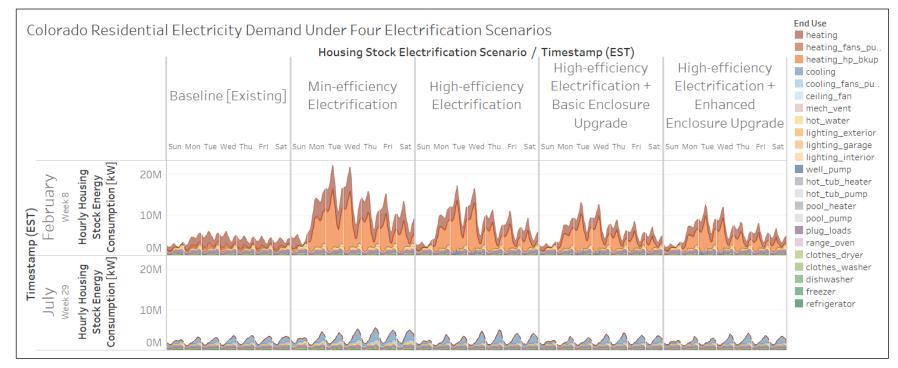
ResStock *and* **End-Use Savings Shapes for the U.S. Housing Stock**



Performing Organization(s): NREL

PI Name and Title: Anthony Fontanini, Senior Researcher (ResStock Core/ResStock Development) and Elaina Present, Researcher (End-Use Savings Shapes)

PI Tel and/or Email: <u>Anthony.Fontanini@nrel.gov</u> and <u>Elaina.Present@nrel.gov</u> WBS #: All of 1.5.1.32 (ResStock Core), Part of 3.4.6.57 (EULP & EUSS), and a smattering of others

Project Summary

Objective and Outcome

- EULP Understand how and when energy is used in homes today
- EUSS Understand how and when energy is used in homes under "what if" energy efficiency and electrification scenarios
- ResStock Core Maintain and continuously improve our ResStock tool for U.S. building stock energy modeling so that we can create credible, consistent, accessible, useful datasets to support stakeholder decision-making

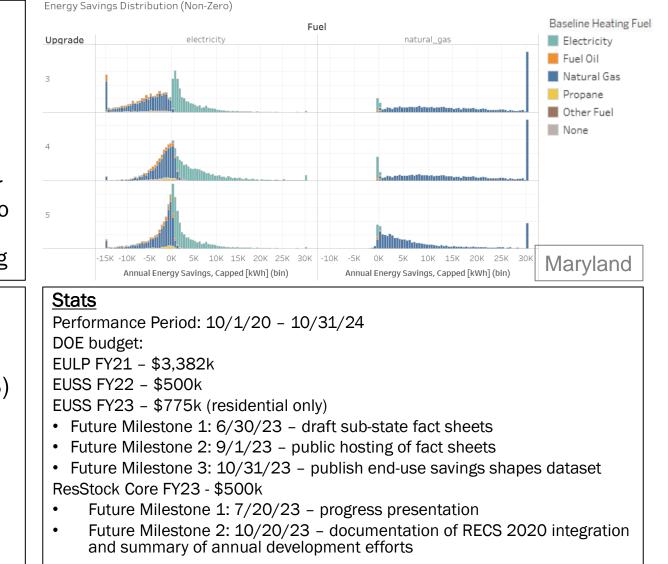
Team and Partners

Current: NREL

5 primary contributors (Residential EULP/EUSS)

5 primary contributors (ResStock Core)

Recent: major collaboration with LBNL and ANL, and support from our 90+ member Technical Advisory Group through fall 2021



Problem: Lack of Credible Information in Support of BTO Goals

Increase building energy efficiency • Accelerate building electrification • Prioritize equity, affordability, and resilience

Achieving BTO's goals requires large-scale retrofitting of the current U.S. residential building stock.

A lack of credible, relevant, and accessible information on the potential impacts of energy efficiency and electrification measures contributes to inaction by cities, states, utilities, and other major stakeholders.

For example, will electrification of buildings...

- Reduce carbon emissions in my city?
- Make our residents' bills increase?
- Overload the grid?

Problem: Information Is Limited, Good Information Is Expensive

- Utility-funded metering studies (Northwest End Use Load Research Project, CA End Use Surveys)
 - Very expensive (estimated \$100M cost for nationally comprehensive study)
 - Limited in geographic scope only available for a fraction of U.S.
 - Out of date quickly
 - Difficult to apply what-if scenarios to measured data

• EPRI Load Shape Library

- $\circ~$ Confidence and precision levels are unknown
- $\circ~$ Collected from a range of sources dating back to 2000
- Scaling prototype model load shapes

(DOE Prototypes, DOE Reference Buildings, DEER Prototypes)

- $\circ~$ Widely used by industry and academia (368 citations)
- o Little or no calibration to measured data
- $\circ \ \ \text{Minimal diversity}$

Alignment and Impact

We are putting information in the hands of decision makers

To reduce barriers and enable work toward BTO energy efficiency, electrification, and equity goals

What ResStock datasets can provide

Housing stock characterization

When and how homes use energy

Potential impacts of energy efficiency

Information on time-sensitive value of energy resources

Potential impacts of building electrification

Key use cases

Electrification prioritization

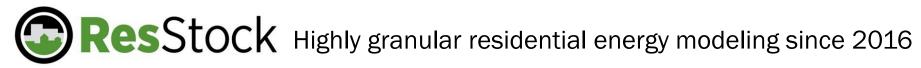
Emissions analysis

Decarbonization planning

Utility integrated resource plans and load forecasts

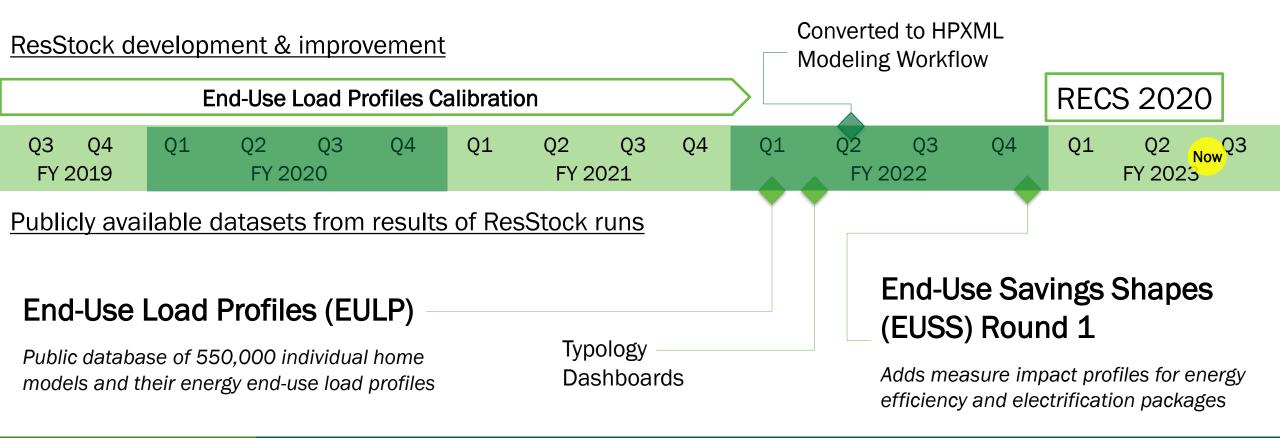
Policy and rate design

Approach – Our ResStock Tool & its Models and Datasets

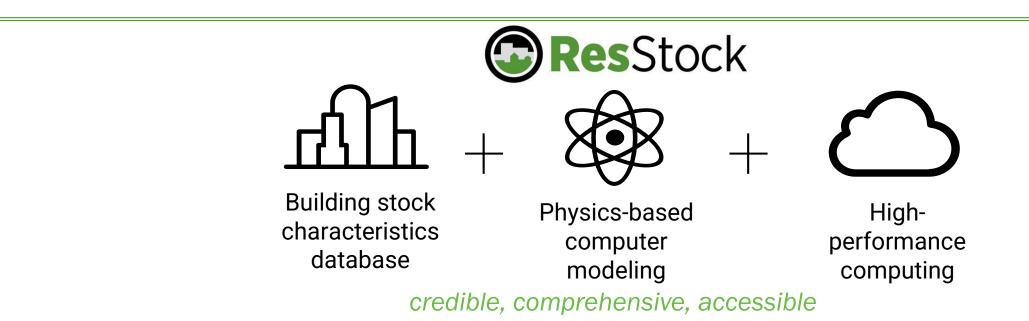


Hundreds of thousands of representative, statistically generated residential energy models run using a supercomputer & cloud computing

Major efforts since last BTO Peer Review in April 2019



Approach – ResStock Workflow Overview



- 1. Describe the U.S. building stock quantitatively
- 2. Sample the description
- 3. Model the samples (typically 550,000 models)
- 4. Model changes to the samples energy efficiency, electrification, etc.
- 5. Publish description, samples, models, results, aggregations, visualizations, and documentation Includes extensive comparisons to other datasets.

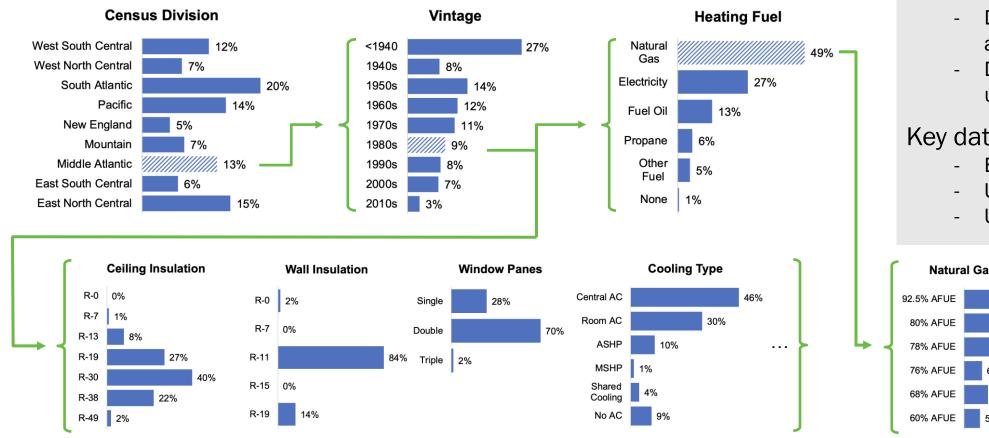
Simple, fast

Simple & fast enough

U.S. DEPARTMENT OF ENERGY

Complex, slow

Approach – ResStock Technical Overview

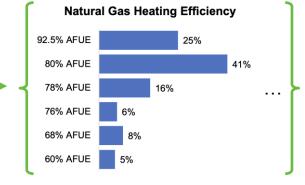


100+ home characteristics

- Distributions based on best available data
- Distribution varies based on upstream factors

Key data sources:

- EIA RECS
- US Census AHS
- US Census ACS



We sample 550,000 homes from these housing characteristics distributions – roughly 1/240 – then model them using open-source DOE models

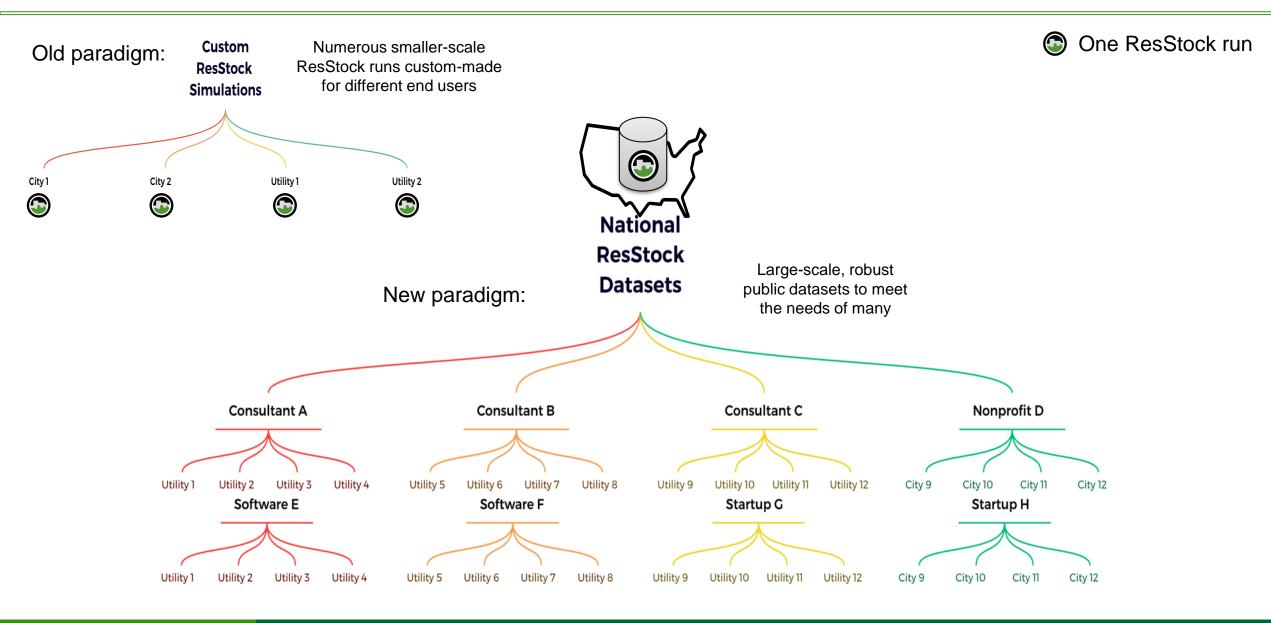


and a big data technology stack

OpenStudio EnergyPlus

U.S. DEPARTMENT OF ENERGY

Approach – ResStock Model Deployment



FY23 ResStock Team Project Summary

2 core BTO-funded efforts: EUSS/EULP & ResStock Core

- **10** total BTO-funded efforts:
- 4 development-focused
- 6 analysis-focused

20 total DOE-funded efforts contributing to or leveraging ResStock

25 total projects using results from ResStock

Variety of large and small efforts. Moving to our new paradigm is a work in progress.

Overview of EULP & EUSS – Public ResStock Datasets

End-Use Load Profiles (EULP)

Describes how and when energy is used in buildings **today**

Public database of 550,000 individual home models and their energy end-use load profiles

End-Use Savings Shapes (EUSS)



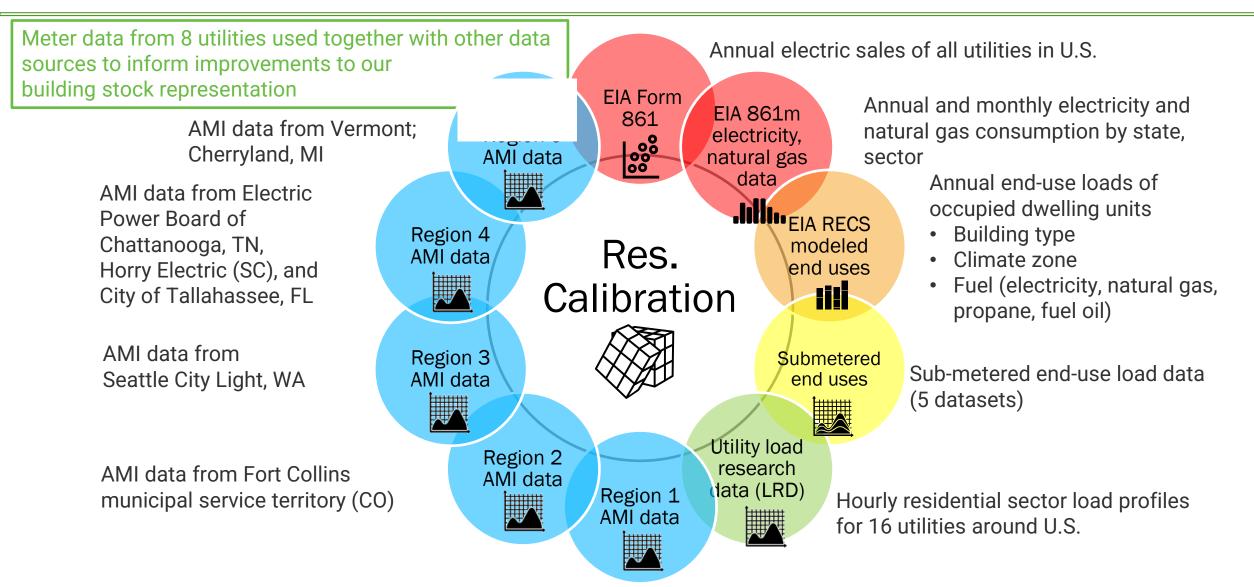
Describes how and when energy is used in "what if" scenarios

Adds measure impact profiles for energy efficiency and electrification packages

"We want to assess potential energy and cost savings for municipal buildings after electrification and energy conservation measure implementations."

Zahra Seblini, City of Detroit's Office of Sustainability

EULP Approach to ResStock Model Improvement



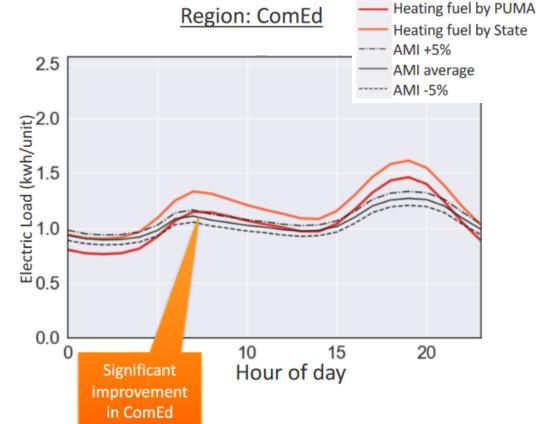
Advanced metering infrastructure (AMI) data from ComEd service territory (IL)

EULP ResStock Model Improvement and Calibration Process

- <u>Not</u> automated tuning to minimize error
- Examined comparisons of our results to other datasets to find areas needing improvement, then found and analyzed stock data with increased **accuracy, diversity, or resolution**
- All model updates overseen by 70+ member Technical Advisory Group and thoroughly documented in our <u>Methodology and Documentation</u> report

Example: Model Improvement Informed by Measured Data

- Observed our electric load results in winter higher than utility data
- Revised geographic resolution of modeled heating fuel distribution to PUMA rather than state level
- Observed closer alignment between our load results and utility data.



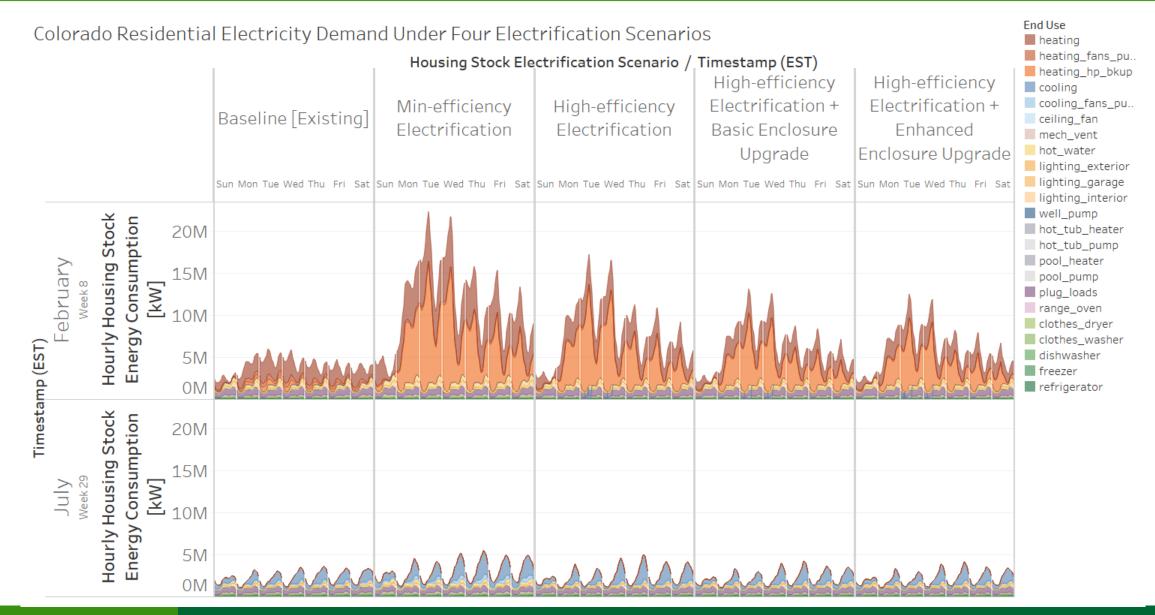
EUSS Residential Round 1 Overview

- 15-minute resolution
- 48 states + DC
- 3 weather years: AMY 2018, AMY 2012, TMY3
- 550,000 representative dwelling units for each run
- End-use energy consumption & savings
- Avoided emissions

10 Measure Packages of Energy Efficiency and Electrification

1	Basic enclosure
2	Enhanced enclosure
3	Heat pumps, min-efficiency, electric backup
4	Heat pumps, high-efficiency, electric backup
5	Heat pumps, min-efficiency, existing heating as backup
6	Heat pump water heaters
7	Whole-home electrification, min-efficiency
8	Whole-home electrification, high efficiency
9	Whole-home electrification, high efficiency + basic enclosure package
10	Whole-home electrification, high efficiency + enhanced enclosure package

EUSS Residential Round 1 – Data Example



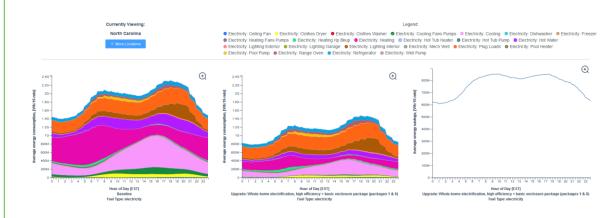
Data Access Paths for EULP & EUSS Public Datasets

Open Energy Data Initiative (OEDI)

- Metadata and Annual files
 - Each modeled home's characteristics, measure applicability, and annual results, for each measure package
 - Excel-friendly at the state level (.csvs < 200 MB)
- Pre-aggregated timeseries files
 - Geographic levels: climate zones, states, ISO/RTO
 - Geography-total energy consumption, pre and post measure, energy savings, carbon emissions & avoided carbon emissions
 - 15-minute results
 - Excel-friendly (approx. 50 MB)
- Individual Model Files
 - Model-level inputs, weather data, schedules, & outputs
 - Not Excel-friendly

Web Data Viewer

- Graphical User Interface



- Custom Data Download & Aggregation Tool
 - Filter on any characteristic
 (e.g., location, vintage, wall type)
 - Download aggregated residential loads from that filter

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	50715.3 49445.8	26781.6 24345.1 22207.5	222831 215085 211398	899.759 899.759	1035.59 1035.59 1035.59	52233.7 53175.4 56724.3 58966.9	2479.91 2479.91 2479.91	354.964 603.148 603.148 603.148	45110.2 44606.6 43912.9 43612.4	780.63 630.025 630.025 630.025	114659 115124 114712	0 9053. 0 9495. 0 9495.	52 -13703 65 -15759 65 -17846 65 -19225	11339 11802.2 11769.5 11936.6	21775.8 21601 21601	1767.07 1819.13 1819.13	0 0 0 0	474.449 458.199 437.265	625.314 0 65.4976	5370.3 5702.97 5993.06 8064.36	2045.18 2105.64 2105.64	1061.3 1138.01 1138.01	0 18038 0 18051 0 17451	94 160.089 54 126.383 59 126.383 87 126.383	215430 223602 231113 215378	210.188 210.188 210.188	8895.25 8895.25
6 5161.02 6 5161.02	50715.3 49445.8 47911.4	26781.6 24345.1 22207.5 19853.8	222831 215085 211398 205557	899.759 899.759 899.759 899.759	1035.59 1035.59 1035.59 1035.59	52233.7 53175.4 56724.3 58966.9 53367.9	2479.91 2479.91 2479.91 2479.91 2479.91	354.964 603.148 603.148 603.148 603.148	45110.2 44606.6 43912.9 43612.4 43239.5	780.63 630.025 630.025 630.025 630.025	114659 115124 114712 114349 114070	0 9053. 0 9495. 0 9495. 0 9495. 0 9495.	52 -13703 65 -15759 65 -17846 65 -19225 65 -20549	11339 11802.2 11769.5 11936.6 10869.7	21775.8 21601 21601 21601 21601	1767.07 1819.13 1819.13 1819.13 1819.13	0 0 0 0	474.449 458.199 437.265 418.106 397.669	625.314 0 65.4976 441.168 310.67	5370.3 5702.97 5993.06 8064.36 10115.3	2045.18 2105.64 2105.64 2105.64 2105.64	1061.3 1138.01 1138.01 1138.01 1138.01	0 18038 0 1805 0 1745 0 17027 0 16515	94 160.089 54 126.383 59 126.383 87 126.383 77 126.383	215430 223602 231113 215378 214043	210.188 210.188 210.188 210.188 210.188	8895.25 8895.25 8895.25 8895.25
6 5161.02 6 5161.02 7 5161.02	50715.3 49445.8 47911.4 48126	26781.6 24345.1 22207.5 19853.8 19552.8	222831 215085 211398 205557 207562	899.759 899.759 899.759 899.759 845.037	1035.59 1035.59 1035.59 1035.59 971.187	52233.7 53175.4 56724.3 58966.9 53367.9 57299.1	2479.91 2479.91 2479.91 2479.91 2561.02	354.964 603.148 603.148 603.148 603.148 603.148	45110.2 44606.6 43912.9 43612.4 43239.5 42236.4	780.63 630.025 630.025 630.025 630.025 748.669	114659 115124 114712 114349 114070 115699	0 9053. 0 9495. 0 9495. 0 9495. 0 9495. 0 9495. 0 9053.	52 -13703 65 -15759 65 -17846 65 -19225 65 -20549 52 -21846	11339 11802.2 11769.5 11936.6 10869.7 12325.9	21775.8 21601 21601 21601 21601 21601 21601	1767.07 1819.13 1819.13 1819.13 1819.13 1819.13	0 0 0 0 0	474.449 458.199 437.265 418.106 397.669 392.347	625.314 0 65.4976 441.168 310.67 233.677	5370.3 5702.97 5993.06 8064.36 10115.3 10045	2045.18 2105.64 2105.64 2105.64 2105.64 2105.64	1061.3 1138.01 1138.01 1138.01 1138.01 1138.01 1192.51	0 18038 0 18051 0 17451 0 17027 0 16515 0 16530	94 160.089 54 126.383 59 126.383 87 126.383 77 126.383 08 118.435	215430 223602 231113 215378 214043 210594	210.188 210.188 210.188 210.188 210.188	8895.25 8895.25 8895.25 8895.25 8474.23
6 5161.02 6 5161.02 7 5161.02	50715.3 49445.8 47911.4 48126 46419.9	26781.6 24345.1 22207.5 19853.8 19552.8 16796.9	222831 215085 211398 205557 207562 198396	899.759 899.759 899.759 899.759 845.037 845.037	1035.59 1035.59 1035.59 1035.59 971.187 971.187	52233.7 53175.4 56724.3 58966.9 53367.9 57299.1 56103.7	2479.91 2479.91 2479.91 2479.91 2561.02 2561.02	354.964 603.148 603.148 603.148 603.148 603.148 603.148 603.148	45110.2 44606.6 43912.9 43612.4 43239.5 42236.4 41922.3	780.63 630.025 630.025 630.025 630.025 748.669 748.669	114659 115124 114712 114349 114070 115699 115454	0 9053. 0 9495. 0 9495. 0 9495. 0 9495. 0 9495. 0 9053. 0 9053.	52 -13703 65 -15753 65 -17846 65 -19225 65 -20549 52 -21846 52 -22957	11339 11802.2 11769.5 11936.6 10869.7 12325.9 14555.5	21775.8 21601 21601 21601 21601 21601 21601	1767.07 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13	0 0 0 0 0 0	474.449 458.199 437.265 418.106 397.669 392.347 422.789	625.314 0 65.4976 441.168 310.67 233.677 560.526	5370.3 5702.97 5993.06 8064.36 10115.3 10045 10782.1	2045.18 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64	1061.3 1138.01 1138.01 1138.01 1138.01 1138.01 1192.51 1192.51	0 18038 0 18051 0 17451 0 17027 0 16515 0 16530 0 15933	94 160.089 54 126.383 59 126.383 87 126.383 77 126.383 08 118.435 64 118.435	215430 223602 231113 215378 214043 210594 208903	210.188 210.188 210.188 210.188 210.188 210.188 210.188	8895.25 8895.25 8895.25 8895.25 8474.23 8474.23
6 5161.02 6 5161.02 7 5161.02 5 5161.02 81 5161.02	50715.3 49445.8 47911.4 48126 46419.9 45063	26781.6 24345.1 22207.5 19853.8 19552.8 16796.9 14734.6	222831 215085 211398 205557 207562 198396 194219	899.759 899.759 899.759 899.759 845.037 845.037 845.037	1035.59 1035.59 1035.59 1035.59 971.187 971.187 971.187	52233.7 53175.4 56724.3 58966.9 53367.9 57299.1 56103.7 50501.3	2479.91 2479.91 2479.91 2479.91 2561.02 2561.02 2561.02	354.964 603.148 603.148 603.148 603.148 603.148 603.148 603.148 603.148	45110.2 44606.6 43912.9 43612.4 43239.5 42236.4 41922.3 41185.3	780.63 630.025 630.025 630.025 630.025 748.669 748.669 748.669	114659 115124 114712 114349 114070 115699 115454 115044	0 9053 0 9495 0 9495 0 9495 0 9495 0 9495 0 9053 0 9053 0 9053	52 -13703 65 -15759 65 -17846 65 -19225 65 -20549 52 -21846 52 -22957 52 -2411	11339 11802.2 11769.5 11936.6 10869.7 12325.9 14555.5 14740.9	21775.8 21601 21601 21601 21601 21601 21601 21601	1767.07 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13	0 0 0 0 0 0 0	474.449 458.199 437.265 418.106 397.669 392.347 422.789 364.388	625.314 0 65.4976 441.168 310.67 233.677 560.526 374.464	5370.3 5702.97 5993.06 8064.36 10115.3 10045 10782.1 10706.5	2045.18 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64	1061.3 1138.01 1138.01 1138.01 1138.01 1138.01 1192.51 1192.51 1192.51	0 18038 0 1805 0 1745 0 17027 0 16515 0 16530 0 15933 0 15468	94 160.089 54 126.383 59 126.383 87 126.383 77 126.383 08 118.435 64 118.435 30 118.435	215430 223602 231113 215378 214043 210594 208903 207374	210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188	8895.25 8895.25 8895.25 8895.25 8474.23 8474.23 8474.23
6 5161.02 6 5161.02 7 5161.02 5 5161.02 81 5161.02	50715.3 49445.8 47911.4 48126 46419.9	26781.6 24345.1 22207.5 19853.8 19552.8 16796.9 14734.6	222831 215085 211398 205557 207562 198396 194219	899.759 899.759 899.759 899.759 845.037 845.037	1035.59 1035.59 1035.59 1035.59 971.187 971.187 971.187	52233.7 53175.4 56724.3 58966.9 53367.9 57299.1 56103.7 50501.3	2479.91 2479.91 2479.91 2479.91 2561.02 2561.02 2561.02	354.964 603.148 603.148 603.148 603.148 603.148 603.148 603.148	45110.2 44606.6 43912.9 43612.4 43239.5 42236.4 41922.3 41185.3	780.63 630.025 630.025 630.025 630.025 748.669 748.669 748.669	114659 115124 114712 114349 114070 115699 115454	0 9053. 0 9495. 0 9495. 0 9495. 0 9495. 0 9495. 0 9053. 0 9053.	52 -13703 65 -15759 65 -17846 65 -19225 65 -20549 52 -21846 52 -22957 52 -2411	11339 11802.2 11769.5 11936.6 10869.7 12325.9 14555.5	21775.8 21601 21601 21601 21601 21601 21601	1767.07 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13	0 0 0 0 0 0 0	474.449 458.199 437.265 418.106 397.669 392.347 422.789	625.314 0 65.4976 441.168 310.67 233.677 560.526 374.464	5370.3 5702.97 5993.06 8064.36 10115.3 10045 10782.1 10706.5	2045.18 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64	1061.3 1138.01 1138.01 1138.01 1138.01 1138.01 1192.51 1192.51	0 18038 0 18051 0 17451 0 17027 0 16515 0 16530 0 15933	94 160.089 54 126.383 59 126.383 87 126.383 77 126.383 08 118.435 64 118.435 30 118.435	215430 223602 231113 215378 214043 210594 208903	210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188	8895.25 8895.25 8895.25 8895.25 8474.23 8474.23 8474.23
6 5161.02 6 5161.02 7 5161.02 5 5161.02 5 5161.02 6 5161.02	50715.3 49445.8 47911.4 48126 46419.9 45063	26781.6 24345.1 22207.5 19853.8 19552.8 16796.9 14734.6 12748.7	222831 215085 211398 205557 207562 198396 194219 187717	899.759 899.759 899.759 899.759 845.037 845.037 845.037	1035.59 1035.59 1035.59 1035.59 971.187 971.187 971.187 971.187	52233.7 53175.4 56724.3 58966.9 53367.9 57299.1 56103.7 50501.3 51539.8	2479.91 2479.91 2479.91 2479.91 2561.02 2561.02 2561.02 2561.02	354.964 603.148 603.148 603.148 603.148 603.148 603.148 603.148 603.148	45110.2 44606.6 43912.9 43612.4 43239.5 42236.4 41922.3 41185.3 40721.6	780.63 630.025 630.025 630.025 630.025 748.669 748.669 748.669 748.669	114659 115124 114712 114349 114070 115699 115454 115044	0 9053 0 9495 0 9495 0 9495 0 9495 0 9495 0 9053 0 9053 0 9053	52 -13703 65 -15759 65 -17846 65 -19225 65 -20549 52 -21846 52 -22957 52 -24111 52 -25148	11339 11802.2 11769.5 11936.6 10869.7 12325.9 14555.5 14740.9 15594.4	21775.8 21601 21601 21601 21601 21601 21601 21601	1767.07 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13	0 0 0 0 0 0 0 0	474.449 458.199 437.265 418.106 397.669 392.347 422.789 364.388	625.314 0 65.4976 441.168 310.67 233.677 560.526 374.464 118.009	5370.3 5702.97 5993.06 8064.36 10115.3 10045 10782.1 10706.5 11496.1	2045.18 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64	1061.3 1138.01 1138.01 1138.01 1138.01 1138.01 1192.51 1192.51 1192.51	0 18038 0 1805 0 1745 0 17027 0 16515 0 16530 0 15933 0 15468	94 160.089 54 126.383 59 126.383 87 126.383 77 126.383 08 118.435 64 118.435 30 118.435 33 118.435	215430 223602 231113 215378 214043 210594 208903 207374 207074	210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188	8895.25 8895.25 8895.25 8895.25 8474.23 8474.23 8474.23 8474.23
6 5161.02 6 5161.02 7 5161.02 5 5161.02 91 5161.02 6 5161.02 6 5161.02 7 5898.31	50715.3 49445.8 47911.4 48126 46419.9 45063 43312.9 44542.2	26781.6 24345.1 22207.5 19853.8 19552.8 16796.9 14734.6 12748.7 15374.4	222831 215085 211398 205557 207562 198396 194219 187717 191994	899.759 899.759 899.759 845.037 845.037 845.037 845.037 845.037 845.037	1035.59 1035.59 1035.59 1035.59 971.187 971.187 971.187 971.187 971.187	52233.7 53175.4 56724.3 58966.9 53367.9 57299.1 56103.7 50501.3 51539.8 49331.8	2479.91 2479.91 2479.91 2561.02 2561.02 2561.02 2561.02 2561.02 2561.02 2479.91	354,964 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148	45110.2 44606.6 43912.9 43612.4 43239.5 42236.4 41922.3 41185.3 40721.6 39750.9	780.63 630.025 630.025 630.025 630.025 748.669 748.669 748.669 748.669 905.812	114659 115124 114712 114349 114070 115699 115454 115044 115044 114811 116215	0 9053 0 9495 0 9495 0 9495 0 9495 0 9053 0 9053 0 9053 0 9053 0 9053 0 9053	52 -13703 65 -15759 65 -17846 65 -19225 65 -20543 52 -21846 52 -22957 52 -24111 52 -25148 77 -25999	11339 11802.2 11769.5 11936.6 10869.7 12325.9 14555.5 14740.9 15594.4 17243.1	21775.8 21601 21601 21601 21601 21601 21601 21601 21601 21601 22507	1767.07 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13	0 0 0 0 0 0 0 0 0	474.449 458.199 437.265 418.106 397.669 392.347 422.789 364.388 343.17 328.481	625.314 65.4976 441.168 310.67 233.677 560.526 374.464 118.009 984.734	5370.3 5702.97 5993.06 8064.36 10115.3 10045 10782.1 10706.5 11496.1 11886.6	2045.18 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64	1061.3 1138.01 1138.01 1138.01 1138.01 1138.01 1192.51 1192.51 1192.51 1192.51 1088.55	0 18038 0 1805 0 1745 0 17027 0 16515 0 16530 0 15933 0 15468 0 14875 0 15383	94 160.089 54 126.383 59 126.383 87 126.383 77 126.383 08 118.435 64 118.435 30 118.435 83 118.435 76 118.435	215430 223602 231113 215378 214043 210594 208903 207374 207074 200000	210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188	8895.25 8895.25 8895.25 8474.23 8474.23 8474.23 8474.23 8474.23 8474.23
6 5161.02 6 5161.02 7 5161.02 5 5161.02 6 5161.02 6 5161.02 7 5898.31 4 5898.31	50715.3 49445.8 47911.4 48126 46419.9 45063 43312.9 44542.2 42024	26781.6 24345.1 22207.5 19853.8 19552.8 16796.9 14734.6 12748.7 15374.4 12648.2	222831 215085 211398 205557 207562 198396 194219 187717 191994 176742	899.759 899.759 899.759 845.037 845.037 845.037 845.037 845.037 845.037 845.037	1035.59 1035.59 1035.59 1035.59 971.187 971.187 971.187 971.187 971.187 971.187	52233.7 53175.4 56724.3 58966.9 53367.9 57299.1 56103.7 50501.3 51539.8 49331.8 48851.1	2479.91 2479.91 2479.91 2561.02 2561.02 2561.02 2561.02 2561.02 2479.91 2479.91	354,964 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148	45110.2 44606.6 43912.9 43612.4 43239.5 42236.4 41922.3 41185.3 40721.6 39750.9 39917.7	780.63 630.025 630.025 630.025 748.669 748.669 748.669 748.669 905.812 905.812	114659 115124 114712 114349 114070 115699 115454 115044 115044 114811 116215 116416	0 9053 0 9495 0 9495 0 9495 0 9495 0 9053 0 9053 0 9053 0 9053 0 9053 0 9053 0 9053 0 8976	52 -13703 65 -15759 65 -17846 65 -19225 65 -20543 52 -21846 52 -22957 52 -24111 52 -25148 77 -25999 77 -26717	11339 11802.2 11769.5 11936.6 10869.7 12325.9 14555.5 14740.9 15594.4 17243.1 17384.3	21775.8 21601 21601 21601 21601 21601 21601 21601 21601 22507 22507	1767.07 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1767.07	0 0 0 0 0 0 0 0 0 0 0	474.449 458.199 437.265 418.106 397.669 392.347 422.789 364.388 343.17 328.481 319.114	625.314 65.4976 441.168 310.67 233.677 560.526 374.464 118.009 984.734 310.954	5370.3 5702.97 5993.06 8064.36 10115.3 10045 10782.1 10706.5 11496.1 11886.6 12147.9	2045.18 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2045.18 2045.18	1061.3 1138.01 1138.01 1138.01 1138.01 1192.51 1192.51 1192.51 1192.51 1088.55 1088.55	0 18038 0 1805 0 1745 0 17027 0 16515 0 16530 0 15933 0 15468 0 14875 0 15383 0 14447	94 160.089 54 126.383 59 126.383 87 126.383 77 126.383 08 118.435 64 118.435 64 118.435 83 118.435 76 118.435 90 118.435	215430 223602 231113 215378 214043 210594 208903 207374 207074 200000 196179	210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188 203.589	8895.25 8895.25 8895.25 8474.23 8474.23 8474.23 8474.23 8474.23 8403.13 8403.13
6 5161.02 6 5161.02 7 5161.02 5 5161.02 6 5161.02 6 5161.02 7 5898.31 4 5898.31 2 5898.31	50715.3 49445.8 47911.4 48126 46419.9 45063 43312.9 44542.2 42024 40401	26781.6 24345.1 22207.5 19853.8 19552.8 16796.9 14734.6 12748.7 15374.4 12648.2 10785.2	222831 215085 211398 205557 207562 198396 194219 187717 191994 176742 172790	899.759 899.759 899.759 845.037 845.037 845.037 845.037 845.037 845.037 845.037 845.037	1035.59 1035.59 1035.59 1035.59 971.187 971.187 971.187 971.187 971.187 971.187 971.187	52233.7 53175.4 56724.3 58966.9 53367.9 57299.1 56103.7 50501.3 51539.8 49331.8 48851.1 44769.5	2479.91 2479.91 2479.91 2561.02 2561.02 2561.02 2561.02 2561.02 2479.91 2479.91 2479.91	354,964 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148 603,148	45110.2 44606.6 43912.9 43612.4 43239.5 42236.4 41922.3 41185.3 40721.6 39750.9 39917.7 39432.5	780.63 630.025 630.025 630.025 748.669 748.669 748.669 748.669 905.812 905.812 905.812	114659 115124 114712 114349 114070 115699 115454 115044 114811 116215 116416 115990	0 9053 0 9495 0 9495 0 9495 0 9495 0 9053 0 9053 0 9053 0 9053 0 9053 0 9053 0 9053 0 8976 0 8976	52 -13703 65 -15759 65 -17846 65 -19225 65 -20543 52 -21846 52 -22957 52 -24111 52 -25148 77 -25999 77 -25802	11339 11802.2 11769.5 11936.6 10869.7 12325.9 14555.5 14740.9 15594.4 17243.1 17384.3 15640.2	21775.8 21601 21601 21601 21601 21601 21601 21601 22507 22507 22507	1767.07 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1819.13 1767.07 1767.07	0 0 0 0 0 0 0 0 0 0 0 0 0	474.449 458.199 437.265 418.106 397.669 392.347 422.789 364.388 343.17 328.481 319.114 310.457	625.314 0 65.4976 441.168 310.67 233.677 560.526 374.464 118.009 984.734 310.954 313.154	5370.3 5702.97 5993.06 8064.36 10115.3 10045 10782.1 10706.5 11496.1 11886.6 12147.9 11564.8	2045.18 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2105.64 2045.18 2045.18 2045.18	1061.3 1138.01 1138.01 1138.01 1138.01 1192.51 1192.51 1192.51 1192.51 1088.55 1088.55 1088.55	0 18038 0 1805 0 1745 0 17027 0 16515 0 16530 0 15933 0 15468 0 14875 0 15383 0 14447 0 13937	94 160.089 54 126.383 59 126.383 87 126.383 77 126.383 08 118.435 64 118.435 30 118.435 30 118.435 76 118.435 90 118.435 31 18.435	215430 223602 231113 215378 214043 20594 208903 207374 207074 200000 196179 193640	210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188 210.188 203.589 203.589	8895.25 8895.25 8895.25 8474.23 8474.23 8474.23 8474.23 8474.23 8403.13 8403.13 8403.13
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Yes!

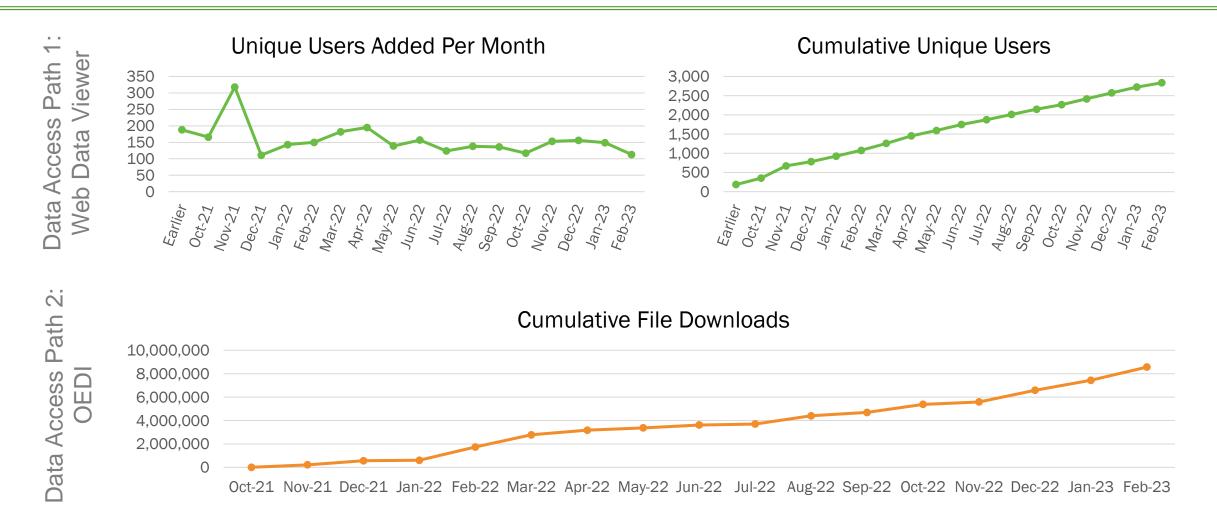
- Data integrated into Willdan/Integral Analytic's DSMore tool, used for IRP and utility program planning at utilities representing 26 million utility customers
- Cedar Falls Utilities using to see what the impact of electrifying heating in community may look like from an electric grid perspective, with a focus on dual fuel systems, in response to IRA incentives

- WattCarbon and other startups using to help large commercial building owners implement carbon reduction plans
- United Power co-op using in design of rebate programs
- NYISO and ISO-NE incorporating into long-term load forecasts for 35 million people
- U.S. EPA using in their Home Upgrade modeling

- CPUC & CA Public Advocates Office using to simulate bill impacts of a rate designed to promote electrification
- Rewiring America using to create state-by-state deployment prioritizations for IRA Efficiency Rebates
- MN Dept of Commerce using to inform creation of regulatory pathways for natural gas utilities

Currently, the datasets are being used across utility planning, utility rate design, load forecasting, decarbonization planning, and market sizing by entities such as the Minnesota Department of Commerce, the California Public Utility Commission, the New York Independent System Operator, and RMI.

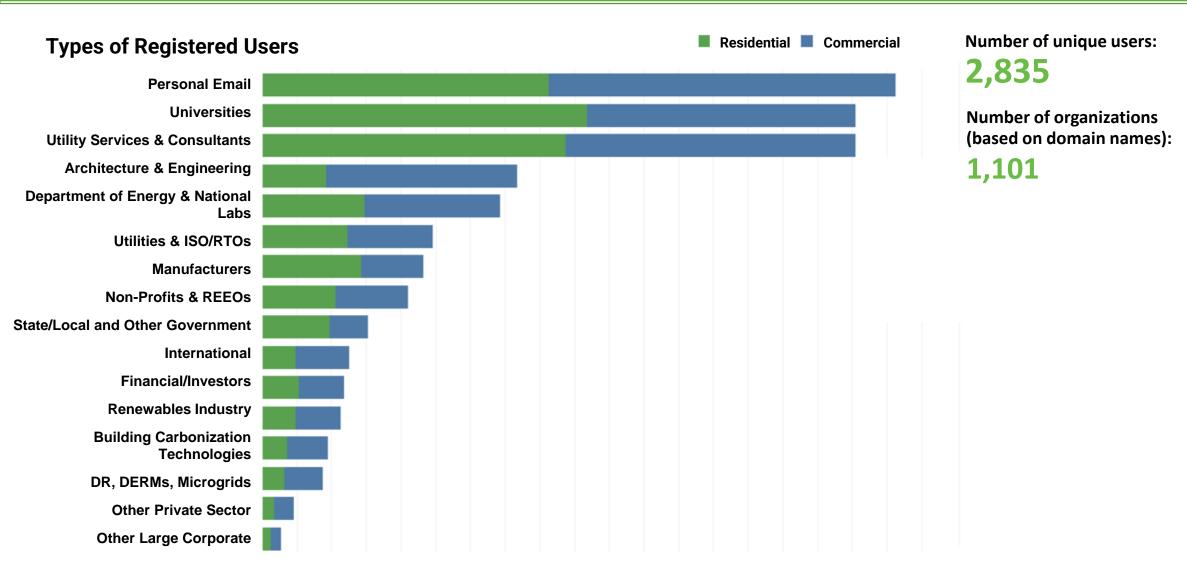
Consistent Interest in the Datasets



Consistently #1 most downloaded of 2,648 datasets on Open Energy Data Initiative (OEDI) since publication

Note: Figures on this slide represent combined EULP & EUSS for both Residential and Commercial

Variety in Dataset Users



"This is incredible. I've been wanting someone to do this since I started at NYSERDA, and here it is already completed."

James Geppner, RetrofitNY Senior Project Manager

Future Work

Development Plan Highlights

- Updating building characteristics informed by RECS 2020 – FY23
- Incorporate improved cold climate heat pump modeling currently in development for OpenStudio-HPXML – FY23
- Modeling electric vehicles and charging profiles
- Demographic correlations in the occupant schedules
- Geothermal heat pump modeling
- Grid-Aligned TMY weather files
- Future building stock scenarios

Planned Public Datasets (2023)

- Large run with annual outputs, with fact sheets and dashboards Summer 2023
 - Likely 40-60 measure packages
- EUSS Residential Round 2 (timeseries) Fall 2023
 - Likely 10 measure packages
 - To include improved heat pump models

The team is open to input on specifics of these planned public datasets

- Run with annual results: email <u>load.profiles@nrel.gov</u> ASAP (window of opportunity is nearly closed)
- Run with timeseries results: use input form available on our <u>website</u> (preferred), or email

Utility Companies:

The results of the EULP research effort will be tremendously helpful to Seattle City Light, allowing us to improve our load modeling of future residential and commercial electrification related to electric vehicles, heat pumps, and other end uses.

Michael Hamilton, Seattle City Light

Building Energy Modeling Industry:

We are excited to help our city and utility clients understand the local impacts of building electrification... with much more confidence than previously available methods such as California DEER or DOE prototype models.

Mudit Saxena, CEO & President, XeroHome / Vistar Energy Inc.

Utility DSM Consultants:

This dataset will be a very valuable resource for the utility demand side management industry.

Justin Spencer Apex Analytics

Technology Developers:

At Lunar Energy, we develop hardware and software products to enable whole-home electrification.

We're excited to engage with this critical dataset to help guide our product direction.

Randol Aikin, Techno Financial Modeling Lead Lunar Energy

Thank You

NREL

Elaina Present, Researcher III (EUSS) and Anthony Fontanini, Researcher IV (ResStock Core Development) Anthony.Fontanini@nrel.gov and Elaina.Present@nrel.gov

WBS # All of 1.5.1.32 (ResStock Core), Part of 3.4.6.57 (EULP & EUSS), and a smattering of others

https://resstock.nrel.gov/

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

REFERENCE SLIDES

Project Execution

EUSS (Residential + Commercial)	FY 202	3			FY24
Planned budget	\$1,200	,000			
Spent budget	\$711,0				
	Q1	Q2	Q3	Q4	Q1
Past Work					
Q1 Milestone: Commercial progress update					
Q2 Milestone: Draft Residential State-Level Dashboards					
Q2 Milestone: Commercial end-use saving shapes dataset - cycle 1					
Current/Future Work					
Q3 Milestone: Draft Residential Sub-State Fact Sheets			•		
Q4 Milestone: Public hosting of available sub-state fact sheets and sub-state public dashboards					
Q4 Milestone: Commercial end-use saving shapes dataset – cycle 2				•	
Q1 Milestone: Residential end-use saving shapes dataset - cycle 2					•
ResStock Core	FY 202	3			FY24
Planned budget	\$500,0	00			
Spent budget	\$419,0	00			
	Q1	Q2	Q3	Q4	Q1
		1	Q3	Q4	Q1

Past Work				
Q1 Milestone: Presentation on RECS 2020 integration and model development progress	\blacklozenge			
Current/Future Work				
Q2 Milestone: Presentation on ResStock Q2 developments		\blacklozenge		
Q3 Milestone: Presentation on ResStock Q3 developments			•	
Q4 Milestone: Documentation of RECS 2020 integration and summary of annual ResStock development				•

Team

EULP & EUSS - WBS 3.4.6.57

Elaina Present – Pl Chioke Harris – Senior contributor Lixi Liu – Senior contributor^ Philip White – Senior contributor Eric Wilson – Senior contributor, former Pl (on DOE detail)

ResStock Core - WBS 1.5.1.32

Anthony Fontanini – Pl Joe Robertson – Senior contributor Noel Merket – Senior contributor Rajendra Adhikari – Senior contributor^ Rohit Chintala – Contributor Prateek Munankarmi – Contributor Janet Reyna – Senior contributor, former Pl (on leave)

^Primary contributor on listed effort; additional contributor on alternative effort

Jenny Erwin – Project manager