

Farhat Mahmood, Ammar M. Khourchid, Fatima-Zahra Lahlou, Sami G. Al-Ghamdi and Tareq Al-Ansari, 2026, Resilience enhancement of community energy systems using integrated stochastic programming and information gap decision theory, *International Journal of Electrical Power & Energy Systems*, vol. 176: 111669.

## Highlights

- Three-stage optimization framework integrates stochastic programming with IGDT.
- Priority-based resource allocation ensures critical infrastructure resilience.
- 5–30% resilience budget increase yields up to 90% reduction in unmet demand.
- Framework quantifies resilience-investment tradeoffs for decision-makers.
- Non-linear relationship between investment and resilience varies by scenario.

**Abstract** Community-integrated energy systems offer promising solutions for enhancing energy security and sustainability by coordinating multiple energy carriers at the local level. However, these systems face significant challenges in maintaining reliability during extreme events and disruptions, a problem that traditional planning approaches often fail to address adequately. This study presents a probability-driven three-stage optimisation framework that balances economic efficiency with resilience enhancement for community-integrated energy systems in cooling-dominated environments. The methodology integrates stochastic optimisation for capacity planning during normal operations, a priority-based resilience assessment under component failures, and an information-gap decision-theory approach for resilience enhancement under uncertain disruptions. Applied to a case study of a 10,000-resident community in Qatar, the framework determines the optimal mix of photovoltaic systems, wind turbines, gas turbines, battery storage, and cooling technologies while systematically evaluating resilience under weather-related disruptions and cyber-physical attacks. Results demonstrate that a 5–30% increase in resilience budget yields significant improvements across the failure scenarios, reducing unmet electricity demand by up to 88.7% and cooling load by 90.6% in scenario 1, and by 53.5% and 26.1%, respectively, in scenario 2. Moreover, the analysis highlights a non-linear relationship between investment levels and resilience enhancement, with the optimal technology mix shifting as the resilience budget increases. Dispatchable generation becomes favoured over additional storage and renewable expansion in higher-budget scenarios. The proposed framework serves as a general decision-support tool, enabling decision-makers to systematically quantify resilience investment tradeoffs while accounting for diverse threat scenarios and community-specific priorities.

**Keywords** Community integrated energy systems, Resilience, Stochastic optimisation, Information gap decision theory, Mixed integer linear programming.