U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building AMERICA U.S. Department of Energy

Building America

ResStock – Evaluating Home Performance Upgrades Across the U.S. Residential Building Stock

March 29, 2017

Moderator:
Linh Truong– National Renewable Energy Laboratory

Panelist:
Eric Wilson– National Renewable Energy Laboratory

Some Housekeeping Items

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http://energy.gov/eere/buildings/building-america-meetings#current

Agenda

- ✓Welcome and Introductory Remarks
- ✓Overview of Building America (buildingamerica.gov)
  - ➢ Linh Truong - National Renewable Energy Laboratory
- ✓Presentations
  - ➢ Eric Wilson- National Renewable Energy Laboratory
- ✓Questions and Answers
- ✓Closing Remarks

Building America

Building America Website:

- Program information
- Top Innovations
- Climate-specific case studies
- *Building America Update* newsletter
- Building America Solution Center
- Publications Library

www.buildingamerica.gov

Eric Wilson, Research Engineer, National Renewable Energy Laboratory

Eric joined NREL in 2010. His recent activities include developing multifamily modeling capabilities for the BEopt building energy optimization software, developing an analysis framework and data visualization for national residential building stock models, and leading updates of the Building America House Simulation Protocols. Prior to joining NREL, Eric researched the energy implications of pressure drop in residential duct systems. He also performed energy audits and design assistance for a state energy program and conducted blower door tests on tribal housing across the country.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY






ResStock:
Evaluating Home Performance Upgrades Across the U.S. Residential Building Stock

Eric Wilson, ResStock Project/Product Lead

Craig Christensen, ResStock Initial Concept & Strategic Direction

Scott Horowitz, Residential Analysis & Tools Team Lead

Residential Buildings Research Group

National Renewable Energy Laboratory

March 29, 2017

Acknowledgments

ResStock development has been supported by:

U.S. Department of Energy

- Office of Energy Efficiency and Renewable Energy
  Building Technologies Office,
  Residential Buildings Integration
- Office of Energy Policy and Systems Analysis (EPSA)
- EERE Office of Strategic Programs

U.S. Environmental Protection Agency (EPA)
  Region 8 Office
  Region 10 Office

Bonneville Power Administration (BPA)

Industry partnerships under development

ResStock and ComStock leverage long-term investment in building energy modeling by DOE

Outline

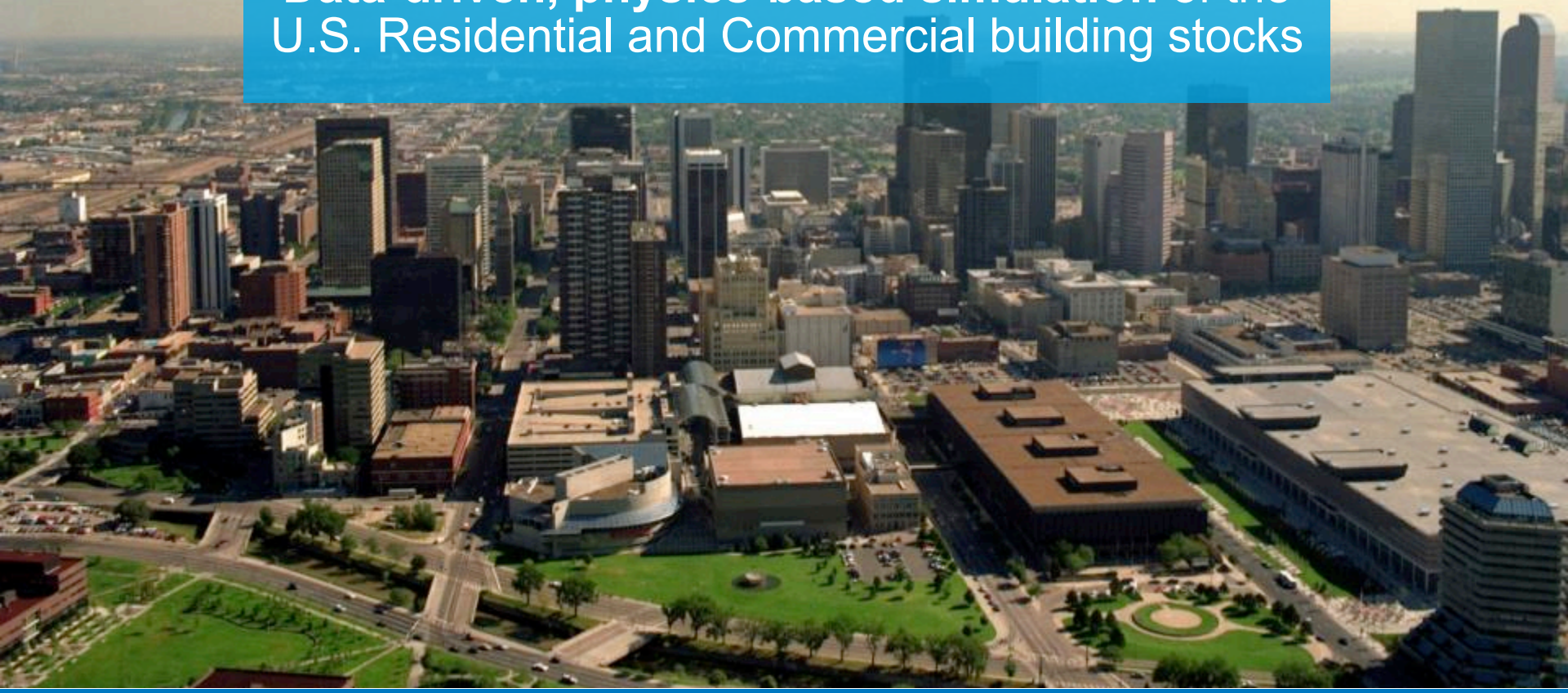
- Context & Motivation
- ResStock Approach
- Example Results
- Looking Ahead

Context & Motivation

ResStock + **Com**Stock

ResStock + **Com**Stock

Data-driven, physics-based simulation of the U.S. Residential and Commercial building stocks



ResStock + **Com**Stock

Data-driven, physics-based simulation of the U.S. Residential and Commercial building stocks

using **large public and private datasets** and **modern computing resources**


ResStock + ComStock
Data-driven, physics-based simulation of the U.S. Residential and Commercial building stocks
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to achieve unprecedented granularity in modeling building energy use and demand

ResStock + ComStock

Data-driven, physics-based simulation of the U.S. Residential and Commercial building stocks

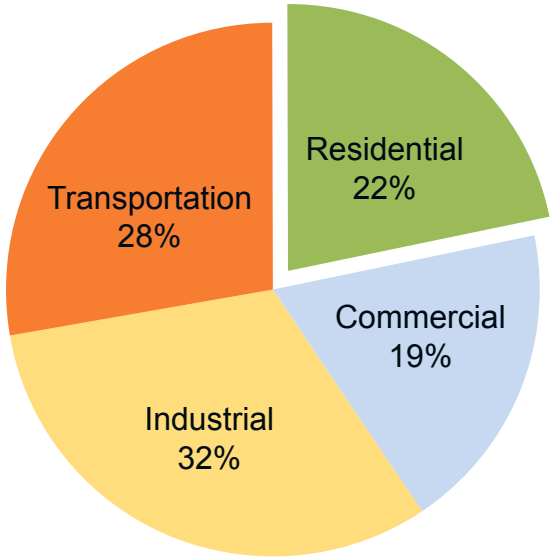
using **large public and private datasets** and **modern computing resources**

to achieve unprecedented **granularity** in modeling building energy use and demand

Context & Motivation

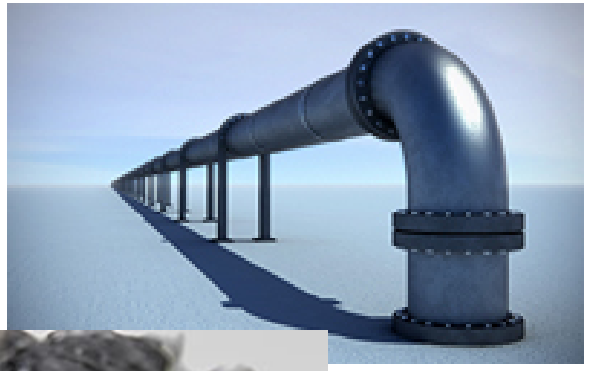
Homes use 22% of primary energy in U.S.

Primary energy consumption by sector, 2014



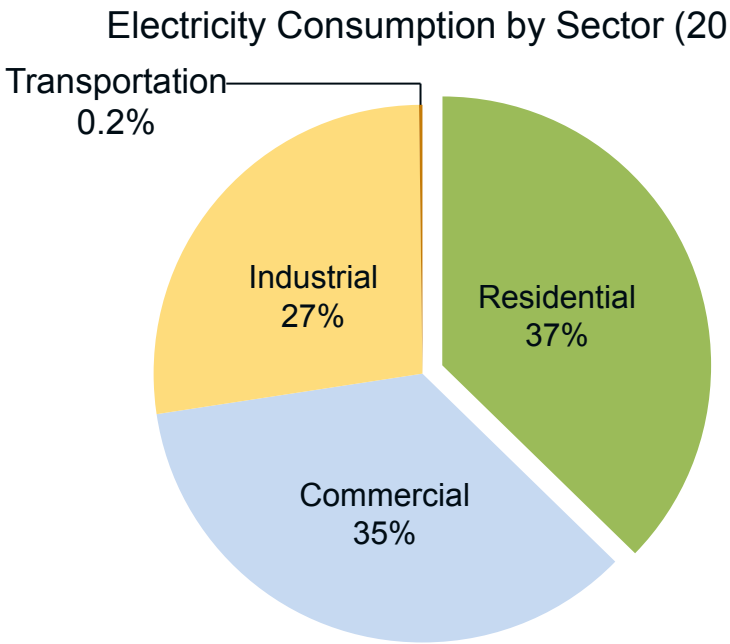
Source: U.S. Energy Information Administration, *Monthly Energy Review,* Table 2.1 (March 2015). Preliminary data for 2014

Note: Sum of individual percentages may not equal 100 because of independent rounding



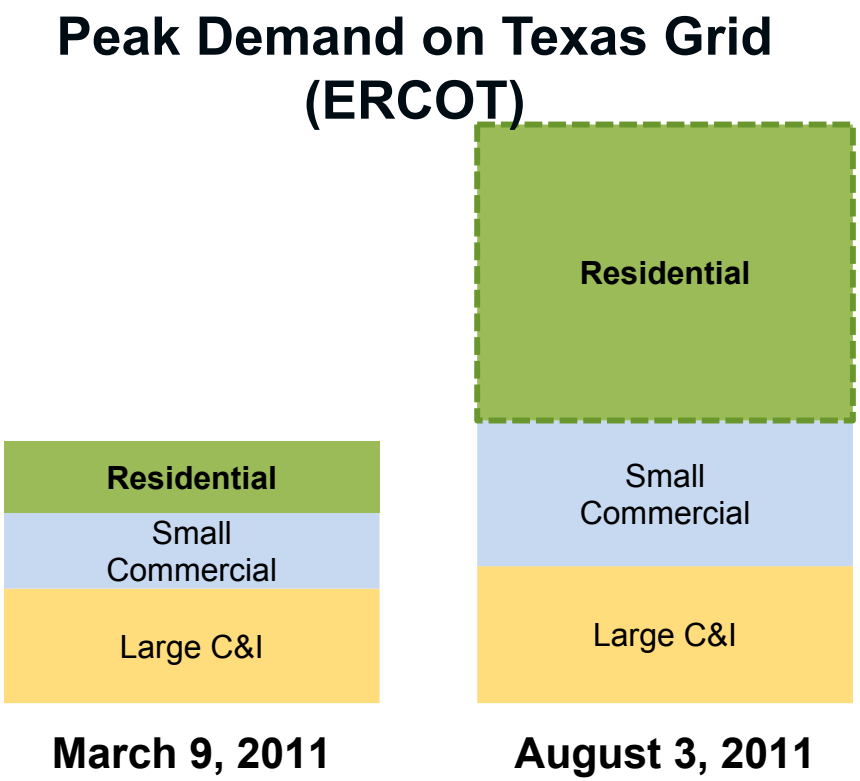
Context & Motivation

Homes use 37% of electricity in U.S.



Context & Motivation

Homes contribute to roughly **50%** of peak electric demand

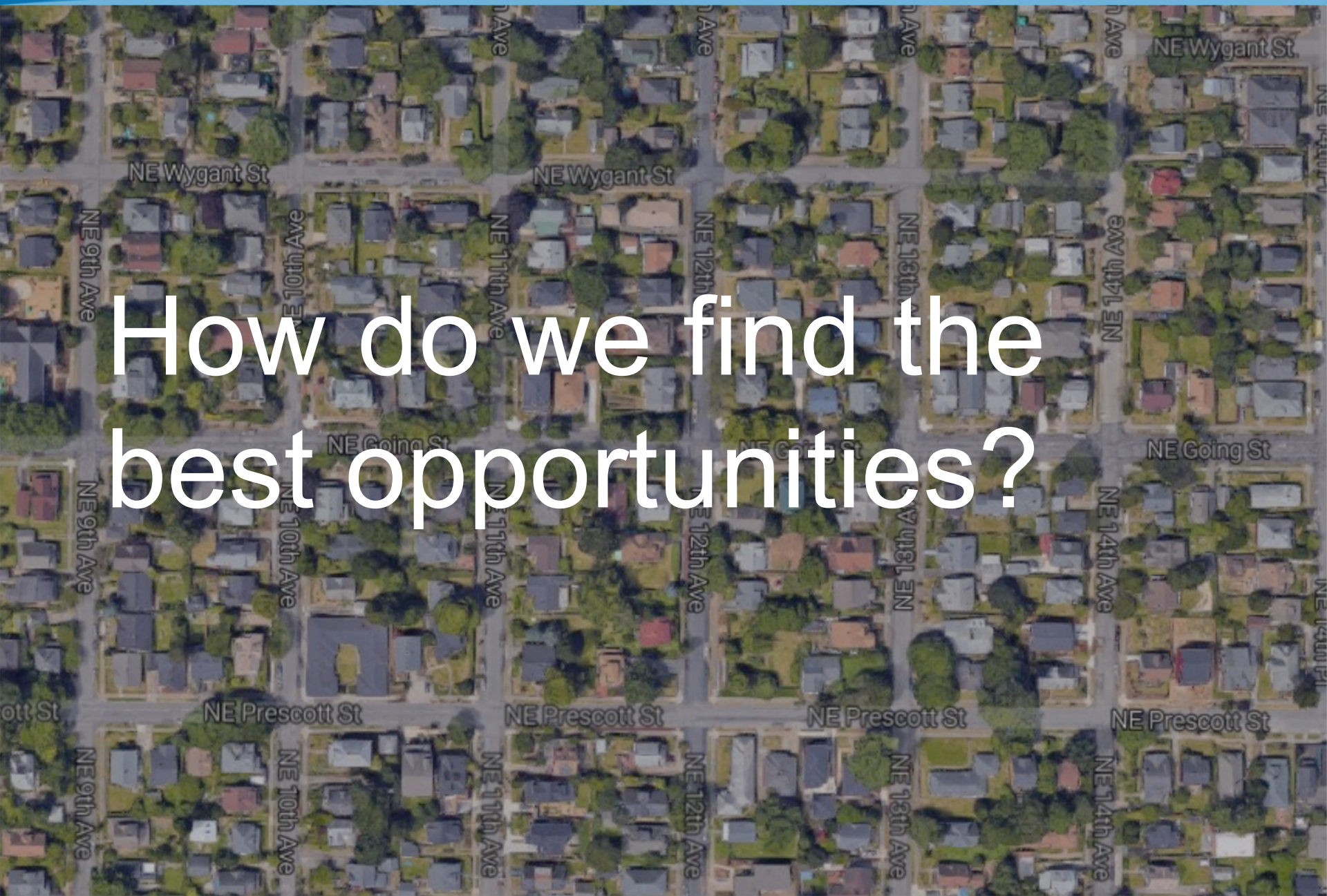


Context & Motivation

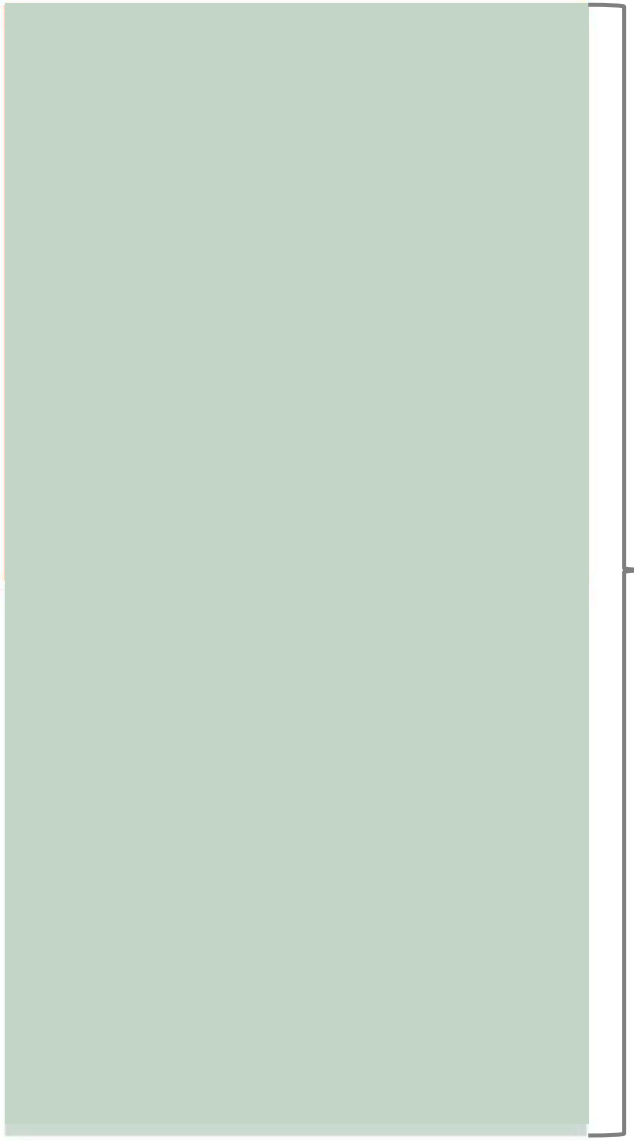
If just one of every 10 U.S. homes cut its energy use by 25%, Americans could save a total of more than **$5 billion per year** on their energy bills.

— U.S. DOE Building Technologies Office's
Multi-Year Program Plan for Fiscal Years 2016 through 2020

Context & Motivation

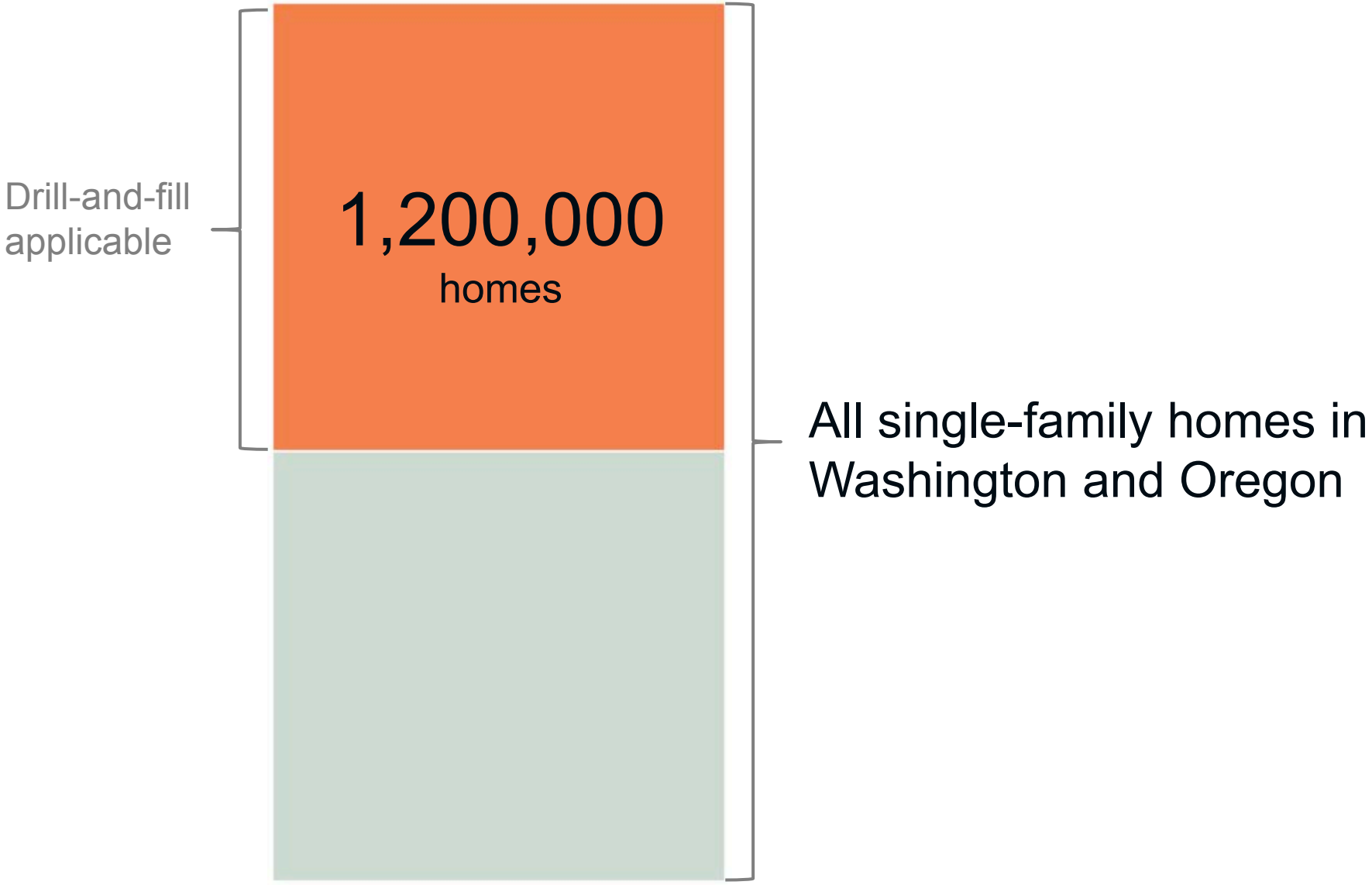


Context & Motivation



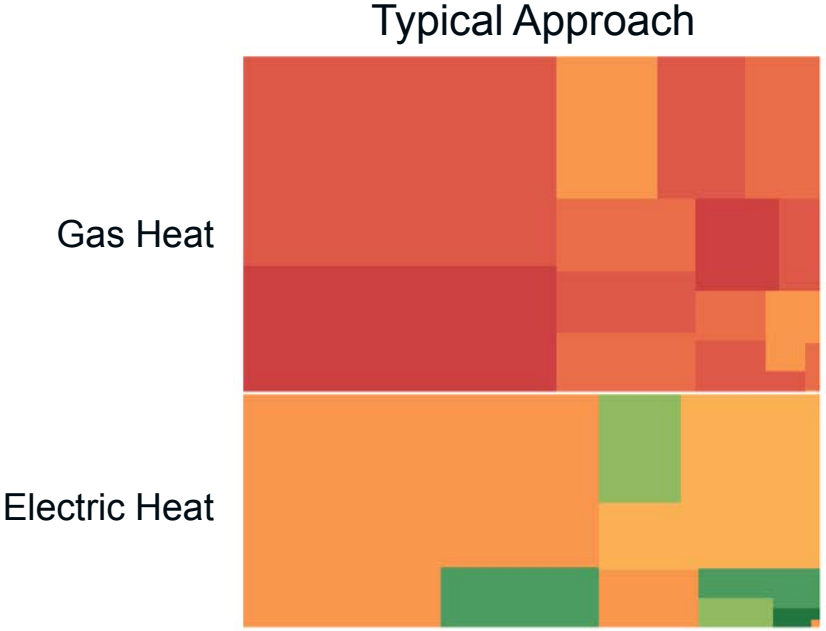
All single-family homes in Washington and Oregon

Context & Motivation



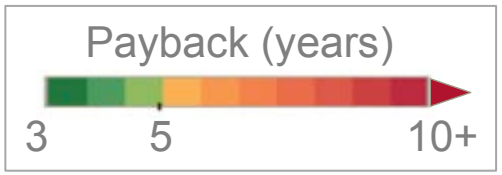
Context & Motivation

Typical Approach

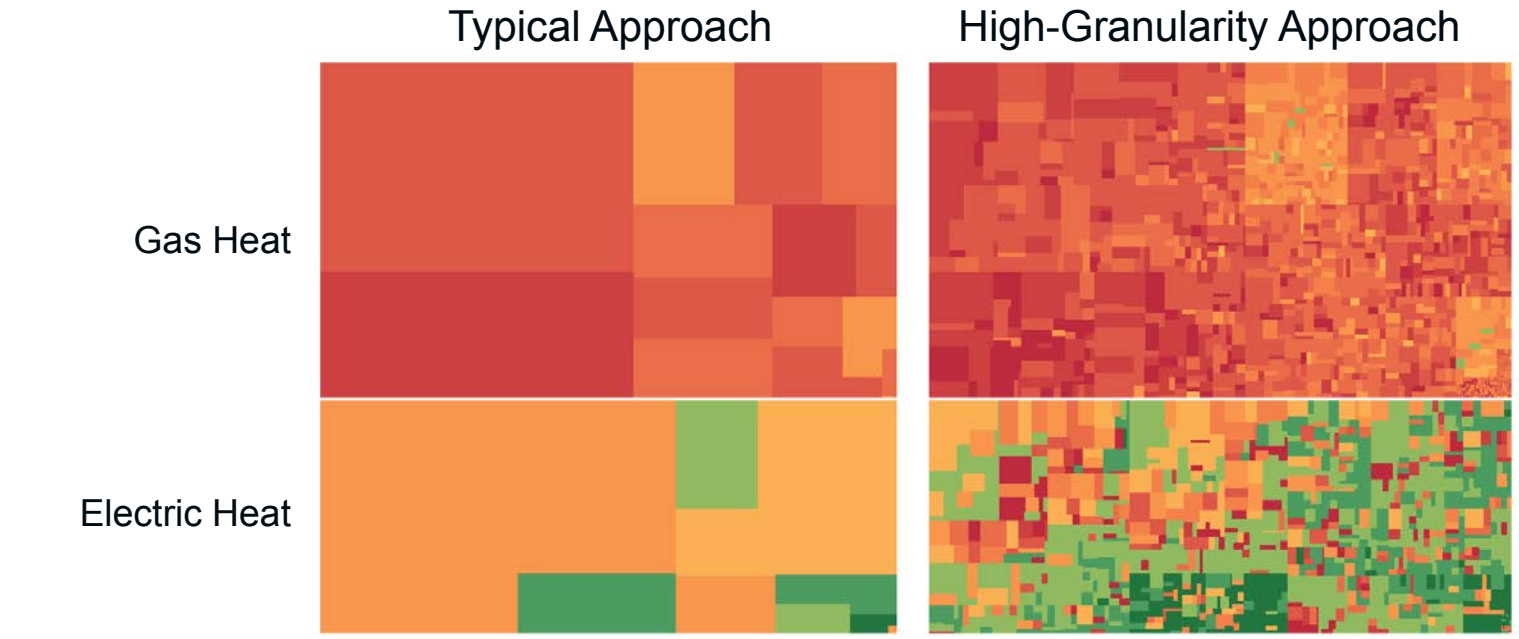


Segmented by:

Heating fuel type
Weather station



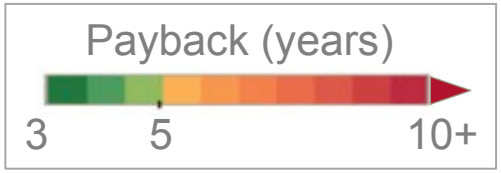
Context & Motivation



Segmented by:

Heating fuel type
Weather station

Heating fuel type
Weather station
Year built
Home size
Number of stories
Foundation type
Occupancy
etc.



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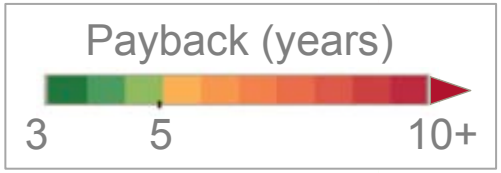
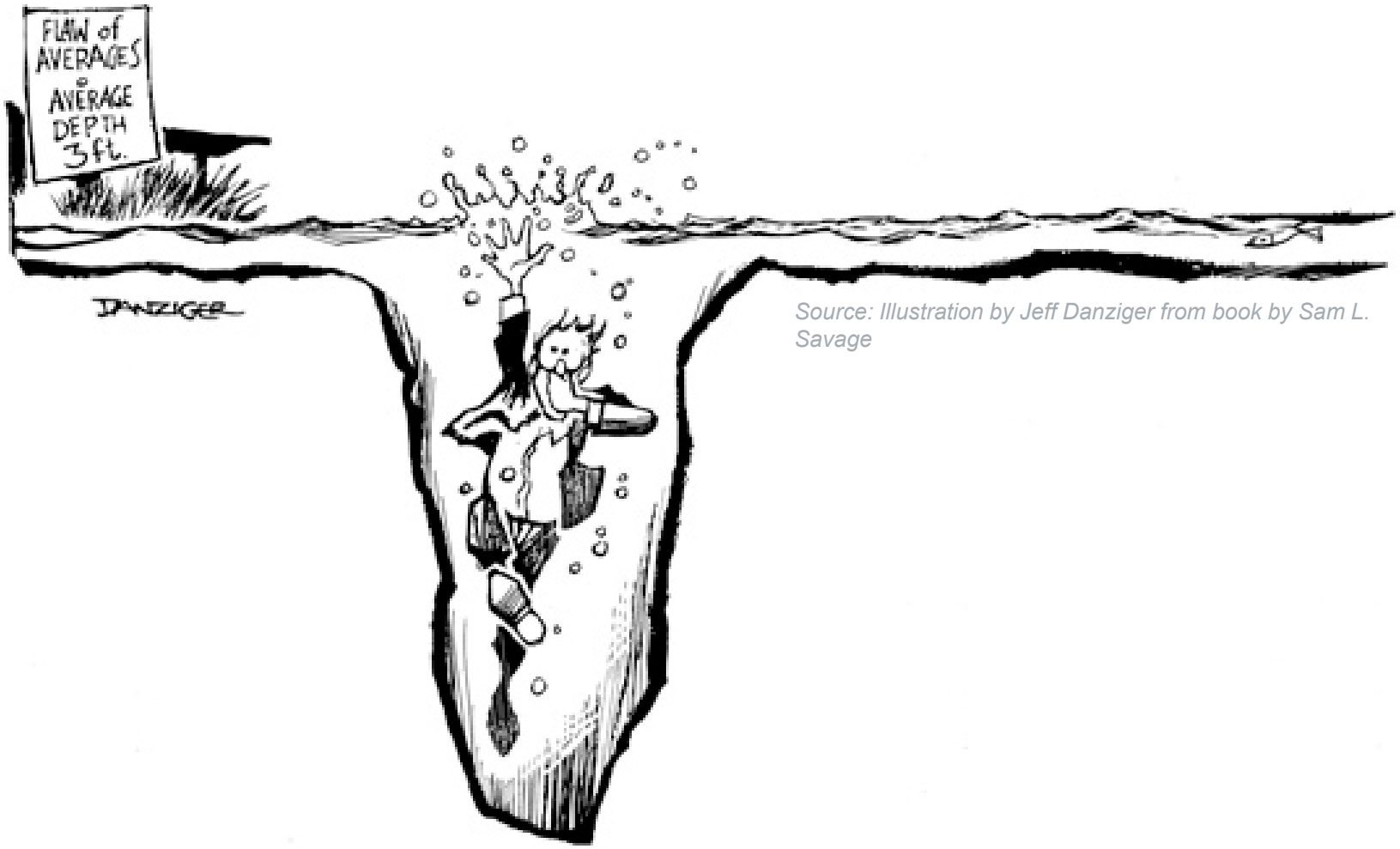


Context & Motivation

For credible estimates of housing stock energy efficiency potential, we need to avoid falling into the *flaw of averages* trap.



Source: Illustration by Jeff Danziger from book by Sam L. Savage

The **Res**Stock Approach

Approach

Low
Granularity

High
Granularity

Model
prototype
buildings

Model
every
building

Approach

Low
Granularity

High
Granularity

Model
prototype
buildings

Model
10s–100s of thousands
of representative buildings

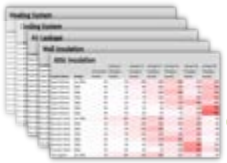
ResStock

Model
every
building

Approach

ResStock

Building Characteristics



Census Data

Costs

Climate Locations

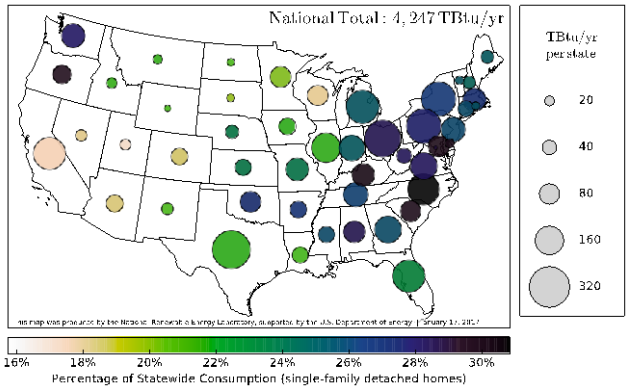
10s–100s of thousands of **statistically representative models**

Baseline Buildings

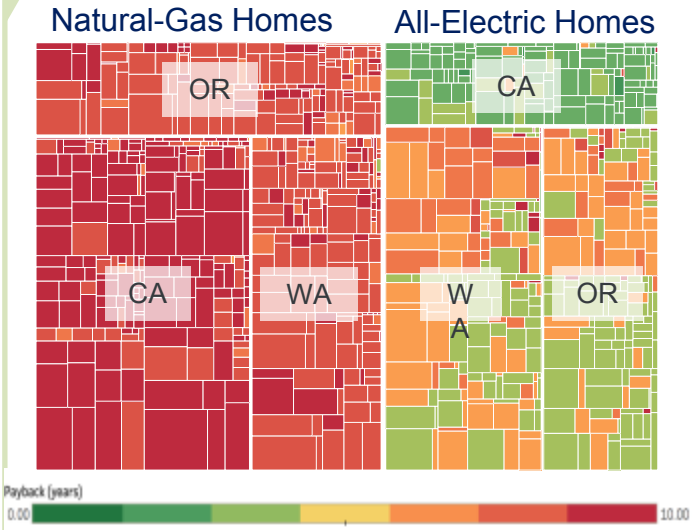
Efficiency Upgrades

NREL supercomputer or Amazon Cloud

National Potential

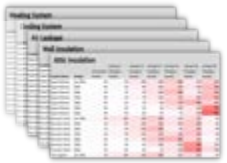


Regional Potential



Approach – Data Sources

Building Characteristics



EIA	**Res. Energy Consumption Survey (RECS)**
NAHB	**Homebuilder Surveys**
IECC	**Historical Energy Codes**

Other national, regional, and local audit databases

Census Data

Census	**American Community Survey (ACS)**

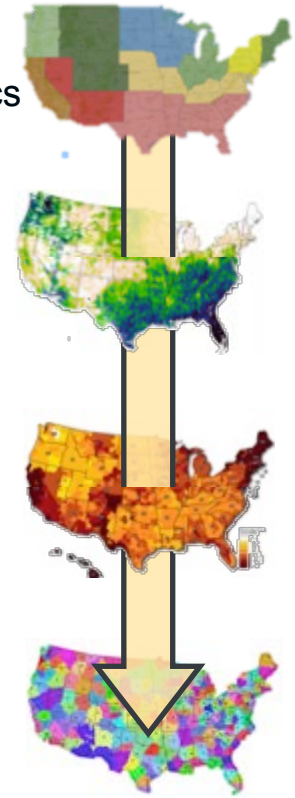
Costs

EIA	**Electricity and fuel costs**
NREL	**OpenEI.org Utility Rate Database**
NREL/Navigant	**Measure Cost Database**

Climate Locations

NREL	**TMY3 weather data**

Approach – Data Sources



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Approach – Conditional Probability Distributions

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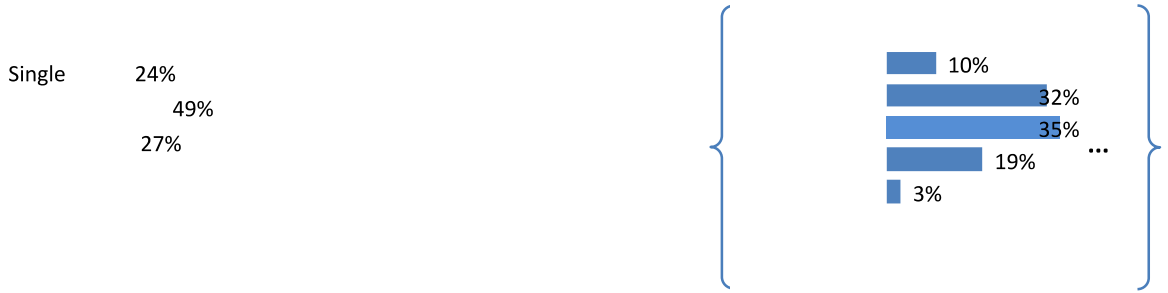
Single 24%

49%

27%

Approach – Conditional Probability Distributions



Approach – Statistical Sampling

- There exists **a very large number of possible combinations** of building characteristics (across different locations and vintages).
- Therefore, **statistical sampling** is used to automatically generate representative models to be simulated.

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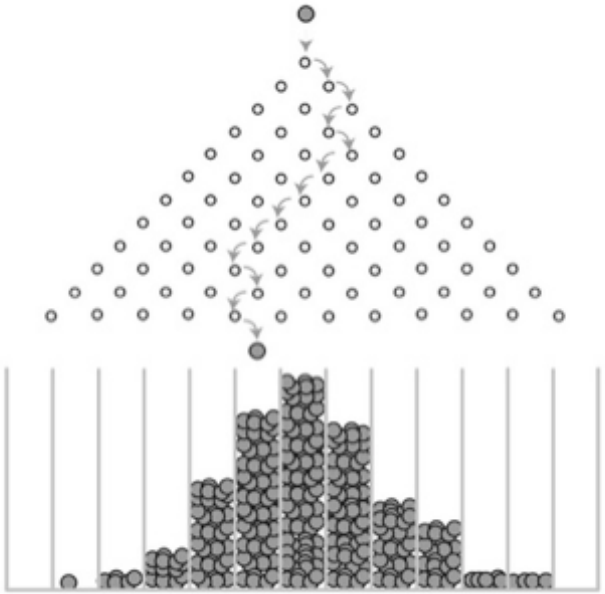
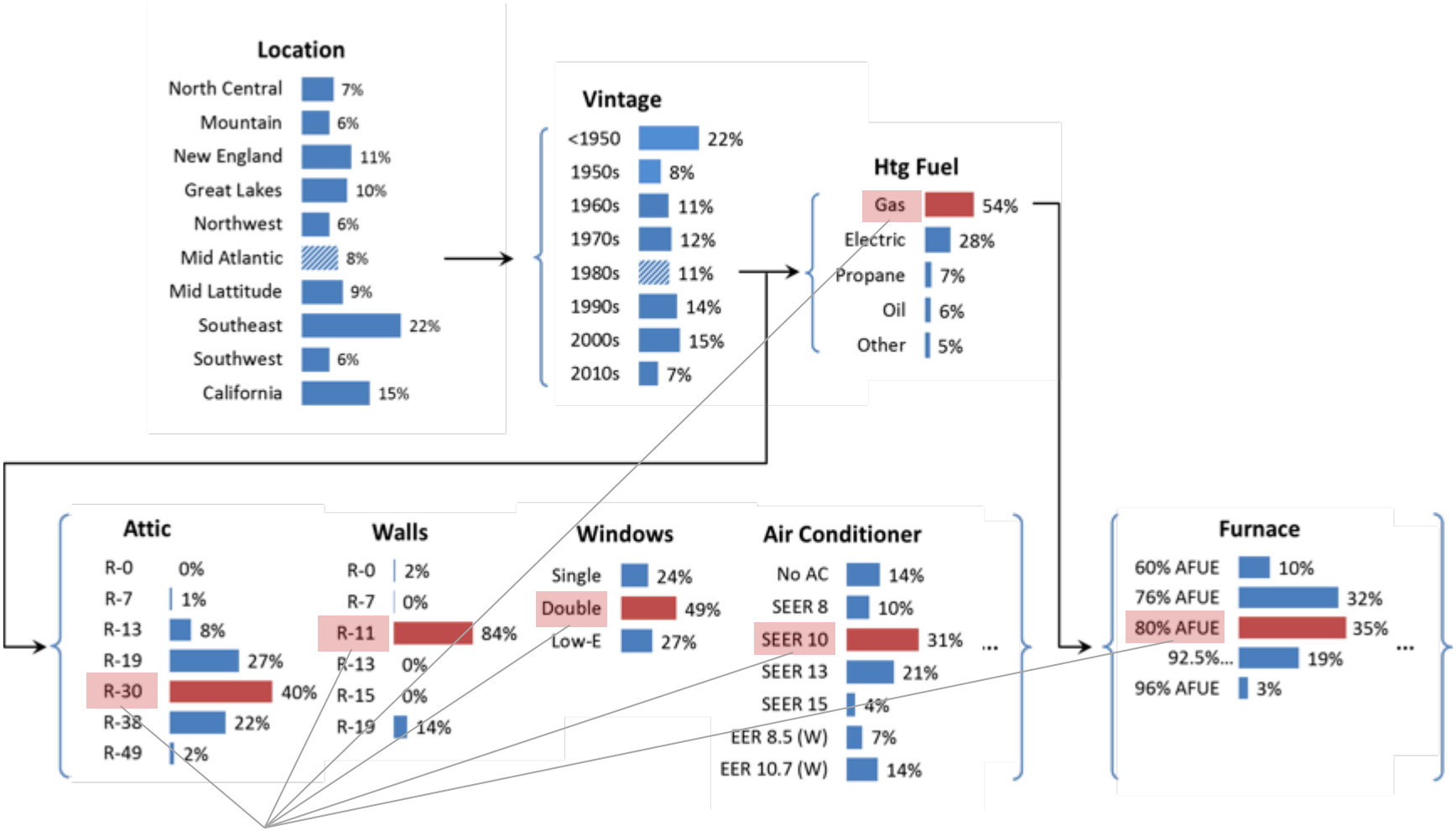
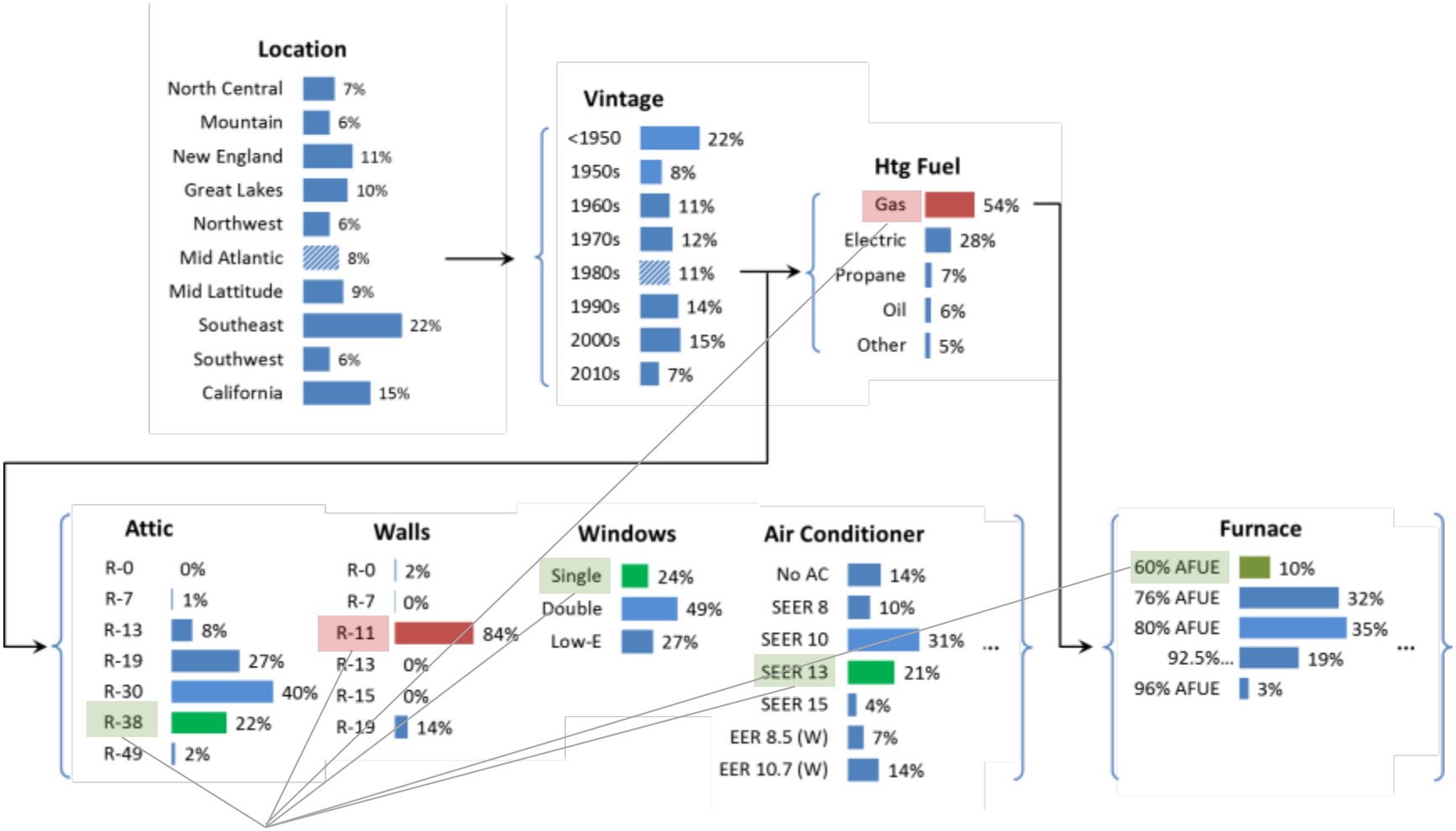


Approach – Statistical Sampling



Example building model
(with *highest* probability characteristics)

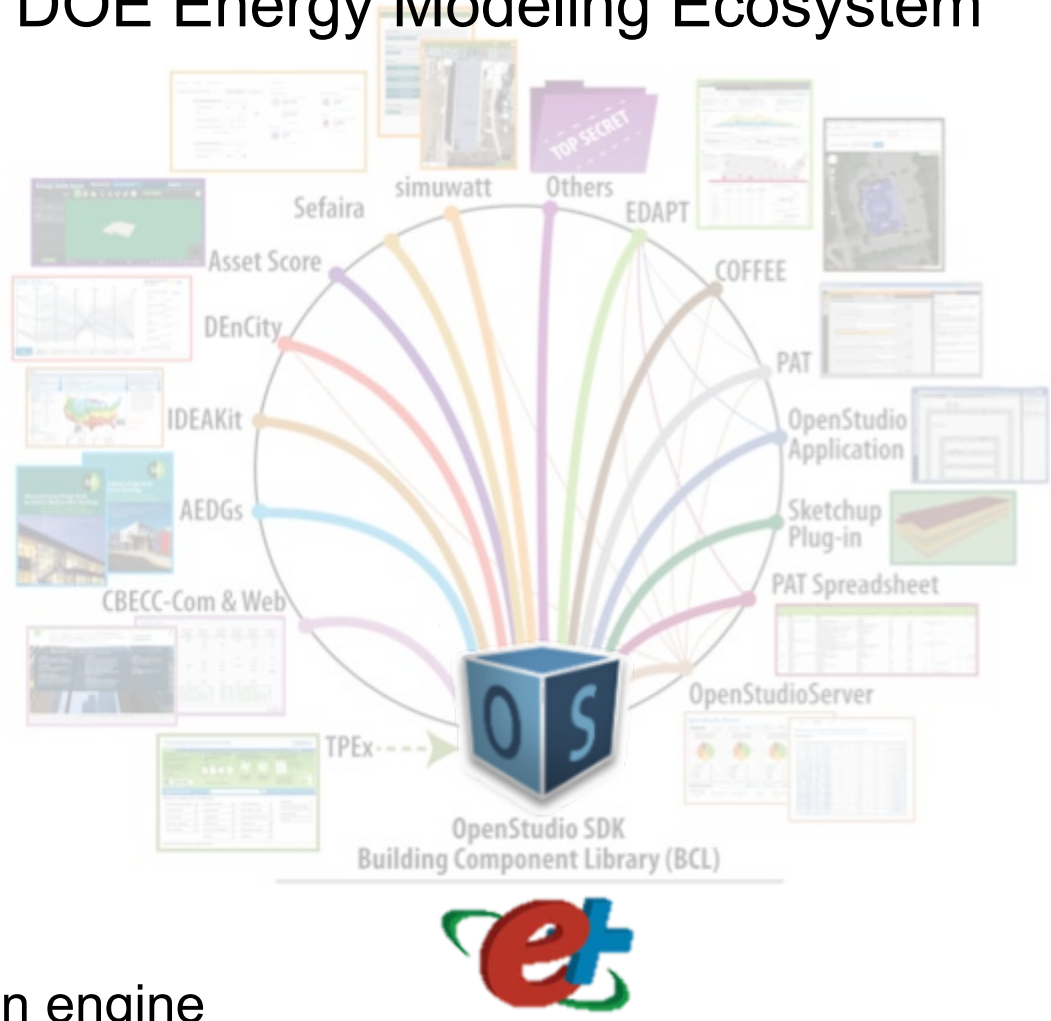
Approach – Statistical Sampling



Example building model
(with some *lower* probability characteristics)

Approach – Building Simulations

DOE Energy Modeling Ecosystem



OpenStudio

open-source platform supporting **applications** that use EnergyPlus

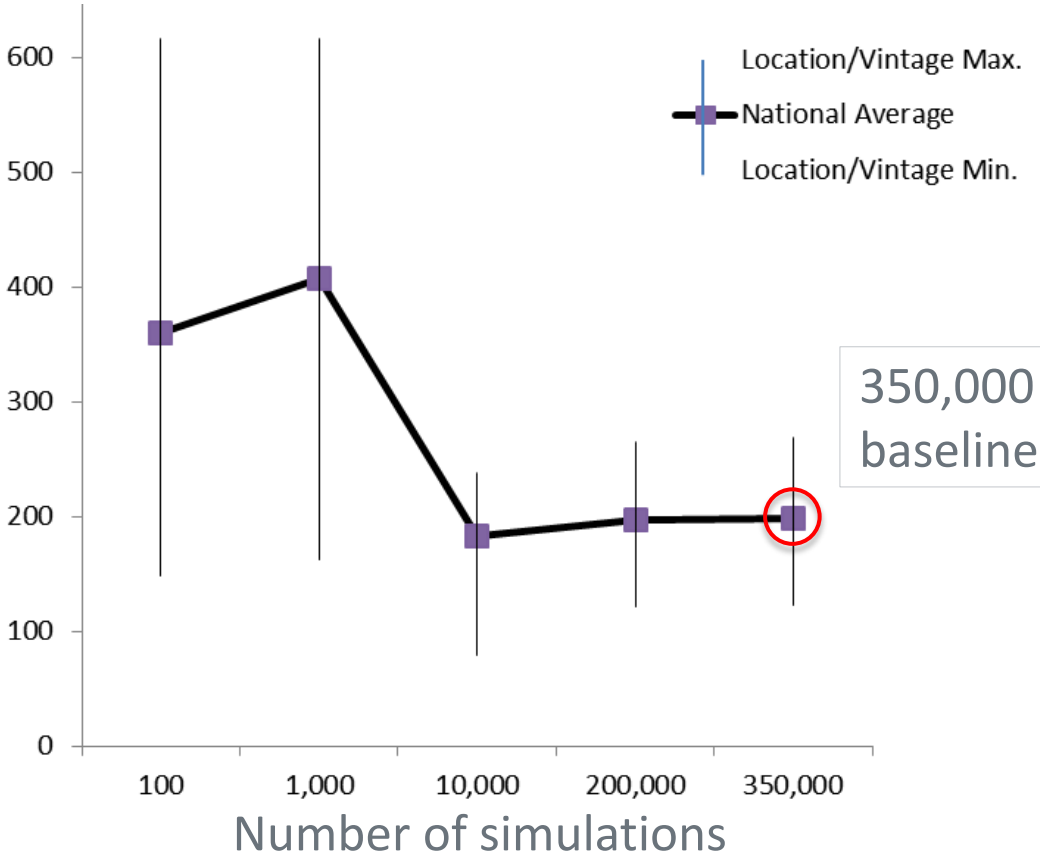
EnergyPlus

Detailed subhourly simulation engine

Approach – Building Simulations

How many simulations are necessary?

Predicted source energy consumption [MBtu/yr/house]



350,000 baseline simulations

350,000 | baseline simulations

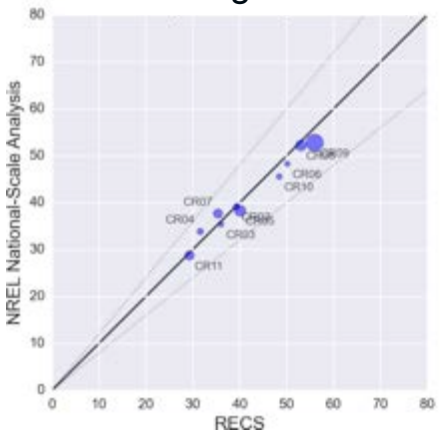
Approach – Validation/Calibration

Modeled (y-axis) vs. EIA RECS (x-axis)

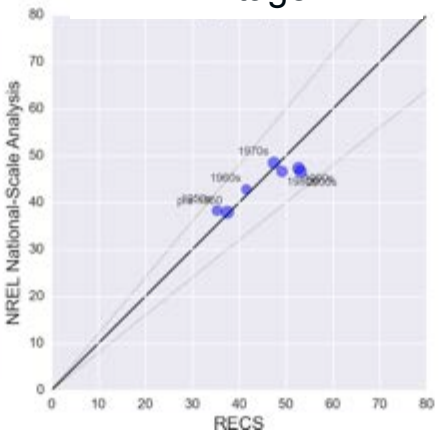
Average Source Energy per House: 10^6 Btu/yr

Electricity

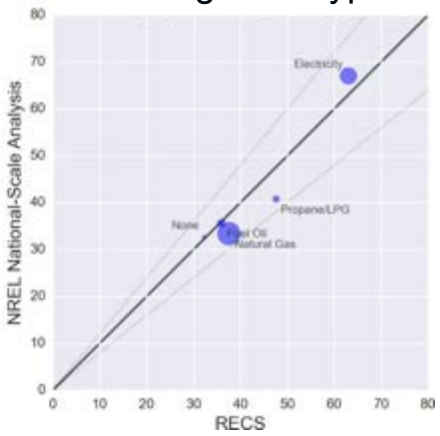
Region



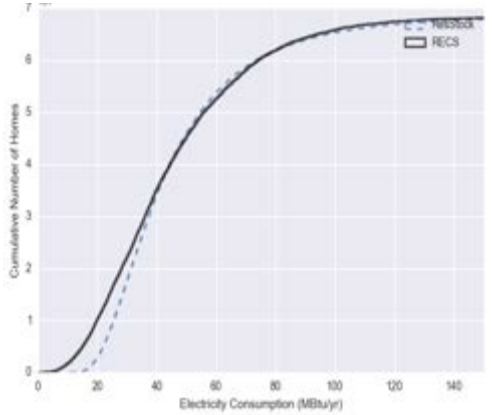
Vintage



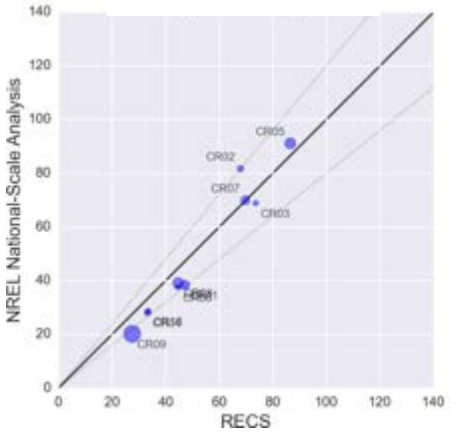
Heating Fuel Type

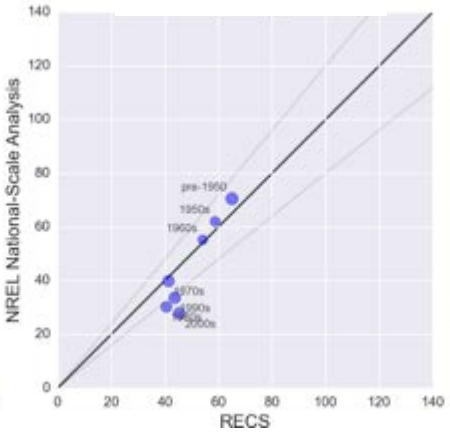


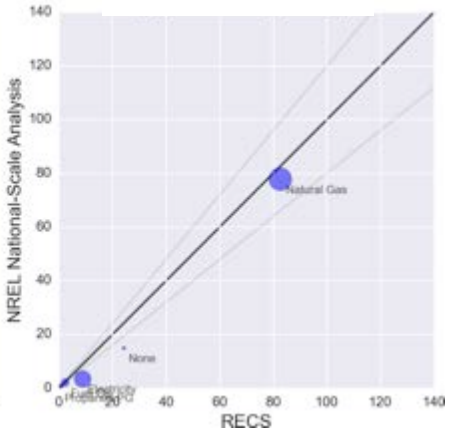
Cumulative Distribution

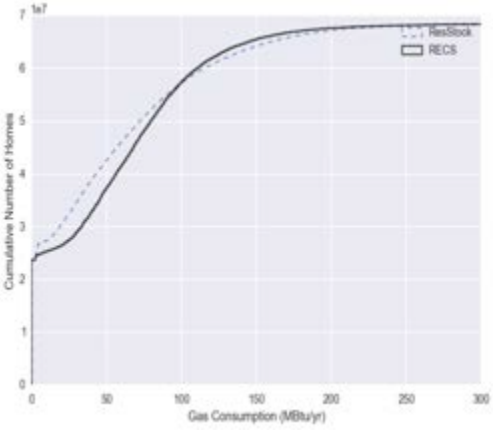


Natural Gas









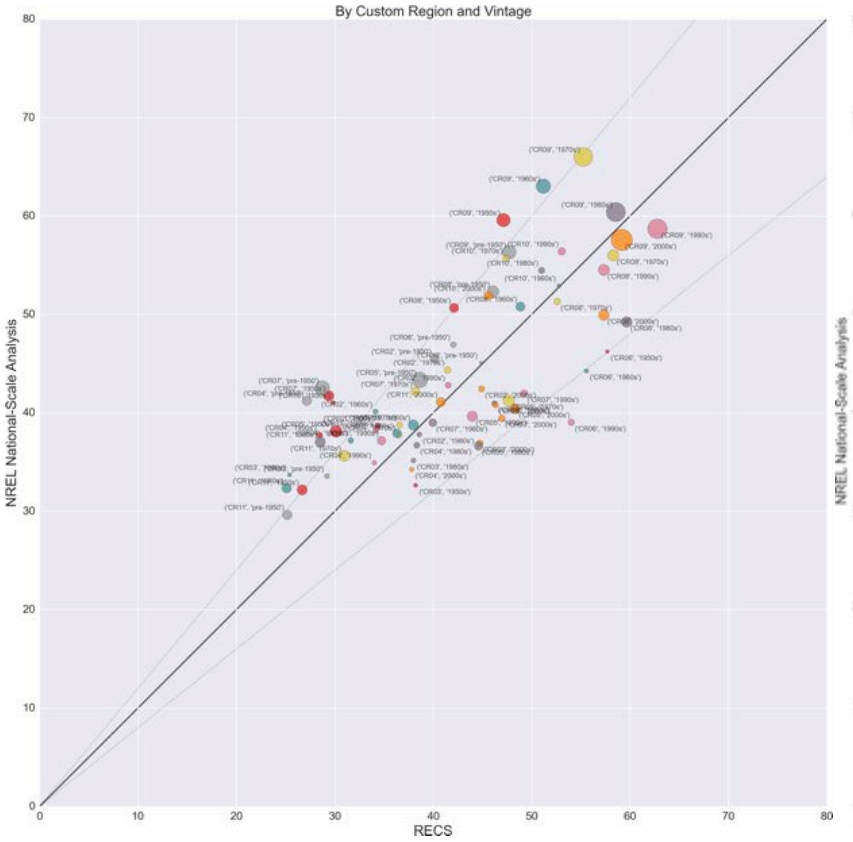
Approach – Validation/Calibration

Modeled (y-axis) vs. EIA/RECS (x-axis)

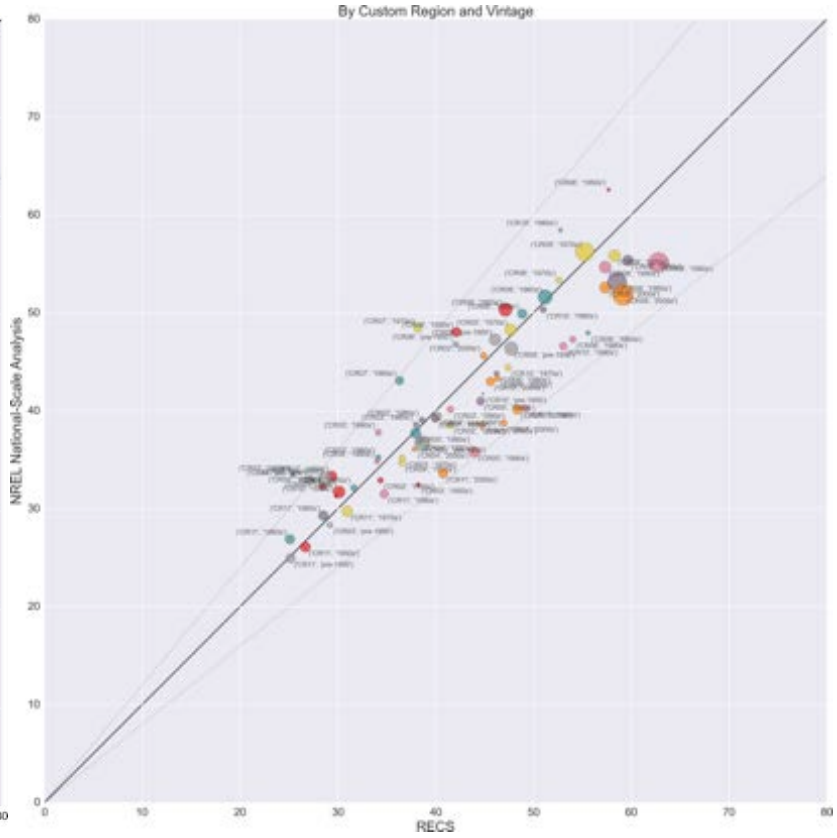
Average Electricity Consumption per House: 10^6 Btu/yr source

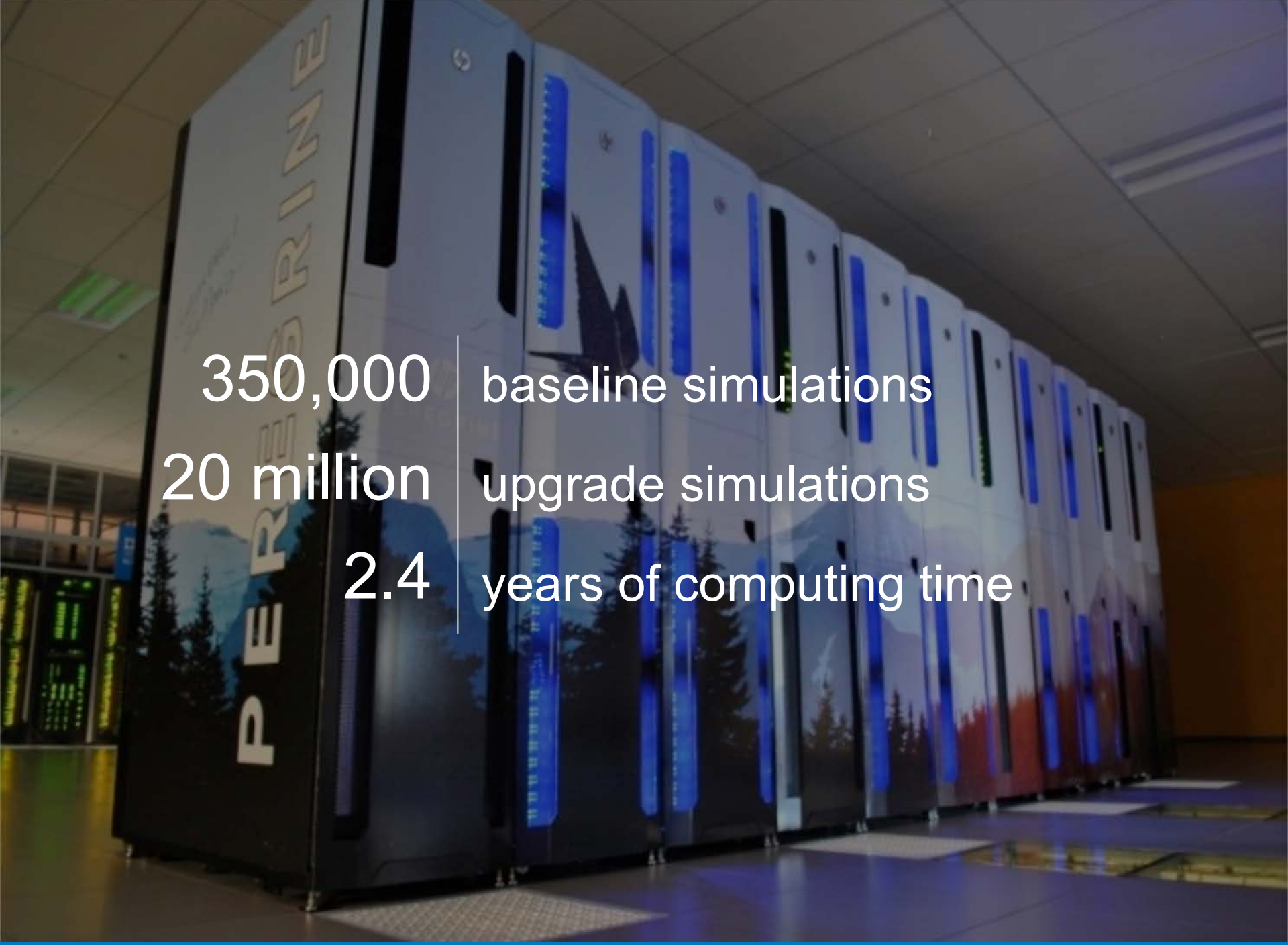
Aggregated by Region/Vintage Combinations

Before Calibration



After Calibration



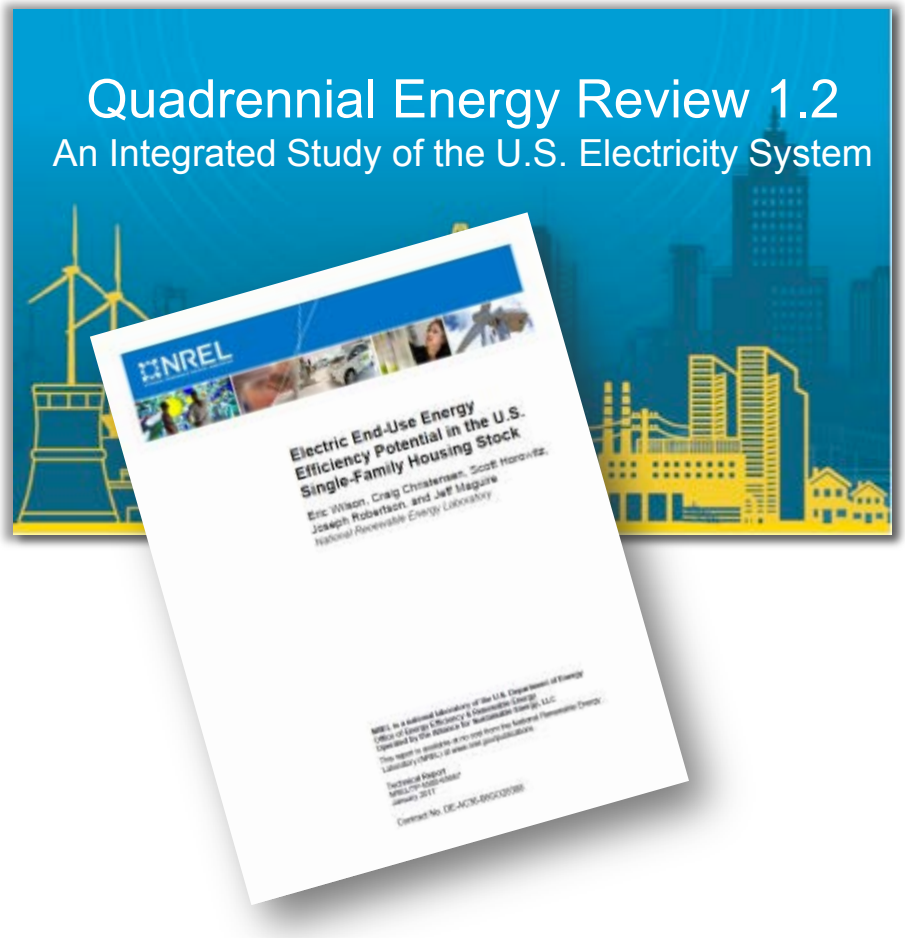


350,000	baseline simulations
20 million	upgrade simulations
2.4	years of computing time

Example Results

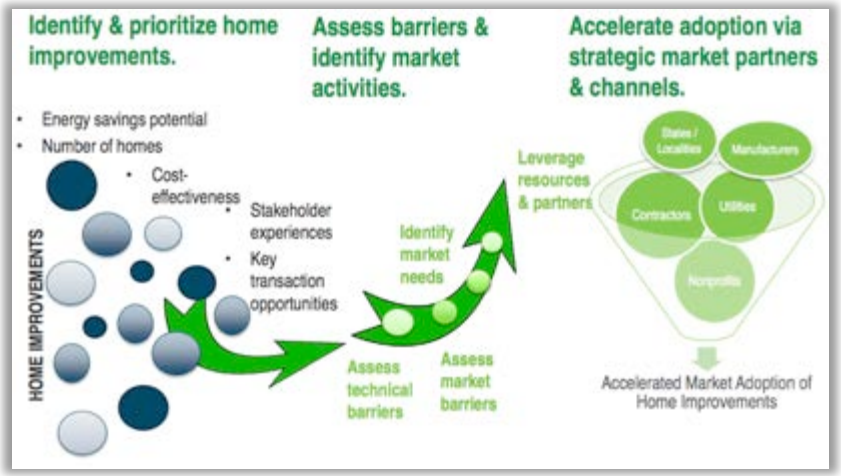
Example Results: 2016 Applications

DOE Office of Energy Policy and Systems Analysis

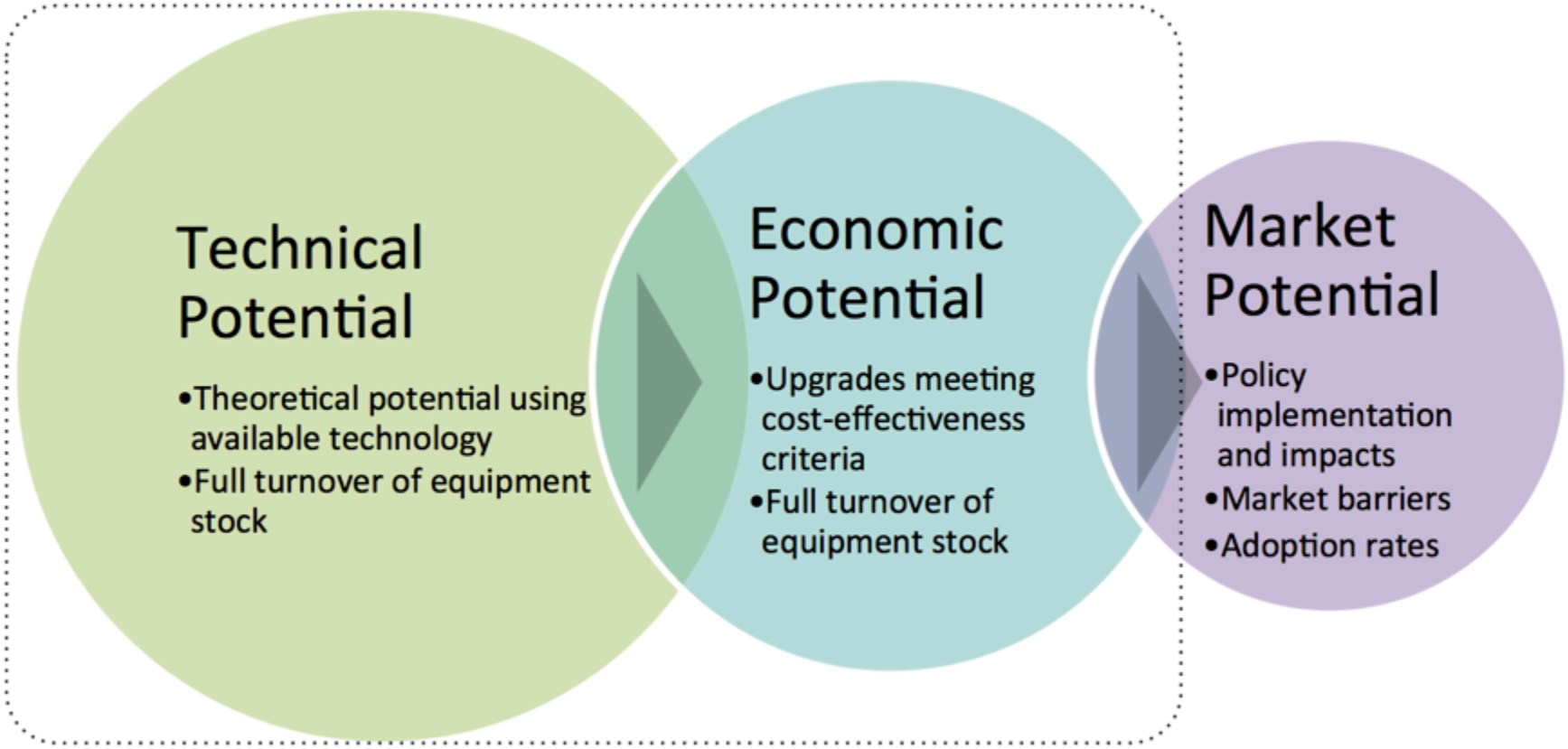


DOE Building Technologies Office

Home Improvement Catalyst (HI-Cat)

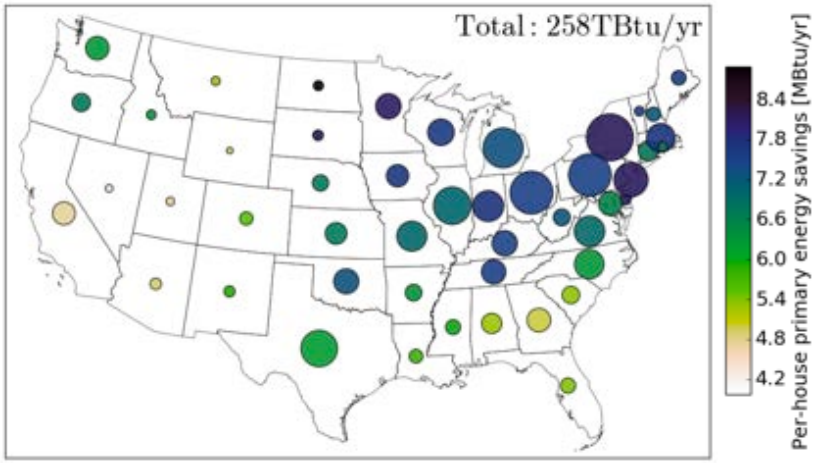


Focus: Technical and Economic Potential

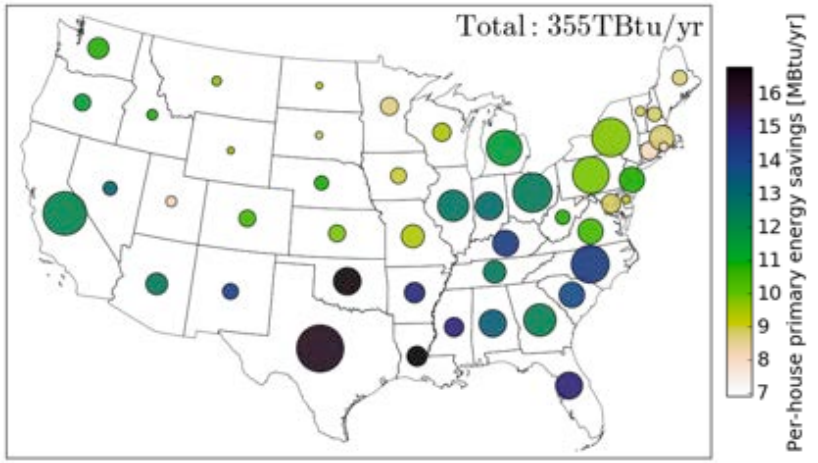


Example Results – Economic Potential (NPV > 0)

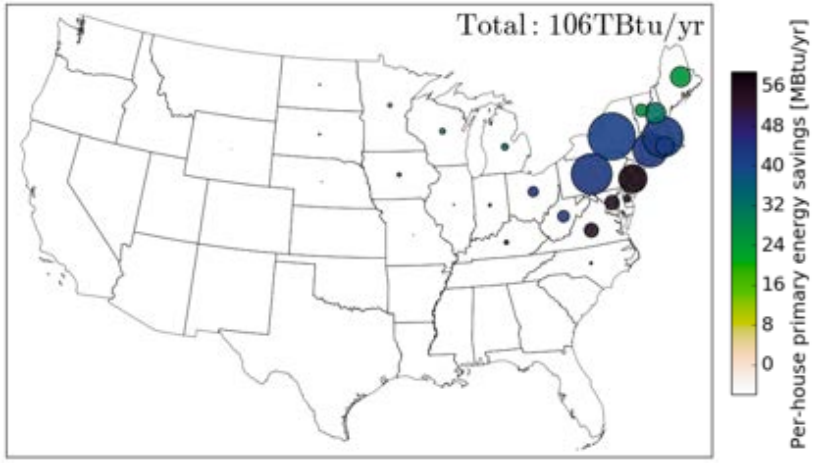
Air Sealing



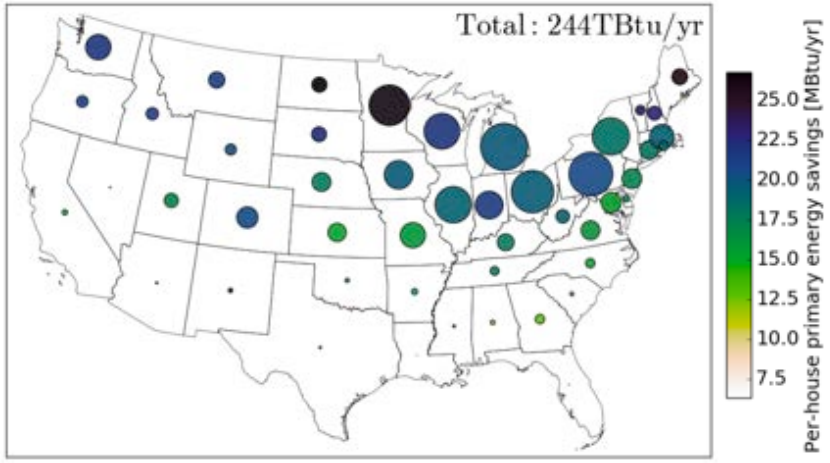
Attic Insulation (R-49)



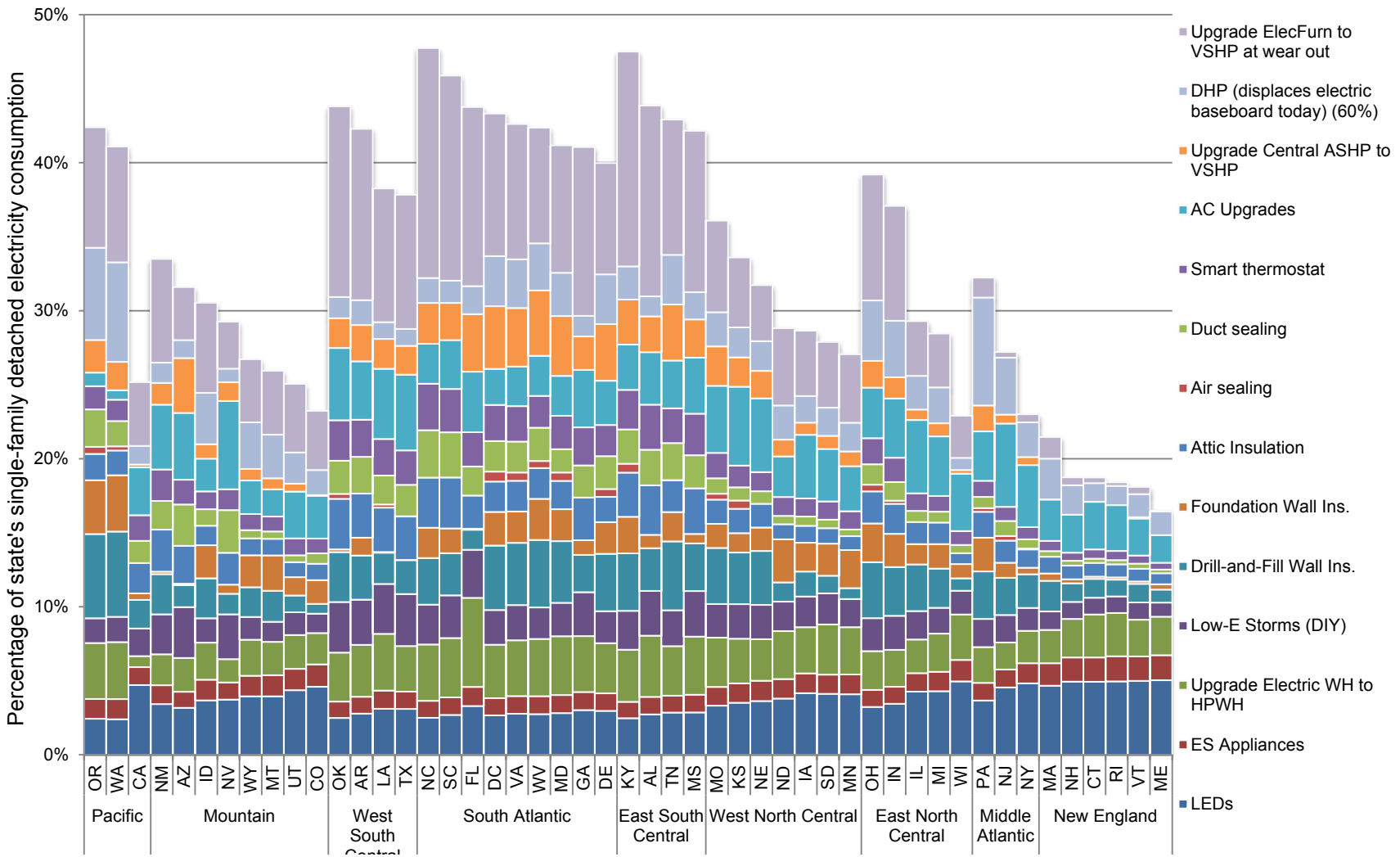
Replacing Oil Boilers with Ductless Heat Pumps



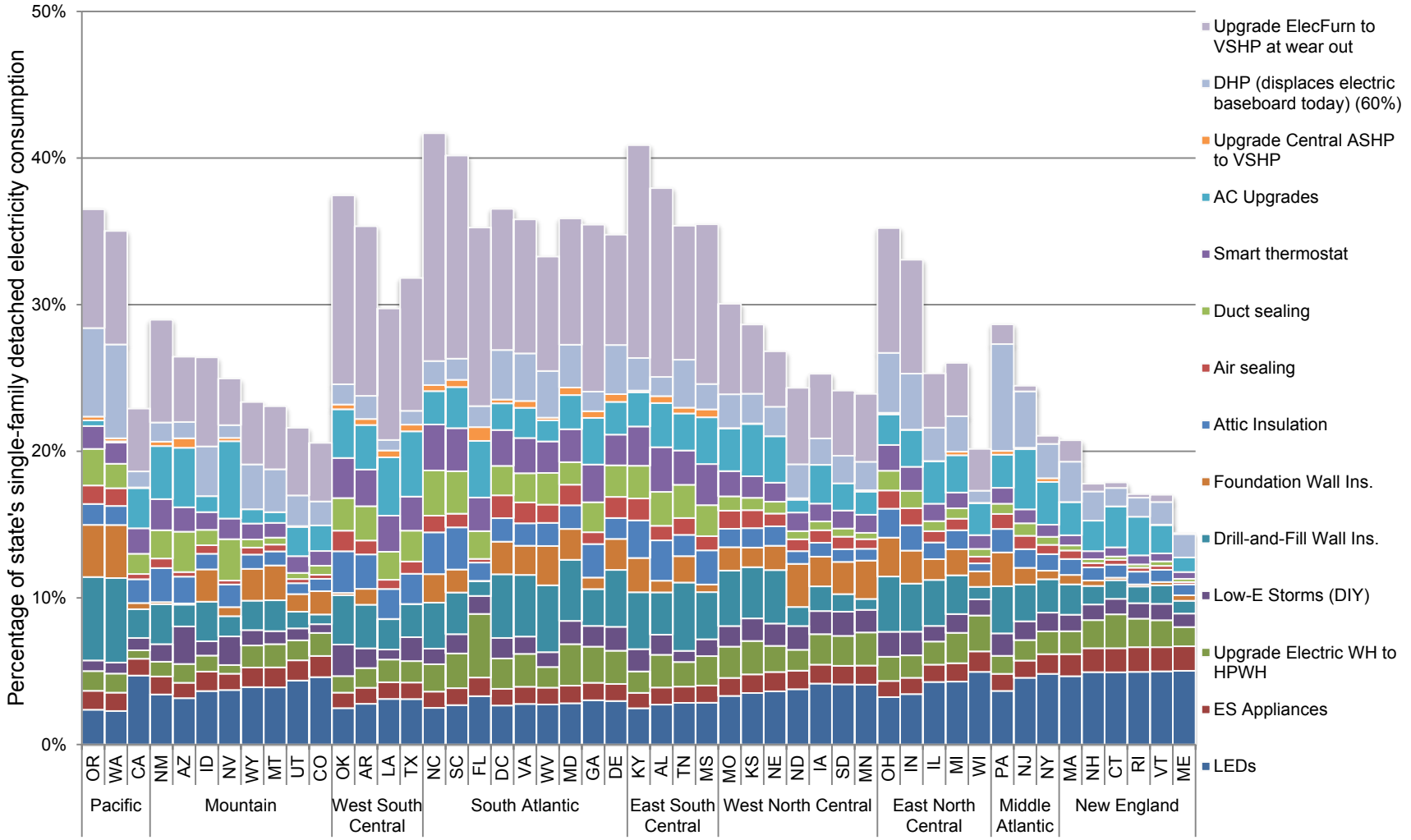
Basement Wall Insulation (R-10)



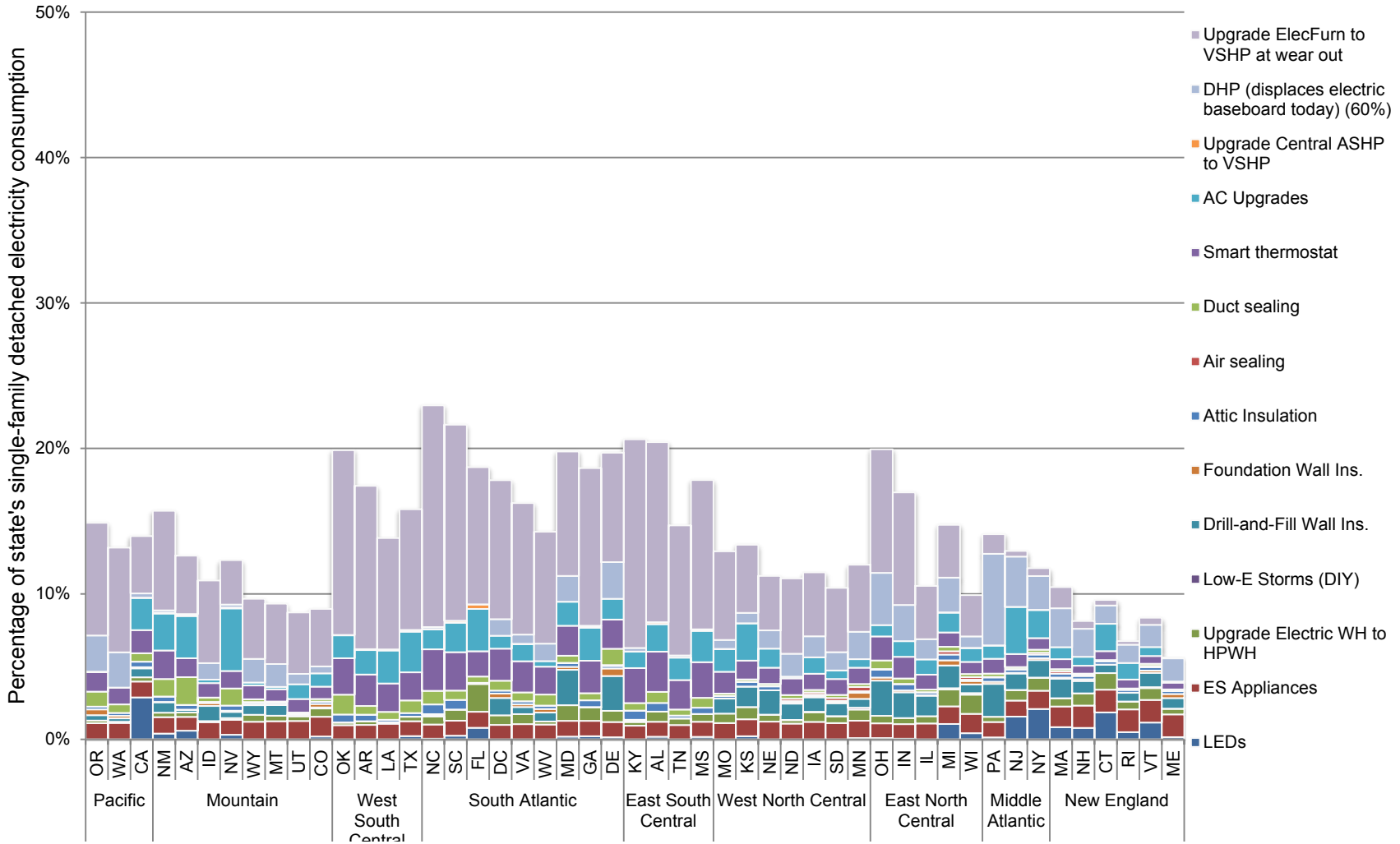
Electric Savings – Technical Potential



Electric Savings – Economic Potential w/ Financing (NPV > 0)

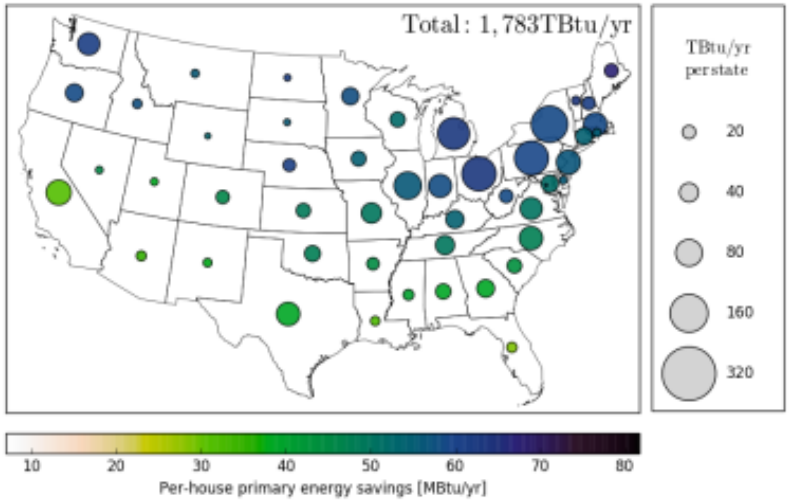


Electric Savings – Market Potential Estimate (payback < 5 years)

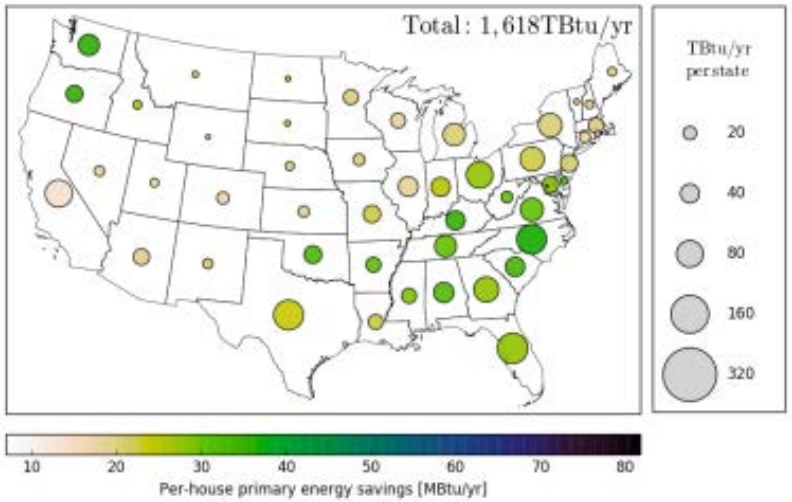


Package Results – Economic Potential w/ Financing (NPV > 0)

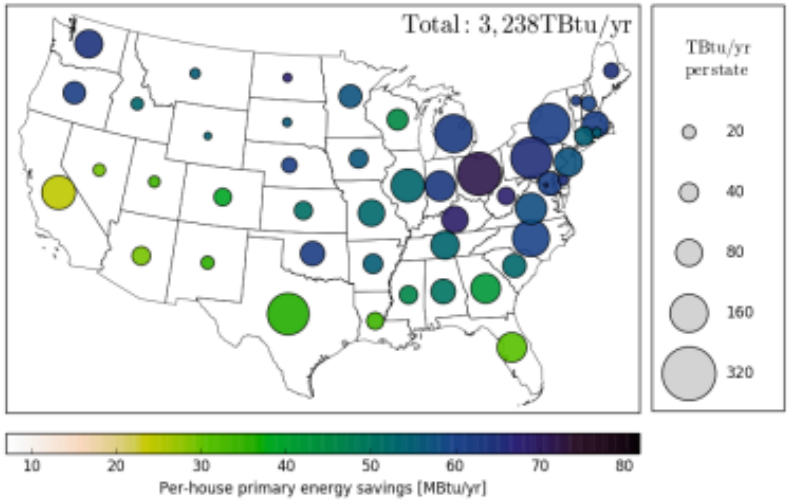
Enclosure Packages



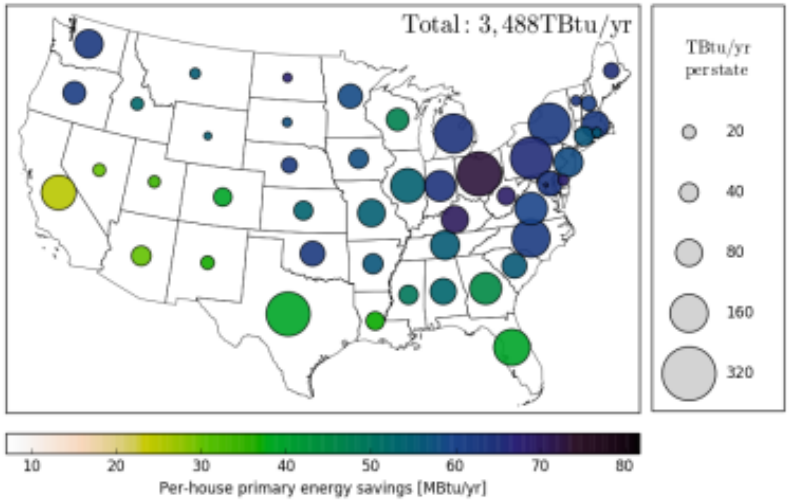
HVAC Packages



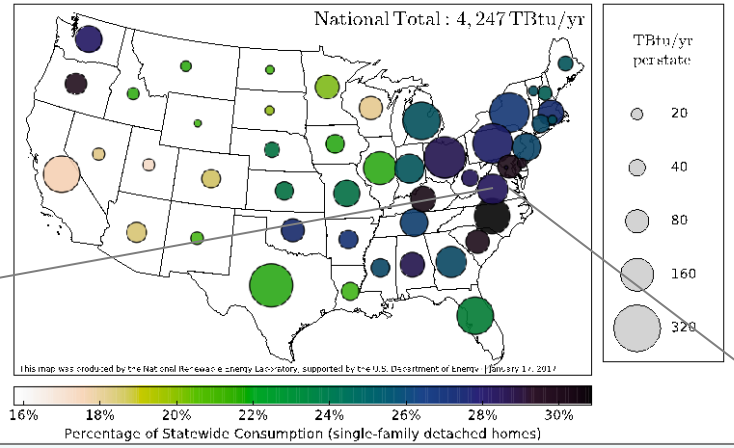
Enclosure+HVAC Packages



Enclosure+HVAC+WH Packages



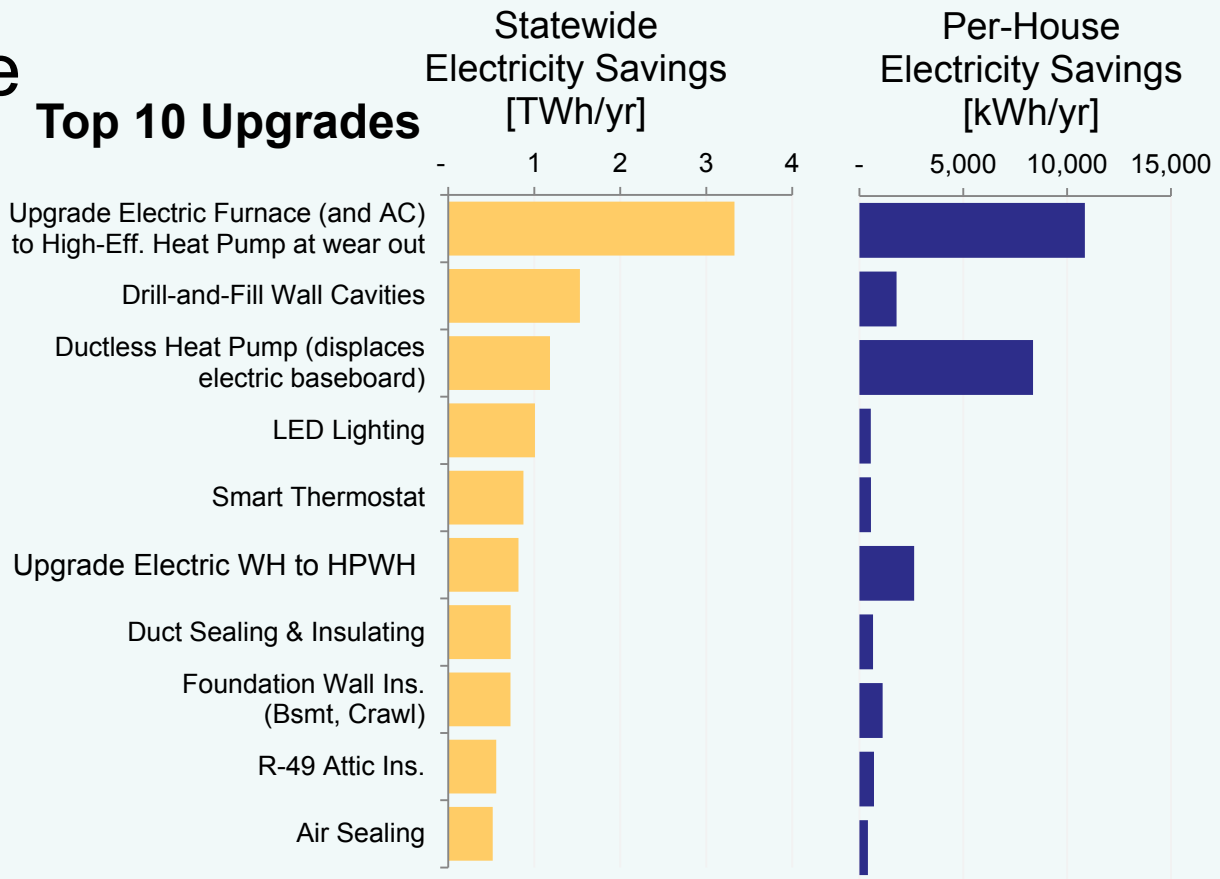
Actionable results for states and cities



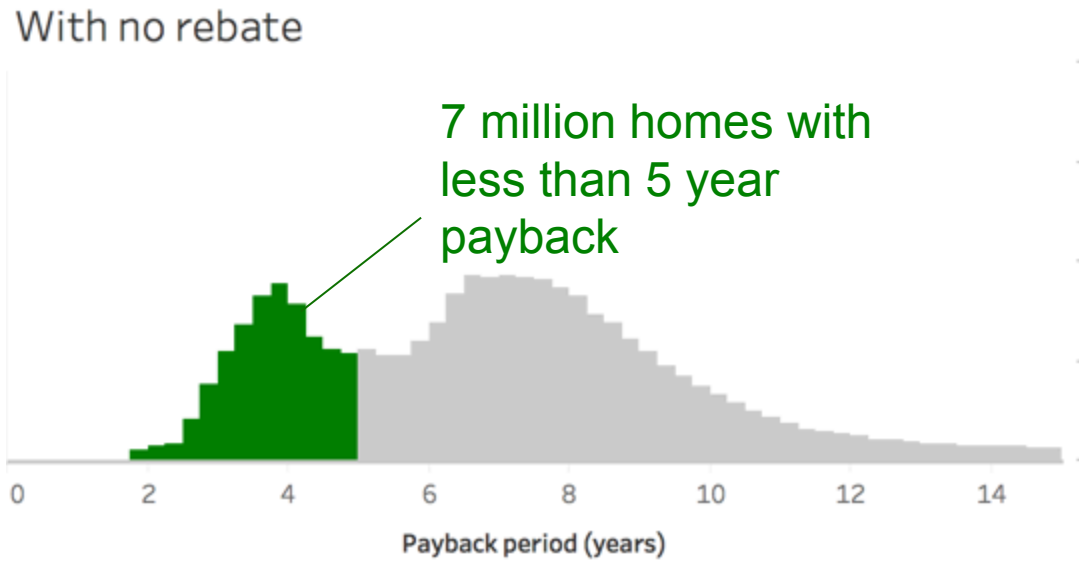
Cost-effective savings for **Virginia**

Utility bills
1.5
billion dollars per year

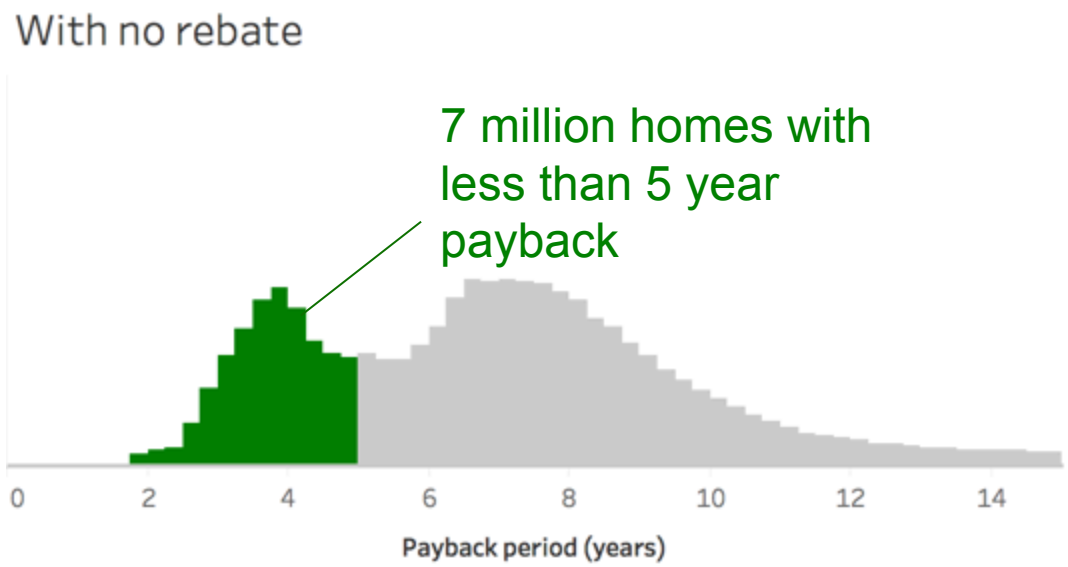
Top 10 Upgrades

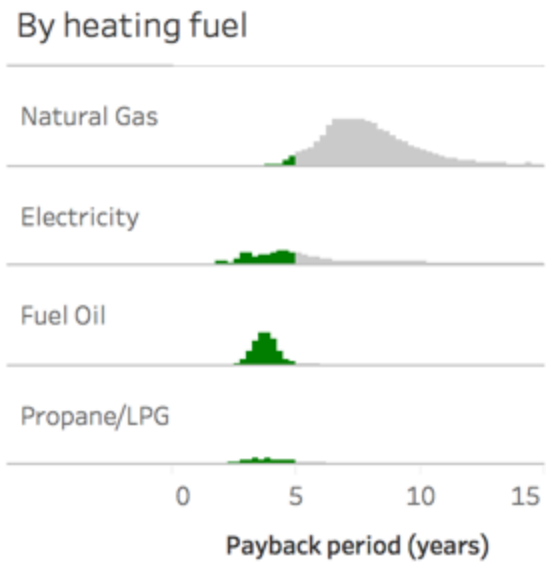


Evaluate incentives – Drill-and-Fill Wall Insulation



Evaluate incentives – Drill-and-Fill Wall Insulation





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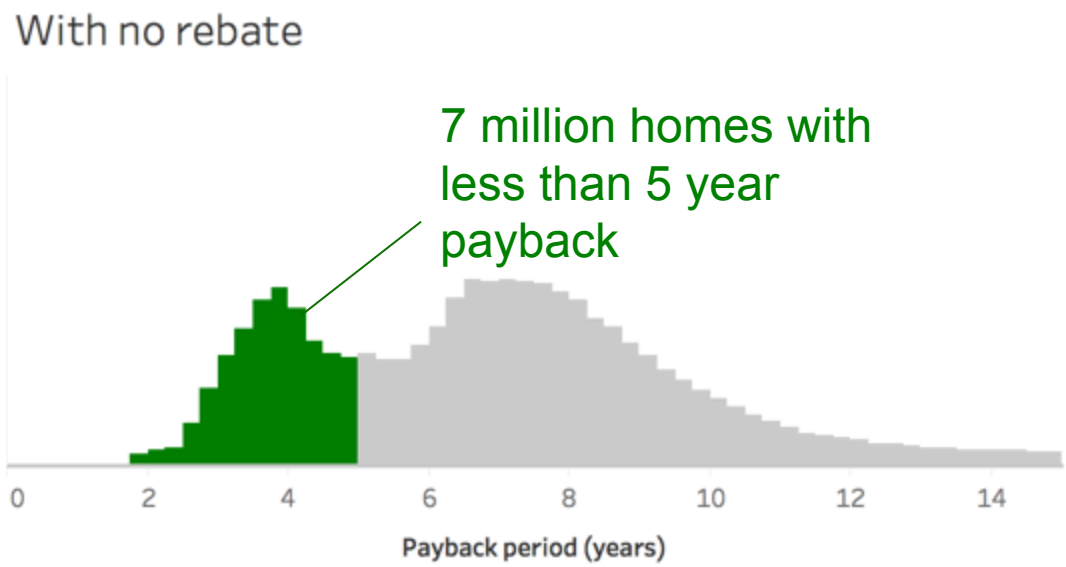
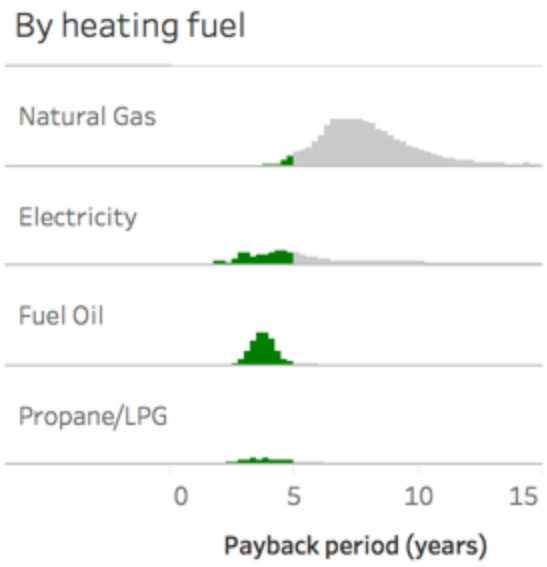
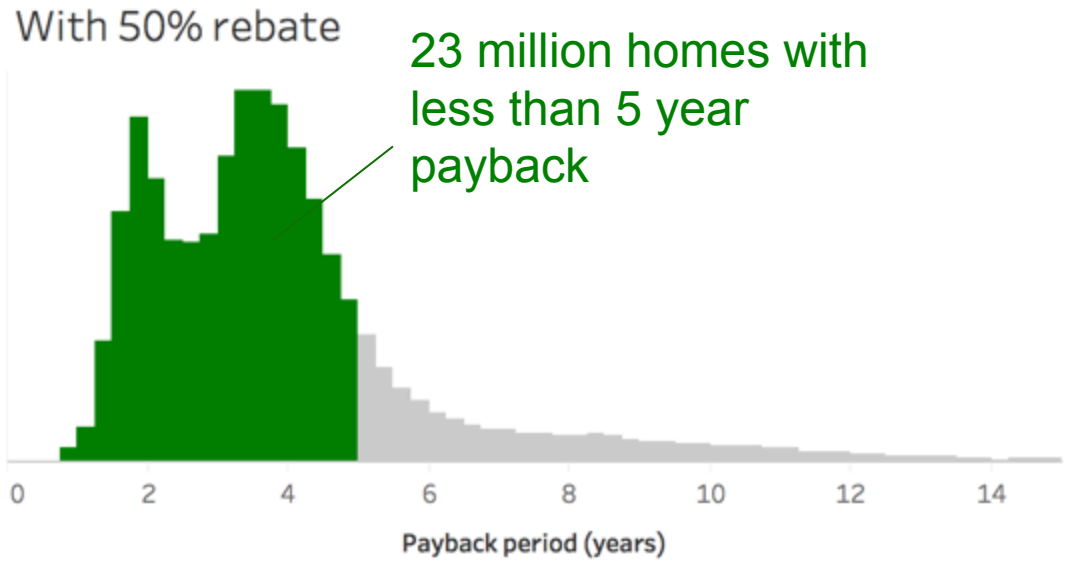
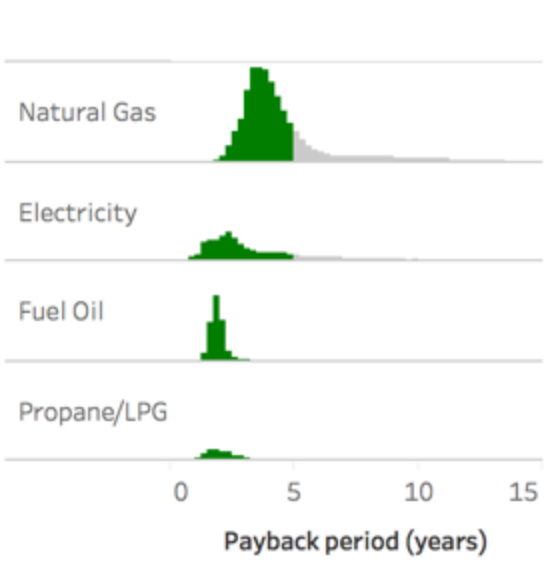








Looking Ahead

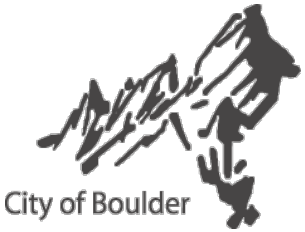
Applications

EERE Building Technologies Office
EERE Office of Strategic Programs
Office of Energy Policy and Systems Analysis

- Quadrennial Energy Review 1.2
- Home Improvement Catalyst
- Grid load modeling

- Regional Planning Tool
- Low-Income EE Potential

- Demand response



- City energy strategy

Looking Ahead: State-Specific Results

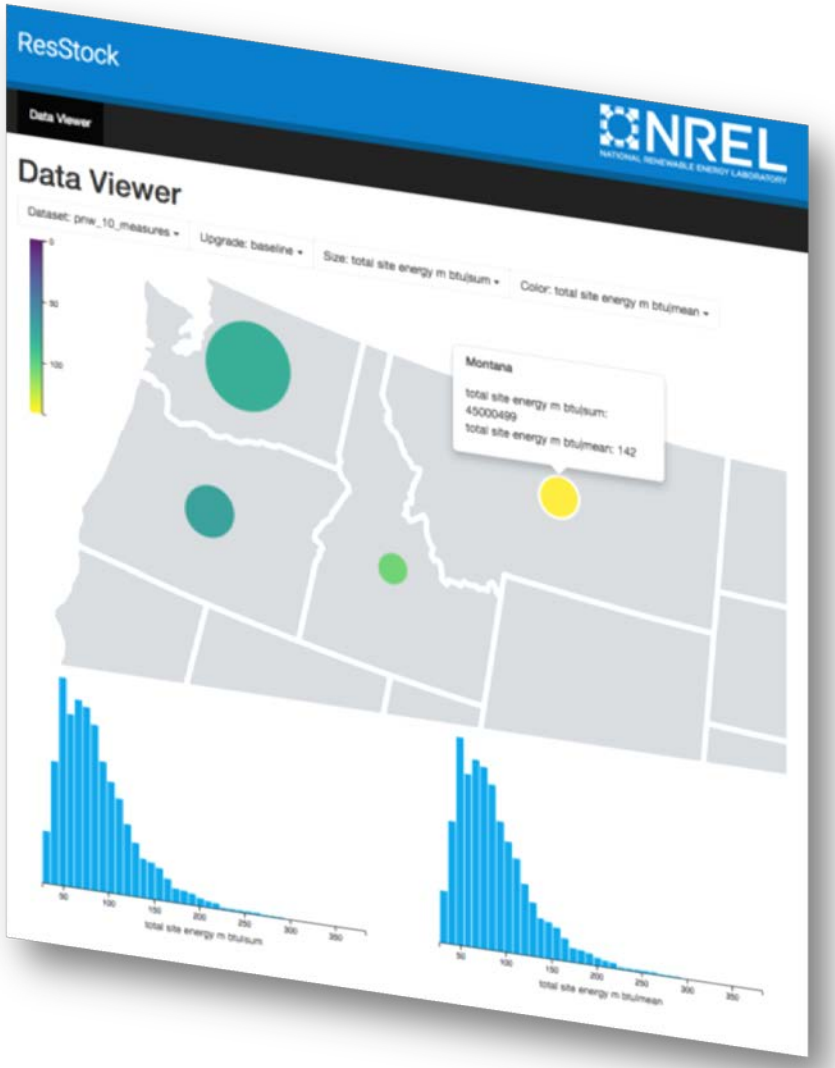
48 state fact sheets
based on QER analysis

- High-level results
- Top priority upgrades

Looking Ahead: ResStock Website

Interactive visualizations of:

- Housing characteristics
- Baseline consumption by end-use, fuel
- Savings and cost-effectiveness for retrofits



Looking Ahead: New capabilities

Demographic parameters

⟶ low-income EE potential

What is the potential for energy efficiency in low-income communities?

Which upgrades have the best Savings-to-Investment Ratio in each city, state, or customer segment?

Looking Ahead: New capabilities

Time-of-Savings + Load Flexibility

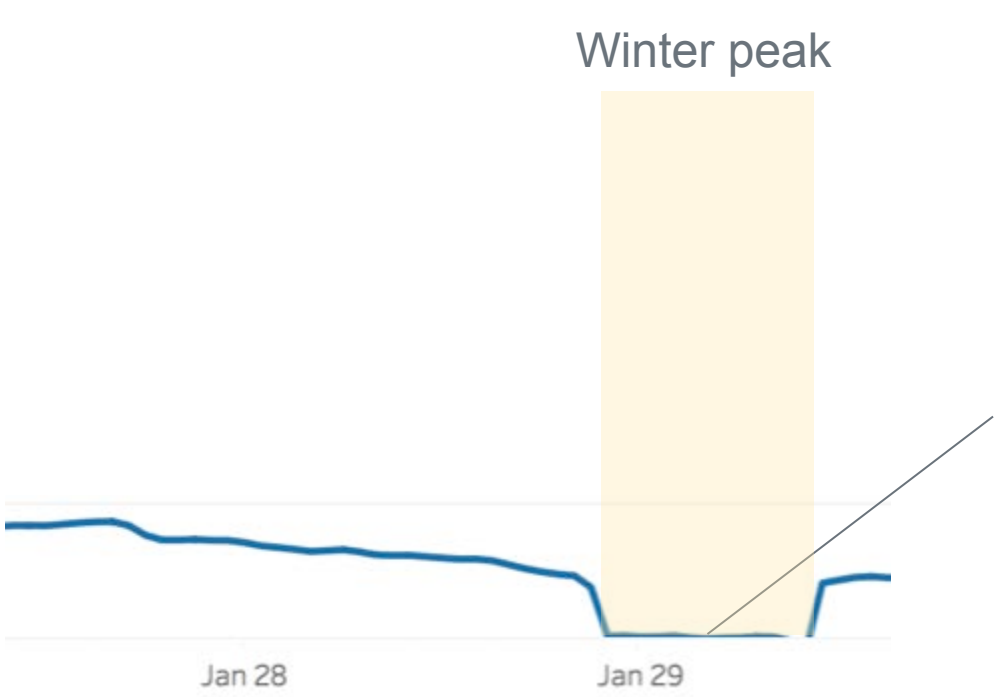
When do savings from home performance upgrades occur?

What is the potential for reducing peak demand?

Time-of-Savings + Load Flexibility

When do savings from home performance upgrades occur?

What is the potential for reducing peak demand?

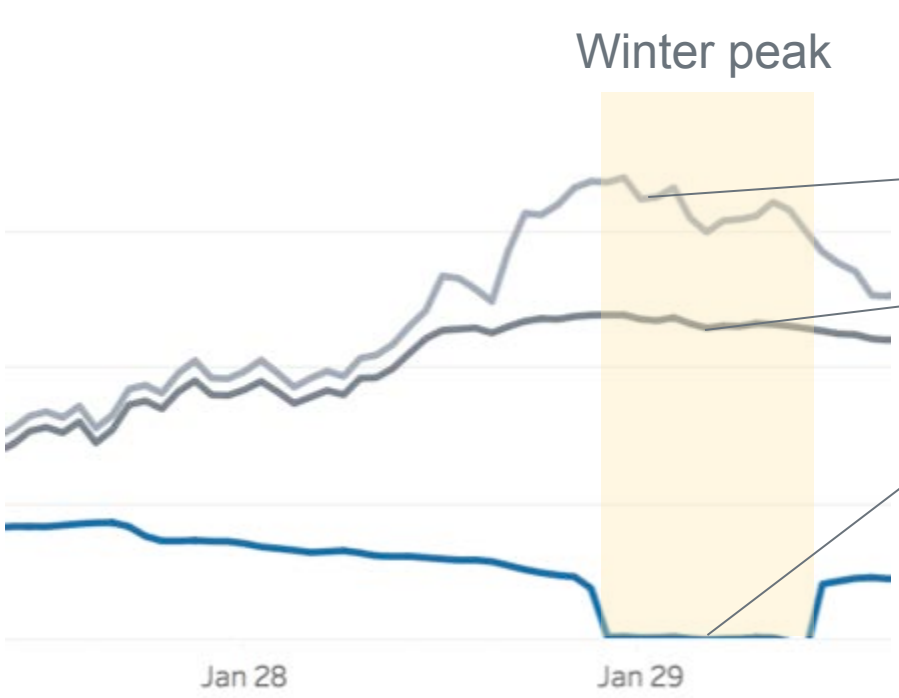


Peak demand reduction achieved by replacing an electric furnace with

Time-of-Savings + Load Flexibility

When do savings from home performance upgrades occur?

What is the potential for reducing peak demand?



Peak demand reduction achieved by replacing an electric furnace with

Heat pump (max. eff.) + Wx

Heat pump (max. eff.)

Heat pump (min. eff.)

Looking Ahead: New capabilities

Time-of-Savings + Load Flexibility

When do savings from home performance upgrades occur?

What is the potential for reducing peak demand?

Quantify the impact that **time-of-use** rates have on utility bills

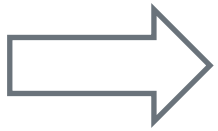
How do home performance upgrades increase the **demand response potential** of smart thermostats?

What are the characteristics of homes that provide the best bang-for-the-buck in **pay-for-performance** programs?

Looking Ahead: City-scale applications

City-specific data
(e.g., assessors' databases)

ResStock workflow and regional characteristics

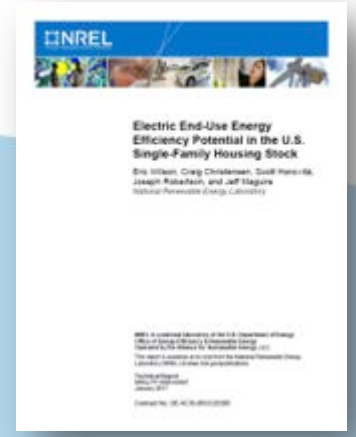


Market engagement tools & analytics

Radiant Labs

Thank you!

https://github.com/NREL/**OpenStudio-ResStock**



Electric End-Use Energy Efficiency Potential in the U.S. Single-Family Housing Stock

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www.nrel.gov

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