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Increasing Affordability and Resilience Against Power Disruptions with Local Multi-Energy Systems

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Extended Abstract

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Abstract Summary

Mitigation efforts to decarbonize the energy system hinge on a rapid electrification of end-use sectors, such as heating. However, it also significantly increases reliance on electricity, whose supply reliability is increasingly challenged by climate change, aging infrastructure, social disparities, and delayed planning due to future uncertainty in generation and demand. Integrating local, renewable-based, and sector-coupled solutions as multi-energy systems can enhance resilience against grid disruptions, but planning these systems to maximize self-sufficiency typically incurs impractical costs. This study investigates the trade-offs in cost of internalizing resilience into system planning to balance energy security with end-user affordability.

A multi-objective stochastic programming approach is taken to generate Pareto fronts that quantify the cost trade-offs to enhance resilience. Appropriate clustering methods are used to reduce computational complexity, while global sensitivity and uncertainty analyses are employed to ensure robustness of our findings.

Results on a Swiss neighborhood with a typical continental climate show that multi-energy systems generate cost savings compared to today's system that runs on grid electricity and natural gas, and these cost savings can be leveraged to enhance resilience. Specifically, systems can meet 100% of end-use demand for 12 hours without compromising affordability today. Load management is highly effective, as shedding just 5% of demand reduces system costs by 12% to achieve 24-hour self-sufficiency. Furthermore, under favorable techno-economic conditions, such as high heat pump efficiency, low solar PV costs, and low electricity-to-gas price ratios, systems can affordably serve 80% of heat demand up to 50 hours.

Incorporating resilience into planning decisions saves 5% to 20% in costs compared with cost-centric design approaches in grids with 97% to 99% availability. We recommend that site planners move beyond cost-centric designs to internalize these trade-offs, and that

policymakers support local multi-energy systems to ensure a fair and resilient heating transition for vulnerable communities.

Presenting Author Biography

Arvind Srinivasan is a PhD candidate at the Laboratory of Reliability & Risk Engineering at ETH Zurich. His research focuses on developing optimization tools to design sector-coupled energy systems at the local scale and to assess their impact on affordability, sustainability, and the security of supply for end consumers.