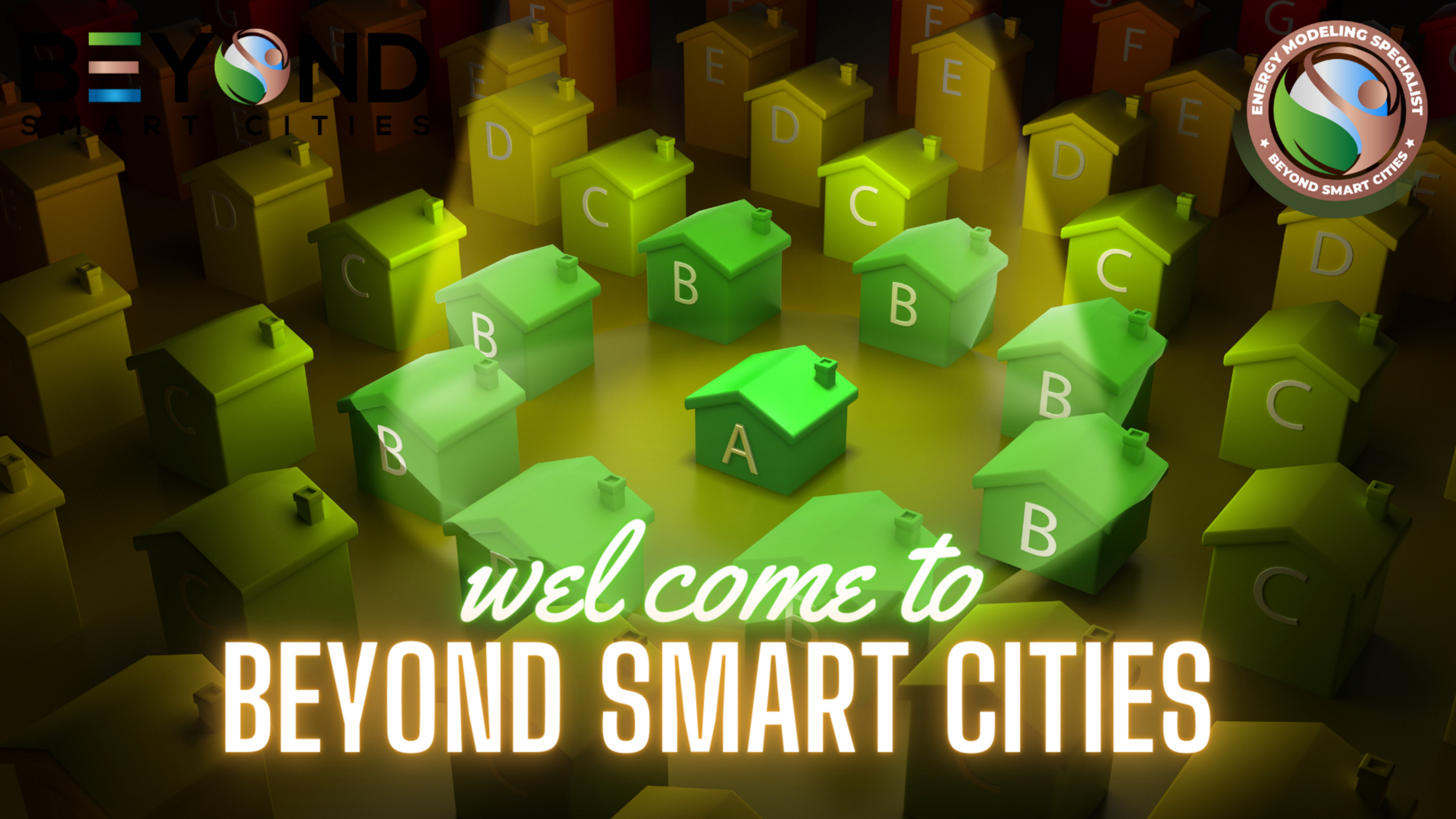

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MODULE 4

What are the available UBEM tools



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FUNDAMENTALS OF URBAN BUILDING ENERGY MODELING OVERVIEW

Current UBEM tools demand different computational resources and user inputs. Some UBEM tools are web-based, like CityBES, while most are standalone apps like CitySim and UMI. CityBES and UrbanOpt employ EnergyPlus, while SimStadt, CitySim, City Energy Analyst, and TASER use reduced-order models.

Learning Objectives

- Introduction
- UBEM simulation engine
- Model calibration and validation
- What are the available UBEM tools?
- What data models and technologies reflect urban building characteristics?
- What's new in the field of 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

- Clarke pioneered dynamic building simulation and energy model studies in the 1970s and 1980s.
- A systematic review shows that engineering studies on urban-scale building energy did not appear until the early 21st century.
- These early-stage engineering models include Huang and Broderick's publication, in which DOE simulates the energy of prototype buildings (building archetypes) and extrapolates the results to the entire stock, and Parekh's work, which defined building archetypes.
- However, CitySIM and SUNtool piqued interest in using urban building models to support sustainable urban planning.
- SUNtool and CitySIM are paradigm-shifting urban building energy modeling tools.

UBEM SIMULATION ENGINE

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- In urban building energy modeling, the main method is to model and simulate structures like BEM.
- However, many model developers rely on the BEM and want to improve its urban building energy modeling capabilities.
- These models use BEM modeling software to properly estimate building energy use, but they are more complicated and expensive.
- Modelers can minimize UBEM computation time, complexity, and detail by creating custom algorithms based on the R-C analogy and simplified heat balance equations.
- In addition to the simulation core, BEM software or custom algorithms, UBEMs may consider single or multi-zone building models.



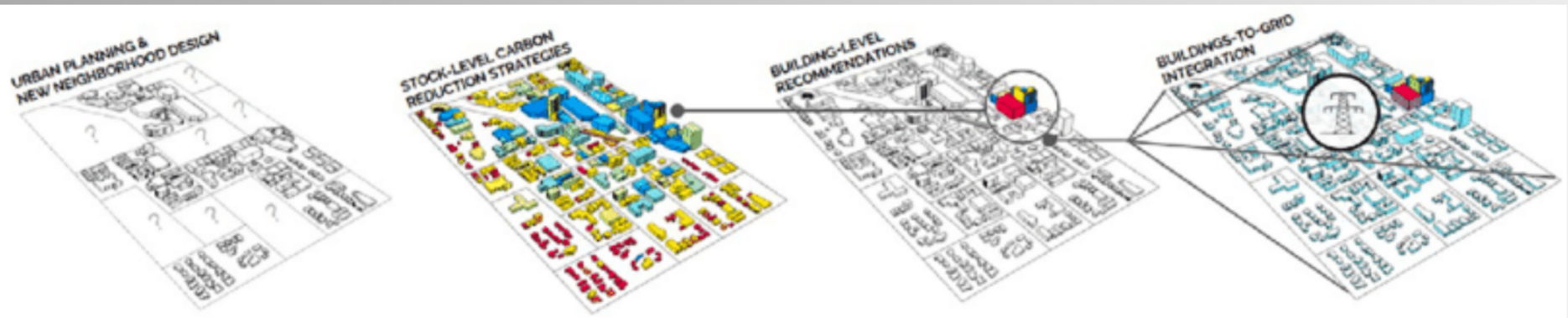
MODEL CALIBRATION AND VALIDATION

- It is customary to simplify UBEMs to reduce complexity, which increases the performance gap between the model and the actual scenario.
- Model calibration is critical in UBEMs to optimize simpler models and reduce input data uncertainty.
- Two main methods for calibrating and refining the model exist in previous research.
- Many research employ an iterative process to alter model parameters and compare results to energy use data.
- Validating the model against real energy usage data appears to be the only way to verify its results.



SUMMARY OF THE ANALYSED UBEM TOOLS.

Tool	Website	Developer	Typology	Energy simulation	Presented in
CitySim	https://citysim.epfl.ch/	EPFL	Software in Java and C++	Equivalent electrical circuit	(Robinson et al., 2009)
SimStadt	http://www.simstadt.eu/de/index.jsp	University of Stuttgart	Software	ISO 13790	(Nouvel et al., 2015)
Umi – Urban modelling interface	http://urbanmodellinginterface.ning.com/	Sustainable Design Lab, MIT	Plug-in for Rhinoceros 5	EnergyPlus	(Reinhart et al., 2013)
CityBES – City Building Energy Saver	https://citybes.lbl.gov/	LBNL	Online Platform	EnergyPlus	(Hong et al., 2016)
CEA – City Energy Analyst	https://cityenergyanalyst.com/	ETH Zürich and Singapore	Plug-in for ArcGIS	(Fonseca and Schlueter, 2015)	(Fonseca et al., 2016)
TEASER - Tool for Energy Analysis and Simulation for Efficient Retrofit	https://github.com/RWTH-EBC/TEASER	RWTH Aachen University	Open source on Phyton	Design-driven reduce order model	(Remmen et al., 2018)



	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



CITYSIM



- EPFL's CitySIM models building energy usage based on human activity, HVAC systems, and urban microclimate at building, district, and city scales.
- CitySIM calculates building energy flows using Java's geography GUI and a backend C++ solver.
- CitySIM building thermal models use R-C network analogies, where conducting walls carry heat between temperature nodes.
- Thermal nodes on external surfaces are affected by microclimatic factors like sun radiation, whereas internal nodes reflect occupant behavior and stochasticity.
- Geometrical data and building attributes seem to provide CitySIM reasonable findings.

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SIMSTADT

- CitySIM is a simulation tool that only simulates buildings dynamically when provided the necessary data.
- SimStadt , developed at the University of Applied Science Stuttgart, proposes a modular workflow based on third-party software like CitySIM for multi-scale urban energy and environmental (CO2 emission) analysis.
- Using its pre-processing modules, missing data is determined from typology and usage (archetype) information or probabilistic interpolation from aggregated data to simplify data handling.
- It uses CitySIM and suggests ways to improve it.
- SimStadt additionally considers energy systems and buildings using other developed technologies.



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CEA

- Modular workflow-based UBEMs like SimStadt are not the sole successes.
- City Energy Analyst (CEA), an integrated framework for building analysis and optimization , has six modules for building demand forecasting, resource availability assessment, conversion simulation, storage and distribution technologies, bi-level optimization, and multi-criteria assessment.
- CEA analyzes dynamic heat and mass transfer, buildings, systems, users, and the environment, corrects it with annual-specific building consumption values, classifies it using K-means clustering, and illustrates it in the output.
- This tool displays and shares results using ArcGIS's innovative 4D interface.

CEA has one interface and Python models, unlike SimStadt.

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WHAT DATA MODELS AND TECHNOLOGIES REFLECT URBAN BUILDING CHARACTERISTICS?

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- Building data from different departments within a city or across cities is usually given in different forms with no uniform building identifier.
- San Francisco's building footprint data is in Shapefile format, while building characteristics are spread among numerous files in fixed-width text, CSV, or Shapefile forms.
- Additionally, different datasets use different nomenclature to represent identical data components.
- Table 2 lists the terminology used to refer to identical data components in San Francisco, Chicago, and Portland building datasets.

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