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FUNDAMENTALS OF URBAN BUILDING ENERGY MODELING

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ONLINE TRAINING BY KRISHNAJI PAWAR

LEED AP(BD+C),GSAS CGP,GCP,ISO 14001

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MODULE 8

What are some examples of applications of UBEM?

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FUNDAMENTALS OF URBAN BUILDING ENERGY MODELING OVERVIEW

People who have an interest in UBEM applications and want to build or run cities and communities that are livable, healthy, profitable, and energy efficient are many and varied. They have different needs and play many parts in urban systems.

Learning Objectives

- Introduction
- UBEM Use cases
- Example applications of UBEM
- What are the main challenges in UBEM?
- Summary and Thoughts on the Future

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INTRODUCTION

- UBEM application stakeholders participating in the construction or management of livable, healthy, economically viable, and energy-efficient cities and communities have varying needs and play various roles in urban systems.
- UBEM stakeholders include decision makers (urban policymakers and city program managers), industry (investors, technology vendors, urban developers, utilities), city users (residents, local communities, visitors), urban energy planners and consultants, and urban researchers.

UBEM USE CASES

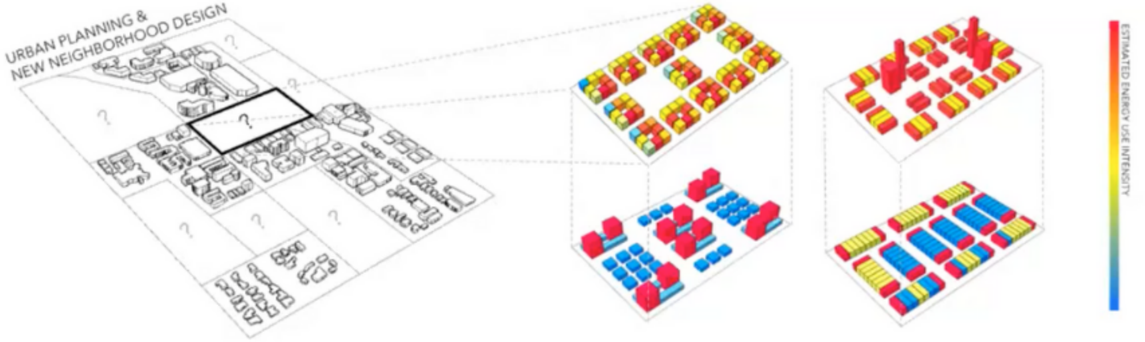
- There are four primary classifications of UBEM implementation: urban planning and the design of new neighborhoods; measures for reducing carbon emissions at the stock level; suggestions for individual buildings; and the integration of buildings with the grid (B2G).

- The requirements pertaining to each application are succinctly presented in Figure 2 and further elaborated upon in the subsequent sections.

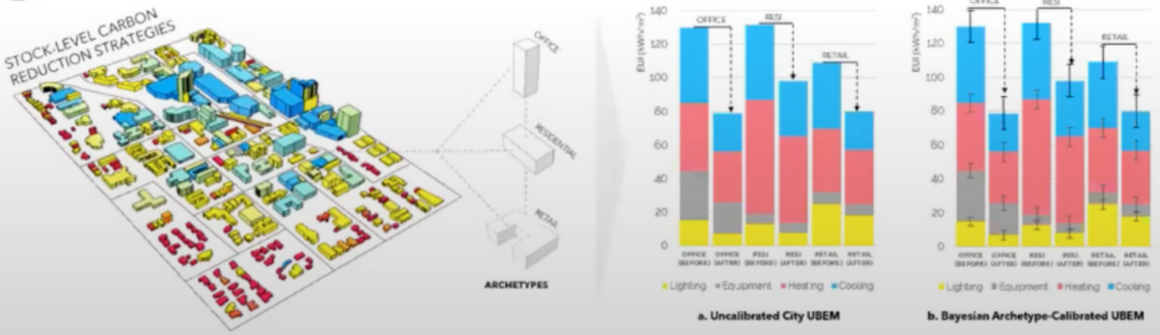


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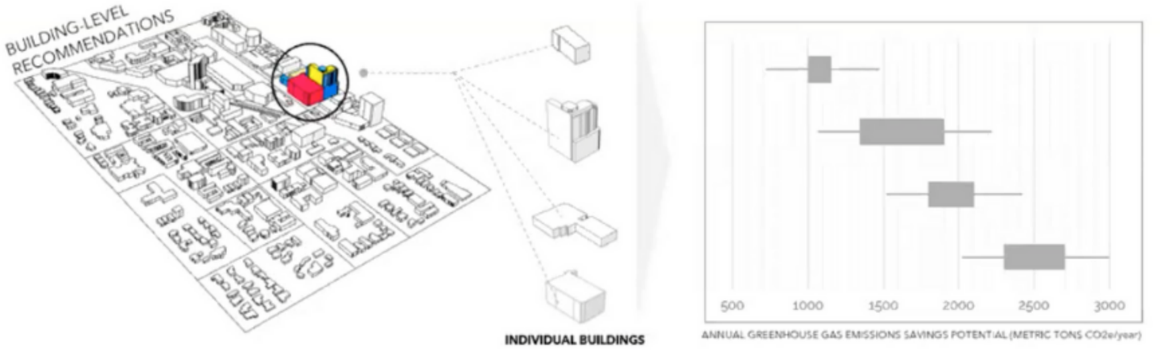
1 Urban Planning & New Neighbourhood Design



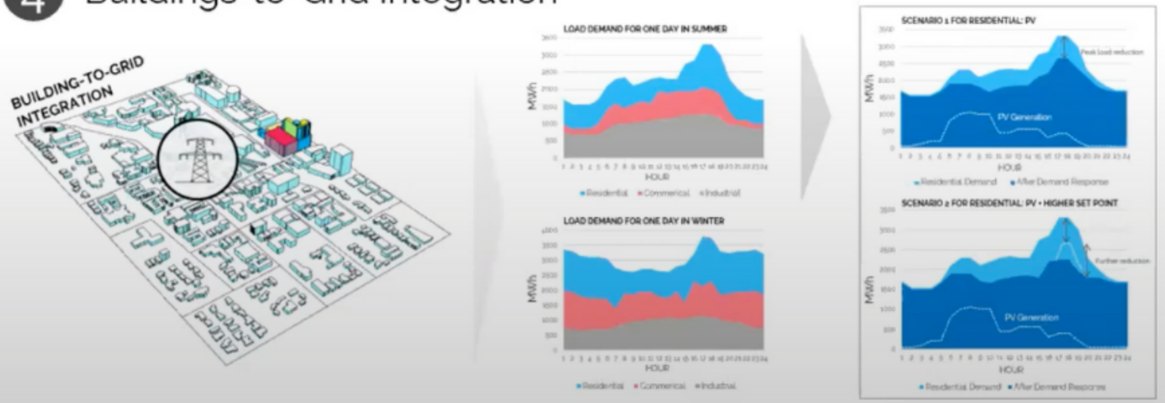
2 Stock-Level Carbon Reduction Strategies

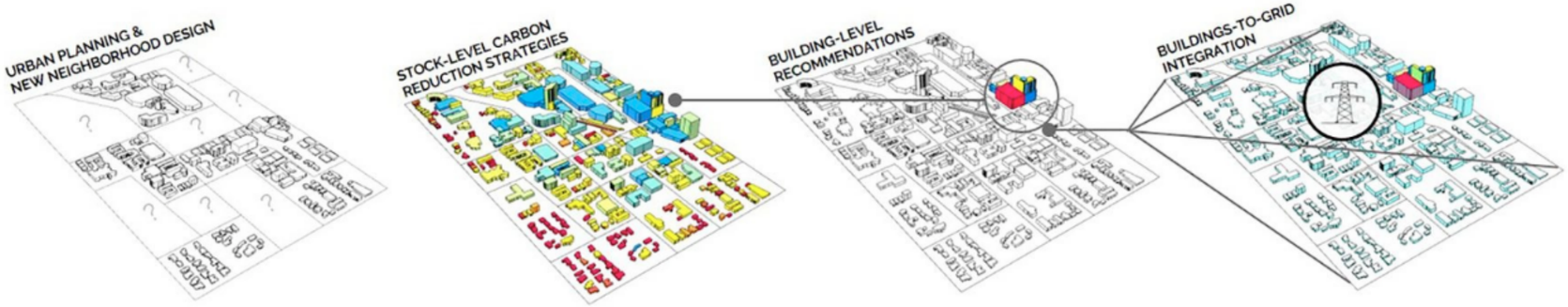


3 Building-Level Recommendations



4 Buildings-to-Grid Integration





	1. Urban planning & new neighbourhood design	2. Stock-level carbon reduction strategies	3. Building-level recommendations	4. Buildings-to-grid integration
PLANNING				
Main Users	Urban planners, architects, policy makers, planning consultancies, etc.	Municipalities and agencies, city planners, policy makers, planning consultancies, etc	Building portfolio owners, individual building owners, facility managers, energy consultancies	Utilities, grid regulators, distribution and transmission system operators
Use cases / Objectives	- Massing studies - Analysis of system designs & options - Window-to-wall ratio or glazing studies - Value engineering for new construction - Others	- Energy policy interventions - Carbon reduction strategies - Building stock retrofit studies - Incentive programs analysis - Others	- Building-level retrofit studies - Analysis of energy savings potential - Specific building-level upgrades - Benchmarking studies - Others	- Grid stability studies - Demand response analysis - Load modifying interventions - Transmission/distribution system analysis - Others
DATA AND MODEL				
Geometry	Simple massing (unless otherwise needed)	Representative geometry (e.g. GIS, CityGML)	Representative geometry (e.g. GIS, CityGML)	Representative geometry (e.g. GIS, CityGML)
Building Templates	Generic	Generic or Archetype level with customizations	Archetype or Building level with customizations	Archetype or Building level with customizations
Weather Data	✓	✓	✓	✓
Measured Energy Data	x	Data from some buildings (annual, monthly, daily)	Building level (monthly, daily, hourly, sub-hourly)	Building level (daily, hourly, sub-hourly)
SIMULATION				
Reliable Outputs	Neighbourhood/Precinct EUI	Annual EUI distribution (medium fidelity, time-step, and uncertainty)	Building level (high fidelity, small time-step and less uncertainty)	Building level (highest fidelity, small time-step, less uncertainty)
CALIBRATION				
Calibrated model	x	A. No calibration B. Archetype level calibration	A. Archetype level calibration B. Building level calibration	A. Archetype level calibration B. Building level calibration
Calibration methods	x	Statistical tools, Bayesian/semi-Bayesian, machine learning, etc.	Surrogate/auto-calibration, statistical tools, Bayesian/semi-Bayesian, machine learning, etc.	Potential new genre of calibrations

DATA PRE-PROCESSING

- Source and process necessary data, and fix gaps

MODEL GENERATION

- Compile data and urban geometry model into "simulation ready" state

SIMULATION

- Generate load profiles, indoor temperature and energy use

CALIBRATION

- Harmonize simulation output with measured energy data (if available)

APPLICATION

- Use UBEM to support end use goals and objectives

GEOMETRIC DATA

- GIS shapefiles
- LiDAR
- CityGML
- GeoJSON

NON-GEOMETRIC DATA

- Open data
- Tax Assessment
- Tabula data
- Building audits
- Gov. websites
- APIs
- Observations

OTHER INPUT DATA

Building Templates

Weather Data

Measured Energy Data

Building Geometry



FILE

Non-Geometric Building Properties

SIMULATION

Simulation Interface

Simulation Engine

Calibration



1. Urban planning and new neighbourhood design



2. Stock-level carbon reduction strategies



3. Building-level recommendations



4. Buildings-to-grid integrations



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Example applications of UBEM

Domain of applications	Objectives	Reference
End use energy auditing and benchmarking	Energy savings	(Gaube and Remesch, 2015; Srebric, Heidarinejad and Liu, 2015; Heidarinejad *et al.*, 2017; Brøgger and Wittchen, 2018; Caro-Martínez and Sendra, 2018)
	Development of codes and standards	(Abdolhosseini Qomi *et al.*, 2016; Hong, Chen, Piette, *et al.*, 2016)
Demand energy auditing and forecasting	Demand flexibility	(Pezzulli *et al.*, 2006; Fu *et al.*, 2009; Delmastro *et al.*, 2017; Mohammadi and Taylor, 2017; Wang *et al.*, 2018)
	Urban resiliency	(Gros, Bozonnet and Inard, 2014; Link, Pillich and Klein, 2014; Caro-Martínez and Sendra, 2018; Frayssinet *et al.*, 2018; Oregi *et al.*, 2018)
Existing urban buildings retrofiting	Energy savings; GHG emissions reduction; Cost effectiveness	(Ward and Choudhary, 2014; Lee *et al.*, 2015; McArthur and Jofeh, 2016; Monteiro *et al.*, 2018; Nagpal and Reinhart, 2018)
Urban energy planning	Energy efficiency	(Chow, Chan and Song, 2004; Fu *et al.*, 2009; Lin *et al.*, 2010; Koch, 2016; Delmastro *et al.*, 2017)
	Urban resiliency under climate	(Pisello *et al.*, 2015; Martin *et al.*, 2017;

- First of all, the formulation of energy policies for urban building stock frequently requires the evaluation of the overall building energy performance of the urban districts.
- Moreover, to study the distribution and determinants of energy use in large buildings, peer-to-peer comparisons by energy benchmarking encourage transparency in energy efficiency markets, and predictive models of building energy use at the district and city scales help capture more generalized energy consumption behaviors.
- Second, UBEM offers a common approach to district planning and retrofitting by evaluating and prioritizing different system design options and energy conservation measures (ECMs) for city-scale analysis.
- In general, UBEM helps users understand the overall potential costs and benefits of retrofitting a large portfolio of diverse-use buildings in terms of reducing global GHG emissions associated with building energy use.
- The results of these studies show that UBEM can be used as a tool for facility planning and maintenance to find the best ways to lower energy use and greenhouse gas emissions.

WHAT ARE THE MAIN CHALLENGES IN UBEM

Although UBEM is gaining popularity (based on papers and talks at the 2017 and 2019 IBPSA Building Simulation conferences and ASHRAE conferences since 2014), it faces problems, such as:

- Interconnected urban systems
- Big data
- Workflow
- Computing resources
- Collaboration





SUMMARY AND THOUGHTS ON THE FUTURE

- UBEM research, development, and applications are growing due to (1) more practical use cases and stakeholder values, (2) cheaper cloud computing or high-performance computing, and (3) big data from diverse sources and low-cost sensing and metering at scale.
- Ten questions in this research highlight major urban building energy modeling difficulties.
- The proposed responses attempt to illuminate present and future urban building energy modeling research and, more crucially, generate new critical inquiries from young researchers.
- Urban buildings will be a key component of smart city digital twins, which are virtually designed and tested using urban information modeling, computational simulation, and virtual reality technologies and operated using augmented reality, real-time sensing and metering, and machine learning-driven predictive controls to optimize energy efficiency, sustainability, and resilience.

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