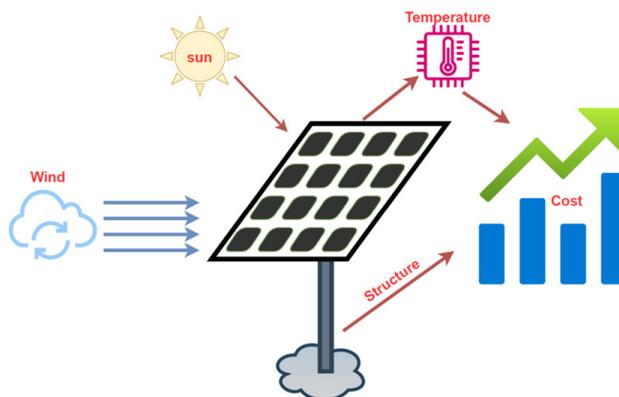
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Abstract – As solar energy continues to gain prominence as a sustainable power source, optimizing solar panel configurations for maximum efficiency and economic viability is crucial. This study explores the interplay between installation height and tilt angle in improving thermal performance and power output while managing structural and economic constraints. This study uses computational models to optimize solar panel installation height and tilt for better thermal performance and cost-efficiency. By analysing convective cooling, wind loading, and structural stresses, the study identified configurations that enhance energy output while minimizing structural costs. It was found that increased heights improve air circulation around panels, lowering solar cell temperatures and thereby enhancing efficiency through passive cooling. Higher tilt angles were also shown to improve heat dissipation by inducing air turbulence, though both increased height and tilt raise wind loading, which in turn requires sturdier and costlier support structures. The optimal configuration was identified as a height of 0.165 meters and a tilt angle of 25.022°, balancing efficiency gains with manageable structural demands. This setup achieved a Levelized Cost of Energy (LCoE) of \$0.07/kWh, an ROI of 16.3 %, and a payback period of 6.25 years, offering a 42 % lower LCoE than a non-optimized configuration with a height of 7.5 meters and a tilt of 75°. This optimization also resulted in a 60 % improvement in ROI and a 37.5 % reduction in the payback period. The study underscores the importance of tailored height and tilt configurations to enhance efficiency without incurring prohibitive costs, particularly in varying climate conditions. It is recommended that future research explore different installation surface types and climates to further refine the balance between performance and cost.

Keywords – Economic analysis; elevated installations; installation optimization; structural integrity; thermal analysis



Techno-economic analysis of solar installations