Coupling Cost-Benefit Analysis with Automated Urban Building Energy Modeling: A Resource Allocation Tool for Retrofit Measures & Building Decarbonization

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Abstract

Building decarbonization is vital for municipal zero-carbon goals. However, stakeholders often struggle with determining the costs and benefits of decarbonization due to a complex interplay of building stock properties, occupant energy use patterns, different efficiency and sustainability metrics, and a range of incentives at the state and federal levels. Thus, it remains difficult to plan and allocate limited resources and to engage property owners in a targeted effort.

This paper couples a socioeconomic model with bottom-up urban building energy modeling (UBEM) to better understand the building-specific financial burden of building retrofitting. The socioeconomic UBEM aims to help analyze the cost-effectiveness of retrofit measures, incentive allocation, and the impact of using different metric systems to prioritize upgrade measures. The bottom-up analysis provides valuable insights to municipal governments in planning equitable community-wide electrification efforts.

Researchers are focusing on quantifying the costs of home upgrades to predict carbon savings (Walker et al., 2022), and developing models to explore homeowners' willingness to adopt energy-efficient retrofits at neighborhood scale (Polly et al., 2011) (Berzolla et al., 2023). However, systematic exploration of a broad range of retrofit solutions for individual buildings within a city, their potential cumulative costs, and the ability of residents to afford these retrofits based on their socioeconomic background and the existing incentive structures is understudied.

We build a UBEM with 6,000 buildings for a small municipality in upstate NY, test the most commonly used building retrofit measures, and then explore different tradeoff systems to identify suitable retrofit combinations for each building individually. We map the incentives by integrating neighborhood data such as building program type, construction year, and income levels. Preliminary findings highlight how incentive structures influence the feasibility of building decarbonization measures, creating a dynamic relationship between economic factors, policy, and building physics. As incentives shift, the financial viability and effectiveness of different retrofit measures change, thus impacting the overall municipal strategy for achieving net-zero goals.

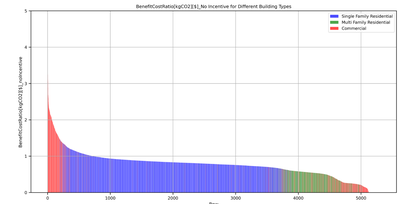
Result

UBEM + Socioeconomic Model of Ithaca, NY

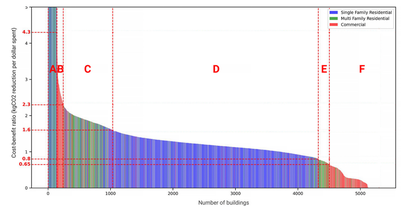
Discussion

The research explores how different incentive structures , metrics and study boundaries lead to varying pathways toward full decarbonization. By testing metrics such as a benefit-cost ratio, EUI, and energy-use/carbon-emissions per capita, we discuss their effectiveness in informing policy decisions and investment strategies for local governments.

Cost-benefit ratio of each building in Ithaca, NY
(No incentives)

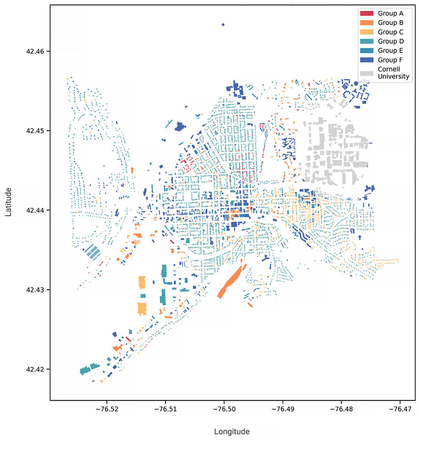


Cost-benefit ratio of each building in Ithaca, NY
(With incentives)



The diagrams show the combined effects of several incentives: Weatherization Assistance Program(WAP), residential 25C & 25D, commercial 179D tax credits. The simulation shows there is limited incentive for commercial builidngs and a only a slight increase in benefit-cost ratio. On the other hand, some multifamily buildings can get sufficient incentives to potentially cover the whole upfront cost.

Map of Ithaca building stock in groups of
cot-benefit ratio of building electrification



Data

Dataset & Usage	Source
Building Footprints (Polygons)	OSM, Microsoft
LIDAR Point Cloud Data (Classified Point Clouds)	USGS, County
Tax Assessment Data (Building use)	City, County
Reference and Prototype Building IDFs (Energy model templates)	DOE
Energy use data (billed or metered) (Validation data)	Utility/Avangrid
Historic Weather Data (Validation)	NREL (PSM3)
TMYx Weather Data (Scenarios)	OneBuilding.org
Retrofit Cost Data (Energy Efficiency Measures)	NREL
Incentives Data	Federal, State

Methods