Toronto Metropolitan University

Centre for Urban Energy
Faculty of Engineering
& Architectural Science

Research case study > Transmission and Distribution

Energy Transition through Hydro-Electric Energy Systems

Version 1 (July, 2026)

Context: A robust pathway to achieve net-zero carbon emissions by 2050 requires rapidly electrifying end use sectors and integrating high shares of renewables, storage, and new energy vectors across power systems.

Problem: The transition toward net-zero emissions in an increasingly electrified energy system is placing unprecedented pressure on utilities and system operators to plan, expand, and modernize their infrastructure.

Solution: Development of two innovative methodologies to support Canada's transition toward net-zero emissions by improving the planning of electricity distribution systems, introducing a comprehensive planning framework that jointly optimizes economic efficiency, emissions reduction, and reliability. The first innovative approach explores a unified optimization model that simultaneously considers cost, emissions, and reliability over long-term horizons. Reliability is embedded using monetized failure probabilities, allowing clear trade-offs. A new Global Failure Rate index is introduced to better capture system-wide vulnerability. The second innovative approach explore a data-driven optimization approach applied to urban, semi-urban, and rural communities in Ontario (2025–2050). It integrates multiple datasets to evaluate realistic net-zero pathways, highlighting how local conditions affect decarbonization strategies.

Impact: The developed methodologies provide rigorous, replicable tools for utilities, policymakers, and communities to evaluate strategies that balance sustainability, reliability, and economic performance.

CUE's Role: Led advanced technical research and analytical activities, including large-scale data analytics, database development, problem formulation, and the design and implementation of optimization algorithms.

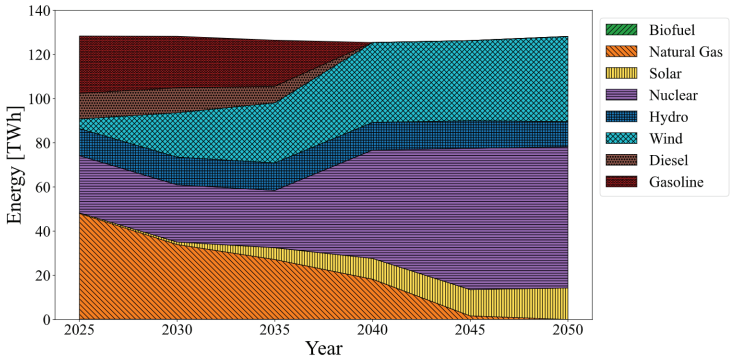

Figure 1 Energy Mix Transition In Toronto

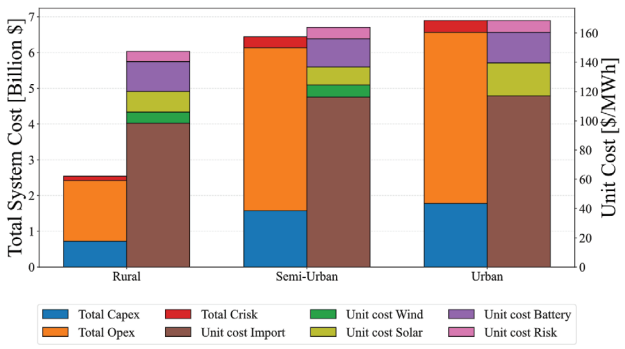

Figure 2 Total And Unit Costs

Partners: NSERC

Timeline: 2024 – 2025

Research team:
Bala Venkatesh, Felipe Bayma B. Rolim, Lidivine Irafasha, Bairavi Mathialagan, Karen Ho-Cespedes

Key Stats:

2 Technical Reports
2 Papers
1 Software