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FUNDAMENTALS OF URBAN BUILDING ENERGY MODELING
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MODULE 2

What is Urban Building Energy Modeling (UBEM)?

KRISHNAJI PAWAR - CEO & FOUNDER

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

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FUNDAMENTALS OF URBAN BUILDING ENERGY MODELING OVERVIEW

UBEM development is difficult since it requires vast data, automated modeling, simulation, and calibration of multiple buildings, and significant computer power. UBEM development requires selecting the correct simulation engine and thermal model complexity, which have not been carefully examined before.

Learning Objectives

- Introduction
- What is urban building energy modeling (UBEM)?
- Urban energy systems transition to sustainability
- The need for a decision-making tool
- Urban building energy modeling workflow.
- How can local weather data be generated and used for UBEM?
- How can results from UBEM be calibrated?
- What are some examples of applications of UBEM?
- Summary and Resources
- UBEM Quiz_Test Your Knowledge!

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INTRODUCTION

- Urban building energy modeling refers to the computational modeling and simulation of the performance of a group of buildings in the urban context to account for not only the dynamics of individual buildings but, more importantly, the inter-building effects and urban microclimate.
- The goal is to provide quantitative insights (e.g., annual or seasonal energy use and demand, potential of renewable power generation) to inform urban building design and operation, as well as energy policymaking.
- For electric vehicle (EV) charging that uses the building power system, UBEM can integrate the EV loads into the building's overall energy demand.
- UBEM can use different modeling approaches.



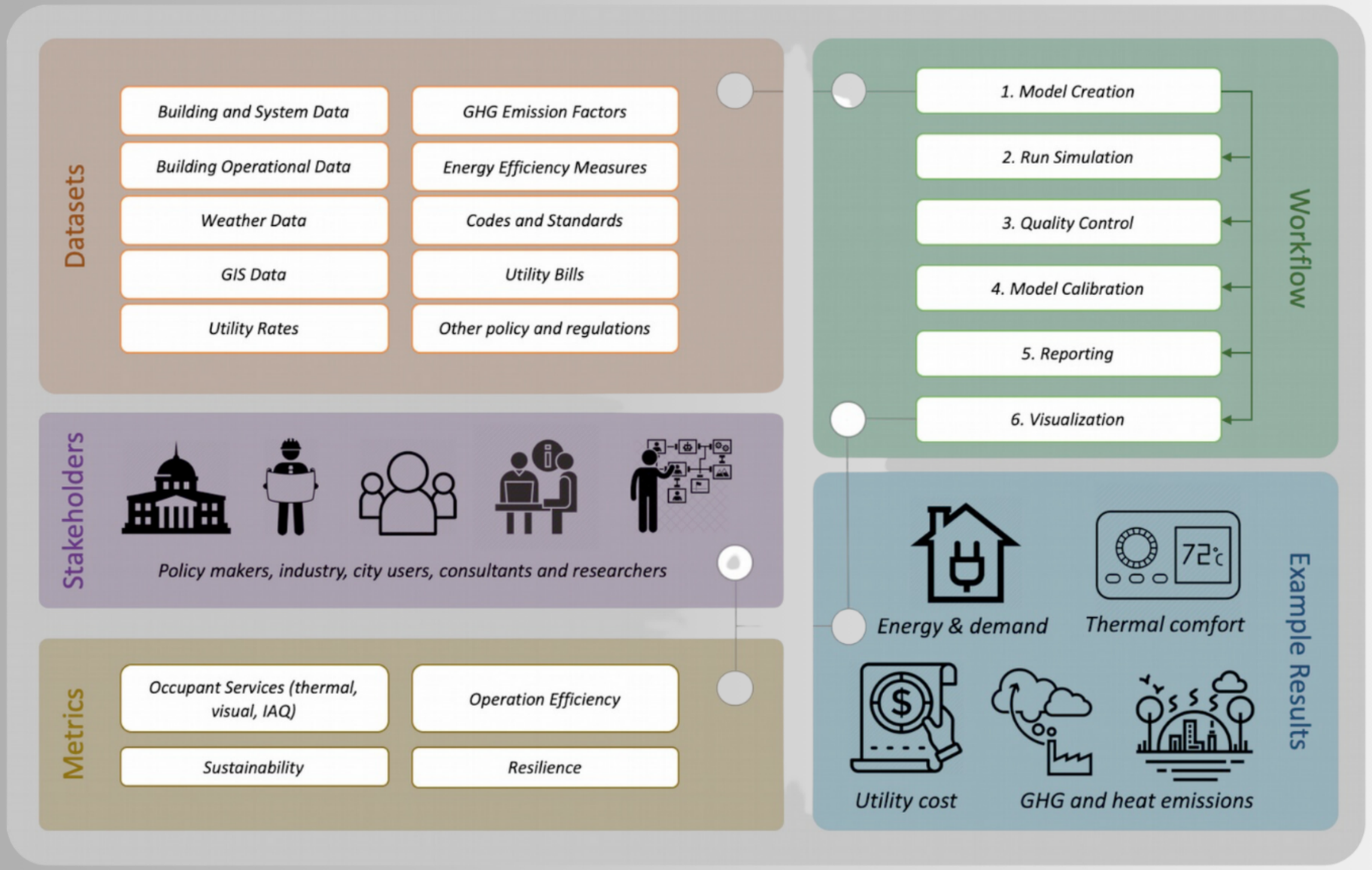
WHAT IS URBAN BUILDING ENERGY MODELING (UBEM)?



- A detailed modeling approach usually requires a much larger amount of data to be input to the UBEM and requires much more computing resources.
- The determination of UBEM at the appropriate spatial and temporal scales, as well as modeling approaches, depends on the use cases, i.e., the questions to be answered.
- Other important factors to consider include the availability and quality of input data, user experience with the chosen UBEM tools, and available computing resources.
- Figure 1 illustrates the key components of a UBEM ecosystem, including datasets, simulation workflows, results, and stakeholder metrics to support decision-making.

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FIG.1 OVERVIEW OF URBAN BUILDING ENERGY MODELING





URBAN ENERGY SYSTEMS IN TRANSITION TO SUSTAINABILITY

Undoubtedly, the future of sustainable urban development is intricately linked to the characterization of urban energy systems. Diverse definitions of the urban energy system can be found in the literature.

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Local governments are uniquely positioned to address climate change's causes and impacts, thus effective climate policies are available.

However, city-specific urban energy transition to sustainability action plans are lacking.

Many components work together to provide and use energy in an urban energy system.

Understanding urban energy systems may help create city-specific, informed, and inclusive energy transition policies.

URBAN ENERGY SYSTEMS

"composition of all components related to the use and provi- sion of energy services associated with a functional urban system, irrespective where the associated energy use and conversion are located in space"

However, the most inclusive definition of urban energy systems are provided by Keirstead et al.

who define the urban energy system as "a formal system that rep- resents the combined processes of acquiring and using energy to satisfy the energy service demands of a given urban area".





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ESTABLISHING ENERGY POLICIES

Building stock significantly contributes to energy demand and GHG emissions in urban energy systems, consuming 40% of EU energy and 36% of GHG emissions.

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To cope with climate change and move toward a more sustainable future, national, regional, and local authorities implement a wide range of construction-oriented policies and building standards that aim to:

- Designed, built, and renovated buildings and HVAC systems to improve energy efficiency.
- Build integrated and decentralized energy systems like building-integrated or building-applied solar technology to increase renewable energy.

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National building codes and regulations aim to increase building energy efficiency, but compliance and enforcement issues limit their efficacy.

However, combining these restrictions with local policies and improving them based on municipal planning and development strategies can be one of the best methods to meet climate mitigation and sustainable development goals.

NEED FOR DECISION-MAKING TOOL

- Benchmarking and certification systems have been used to identify and implement energy efficiency and use reduction measures in buildings.
- Green certification methods like LEED and BREEAM are used by decision-makers and stakeholders worldwide.
- Benchmarking compares a building's energy performance over time to similar buildings or simulations of a reference building.
- Dynamic energy modeling and simulation of individual buildings have been used in benchmarking for years to plan, demonstrate, and evaluate energy conservation and thermal comfort improvements.



NEED FOR DECISION-MAKING TOOL +

- Considering interactions between buildings and the urban environment, their role in renewable resource envelope solutions, and the dynamic effects of building energy use on district energy systems, bench-marking and individual building energy studies have given way to district and city-level solutions.
- In the latest carbon-free Boston action plans, urban building energy modeling is the only metric of building energy efficiency improvement.



WHAT IS URBAN BUILDING ENERGY MODELING?

This section introduces city-scale energy modeling of buildings, specifically bottom-up engineering energy models (UBEMs).

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CITY-SCALE ENERGY MODELING OF BUILDINGS

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- City-scale dynamic energy modeling of buildings is highly dependent on the availability and granularity of input data and can vary from top-down to bottom-up models.
- This means that, similar to top-down models, statistical models are also capable of capturing consumption patterns based on end-use-related variables.
- Thus, the third type of model, so-called hybrid models, has gained increasing popularity among model developers.
- A hybrid model is a collection of both statistical and engineering models with all their respective advantages.
- In the hybrid models, while the building is modeled according to engineering methods, the uncertainty of the input variables as well as the simplified model are approached by statistics and statistical models.

In the existing literature, bottom-up models that benefit from engineering models of buildings are commonly referred to as "urban building energy models."



COMPARISON OF BOTTOM-UP CITY-SCALE ENERGY MODELS OF BUILDINGS: STATISTICAL, ENGINEERING AND HYBRID MODELS

Models	Strengths	Weaknesses	References
Statistical models	• End-user information and variability in occupant behaviour is covered. • No detailed technological information is needed. • Demographic factors can be considered.	• Extensive data and a large number of samples are required. • Highly dependant on historical data. • Not applicable for development studies.	Torabi Moghadam et al. [12], Nutkiewicz et al. [49], Yang et al. [50], Lo et al. [51]
Engineering models	• Estimation of energy use for different spatio-temporal resolutions is possible. • Detailed technical information and systems are considered. • Development studies, e.g., efficiency measure and urban development, are possible.	• Detailed technical information on buildings and systems is required. • Extensive computational effort is required. • No information on end-user as well as demographic information is included.	Nageler et al. [52], Cerezo Davila et al. [53]
Hybrid models	• Estimation of energy use for different spatio-temporal resolutions is possible. • End-user information and variability in occupant behaviour is covered. • Detailed technical information and systems are considered. • Results in the most accurate urban energy development tool.	• Detailed technical information on buildings and systems is required. • Extensive data is required. • Extensive computational effort is required.	Nouvel et al. [54], Ghiassi et al. [55]



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