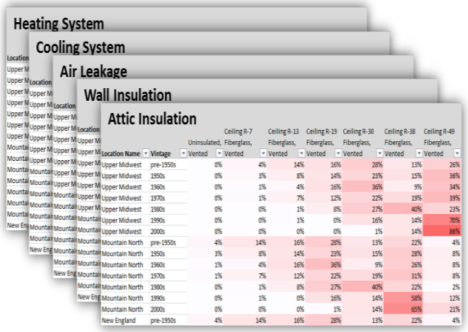
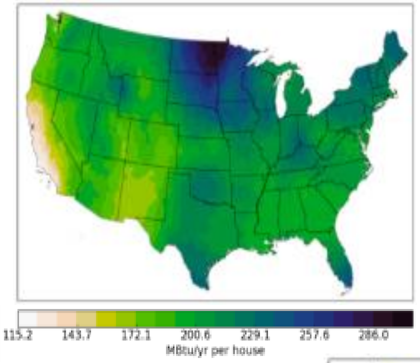
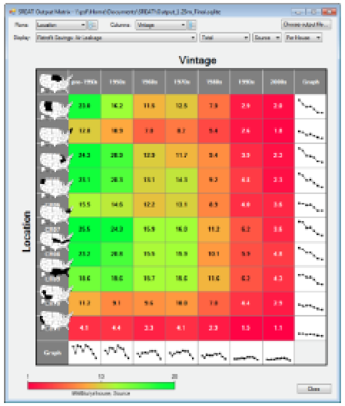
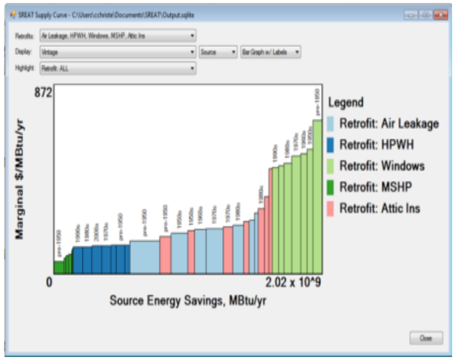
NREL Energy Efficiency Potential Mapping

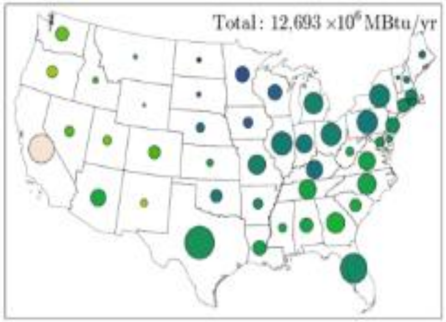
2015 Building Technologies Office Peer Review











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NREL

Project Summary

Timeline:

Start date: 2013

Planned end date: ?

Key Milestones

- 2013: Draft Methodology
- 2014: Input Database, High Performance Computing, Preliminary Results
- 2015: Use Cases, Validation/Calibration, Cost-Optimized Results

Budget:

Total DOE $ to date: $925k

Total Non-DOE $ to date: $540k

Total future Non-DOE $: 280k

Target Market/Audience:

Market: Residential new/existing homes; single family and multifamily

Audience: National/regional/state policy makers, utilities, manufacturers

Key Partners:

- CPS Energy
- Bonneville Power Administration

Project Goal:

To produce actionable national-scale analysis and visualizations that assess technical and economic potential of residential energy efficiency technologies through comprehensive EnergyPlus building models.

Purpose and Objectives

Problem Statement:
To accelerate the widespread uptake of cost-effective energy efficiency in the marketplace through target marketing or incentives, federal, state, and local decision makers need to be able to accurately assess national technical and economic potential of residential energy efficiency, accounting for the full range of U.S. building stock characteristics and weather.

Target Market and Audience:
Market: Existing homes (10.2 quads) and residential new construction (1.4 quads/decade)
Audience: National/regional/state policy makers, utilities, manufacturers

Impact of Project:
1. Project Outputs: Technical and economic potential analysis for EE technologies
2. Impact Measures: Number of active use cases of EE potential analysis, number of EE potential results (visualizations) delivered

Approach

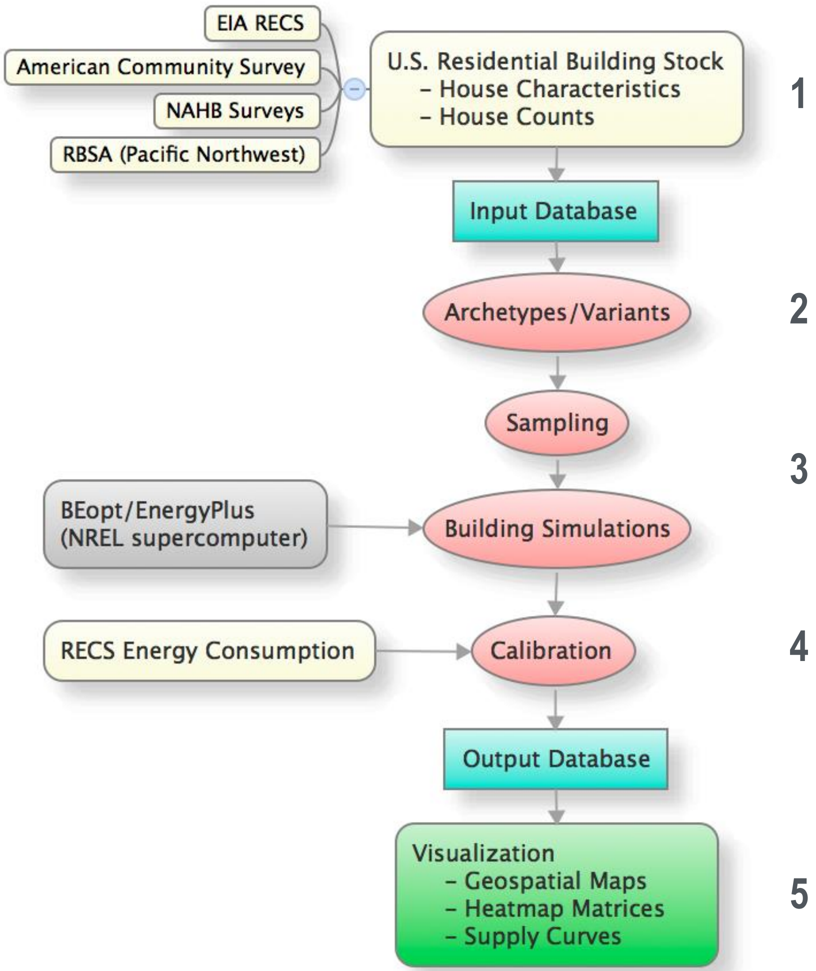
Approach:
Use high-resolution data (building characteristics and weather) and models (building energy simulations) to analyze and visualize energy efficiency potential across the U.S. residential building stock.

1. **Housing Stock Characteristics** – Input Database
2. **Archetype Buildings/Occupants/Climates** – Auto-Generated Models
3. **Building Simulations** – High Performance Computing
4. **Validation/Calibration** – Comparison to RECS consumption data
5. **Output Visualization** – Geospatial Maps, Heatmap Matrices, Supply Curves

Key Issues:
- Compiling comprehensive building characteristics (by vintage and location) and house counts required gathering and processing multiple sources of data into a single large input database.

Distinctive Characteristics:
- Expands analysis from individual buildings to regional/national scale
- Combines data (EIA/RECS, etc.) and simulation modeling (EnergyPlus)
  - Data based inputs and validation/calibration (energy consumption)
  - Modeling to answer what-if questions regarding retrofit savings
- Large-scale analysis: hundreds of thousands of simulations and use of high performance computing

Approach



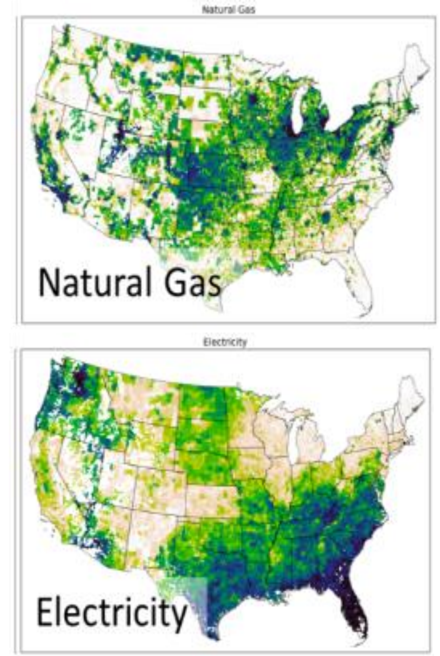
EIA RECS
American Community Survey
NAHB Surveys
RBSA (Pacific Northwest)
U.S. Residential Building Stock
– House Characteristics
– House Counts
1
Input Database
Archetypes/Variants
2
Sampling
3
BEopt/EnergyPlus
(NREL supercomputer)
Building Simulations
RECS Energy Consumption
Calibration
4
Output Database
Visualization
– Geospatial Maps
– Heatmap Matrices
– Supply Curves
5

Approach – 1) Housing Stock Characteristics

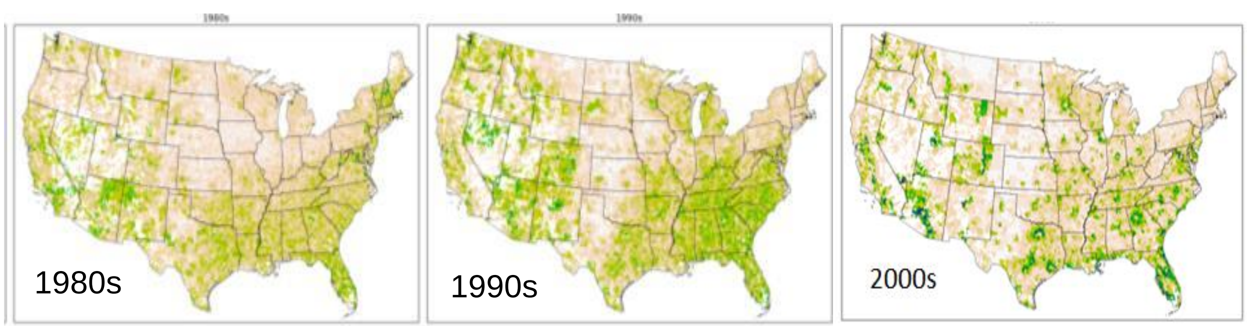
Probability distribution data	2012 ACS	2009 RECS	NAHB Surveys	RBSA	IECC Codes	Ritschard et al. 1992	Chan et al. 2012	HES Eng. Doc.	Geographic Resolution	Location	Vintage	Heating Fuel	Floor Area	Number of Stories	Found. Type	Usage Level
	Data Sources									**Dependencies**						
Total # single-family detached	•								C	✓						
Vintage %s	•								C	✓						
Heating fuel %s	•								C	✓						
Floor area %s		•							R	✓	✓					
Foundation type %s		•	•						R	✓	✓					
Attached garage %s		•							R	✓	✓					
Number of stories %s		•							R	✓	✓		✓			
Heating/DHW system types/ages		•	•						R	✓	✓	✓				
Cooling system type/age		•							R	✓	✓					
Cooking, clothes dryer fuel		•							R	✓		✓				
Heating, cooling setpoints		•							U.S.							
Lighting, appliances, MELs[a]		•							R	✓			✓			✓
Window type		•			•				R	✓	✓					
Wall insulation[b]			•		•	•			R	✓	✓					
Foundation insulation[b]			•		•				R	✓	✓				✓	
Ceiling insulation[c]			•	•	•				R	✓	✓		✓			
Air leakage							•		R	✓	✓		✓	✓		
Equipment efficiency (Htg, Clg, WH)			•					•	U.S.							

C = Census tract (avg. 4,000 people)
R = Regional (27 RECS reportable domains, 10 census divisions, or 8 IECC climate zones)

Heating Fuel Type



Vintage (% by Decade Built)



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Approach – 2) Archetypes/Characteristics/Climates

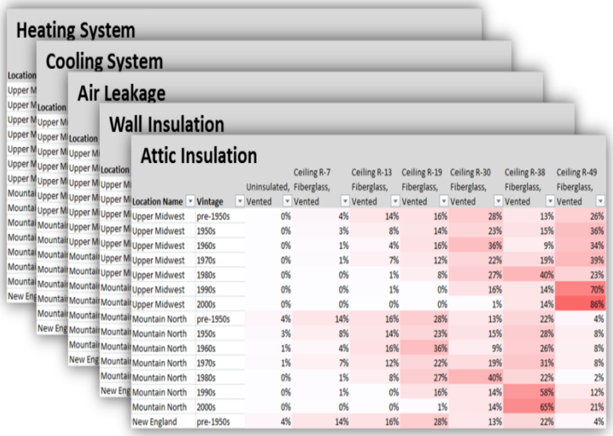
To represent the U.S residential building stock, auto-generate simulation models for combinations of archetypes/characteristics/climates, ranked by house-count weighting factors.

Archetypes

6 Floor areas
3 # stories
5 Foundation types
7 Vintages
6 Heating fuel types
3 Occupancy usage levels

~11K
Possible
Combinations

Characteristics

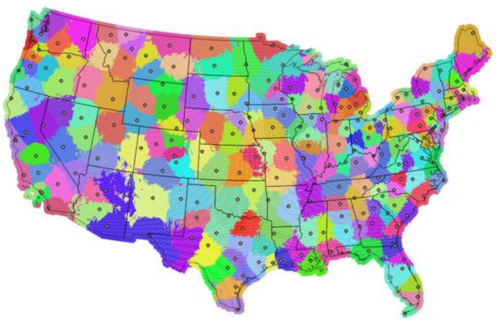


Location Name	Vintage	Uninsulated, Vented	Ceiling R-7 Fiberglass, Vented	Ceiling R-13 Fiberglass, Vented	Ceiling R-19 Fiberglass, Vented	Ceiling R-30 Fiberglass, Vented	Ceiling R-38 Fiberglass, Vented	Ceiling R-49 Fiberglass, Vented
Upper Midwest	pre-1950s	0%	4%	14%	16%	28%	13%	26%
Upper Midwest	1950s	0%	3%	8%	14%	23%	15%	36%
Upper Midwest	1960s	0%	1%	4%	16%	36%	9%	34%
Upper Midwest	1970s	0%	1%	7%	12%	22%	19%	39%
Upper Midwest	1980s	0%	0%	1%	8%	27%	40%	23%
Upper Midwest	1990s	0%	0%	1%	0%	16%	14%	70%
Upper Midwest	2000s	0%	0%	0%	0%	1%	14%	86%
Mountain North	pre-1950s	4%	14%	16%	28%	13%	22%	4%
Mountain North	1950s	3%	8%	14%	23%	15%	28%	8%
Mountain North	1960s	1%	4%	16%	36%	9%	26%	8%
Mountain North	1970s	1%	7%	12%	22%	19%	31%	8%
Mountain North	1980s	0%	1%	8%	27%	40%	22%	2%
Mountain North	1990s	0%	1%	0%	16%	14%	58%	12%
Mountain North	2000s	0%	0%	0%	1%	14%	65%	21%
New England	pre-1950s	4%	14%	16%	28%	13%	22%	4%

⋮

~6M
Possible
Combinations

Climates



1080
545
250
125
?

Note: Not all possible archetype/characteristic/climate combinations have non-zero house-count weighting factors.

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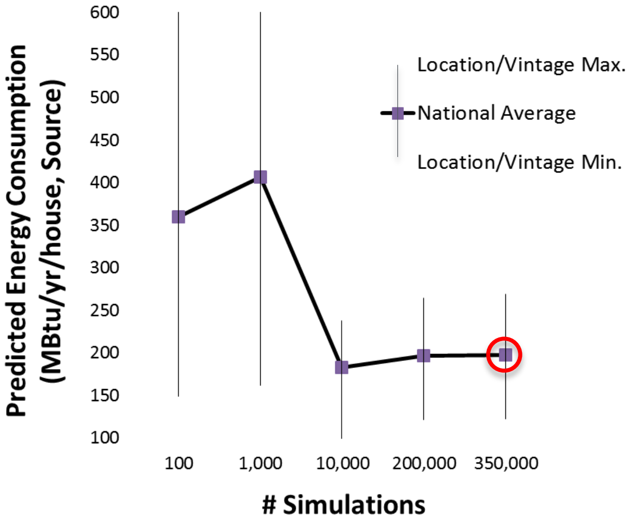
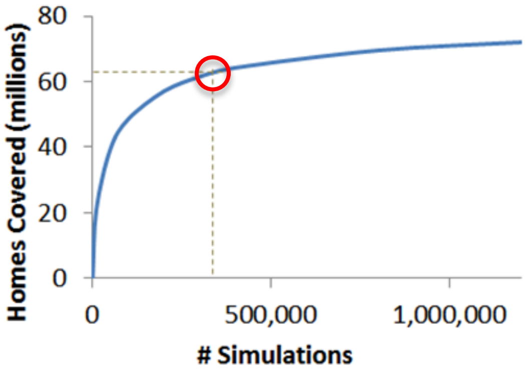
Approach – 3) Building Simulations

Whole-building archetype/occupant/climate simulations were run (using BEopt/EnergyPlus on NREL's **high-performance supercomputer**).





- Simulations based on sample of high house-count combinations of archetypes/characteristics/climates
- 350K simulations for existing homes (**1.2 million simulations** w/retrofits)
- 2.4 years worth of CPU runtime
- Simulations cover 62 million homes; results will be scaled to represent all 72 million single family detached homes

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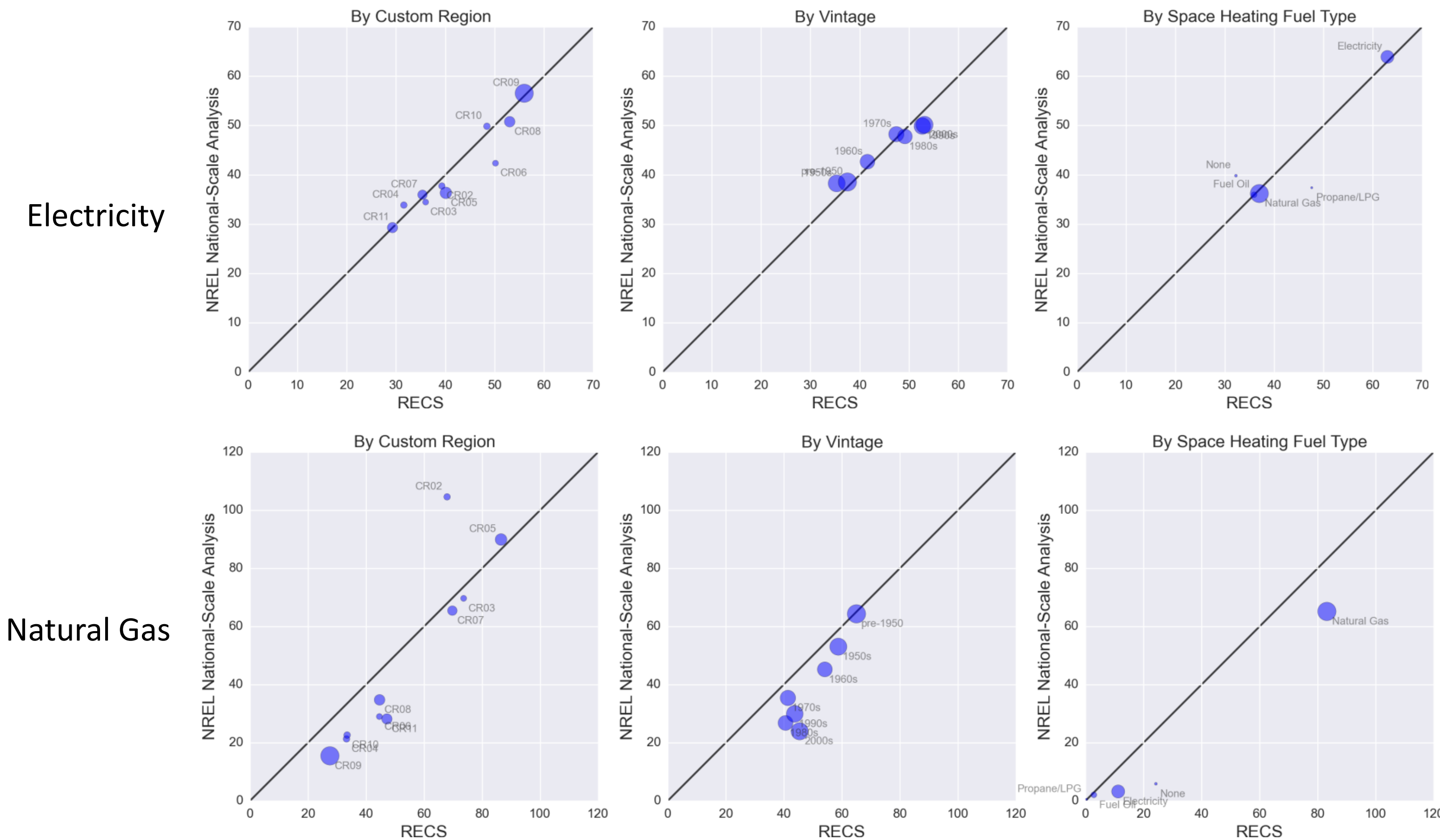
Approach – 4) Validation/Calibration

Modeled results are compared to EIA/RECS values

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



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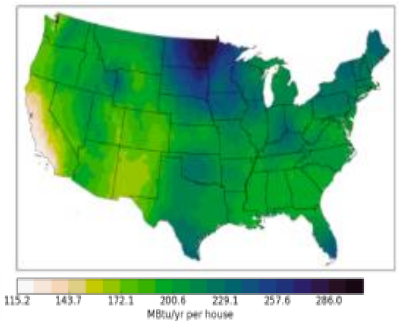
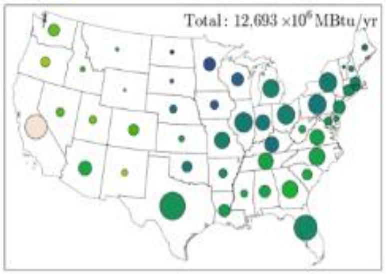
Approach – 5) Output Visualization

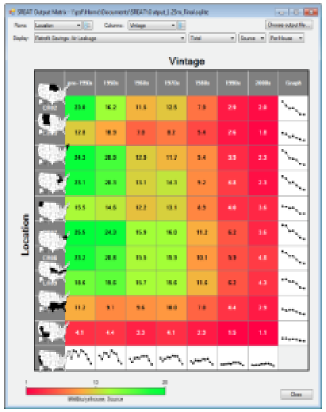
Results, from the output database, **can be sliced in many ways** (consumption, retrofit savings, end uses, year-built, fuel types, etc.) and **visualized in various forms**.

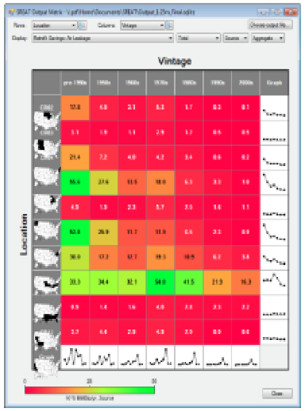
Maps



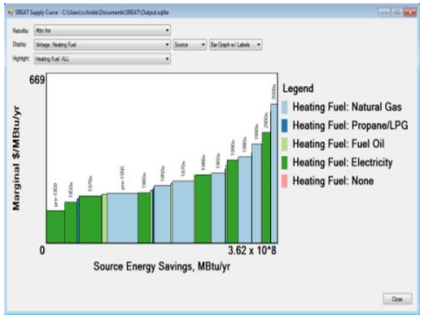


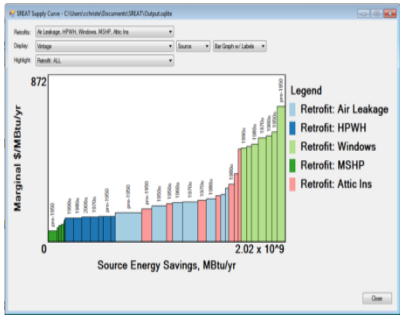
Matrices





Supply Curves





Progress and Accomplishments

Lessons Learned:
Some users may want a stand-alone version that does not require use of NREL's supercomputer (cloud computing could be used to meet this need).

Accomplishments: Implementation of the technical approach:

1.	Housing Stock Characteristics – Input Database	80%
2.	Archetypes/Occupants/Climates – Auto-Generated Models	100%
3.	Building Simulation – High Performance Computing	100%
4.	Validation/Calibration – Comparison with RECS Data	70%
5.	Output Visualization – Maps, Heatmap Matrices, Supply Curves, etc.	90%

Market Impact: Exploring a wide range of use cases, initially focusing on DOE (RBI, BTO, EIA, EPSA).

- Policy makers: Potential studies and technology gaps
- Program planners: Optimize incentive spending and marketing
- Manufacturers: R&D planning and marketing
- Retailers: Product offering and marketing

Awards/Recognition: No awards to date.

Possible Users/Uses

Federal

- Policy Analysts
  - carbon savings potential
- DOE/BTO
  - RBI BA Solution Center
  - ET technology potential
  - Codes and Standards
  - Staged Upgrade Initiative (SUI)

Private

- Manufacturers
  - Prioritized technology R&D and product development
  - Marketing
- Vendors/Retailers (big-box /internet)
  - Product offerings
  - Marketing

Non-Federal

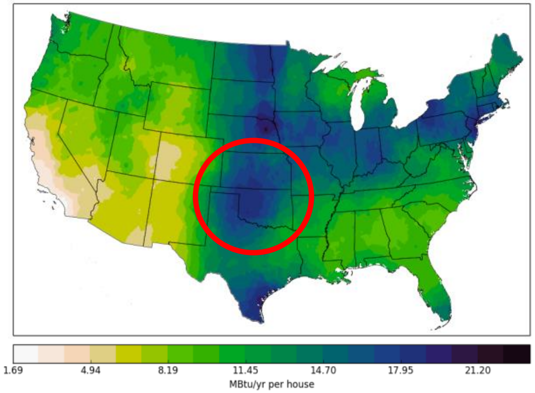
- NGO's , Advocates
- Program Planners (Utility, Regional, State and Local)
  - Technology selection
  - Potential studies
  - Setting incentives

Preliminary Results

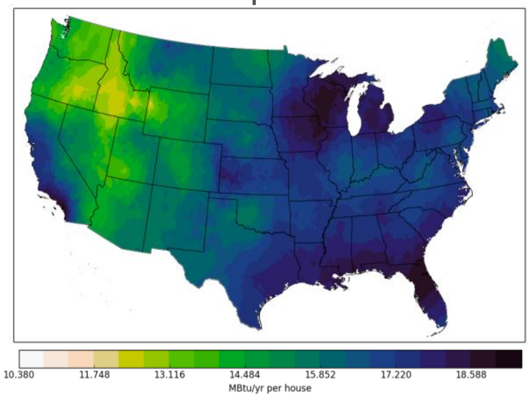
State and Local Program Planners

Identify Best Upgrades -- for a Particular State (e.g., Oklahoma)

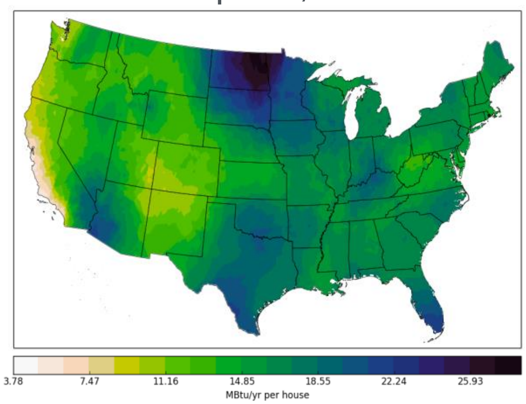
Air Sealing [1]



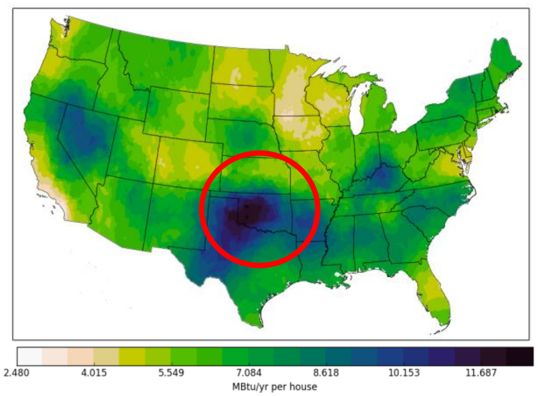
Heat Pump Water Heater [2]



Double-pane, low-e [3]



Attic Insulation [4]



(MBtu/yr per home)

Technical Potential:

[1] to 5 ACH50

[2] replacing electric tank WH

[3] single pane to double low-e

[4] to R-49

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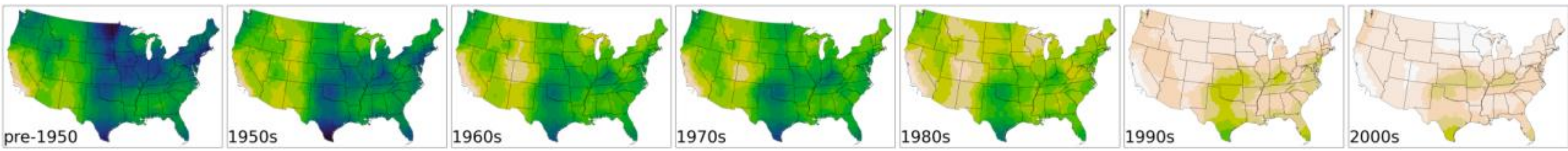
Preliminary Results

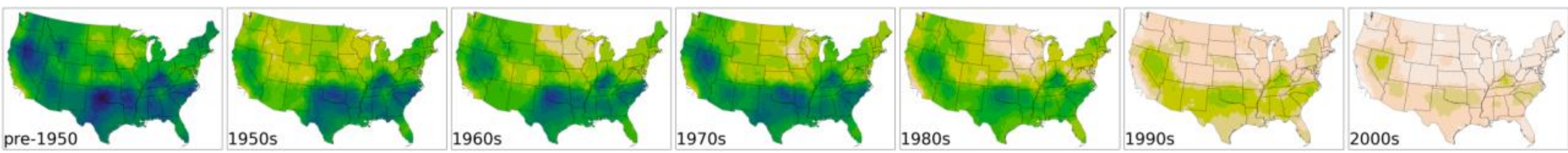
National Program Planners

Target Markets – by Location and Year-Built

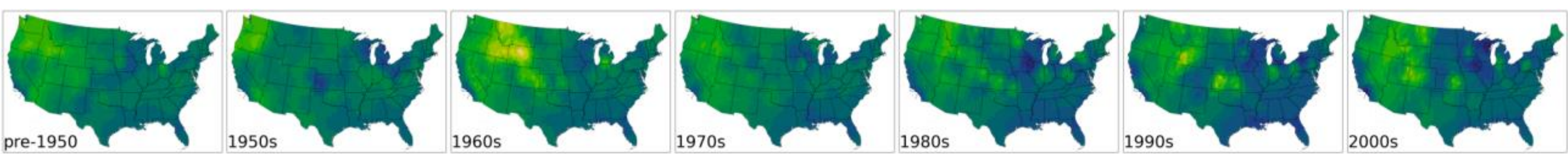
Air Sealing (to 5 ACH50)



Attic Insulation (to R49)



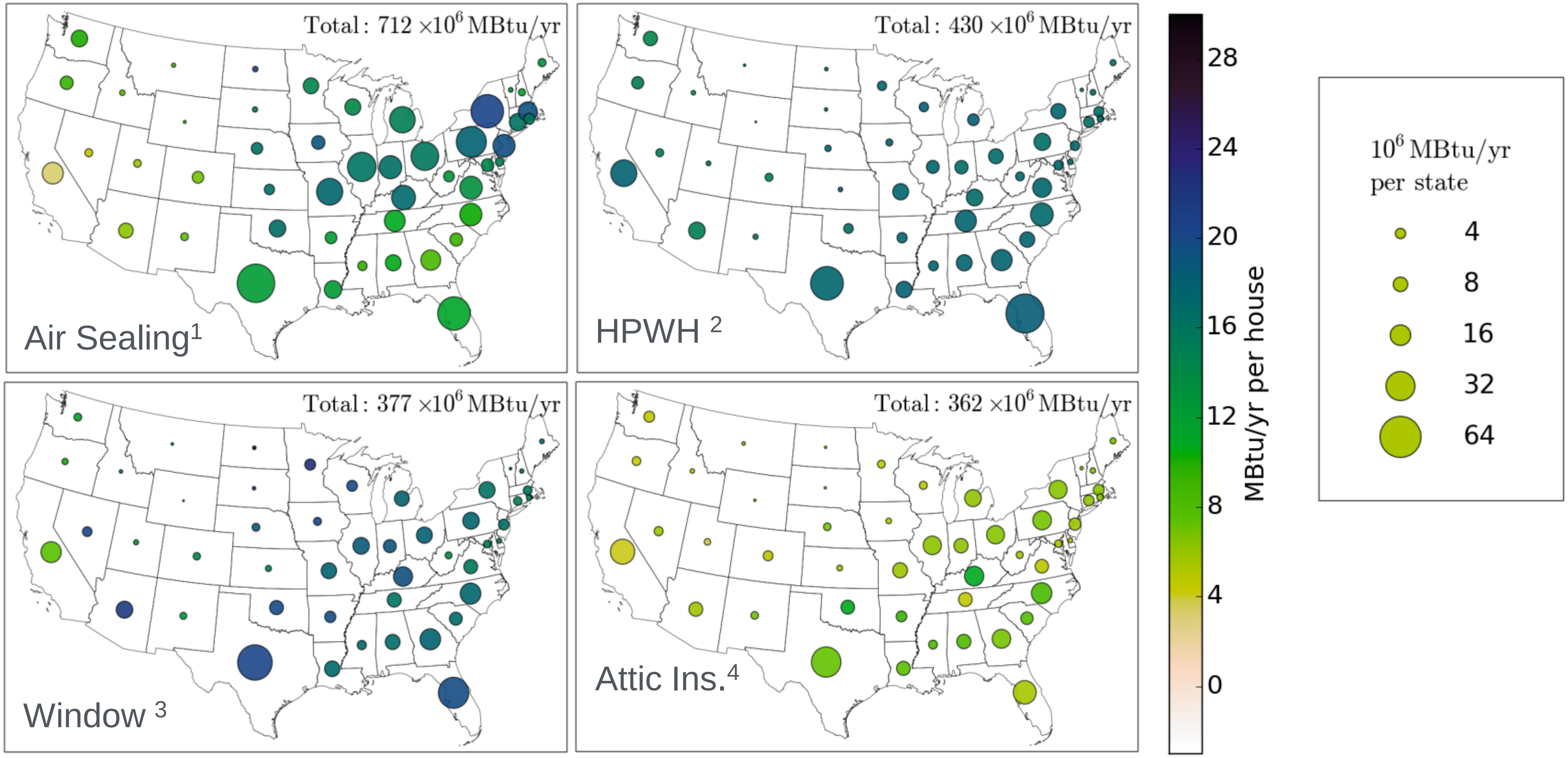
Heat Pump Water Heater



Preliminary Results

Policy Analysts

Quantify Aggregate Savings Potential



Technical Potential:

[1] to 5 ACH50

[2] replacing electric tank WH

[3] single pane to double low-e

[4] to R-49

Project Integration and Collaboration

Project Integration:

- Based on data from: EIA (RECS), Census (ACS), BPA/NEEA (RBSA), NAHB.
- Working with DOE RBI to coordinate use cases with others at DOE.

Partners, Subcontractors, and Collaborators:

- CPS Energy, University of Texas–San Antonio (past)
- Bonneville Power Administration (future)

Communications:

- 2014 ACEEE Building Energy Efficiency Summer Study
- Webinar for DOE RBI managers
- Follow-on discussions with others at DOE
- Webinar for BPA managers

Next Steps and Future Plans

Next Steps and Future Plans:

- Work with user audience to initiate specific use cases
- Coordinate with NREL Commercial Buildings Group
- Collaborate on OpenStudio version (that can use cloud computing)
- BPA Regional Analysis Tool (FY2016)
- Calibration to utility hourly load shapes

REFERENCE SLIDES

Project Budget

Project Budget:

- $100k 2013
- $425k 2014
- $400k 2015

Additional Funding:

- $200k 2011-2012 CPS Energy
- $340k 2012-2013 NREL
- $280k 2016 BPA

Budget History					
FY2013 – FY2014 (past)		FY2015 (current)		FY2016 – ? (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$525k	$540k	$400k	–	TBD	$280k

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Project Plan and Schedule

- FY2015 plan builds on substantial cross-cutting work from prior years

Project Schedule												
Project Start: 2013		Completed Work										
Projected End: ?		Active Task (in progress work)										
		Milestone/Deliverable (Originally Planned)										
		Milestone/Deliverable (Actual)										
	FY2013				FY2014				FY2015			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Q4Milestone: Draft methodology												
Q3 Milestone: Draft EE potential maps												
Q4: Deliverable: Final EE potential maps												
Current/Future Work												
Q1: Go/No Go decision												
Q2 Milestone: Presentation of two use cases												
Q4 Deliverable: Beta version with cost optimizaton												