



Ph.D. DISSERTATION DEFENSE

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Title:	Planning Urban Energy Systems: A Data-Driven Framework for Analyzing Building Heterogeneity and Designing Robust Building Clusters
Chairperson:	Dr. Philip Odonkor, Department of Systems Engineering, School of Engineering and Science
Committee Members:	Dr. Nafiseh Ghorbani Renani, Department of Systems Engineering, School of Engineering and Science Dr. Jose Ramirez-Marquez, Department of Systems Engineering, School of Engineering and Science Dr. Gregg Vesonder, Department of Systems Engineering, School of Engineering and Science Dr. Lei Wu, Department of Electrical and Computer Engineering, School of Engineering and Science

ABSTRACT

The rapid growth of distributed energy resources is reshaping urban energy systems, yet most planning and deployment strategies remain focused on individual buildings. This building-centric perspective overlooks a defining property of distributed systems, where value arises from coordination across buildings rather than isolated performance. As a result, current approaches systematically underutilize opportunities for coordination, cost reduction, and resilience at the urban scale. This dissertation shows that effective DER planning requires treating groups of buildings as interconnected systems. It develops a unified framework for designing and evaluating such building clusters, in which system-level performance emerges from three interdependent factors, the composition of buildings, their spatial arrangement, and the structure of their interconnections. First, the dissertation demonstrates that diversity among building types is a primary driver of system performance. Through large-scale simulation, heterogeneous clusters consistently outperform homogeneous ones because complementary demand and generation profiles reduce variability and improve resource utilization. This establishes diversity as a fundamental design principle for distributed systems. Second, the work identifies where high-performing clusters are most likely to emerge within cities. By integrating energy characteristics with spatial and infrastructure constraints, it reveals that cluster potential is unevenly distributed. Strategic siting can therefore significantly amplify the benefits of DER deployment. Finally, the work demonstrates how interconnection strategies shape the tradeoff between infrastructure cost and system robustness. Prioritizing links that contribute most to collective performance enables near-optimal designs without exhaustive search. Together, these results reframe distributed energy planning as a problem of coordinated system design, providing a foundation for more scalable and effective urban energy strategies.