

Panel 7 - Modeling Occupant Behavior in Buildings

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Improving Building Performance
Simulation with Detailed Occupant
Movement and Behavior Modeling



Learning Objectives

- Understand the paradigm shift of occupant behavior modelling
- Learn the occupant behavior tools we developed and how they could be used for building analytics
- Understand the challenges of occupant behavior study and potential future research areas

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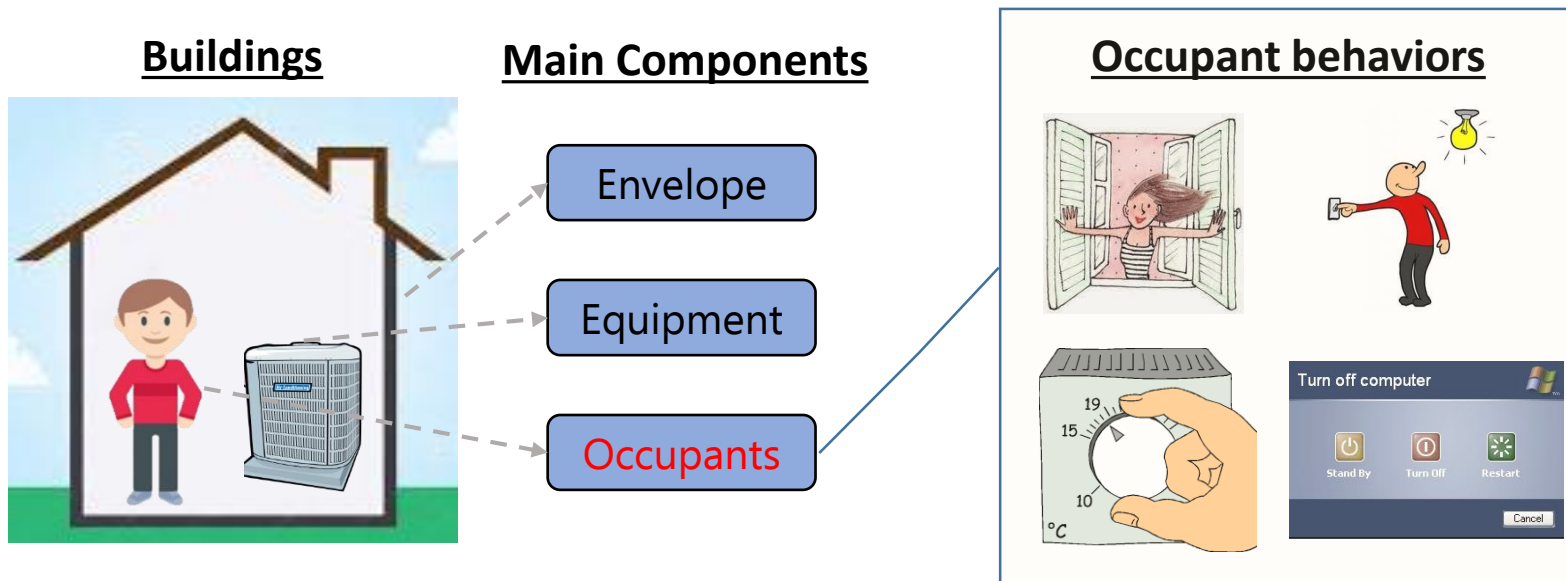
Agenda

- Motivation
 - Why we need to model occupant behaviors
- Previous work
 - Tools
 - Case studies
- Discussion
 - Challenges
 - On-going work
- Conclusions



Motivation

- Three pillars of building simulation
 - Envelope
 - Equipment
 - Occupant behaviors (OB)

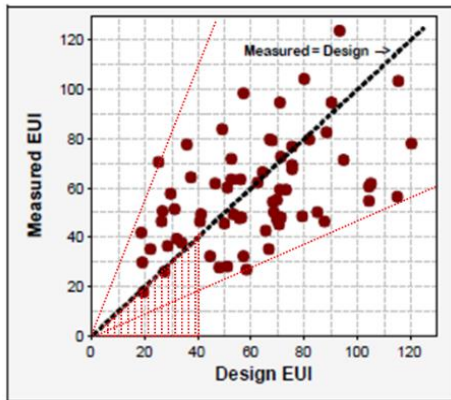




Motivation

- OB should not be ignored
 - **Modelling accuracy:** OB is a major source for building energy discrepancy and performance gap
 - **Energy saving potentials:** Behavior changes, usually at no or low cost, has demonstrated from 5 to 20% energy savings in buildings

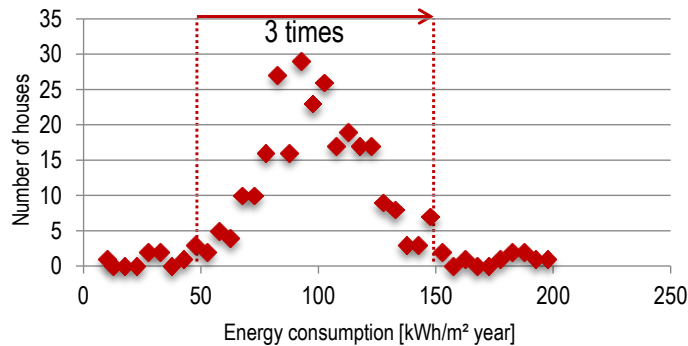
US



Measured vs Design EUIs of 100 LEED buildings in USA

(Turner and Frankel, 2008)

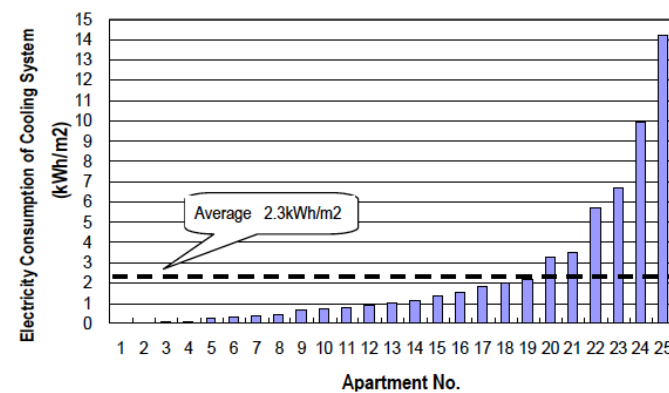
Europe



Energy consumption 35 apartments same block of building Copenhagen, EU

(Andersen et al, 2012)

China



Summer air-conditioning electricity consumption Residential building Beijing, China

(Yan et al, 2015)



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Previous work: tool development

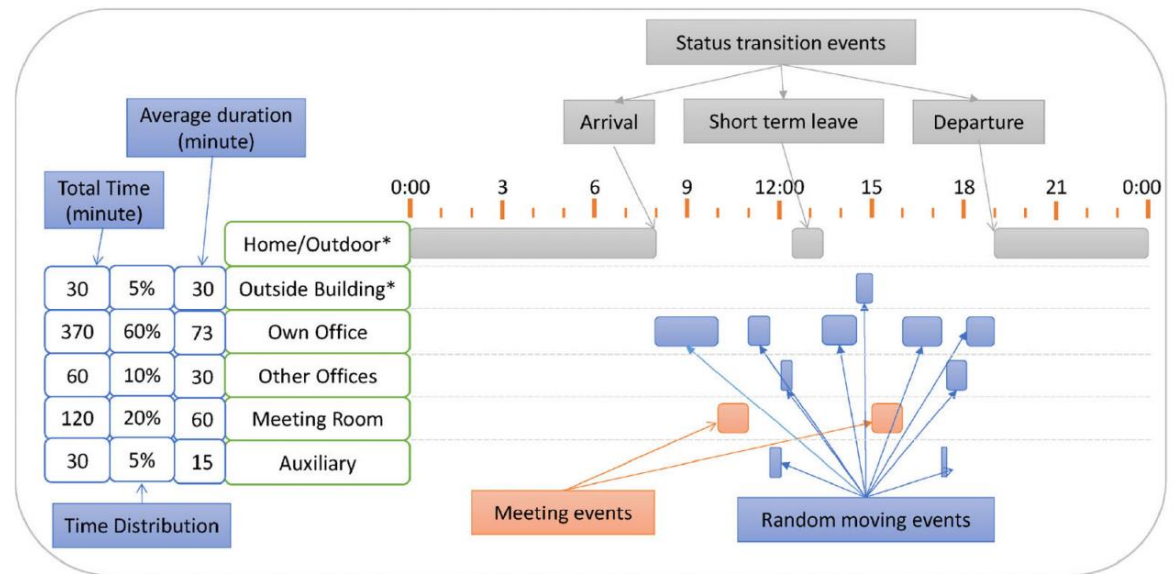
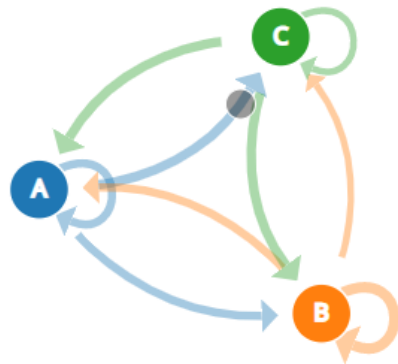
- OB simulation paradigm shift
 - Fixed vs. stochastic
 - Pre-determined vs. depends on the current states
- We developed and open sourced OB simulation tools
 - **obXML**: a standardized XML schema to represent and exchange OB models
 - **obFMU**: a Functional Mockup Unit of OB models for co-simulation with BPS programs
 - **Occupancy Simulator**: a web App simulating occupant presence and movement in buildings using stochastic models, producing realistic occupant schedules
 - **Buildings.Occupants**: A Modelica package of occupant behavior in buildings



Previous work: tool development

- Fixed vs. stochastic
 - Example: number of occupants in the building is stochastic
 - Tools: Occupancy simulation

Markov-chain process



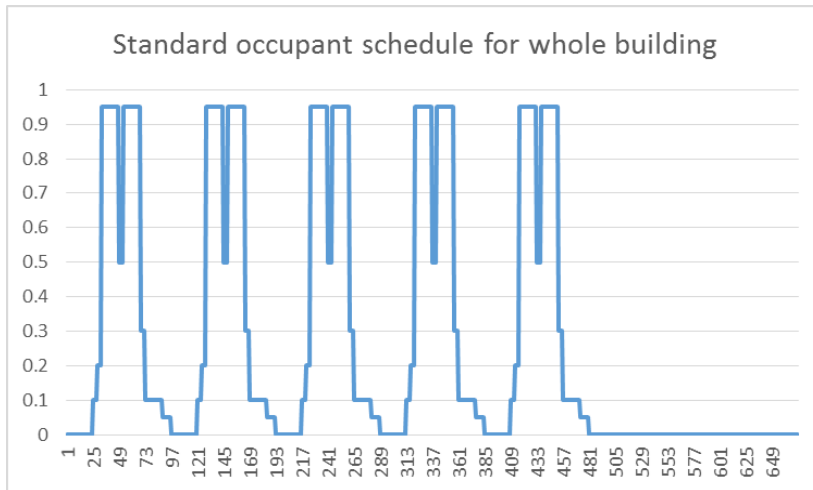
- Y. Chen, T. Hong, X. Luo. [An agent-based stochastic occupancy simulator](#). Building Simulation, 2017.
- Luo, X., Lam, K.P., Chen, Y. and Hong, T., 2017. Performance evaluation of an agent-based occupancy simulation model. Building and Environment.



Previous work: tool development

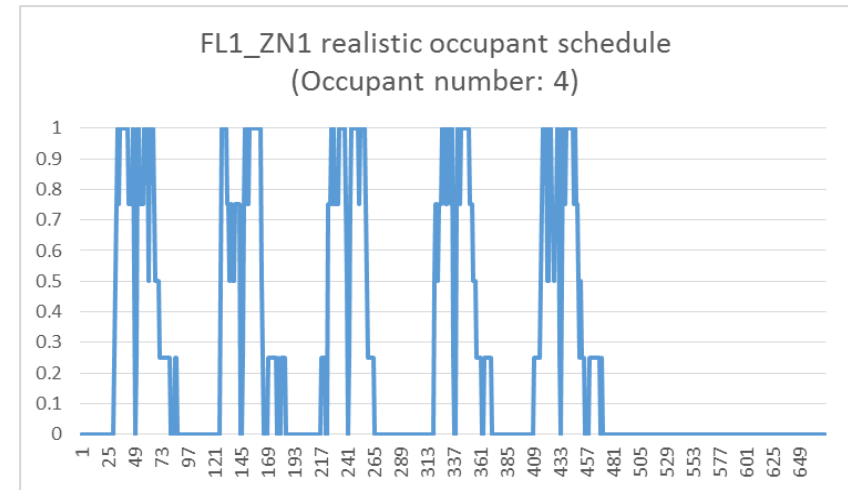
- Fixed vs. stochastic
 - Tool: Occupancy simulation

Standard



VS.

Realistic



- Homogeneous for all zones
- Always occupied during working hours

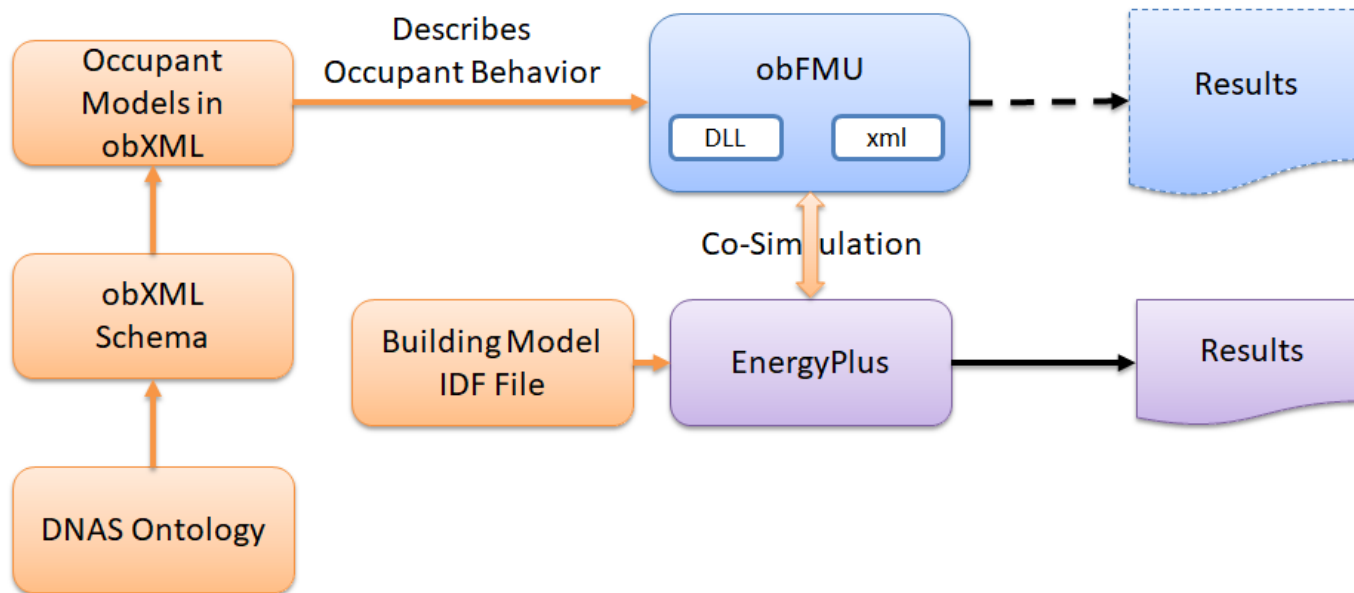
- Reflect realistic movement
- Closely related to occupant behaviors

Please feel free to try the tool: OccupancySimulator.lbl.gov



Previous work: tool development

- Pre-determined vs. depends on the current states
 - Example: window behavior depends on current indoor temp
 - Tools: obFMU, Modelica Buildings.Occupants library
 - Function: Facilitate co-simulation with EnergyPlus or Modelica





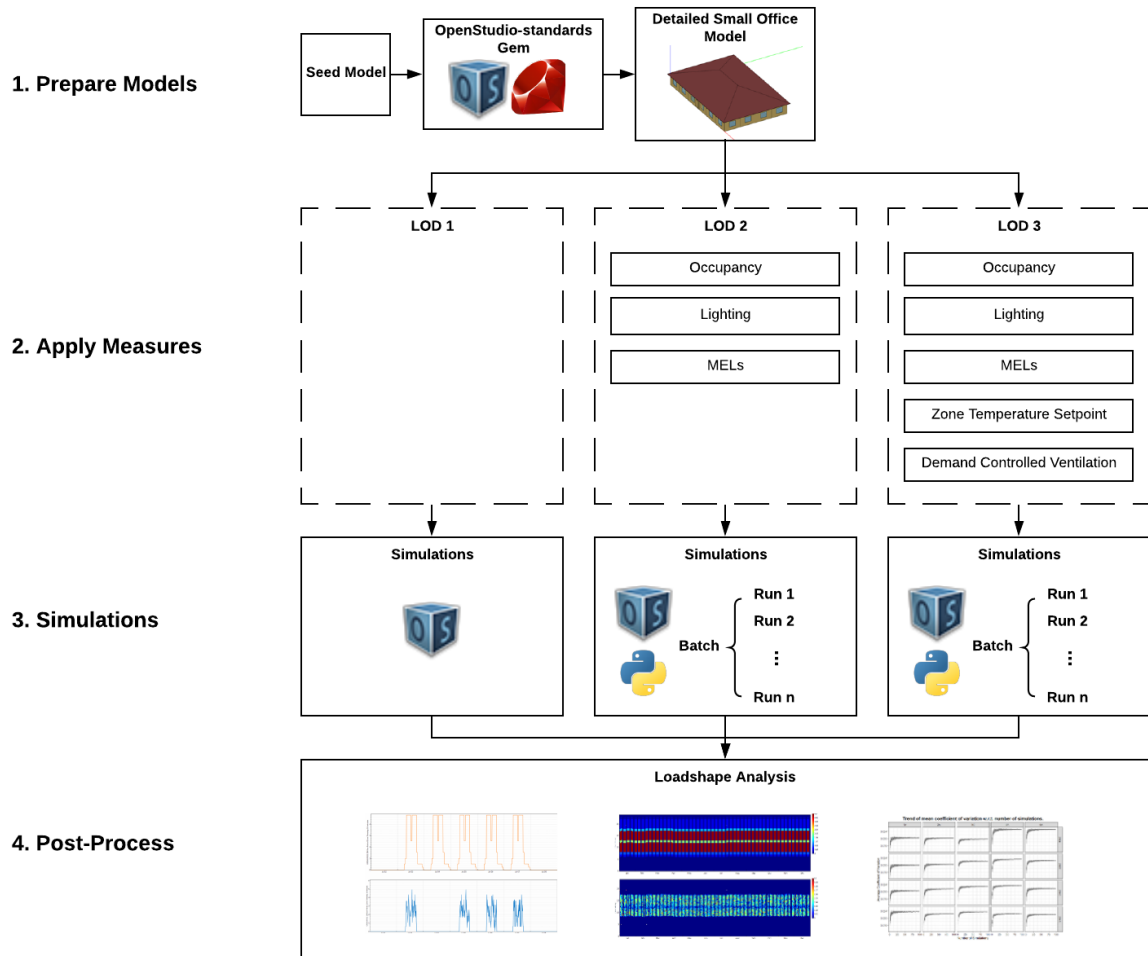
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Previous work: case study

- How the tools we developed could be used
 - Application 1 – generate more realistic building load profiles



Source of assumptions

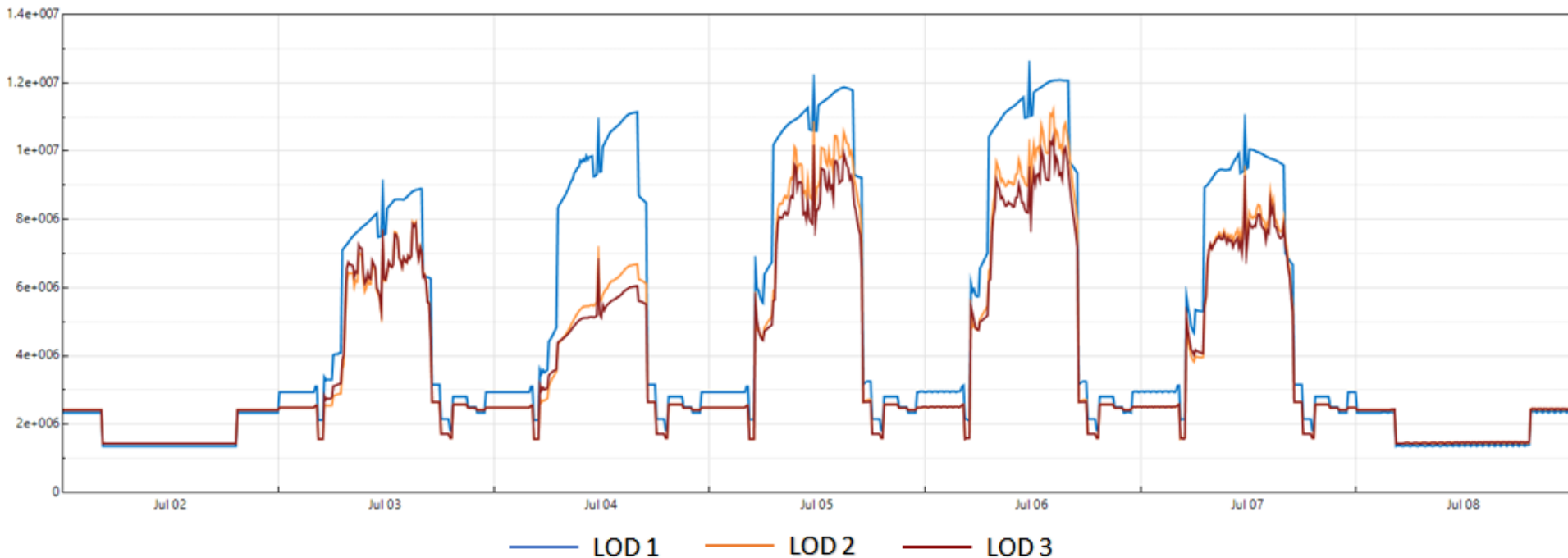
	Source
Occupancy	Literature review
Lighting	Literature review
MELs	Literature review
Temperature set-points	ASHRAE Thermal Comfort Database
Ventilation	Standard



Previous work: case study

- Application 1 – generate more realistic building load profiles
 - Level of Details Concept
 - LOD1: Baseline
 - LOD2: Occupancy, lighting, MELs
 - LOD3: Temperature set-point, ventilation

Whole-building electricity consumption (J) in a typical week (10-min timestep)

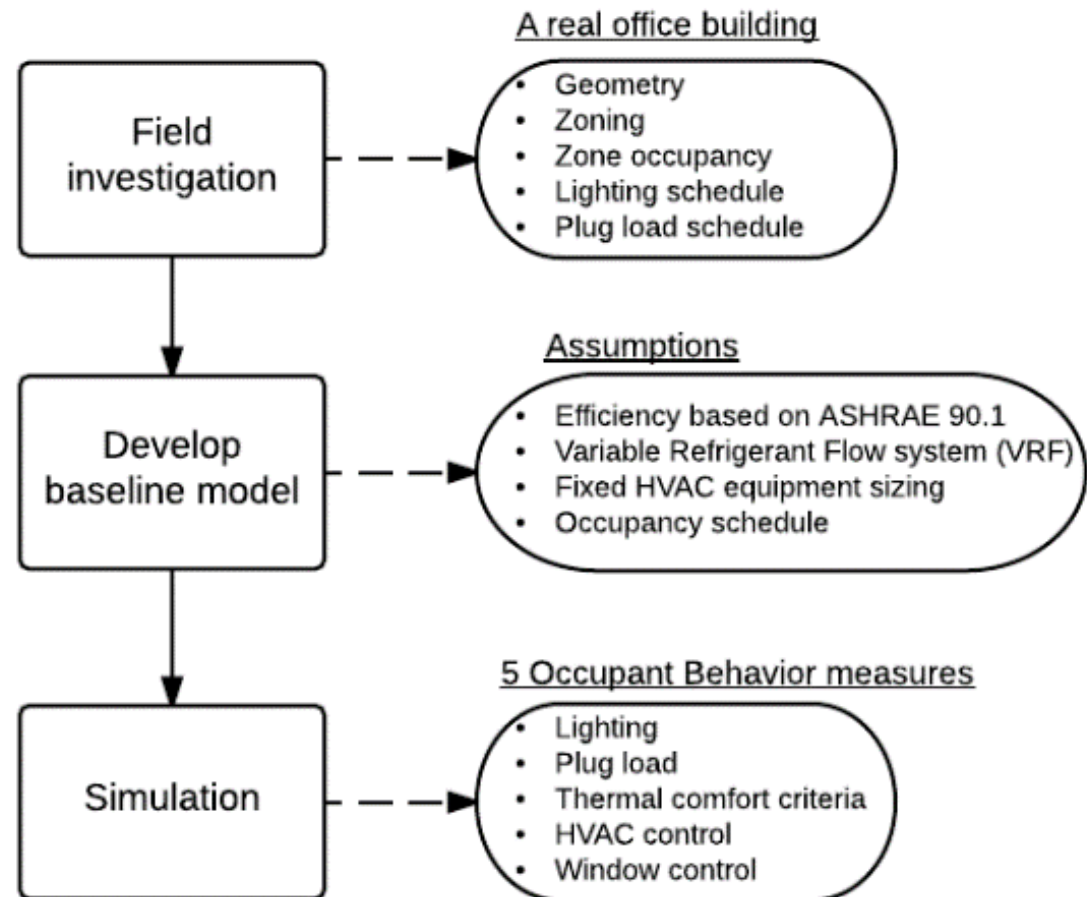




Previous work: case study

- How the tools we developed could be used
 - Application 2 – quantify the energy saving potential from OB changes

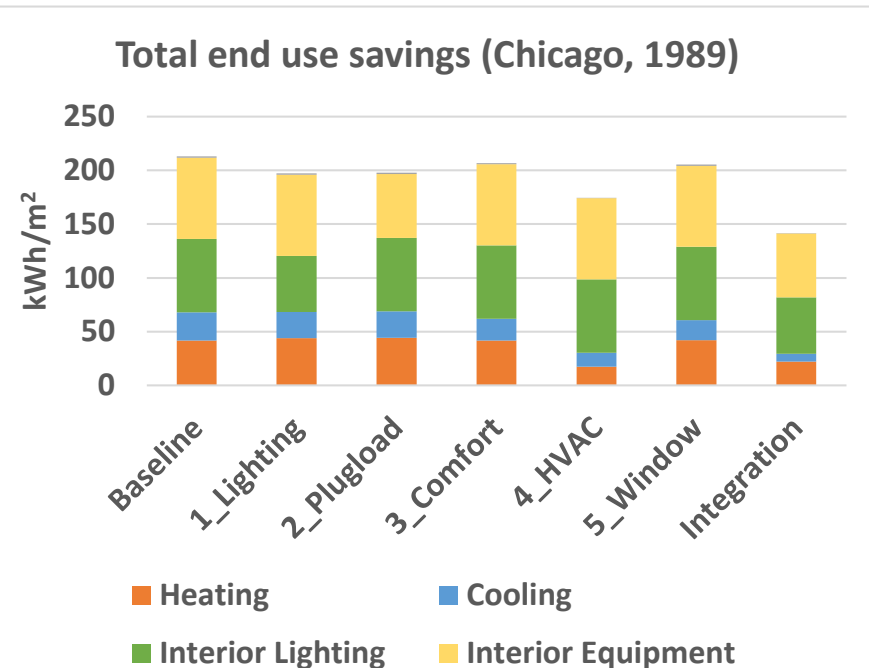
- Two-story office building, 18,550 ft²
- Office, conference room, classroom and lounge
- VRF (Variable Refrigerant Flow) system





Previous work: case study

- Application 2 – quantify the energy saving potential from OB changes
 - Integration of the five measures saves the whole building energy use by **25%-41%** in four climates and two vintages.
 - The main energy savings captured by the OB measures come from the **avoidance of energy waste in unoccupied rooms** for lighting, plug load, and HVAC systems



Sun, K. and Hong, T., 2017. A simulation approach to estimate energy savings potential of occupant behavior measures. *Energy and Buildings*, 136, pp.43-62.



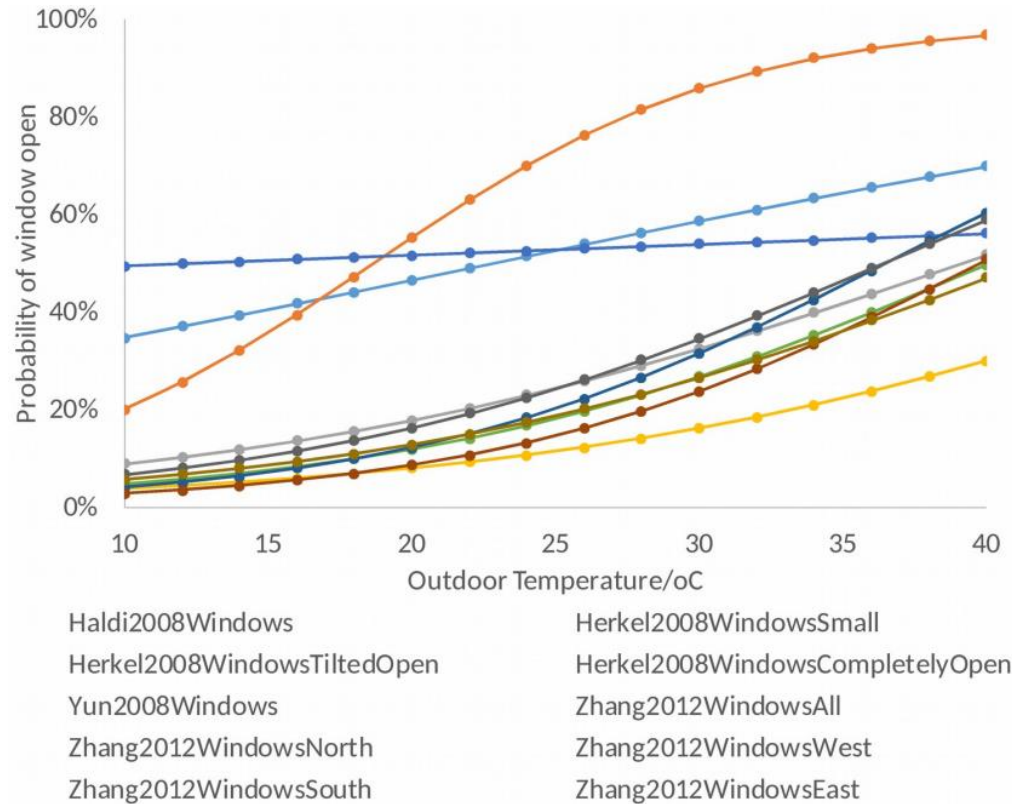
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Discussion

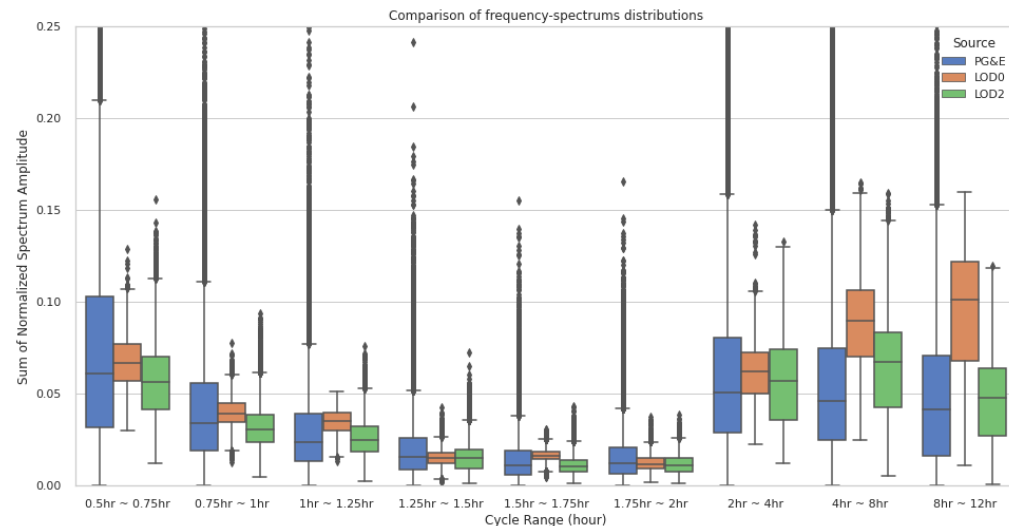
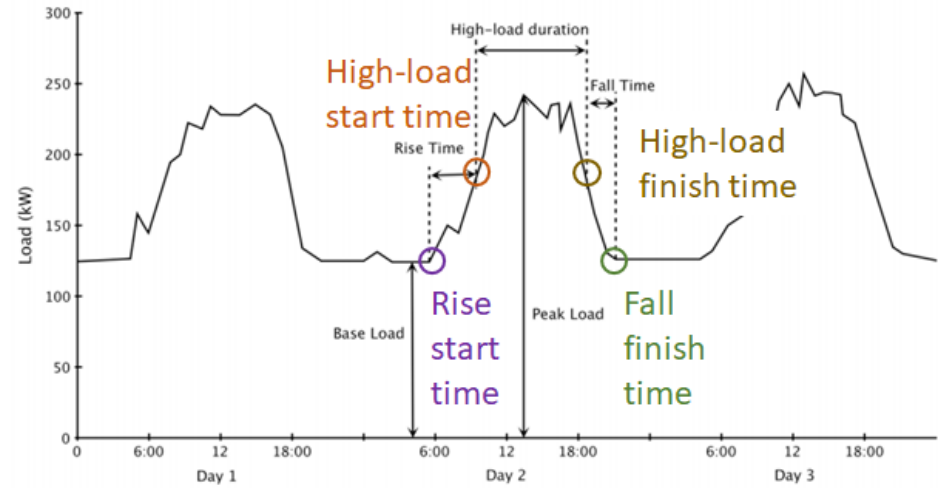
- Challenge1
 - The assumptions for occupant behaviors vary significantly
- On-going work
 - ASHRAE occupant behavior database
 - Easily compare and select
 - BRICK schema for OB data
 - Easily share data





Discussion

- Challenge2
 - How to quantify the performance of different stochastic models
- On-going work
 - Compare the generated and real building load from the *time* and *frequency* domain





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Conclusions

- Occupant behavior modelling is important in building energy simulation
- We developed tools to consider the stochastic and interactive nature of human building interaction
- We applied our tools to generate more realistic building energy consumption and to quantify building energy saving potentials
- Future works include more robust OB assumptions and model validations



QUESTIONS?

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