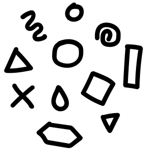
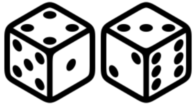
Large-scale modeling of building demand flexibility

Eric Wilson, NREL
November 12, 2019
EBC Technical Day
Panel #3 Modeling Demand Flexibility

To represent demand flexibility, we need to model

1. Heterogeneity 
2. Stochasticity 

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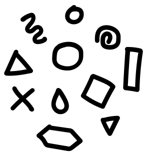
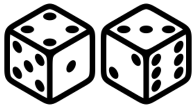
1. Heterogeneity 

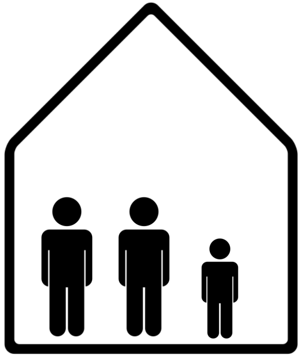
2. Stochasticity 

Agenda

Why?
How?
Example applications

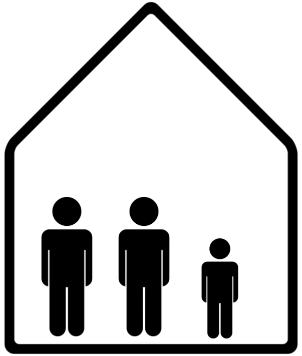
Why do heterogeneity and stochasticity matter?

Why does heterogeneity matter?

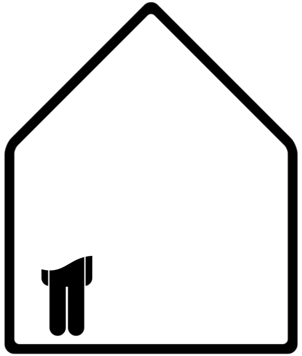


06:00
3 occupants

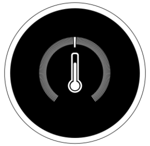
Why does heterogeneity matter?



06:00
3 occupants

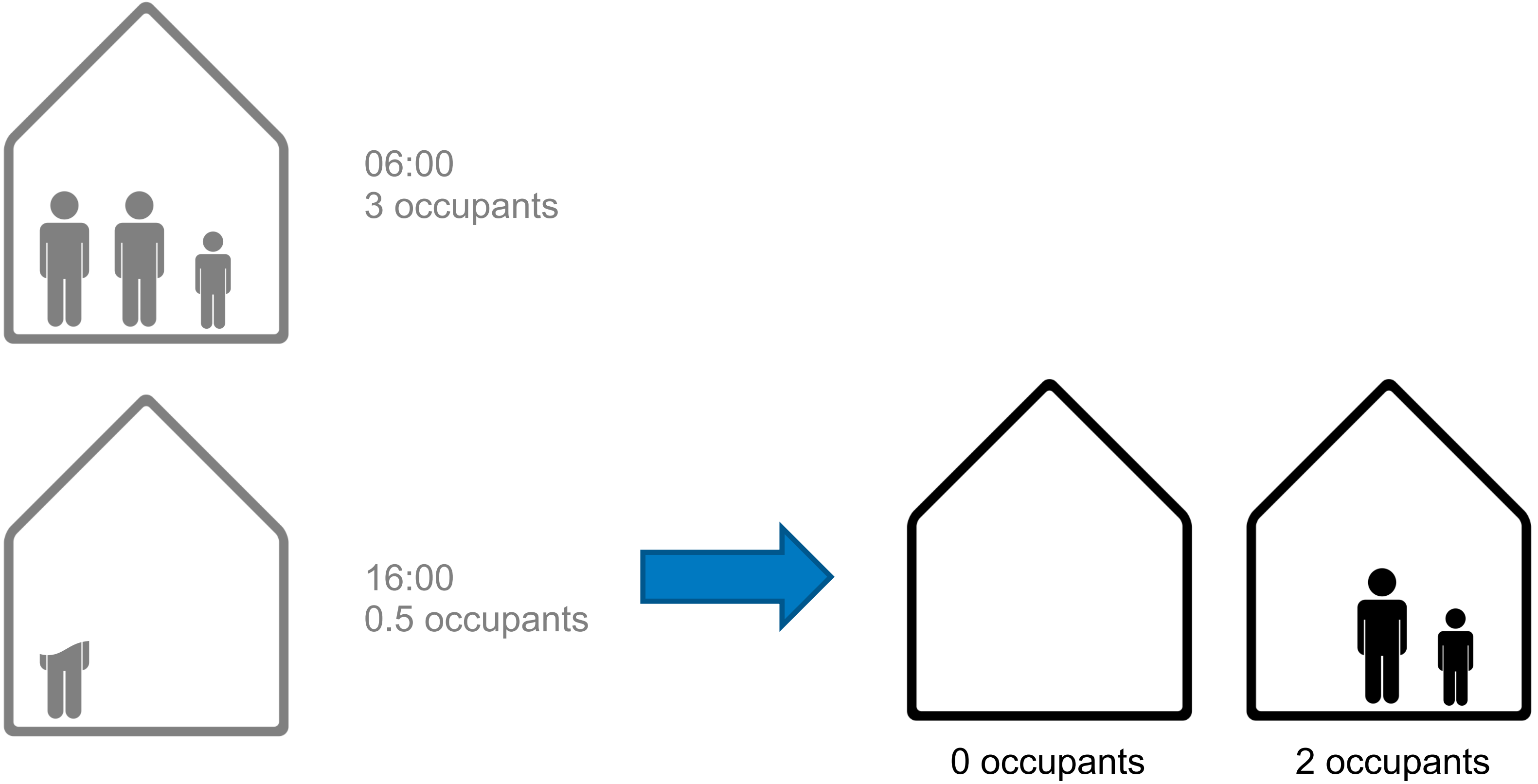


16:00
0.5 occupants



What is the demand flexibility?

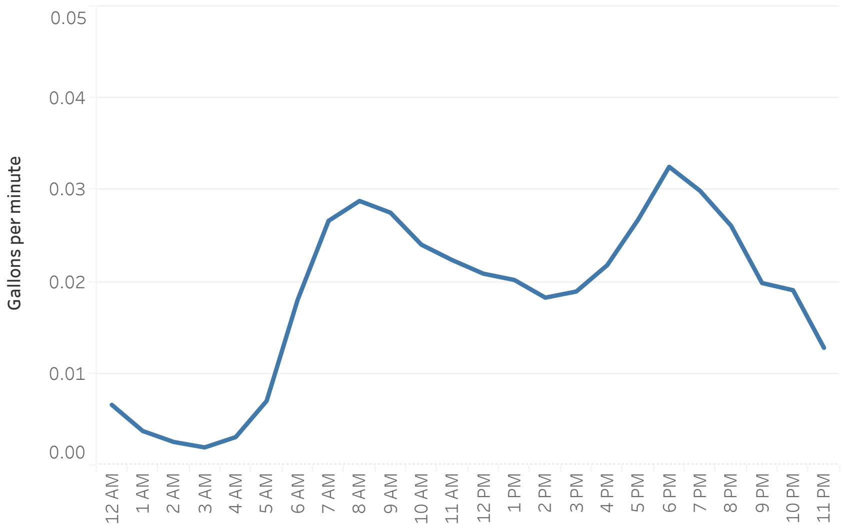
Why does heterogeneity matter?



Why does stochasticity matter?

Daily hot water draw profiles

Blended average of all households



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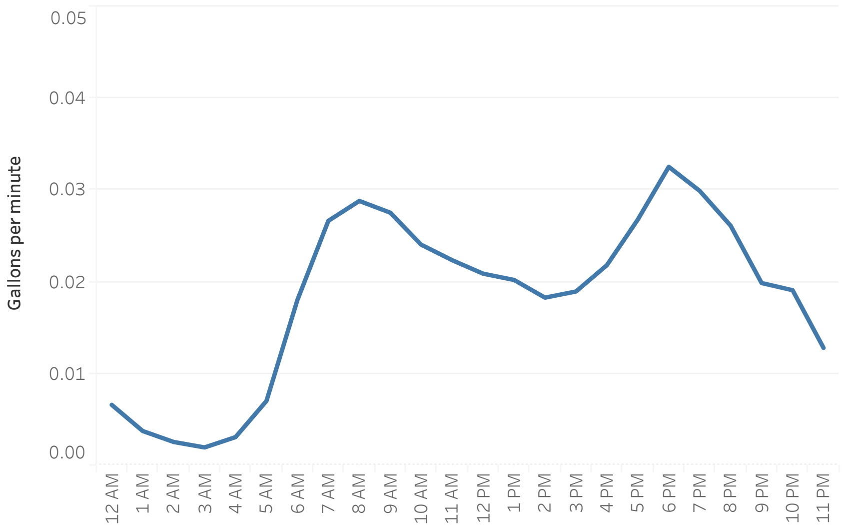
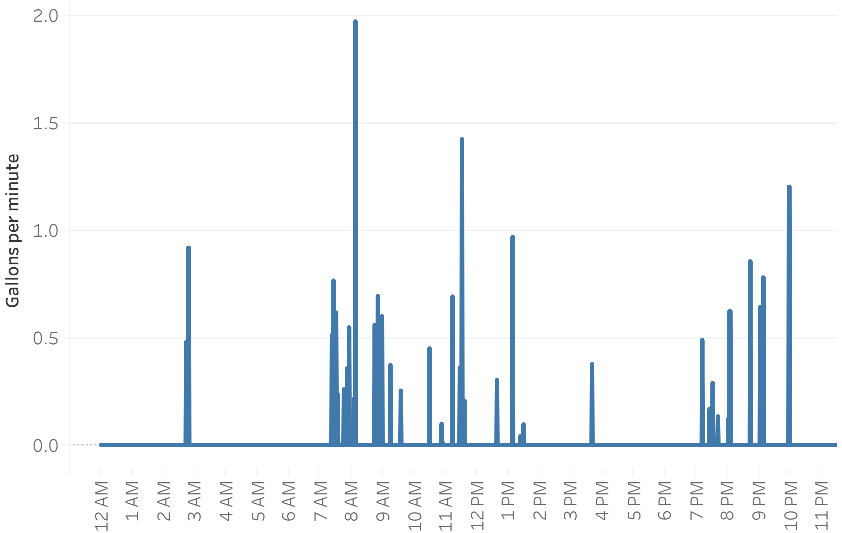


An individual household

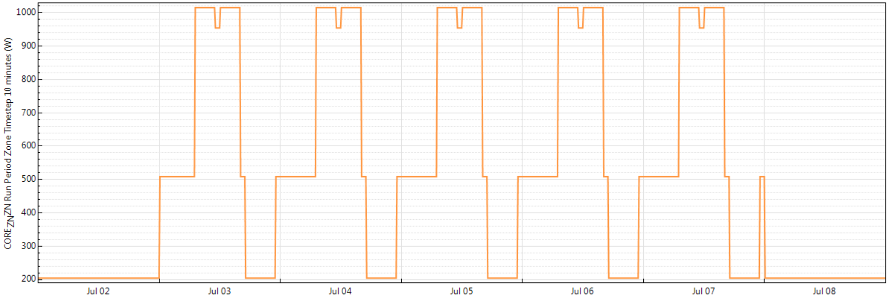


What is the demand flexibility?

Why does stochasticity matter?

Typical occupancy model

Office Misc. plug loads



Why does stochasticity matter?

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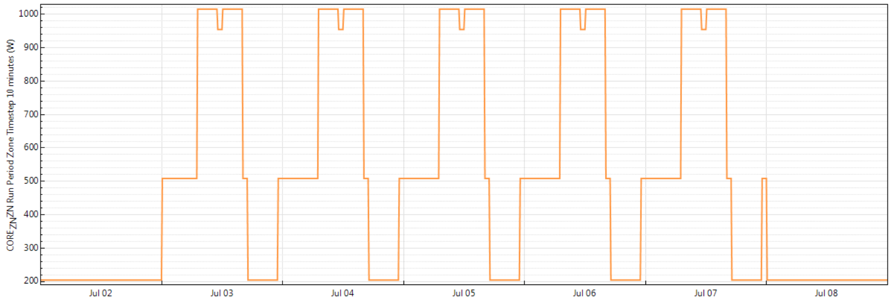
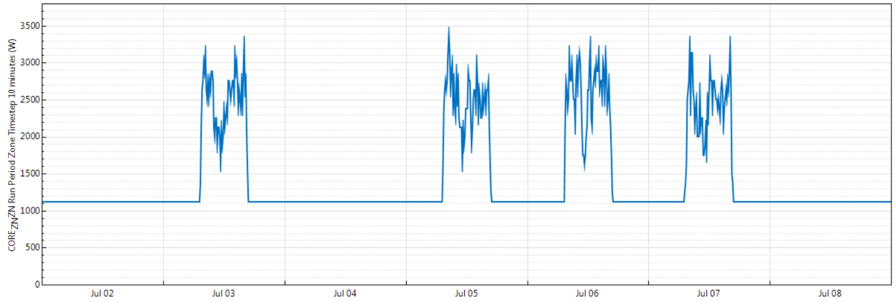


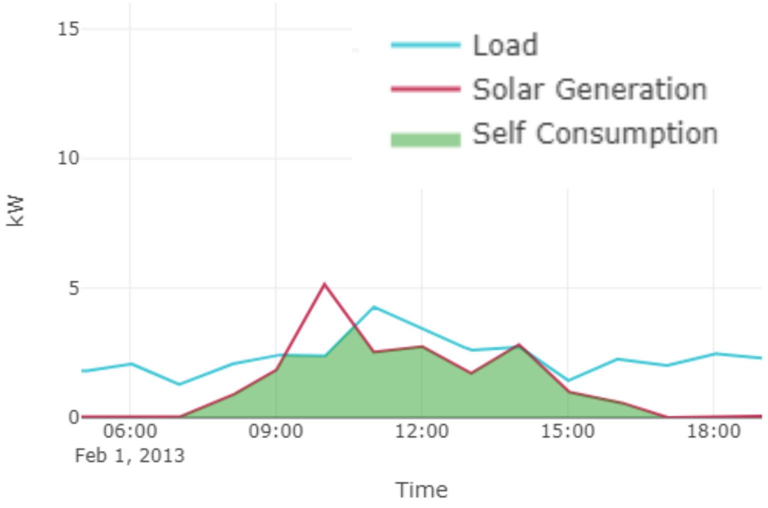
With stochastic office occupancy model



What is the demand flexibility?

Hourly vs. minutely resolution

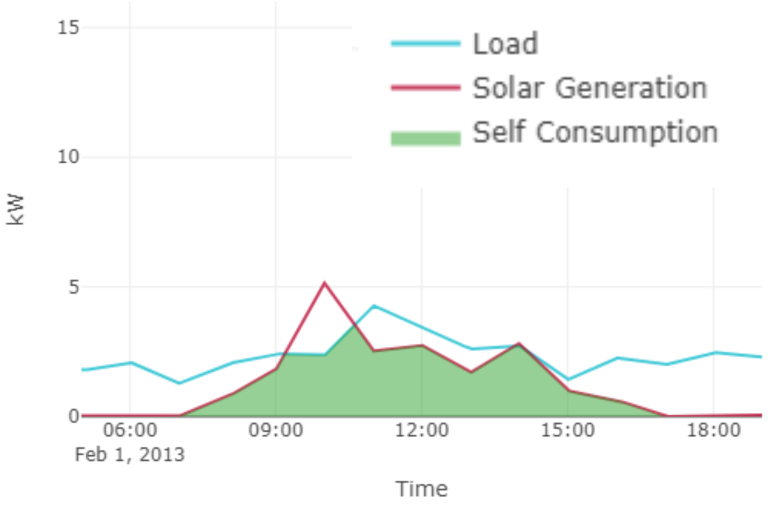
1-hour resolution
self-consumption = 17 kWh



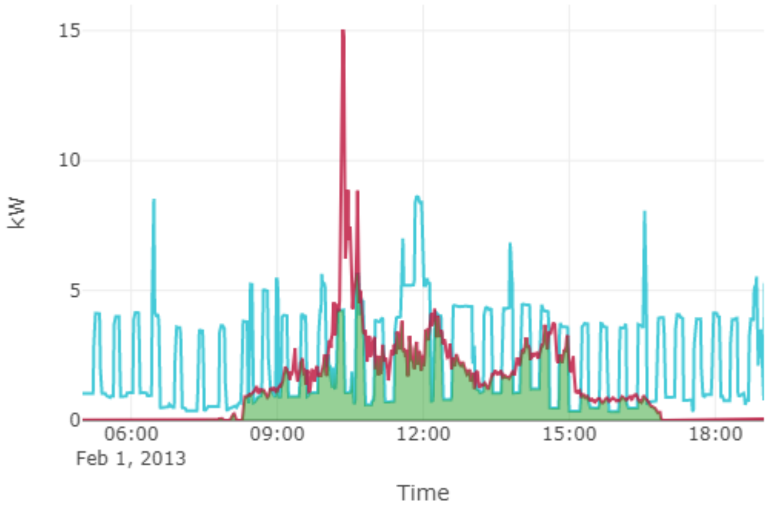
Hourly vs. minutely resolution

Overpredicts self-consumption by 30%

1-hour resolution
self-consumption = 17 kWh



1-minute resolution
self-consumption = 13 kWh



How are we modeling large-scale building stock demand flexibility?

Building Load Modeling

Top-down
econometric models

Bottom-up
engineering models

See forthcoming IEA-EBC Annex 70 paper:
"Developing a common approach for classifying building stock energy models"

Building Load Modeling

Top-down
econometric models

Difficulty representing “what if” impact of new technologies

Bottom-up
engineering models

See forthcoming IEA-EBC Annex 70 paper:
“Developing a common approach for classifying building stock energy models”

Building Load Modeling

Top-down econometric models

Difficulty representing “what if” impact of new technologies

Bottom-up engineering models

Traditionally do not to represent diversity of buildings and occupants

See forthcoming IEA-EBC Annex 70 paper:
“Developing a common approach for classifying building stock energy models”

Scaling-up building stock modeling

Bottom-up
engineering models

Typical: detailed subhourly models of 10s of prototype building models

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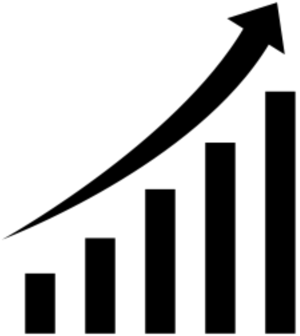
Scaling-up building stock modeling

Bottom-up engineering models

ResStock ComStock

100,000s of detailed subhourly models

Typical: detailed subhourly models of 10s of prototype building models



Traditionally do not to represent diversity of buildings and occupants

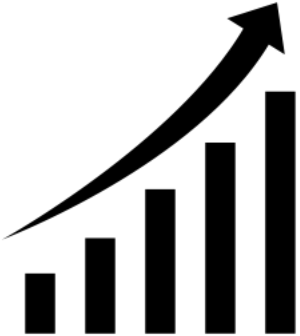
Scaling-up building stock modeling

Bottom-up engineering models

ResStock ComStock

100,000s of detailed subhourly models

Typical: detailed subhourly models of 10s of prototype building models



House icons by HAWRAF via autodraw.com

Traditionally do not to represent diversity of buildings and occupants

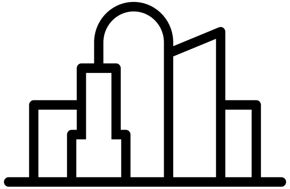
Designed to represent full diversity of buildings and occupants

How do we scale up the models?

ResStock ComStock

Building stock characteristics database + Physics-based computer modeling + High-performance computing

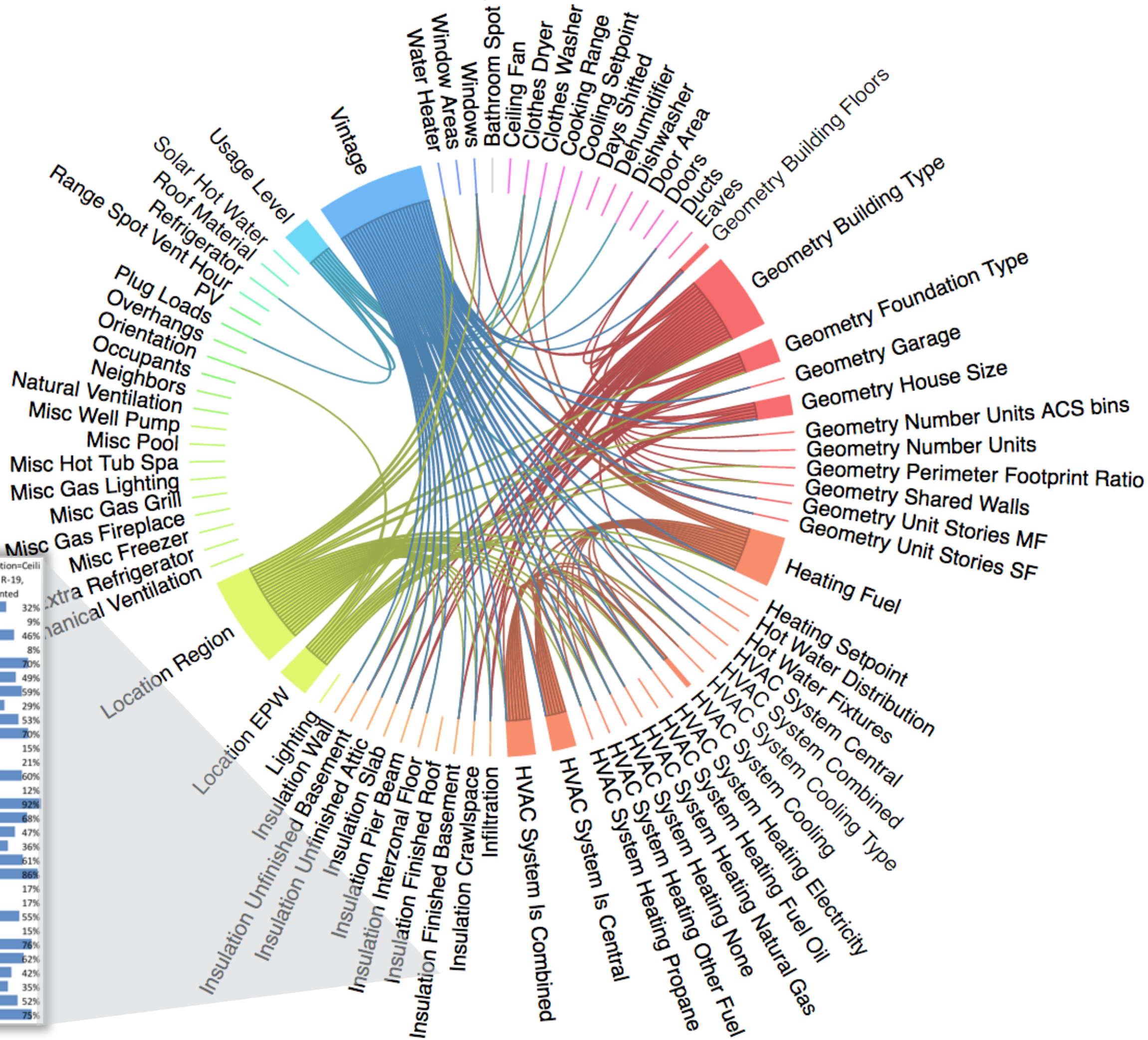
Diversity represented using 6000 probability distributions for 100 parameters structured in a dependency tree



Building stock characteristics database

1 model for every 200 dwelling units

Dependency=Location Region	Dependency=Vintage	Option=Uninsulated, Vented	Option=Wall R-5, Unvented	Option=Wall R-10, Unvented	Option=Ceiling R-13, Vented	Option=Ceiling R-19, Vented
CR02	1980s	52%	0%	16%	0%	32%
CR05	1980s	30%	0%	61%	0%	9%
CR03	1980s	32%	0%	22%	0%	46%
CR04	1980s	10%	0%	83%	0%	8%
CR06	1980s	21%	0%	9%	0%	70%
CR07	1980s	44%	0%	7%	0%	49%
CR08	1980s	41%	0%	0%	0%	59%
CR09	1980s	39%	0%	31%	0%	29%
CR10	1980s	37%	0%	9%	0%	53%
CR11	1980s	21%	0%	9%	0%	70%
CR02	1990s	0%	20%	24%	40%	15%
CR05	1990s	0%	0%	39%	40%	21%
CR03	1990s	0%	0%	4%	35%	60%
CR04	1990s	1%	20%	44%	23%	12%
CR06	1990s	2%	1%	1%	5%	92%
CR07	1990s	0%	13%	11%	8%	68%
CR08	1990s	18%	3%	21%	11%	47%
CR09	1990s	10%	0%	0%	53%	36%
CR10	1990s	0%	0%	1%	39%	61%
CR11	1990s	3%	0%	1%	10%	86%
CR02	2000s	2%	12%	24%	44%	17%
CR05	2000s	0%	1%	48%	33%	17%
CR03	2000s	0%	5%	7%	32%	55%
CR04	2000s	8%	22%	26%	29%	15%
CR06	2000s	2%	0%	19%	4%	76%
CR07	2000s	3%	6%	22%	7%	62%
CR08	2000s	13%	6%	29%	10%	42%
CR09	2000s	10%	0%	4%	51%	35%
CR10	2000s	0%	10%	5%	33%	52%
CR11	2000s	7%	0%	9%	9%	75%

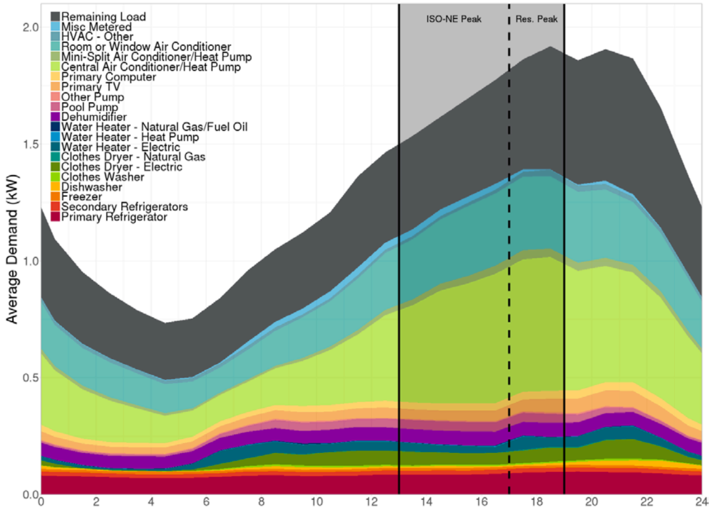


Two applications of
large-scale building demand modeling

End-use load profiles for the U.S. Building Stock

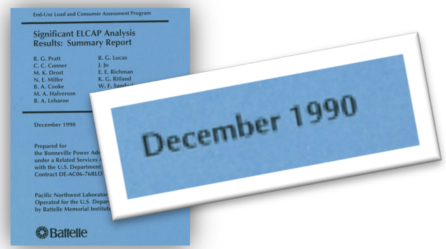
End-use load/savings profiles are…

- the **most essential** data resource currently missing for Time-Sensitive Valuation of Energy Efficiency (TSV-EE)
- needed for **R&D prioritization, utility resource and distribution system planning, state and local energy planning and regulation**
- critical for widespread adoption of grid-interactive and efficient buildings.



Source: Navigant Massachusetts RES 1 Baseline Load Shape Study

Existing profiles are often **outdated, regionally limited, based on small sample size, and limited to a subset of the building stock** because of the high cost of the historical sub-metering approach.


End-Use Load and Consumer Assessment Program

Significant ELCAP Analysis Results: Summary Report

R. G. Pratt
C. C. Conner
M. K. Drost
N. E. Miller
B. A. Cooke
M. A. Halverson
B. A. Lebaron

R. G. Lucas
J. Jo
E. E. Richman
K. G. Ritland

December 1990

December 1990

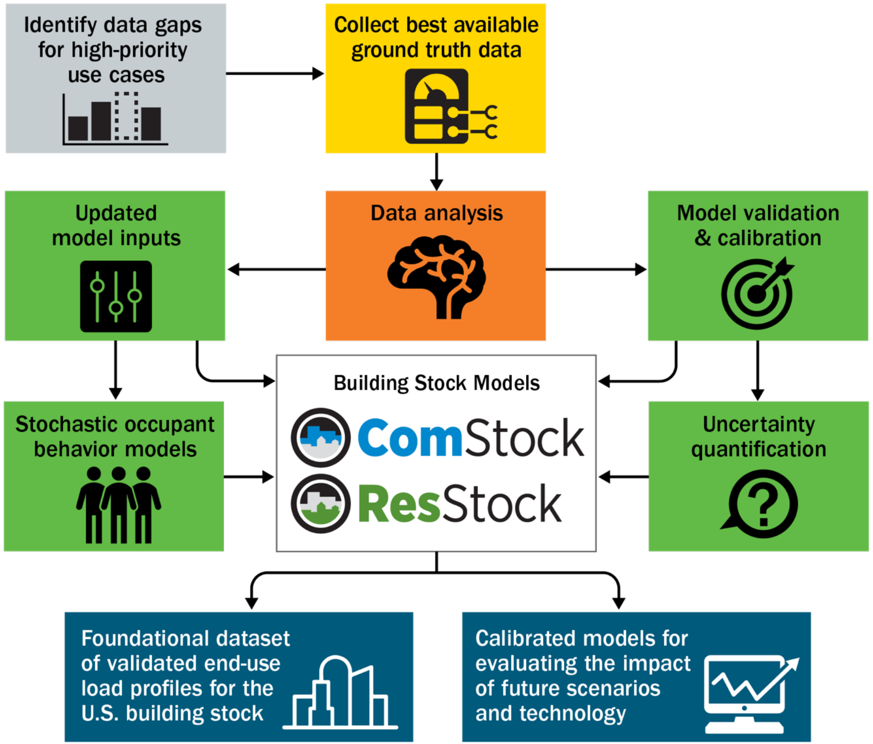
Battelle

End-use load profiles for the U.S. Building Stock

2019–2021 U.S. DOE project
NREL, Berkeley Lab, Argonne, EPRI, NEEP

Hybrid approach combines best-available ground-truth data with the reach, cost-effectiveness, and granularity of physics-based and data-driven building stock modeling capabilities

The novel approach delivers a nationally-comprehensive dataset at a fraction of the historical cost.



Application: Los Angeles 100% Renewable Energy Study

Building load modeling

ResStock ComStock

First-of-its-kind analysis

What role do energy efficiency, electrification, and demand flexibility play in achieving 100% renewable energy for a city AND utility?

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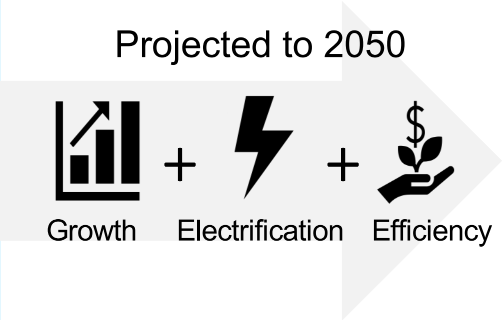

Electricity system modeling

First-of-its-kind analysis

What role do energy efficiency, electrification, and demand flexibility play in achieving 100% renewable energy for a city AND utility?

Key study considerations

- Necessary infrastructure upgrades
- Critical transmission investments
- Maintaining system reliability
- Impact on equity, jobs, and local economy

Thank you

Eric Wilson, eric.wilson@nrel.gov

https://resstock.nrel.gov/
www.nrel.gov/buildings/end-use-load-profiles.html

NATIONAL RENEWABLE ENERGY LABORATORY