ABMS Approach for Modeling Commercial Buildings, Storage, and Power Grid

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Argonne's Technical Approach for Modeling Buildings and Grid Interaction

- Objective: Analyze energy consumption patterns of commercial buildings with and without energy storage options and the interaction with the electric power grid under multiple energy conservation scenarios and demand-side programs

- Agent-Based Modeling and Simulation approach was selected to model both the physical system and the decision-making processes by commercial building operators

- For this analysis Argonne has developed ABMS representations of various types of commercial building agents to investigate their behavior in the electricity market and how they may respond to real-time electricity price signals

- During the simulation, building agents are modifying and adjusting their load profiles through the use of energy storage and demand- and price-based response mechanisms to minimize their energy use and energy costs

- The modeling framework also allows for the analysis of impacts of building agents' actions on the supply side of power grid and on electricity prices

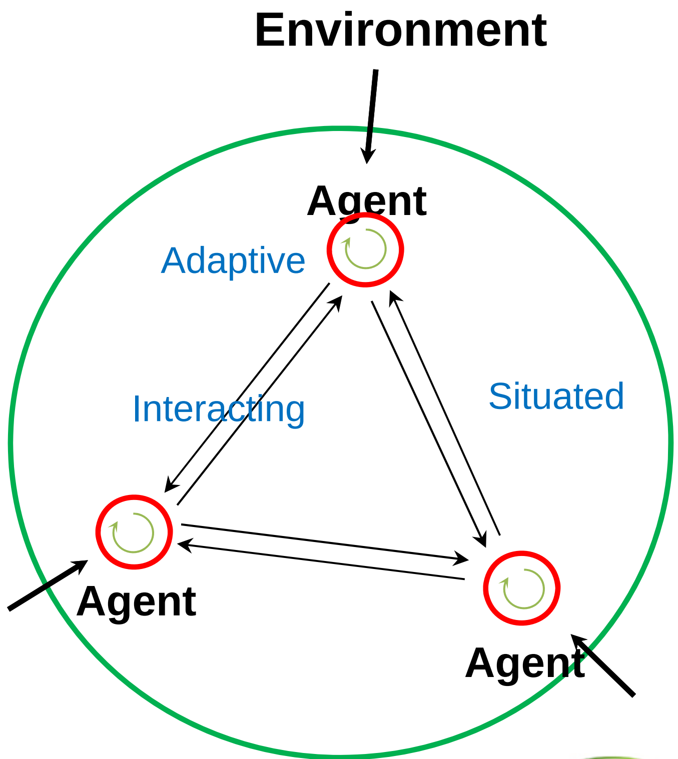
ABMS Representations Have Been Developed for Top 10 Electricity Consuming Commercial Building Types

- What is an agent-based system?
  - An agent-based system is made up of agents that interact, adapt, and sustain themselves while interacting with other agents and adapting to a changing environment
  - Agent-based Modeling and Simulation (ABMS) is grounded in the theory of Complex Adaptive Systems (CAS)

- What is an agent?
  - A discrete entity with its own goals and behaviors
  - Autonomous and able to act independently
  - Possibly has a capability to adapt and modify its behaviors

Selected Commercial Building Type	Annual Electricity Consumption (Billion kWh)	% of Total
Office	211	20.2
Supermarket Strip Mall	153	14.7
Education	109	10.5
Healthcare	73	7.0
Warehouse and Storage	72	6.9
Lodging	69	6.6
Food Service	63	6.0
Retail (other than mall)	62	5.9
Food Sales	61	5.8
Total	**873**	**83.7**

Source: EIA (2003) Commercial Building Energy Consumption Survey

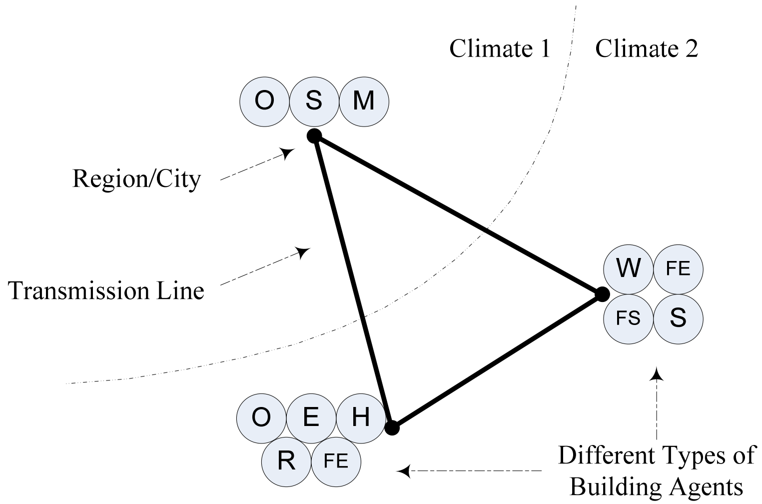


During the Simulation Building Agents are Differentiated by their Characteristics and Geographical Locations

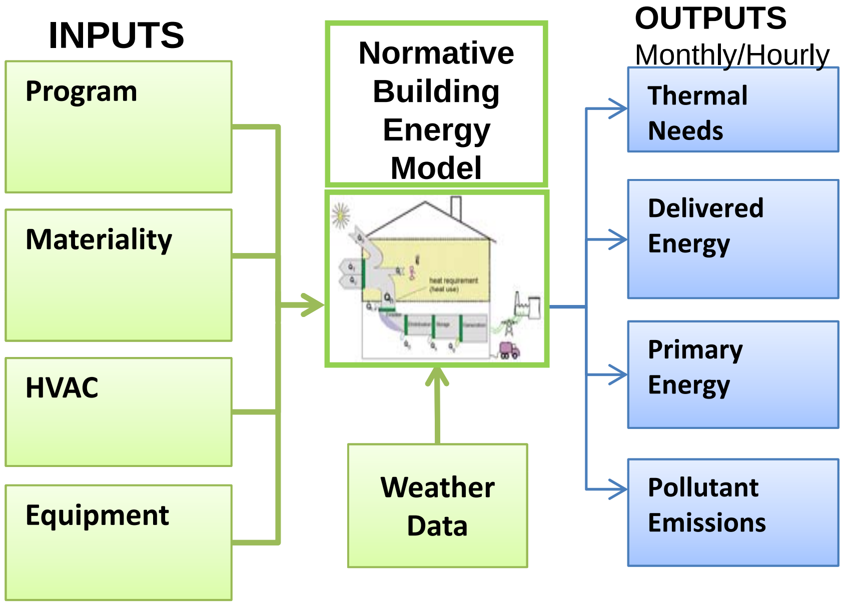
Characteristics of Building Agents

Program	Materiality
Building location Total conditioned floor area Building height Opaque wall area (all directions) Window area (all directions) Occupancy	U-value of envelope Solar transmittance Solar Heat Gain Coefficient (SHGC) of glazing Reflectance of opaque walls Solar shading factor of glazing Building thermal inertia
HVAC	**Equipment**
Ventilation needs and schedule Thermostat set-point temperature Heating energy source H/C generation efficiency H/C distribution efficiency Fan and pump size and schedule	Int. lighting intensity and schedule Ext. lighting intensity and schedule Int. equipment intensity and schedule Ext. equipment intensity and schedule Refrigeration capacity and schedule

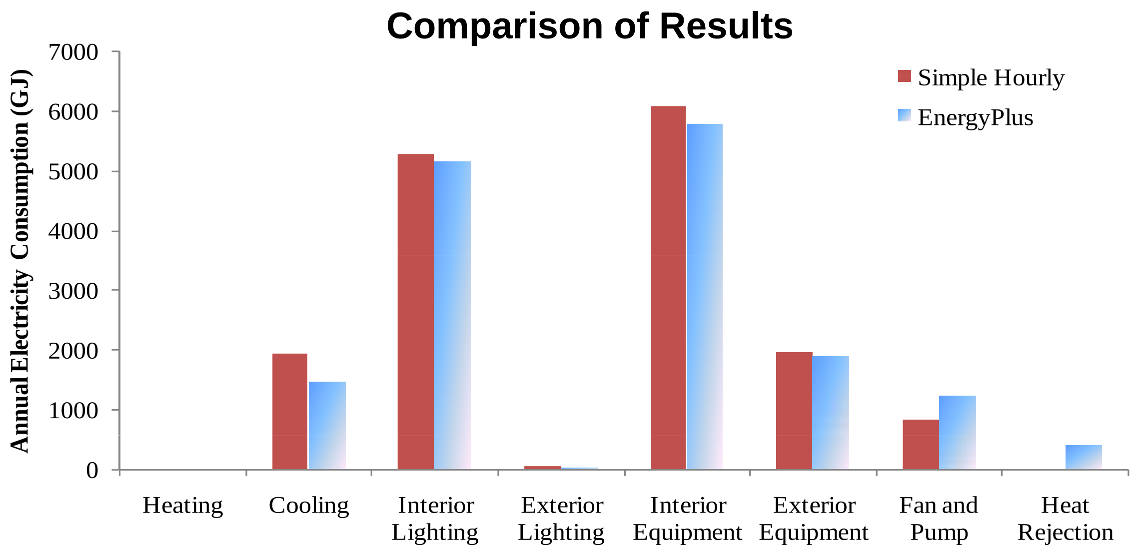
Spatial distribution of building agents determines climate characteristics as well as electricity market prices (e.g., market hub) for their location



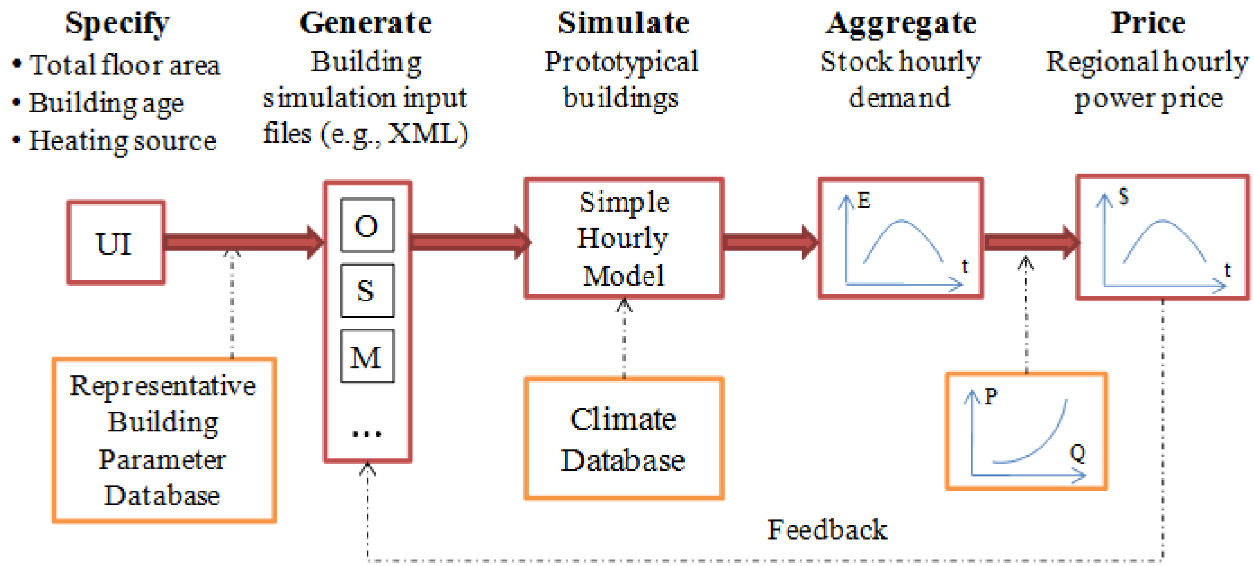
A Normative Building Energy Model Was Developed to Calculate Heating and Cooling Needs on Hourly Basis



- The simple hourly normative energy model was validated against EnergyPlus

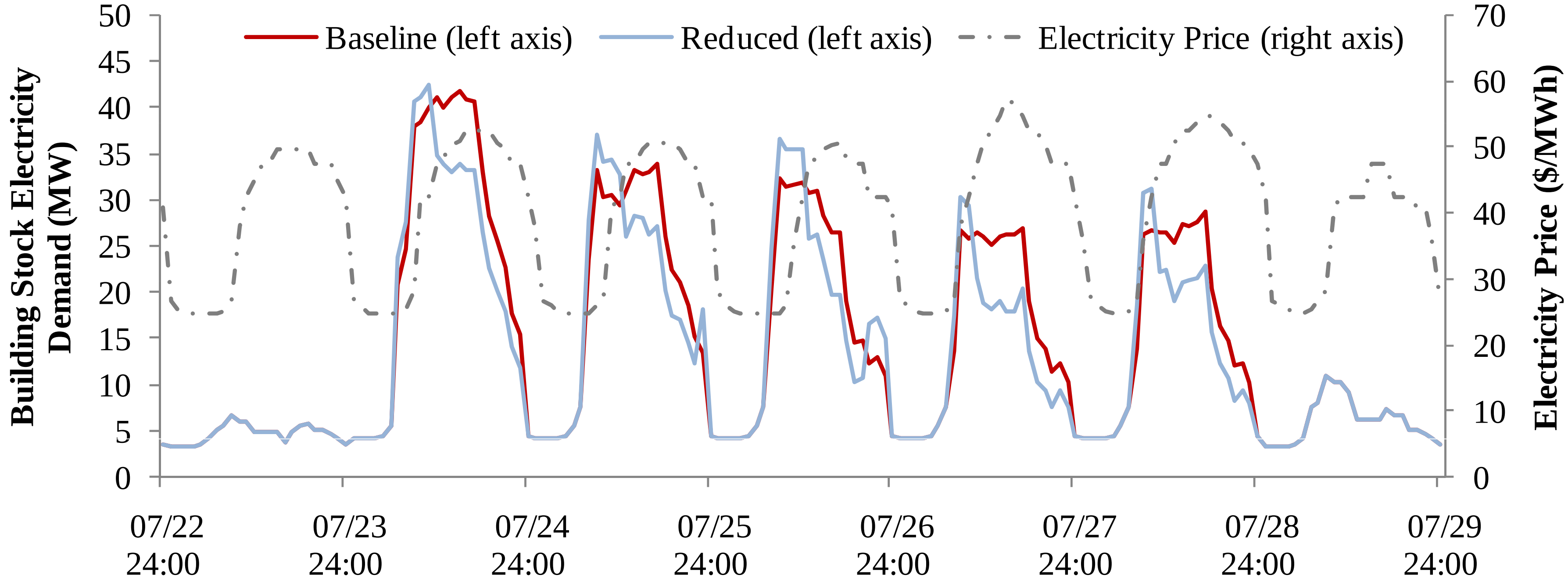


An Agent-Based Model Has Been Developed to Simulate the Interaction between Commercial Buildings and Power Grid



- During the simulation building agents have several options for modifying their demand:
  - Load Reduction
    - Turn off the unneeded electrical equipment
    - Increase/decrease AC set-point temperature for cooling or heating
    - Reduce the lighting intensity/power
  - Load Shifting without Energy Storage
    - Chang operation schedule or postpone certain electricity consuming processes for off-peak period
  - Load Shifting with Energy Storage
    - Electrochemical storage (e.g., batteries)
    - Thermal storage (e.g., ice, chilled water, etc.)

Test Case Results for Load Reduction



Demand Reduction Scenario	Annual Electricity Reduced		Annual Monetary Savings	
	(MWh)	(%)	($)	(%)
(a) Cooling set-point temp.	2,733	2.83%	93,707	3.41%
(b) Lighting	231	0.24%	12,163	0.44%
(c) Internal equipment	44	0.05%	2,549	0.09%
(a), (b), and (c)	3,009	3.11%	108,418	3.95%

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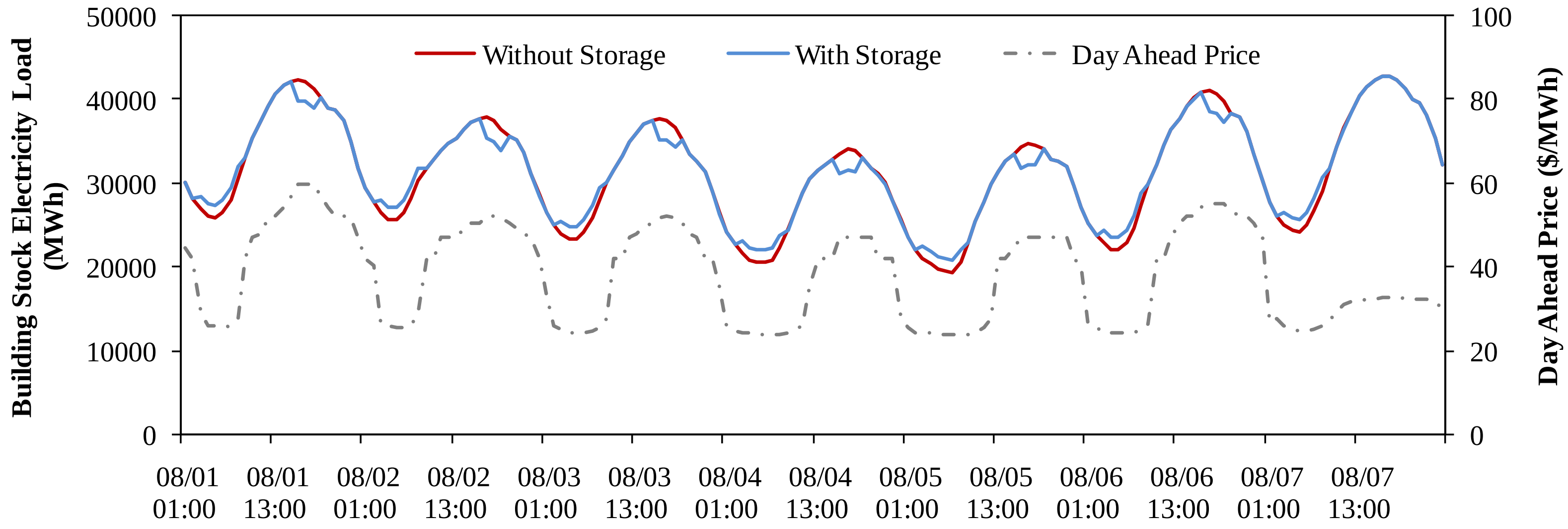
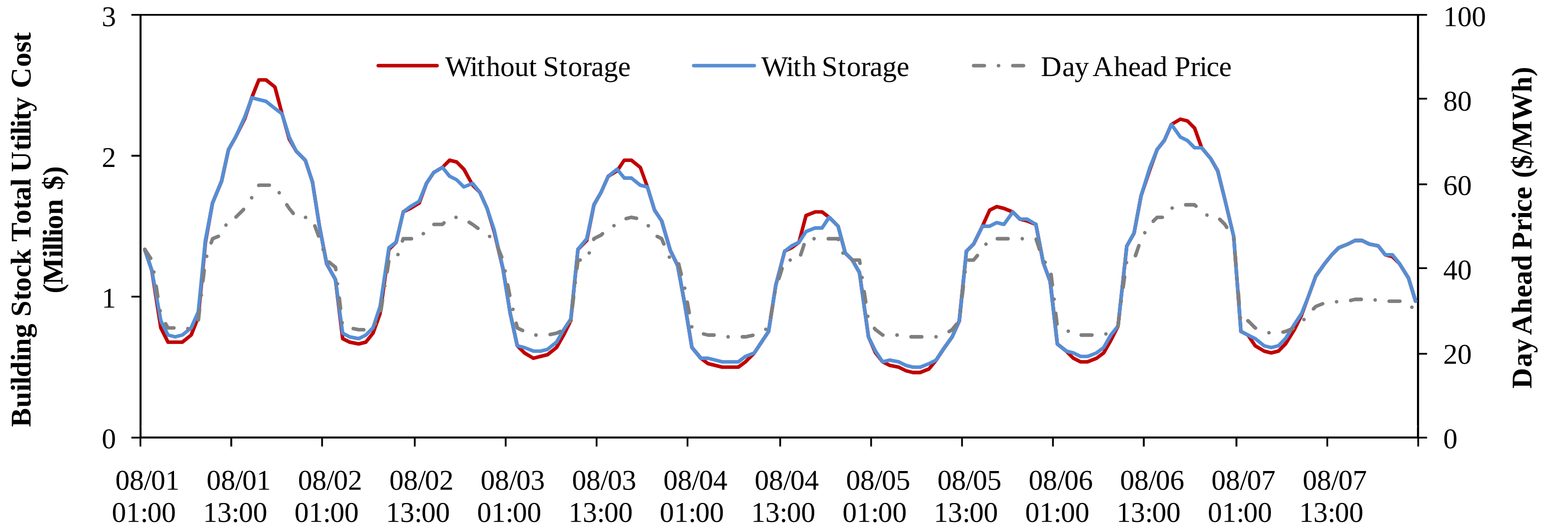
Test Case Results for Load Shifting using Electrical Energy Storage





THANK YOU!

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