End-use Load Profiles for the U.S. Building Stock

Technical Advisory Group meeting #3
June 18, 2019

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Logistics

- Welcome back!
- Because of the large number of participants on the phone, everyone is in *listen-only* mode during presentations.
- Please use the chat box to send us clarifying questions during presentations. We will unmute lines after each topic for open dialogue.

Agenda

- Project background
- Technical advisory group use case priorities
- Data requirements
- Update: Modeling and calibration
- Progress on obtaining data & data gaps
- Next steps
- General discussion and Q&A

Project Background

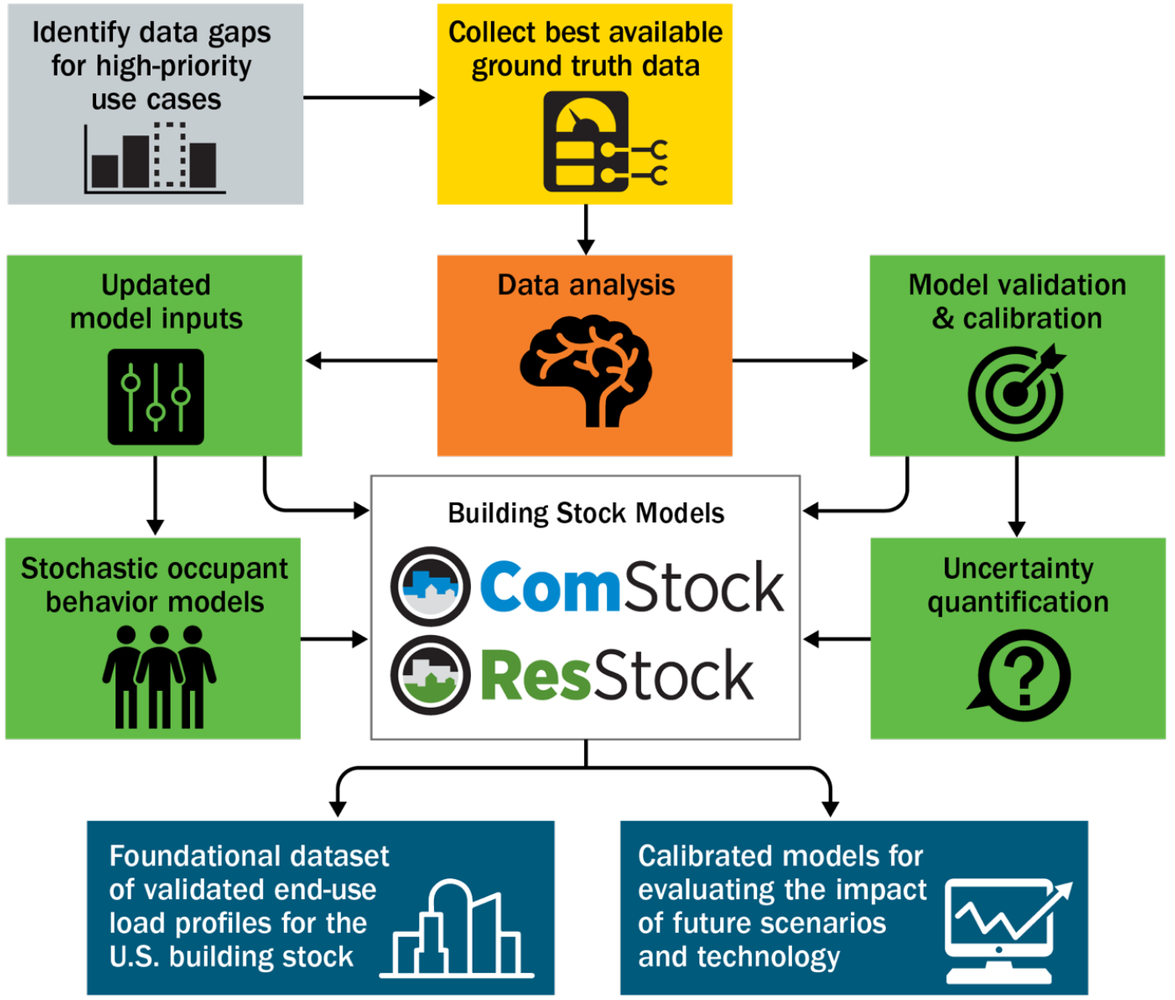
Project Overview

Hybrid approach combines best-available ground-truth data—

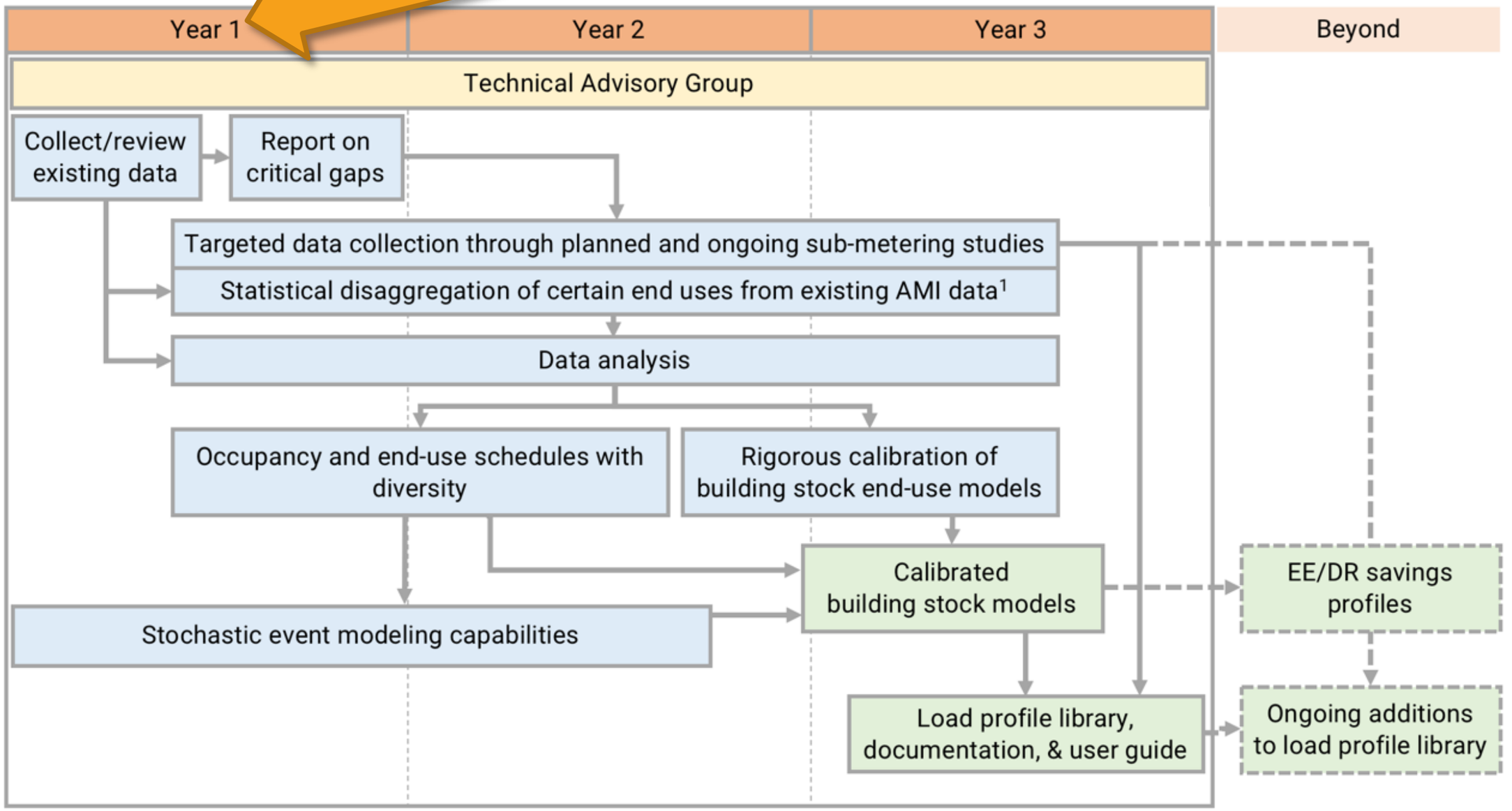
- submetering studies,
- statistical disaggregation of whole-building interval meter data, and
- other emerging data sources

—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**.



Project Timeline



[1] For example, conditional demand analysis, or inverse (changepoint/degree day) models (KEMA 2009)

Key Milestones and Deliverables

2018 (December)	**Establish TAG**
2019 (Fall)	**Publish Report on Market Needs, Use Cases and Data Gaps** that discusses applications of end-use load profiles, use cases and identify gaps in existing data
2020	**Complete models to represent stochastic behavior** of discrete end-use events in building operation
	Produce working but uncalibrated model of national residential and commercial building stocks that generates end-use load profiles
2021	**Complete calibrated model** of national residential and commercial building stocks that generates average and typical end-use load profiles
	Publish dataset of end-use load profiles on one or more free, publicly accessible websites such as OpenEI.org, Data.gov, and the EPRI Load Shape Library
	Publish Technical Project Documentation that describes technical details, assumptions and methodologies used to develop and calibrate the models and create end-use load profiles
	Publish User's Guide describes approach, results, and applications (e.g., load forecasting, resource planning, program, and policy design)

Technical Advisory Group Use Case Priorities

Use cases in survey (1)

1. **Electricity resource planning**: Long range planning such as integrated resource planning or long range load or avoided cost forecasting.
2. **Energy efficiency planning**: Benefit-cost analysis, estimating potential, planning, design and implementation of energy efficiency programs.
3. **Policy and rate design**: Support for utility, local, state or federal policy decision-making. Examples include codes and standards development, electricity rate design including evaluating time-based rates and climate policy.
4. **Distribution system planning**: Assessing needed physical and operational changes to the distribution grid. Examples include non-wires alternatives.
5. **Energy efficiency program impacts**: Improving assumptions used in efficiency impact evaluations.

Use cases in survey (2)

6. **New building design/modeling/rating**: Improving default assumptions at the building level for new building design and identifying major regional differences for multi-building modeling.

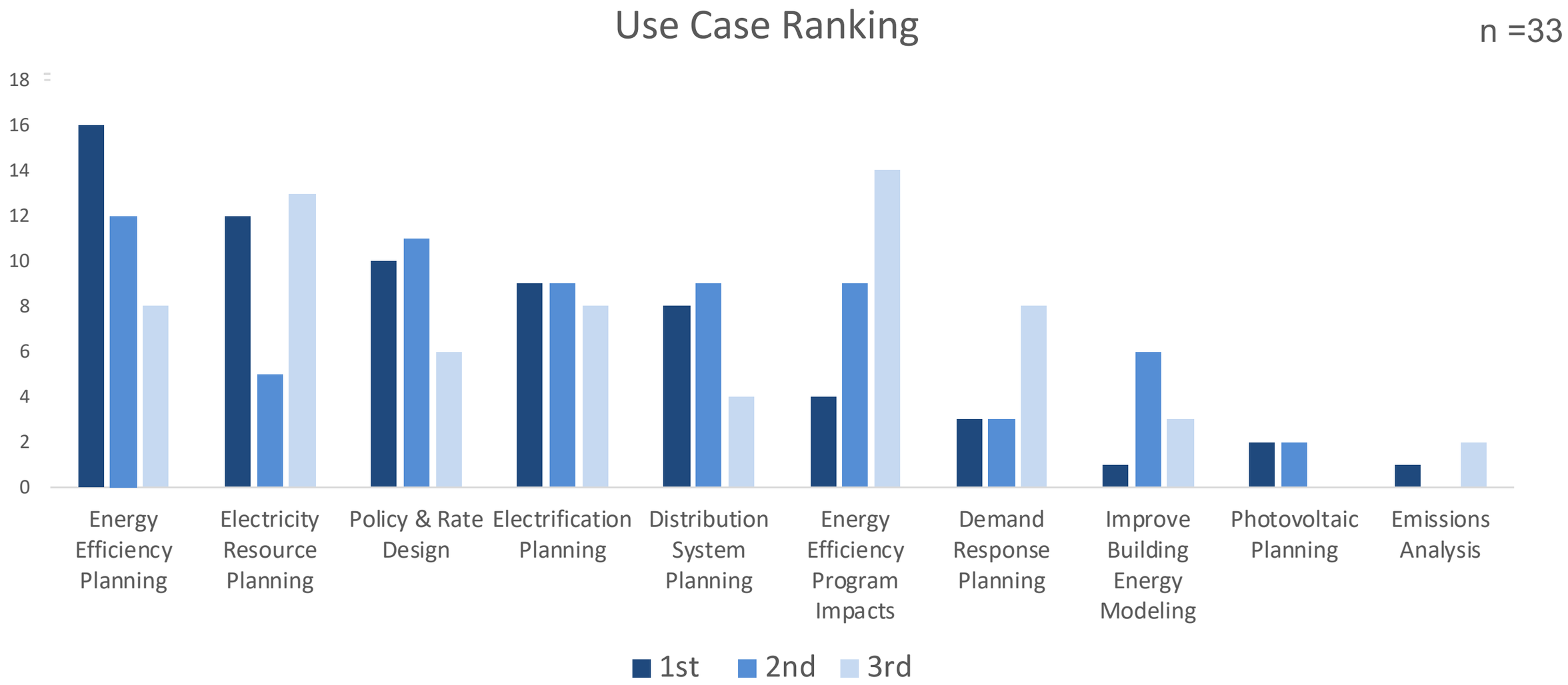
7. **Electrification planning**: Evaluation of electrifying technologies at the building stock level. Examples include heat pump water heaters.

8. **Emissions analysis**: Evaluation of emissions profiles correlated with end uses for developing abatement strategies.

9. **Photovoltaic planning**: Assessing viability of new photovoltaic systems for utilities and the solar industry.

10. **Demand response planning**: Estimating potential, planning, design and implementation of demand response programs.

Top three use cases identified by TAG



Data Requirements

Data requirements for top use cases

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Use Case	Rank	Time resolution	Geographic resolution	End-uses	Stochastic Occupancy	Electrical Characteristics
Energy Efficiency Planning	1	Hourly or peak day	Service territory	Yes	No	Real power
Electricity Resource Planning	2	Hourly or peak day	Service territory	Yes	No	Real power
Policy & Rate Design	3	15-min	Service territory or smaller	Yes	Yes	Real power
Electrification Planning	4	Hourly	Service territory or smaller	Yes	Yes (for distribution)	Real power
Distribution System Planning/Non-Wires Alternatives	5	15-min	Distribution feeder	Yes	Yes	Real, reactive power, voltage
Energy Efficiency Program Impacts	6	Hourly or peak day	Service territory	Yes	No	Real power
Demand Response Planning	7	15-min	Feeders to markets	Yes	Yes	Depends on application
New Building Design/Modeling/Rating	8	15-min to hourly	Weather station	Yes	Yes	Real power
Photovoltaic Planning	9	1-min	Weather station	No	Yes	Real power
Emissions Analysis	10	Hourly	Service territory or larger	Yes	No	Real power

Data requirements for use cases

Time Resolution

15-minute

- Highest impact cases require only hourly results
- PV Planning is the only top use case that requires less than 15-minute data

Geographic Resolution

Utility territory

- Distribution System Planning requires feeder-level data
- A “mix-and-match” approach from a bank of load profiles could help build specific utility and feeder level information

Occupancy

Stochastic

- This is a significant gap and will require new modeling techniques

Electrical Characteristics

Real power

- Some distribution system planning use cases might benefit from reactive power
- Data requirements for some use cases are not well understood

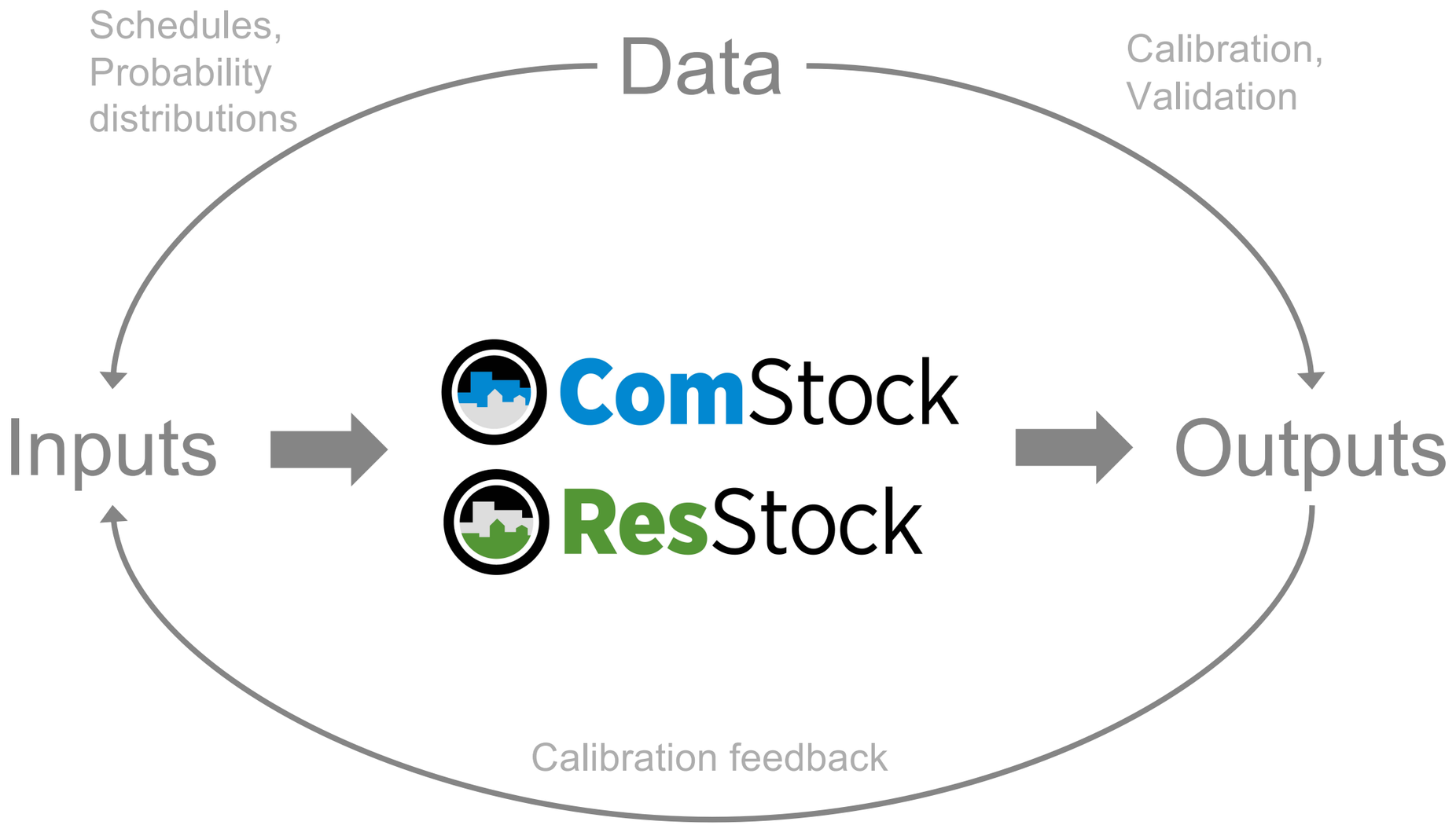
Data collection discussion

We are going to unmute all of the phone lines,

so please mute yourself if you are not speaking.

Update: Modeling and Calibration

Data needs


Schedules,
Probability
distributions
Data
Calibration,
Validation
Inputs
ComStock
ResStock
Outputs
Calibration feedback

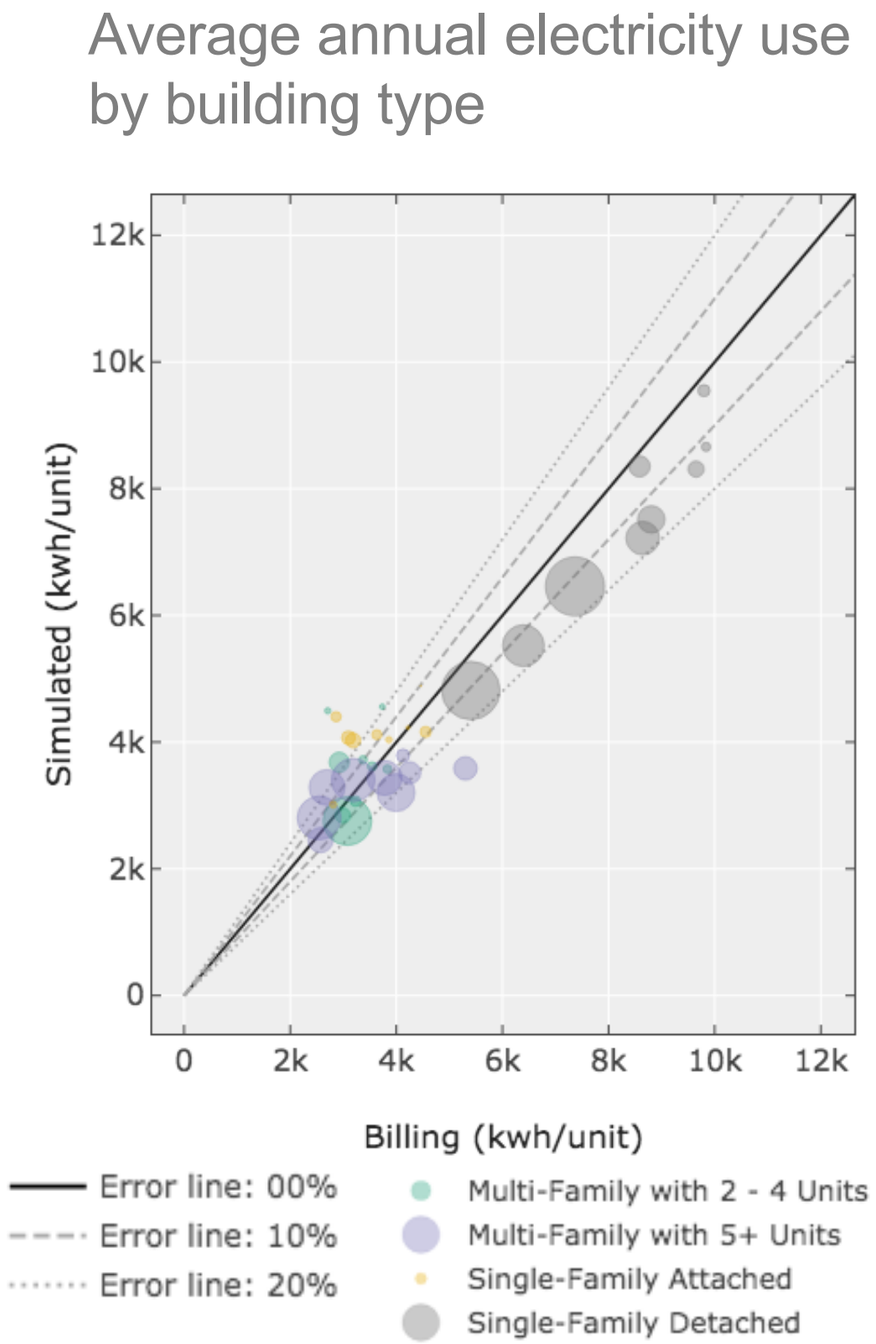
Update: Modeling and Calibration

- Continued focus on:
  - ComStock development
  - Stochastic occupancy modeling for commercial (LBNL) and residential (NREL)
- Beginning calibration work for several locations
- Developed data-driven algorithms for truing-up residuals

How we use data for calibration

Example 2: Annual usage validation by building type

Data:
Customer monthly billing data

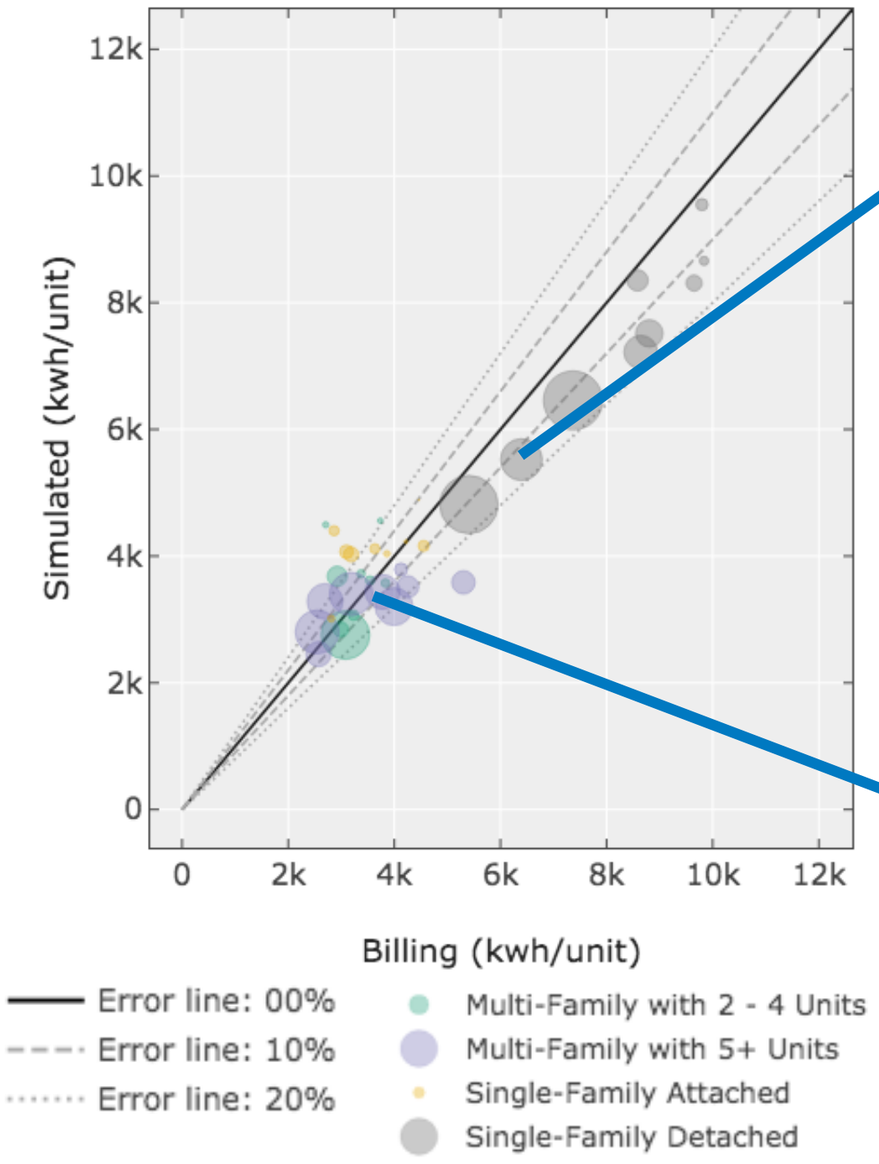


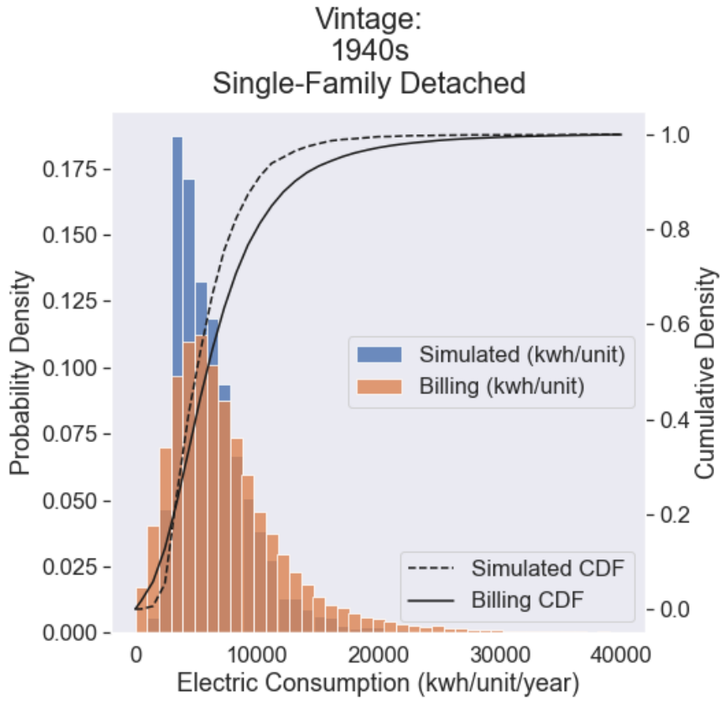
How we use data for calibration

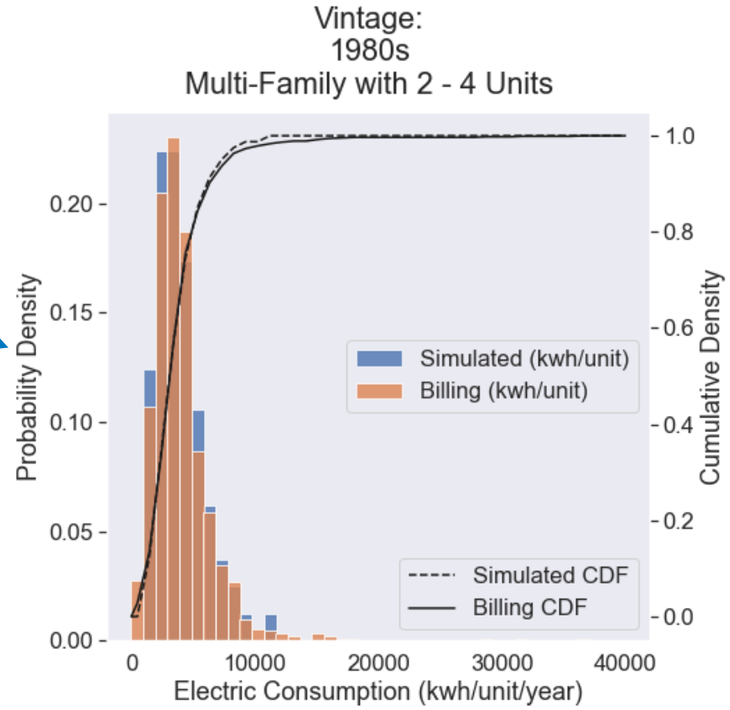
Example 2: Annual usage validation by building type

Data:
Customer monthly billing data

Average annual electricity use by building type







How we use data for calibration

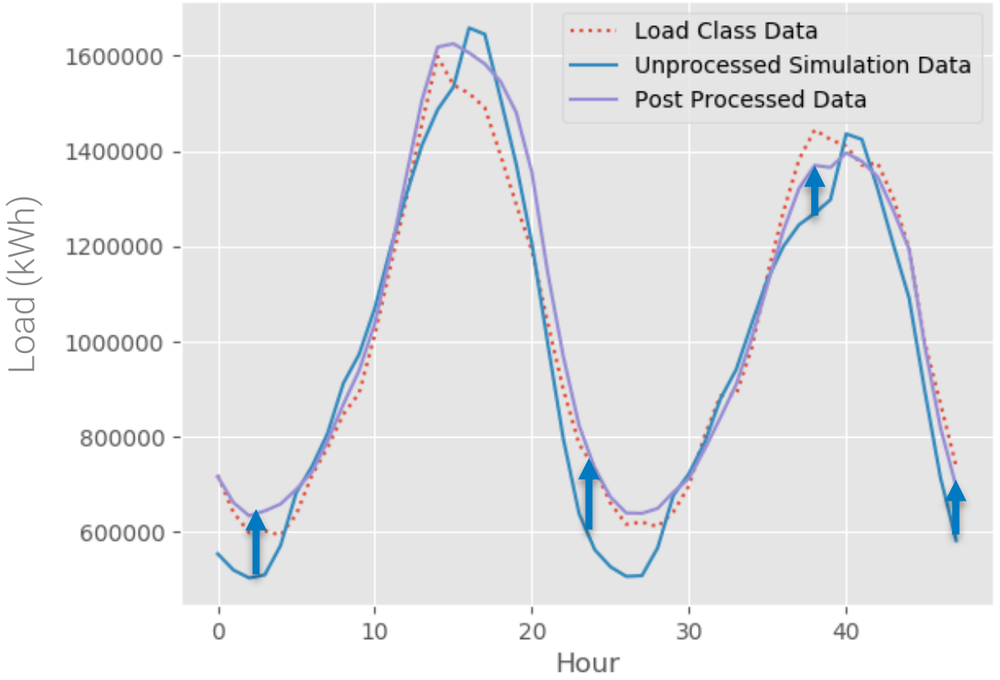
Example 2: Truing-up model residuals

Data:

Utility customer class hourly load data

Data-driven calibration approaches: Cooling Load Shape

Residential building stock load: 09/09 – 09/10



- Cooling load shape shifted and scaled
- Total cooling load is conserved

- Fixes large diurnal swings
- Similar model for heating

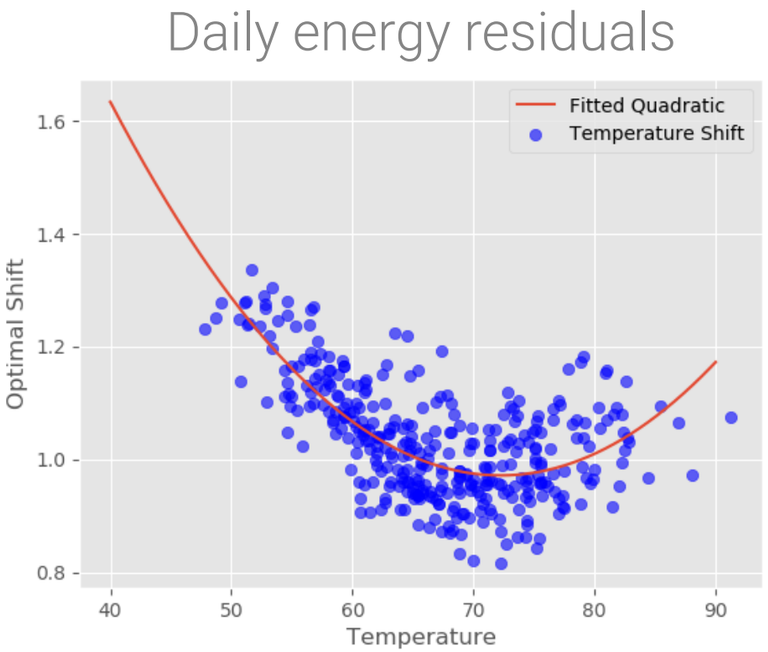
How we use data for calibration

Example 2: Truing-up model residuals

Data:

Utility customer class hourly load data

Data-driven calibration approaches: Temperature Shift



- Scales simulation data based on temperature
- Fixes errors on days with very high/low temps

How we use data for calibration

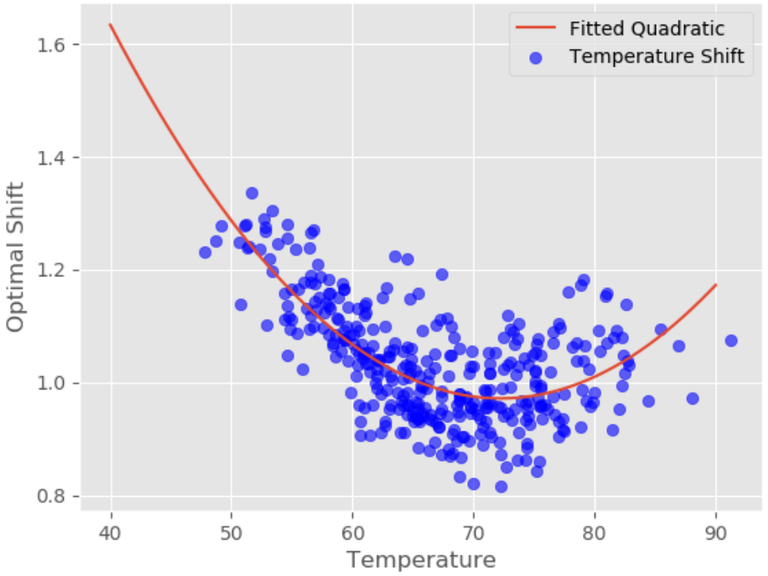
Example 2: Truing-up model residuals

Data:

Utility customer class hourly load data

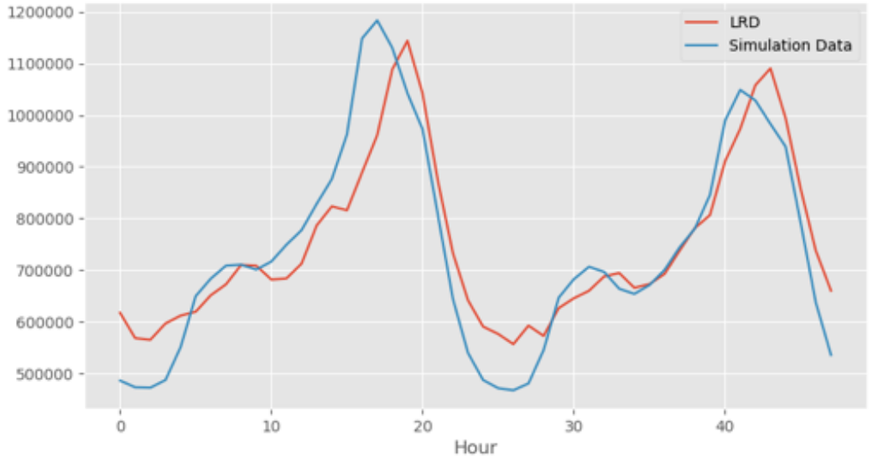
Data-driven calibration approaches: Temperature Shift

Daily energy residuals

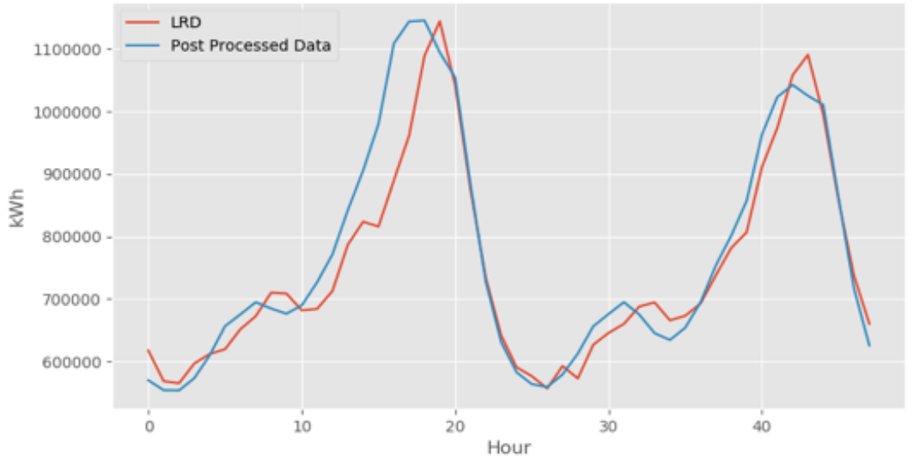


- Scales simulation data based on temperature
- Fixes errors on days with very high/low temps

Before processing

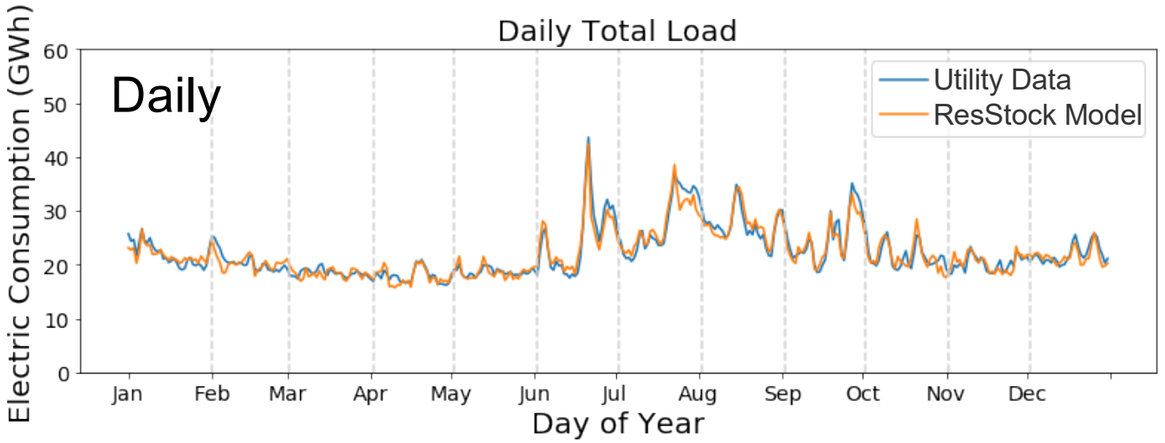


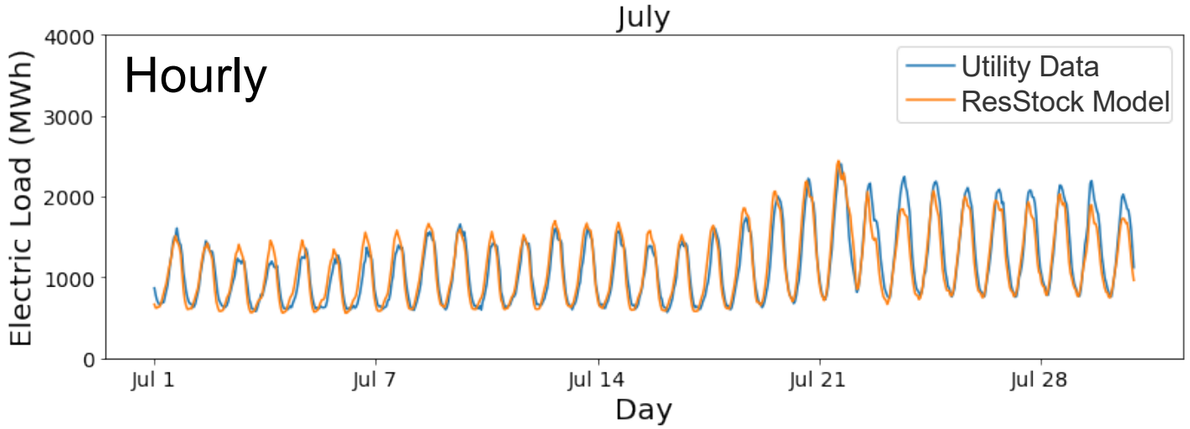
After cooling and temperature shift



Example calibration results (work in progress)
After 30 iterations of input changes and truing-up residuals

2016 (Training Dataset)





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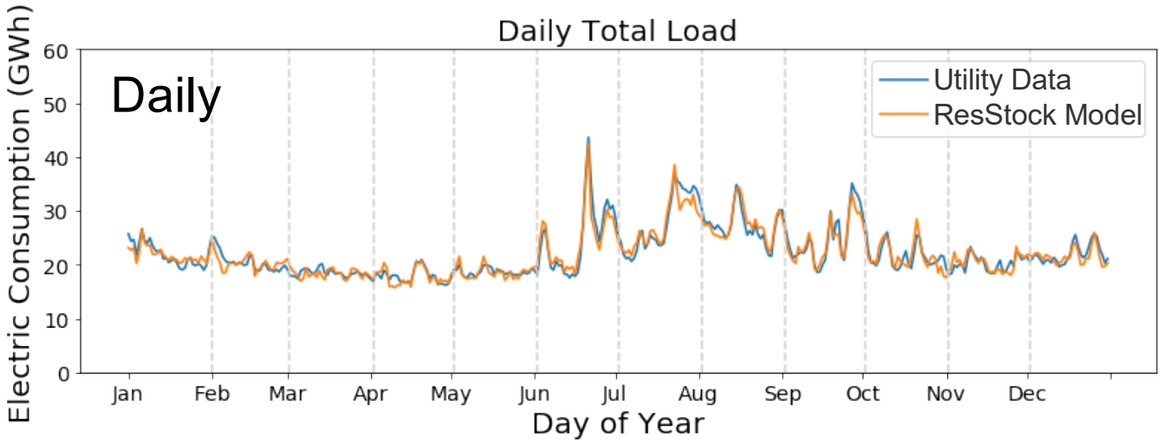
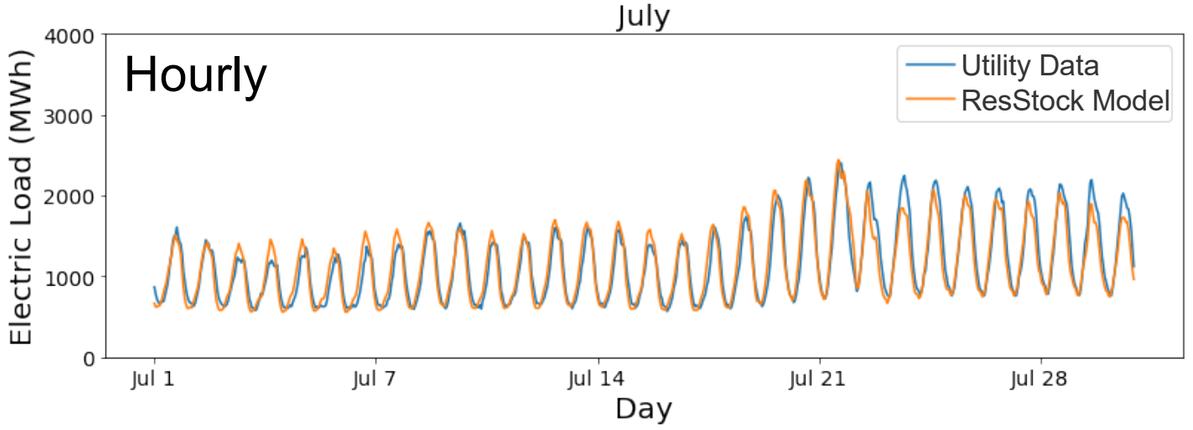
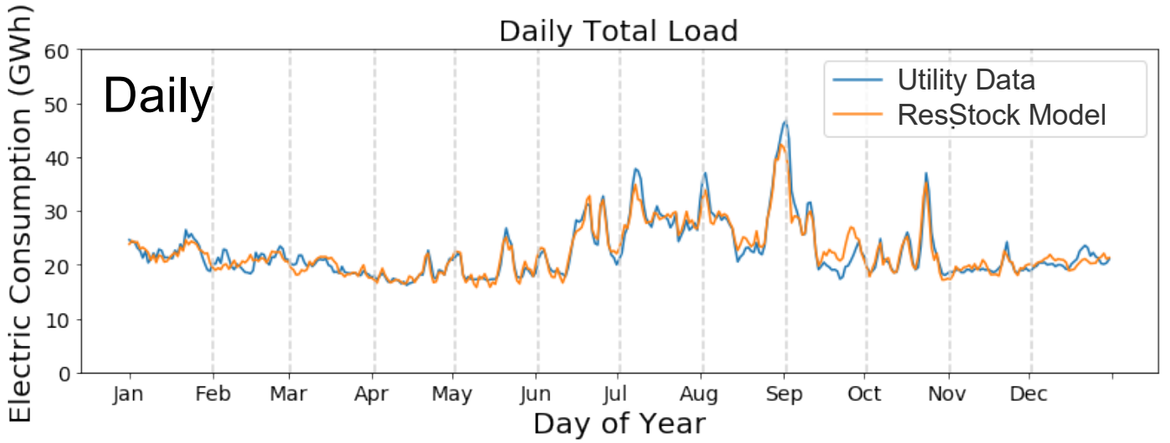
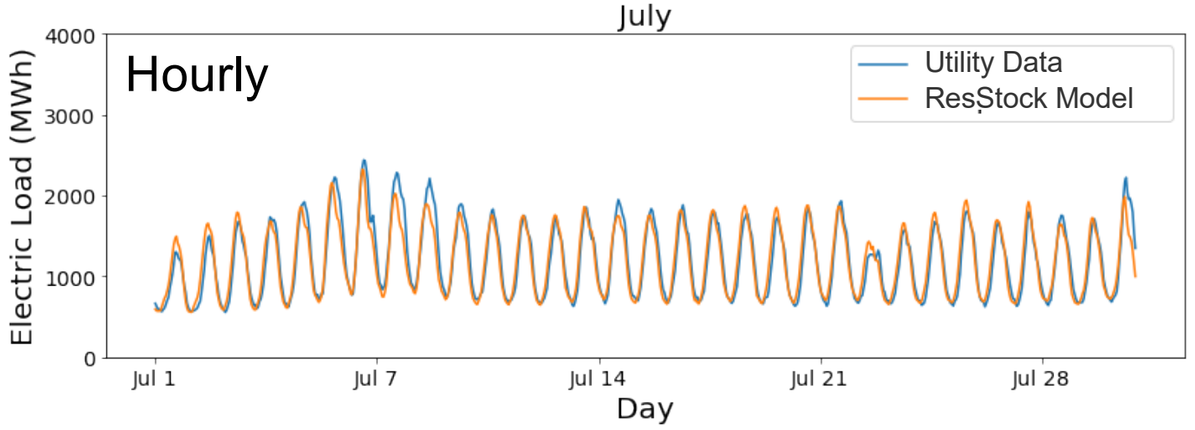




2017 (Test Dataset)





Modeling, outputs and calibration discussion

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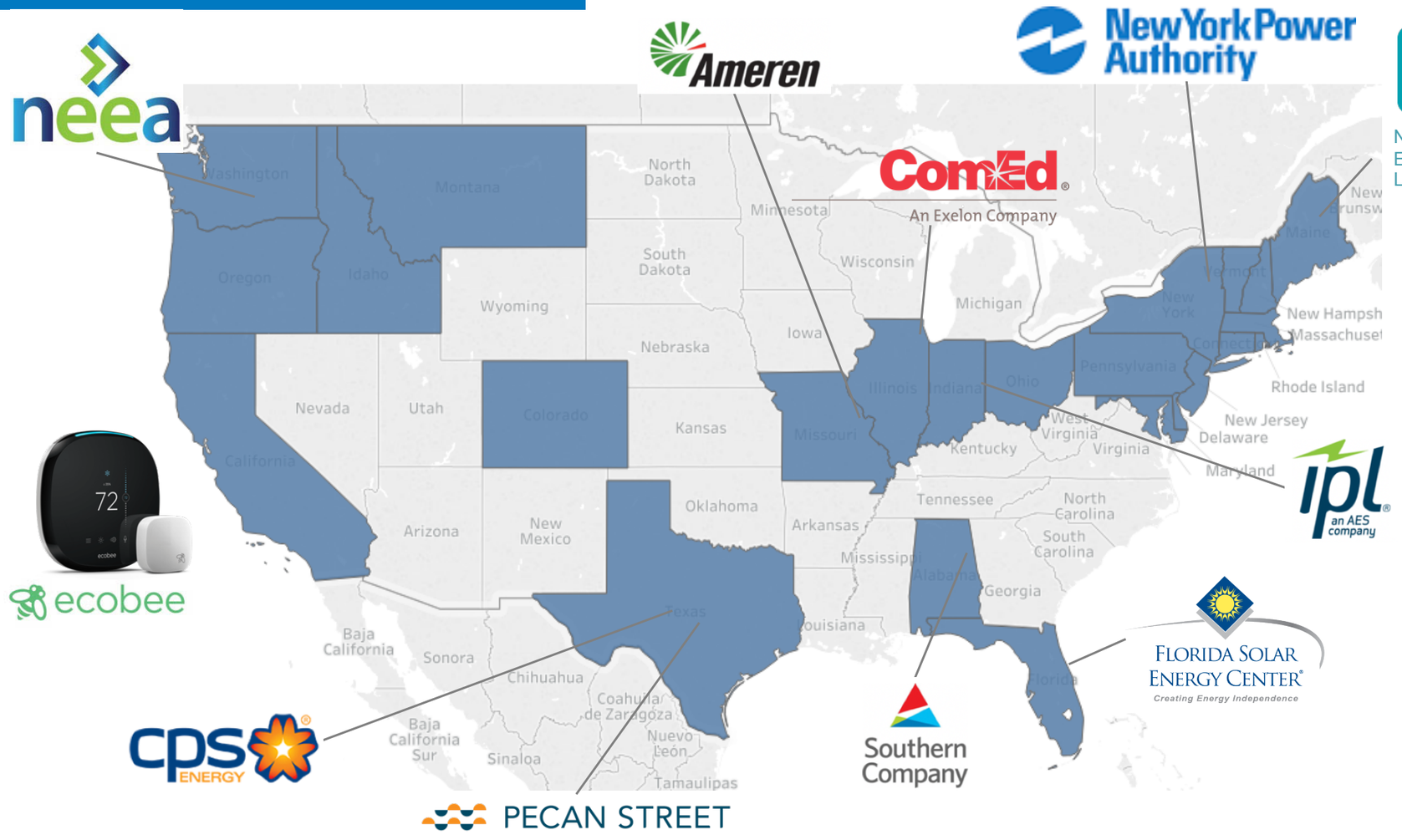
Progress on obtaining data & data gaps

Examples of Data Sources

Acquired or actively pursuing 20 (and growing) data sources from around the U.S.



Calibration Data Sources (selected examples)

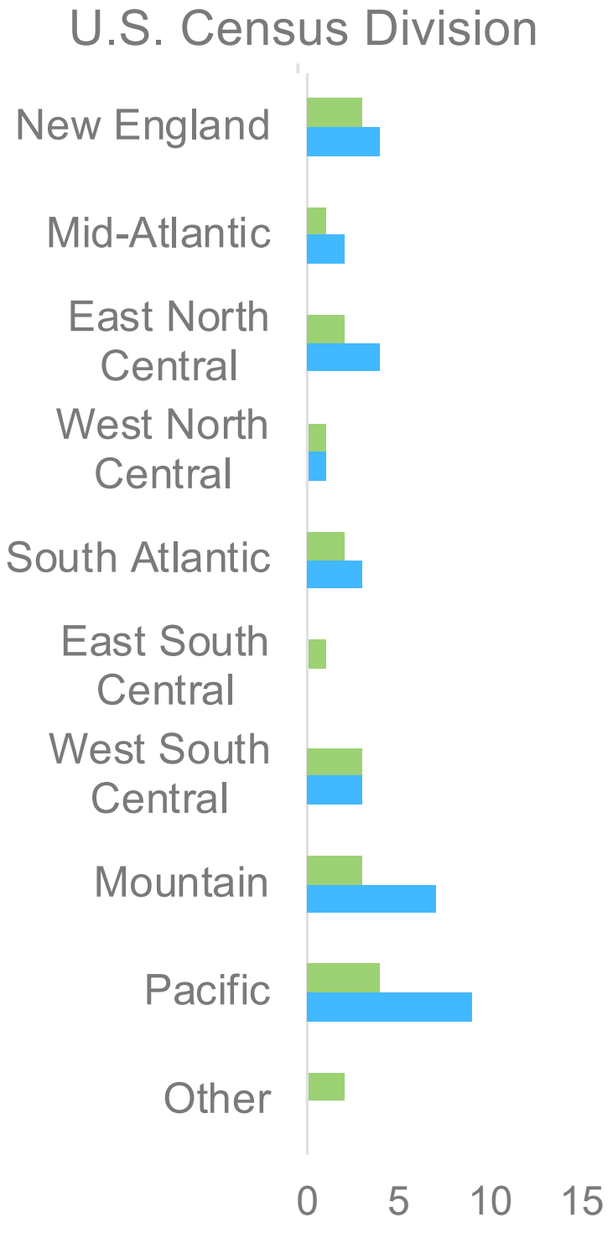
In Hand

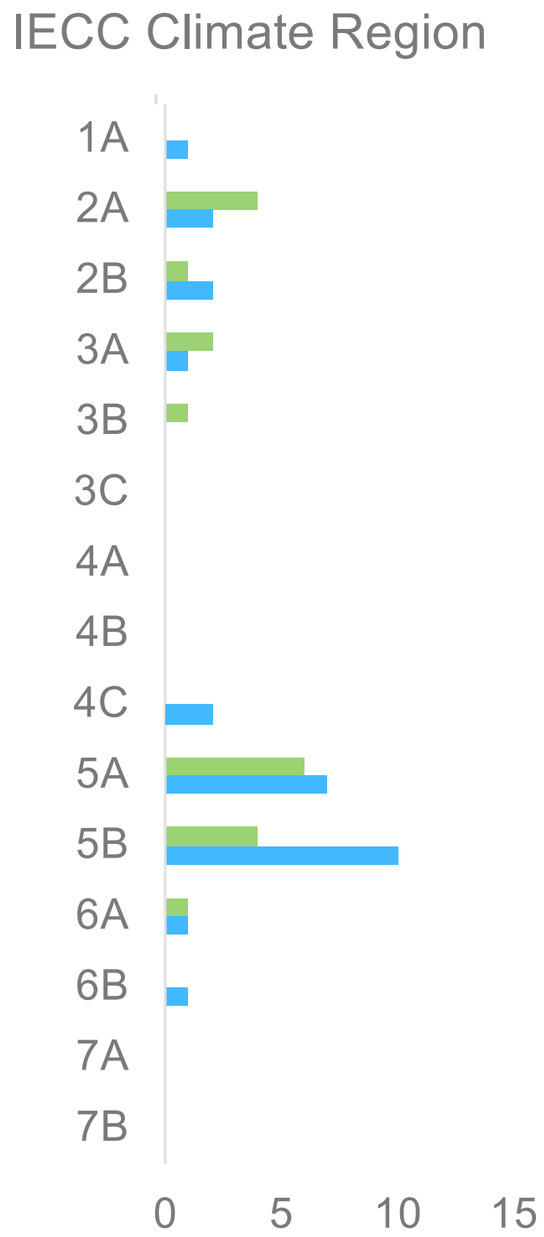
- RBSAM *(End Use)*
- ELCAP *(End Use, 30 years old)*
- FSEC Phased Deep Retrofit monitoring *(End Use)*
- Massachusetts *(Aggregate end-use shapes)*
- Ecobee *(Setpoints, temperatures, heating/cooling runtime)*
- Building Data Genome *(Whole building hourly)*
- Colorado Schools *(Whole building subhourly)*
- ComEd *(AMI)*
- California Energy Commission *(building type clusters)*
- Load research data from 21 entities *(including Ameren Missouri, ERCOT, etc.)*

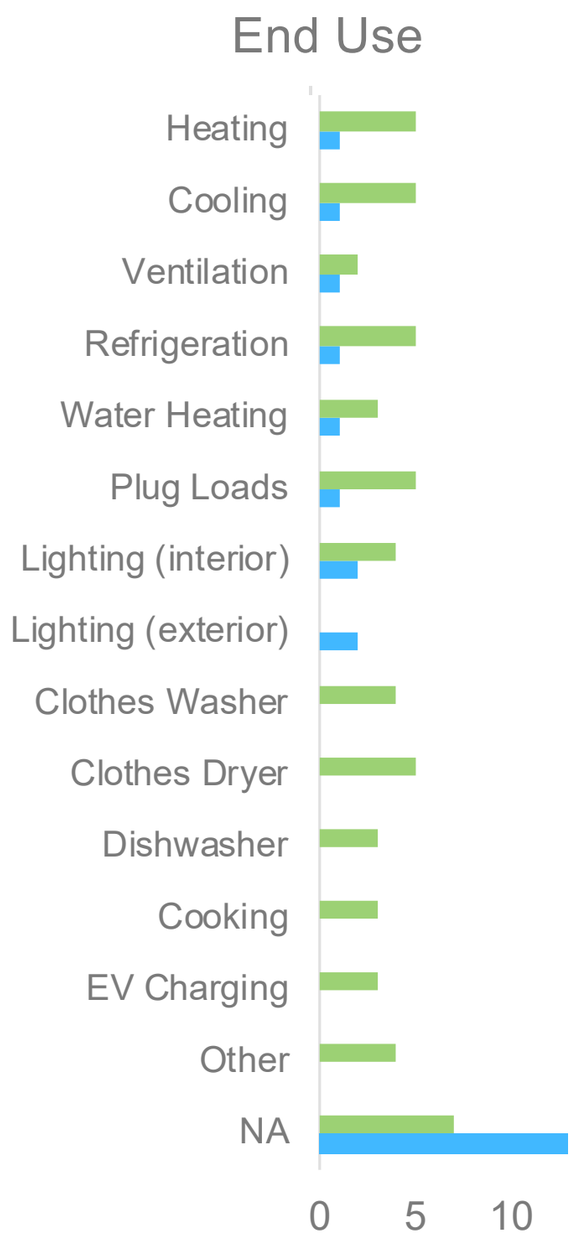
Expecting/Pursuing

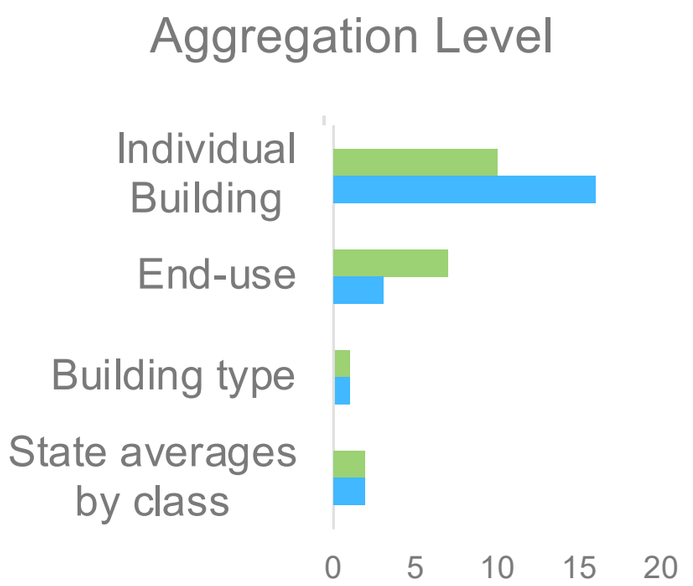
- Pecan Street
- NEEA EULR
- Southern Company
- Xcel Energy
- Fort Collins Utilities
- Indianapolis Power & Light
- Johnson Controls
- CPS Energy
- 12 hot water use datasets
- Resource Central (schools)
- Sagewell
- NEEP Load Shape Catalog

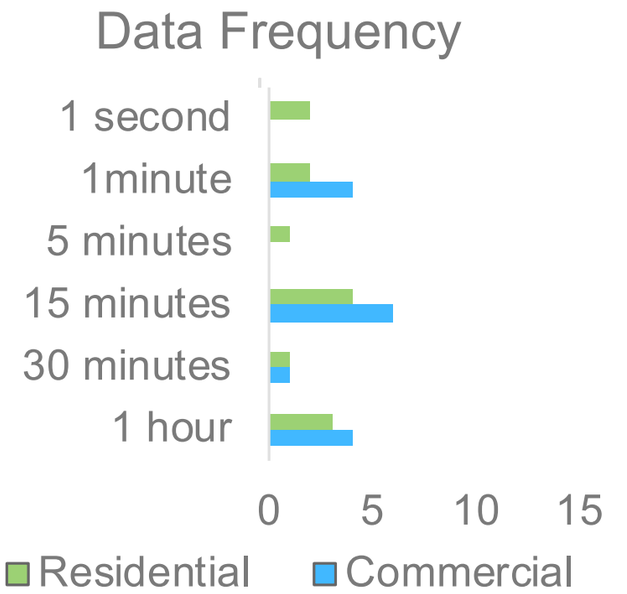
Data Coverage: Breakdown of Sources & Leads







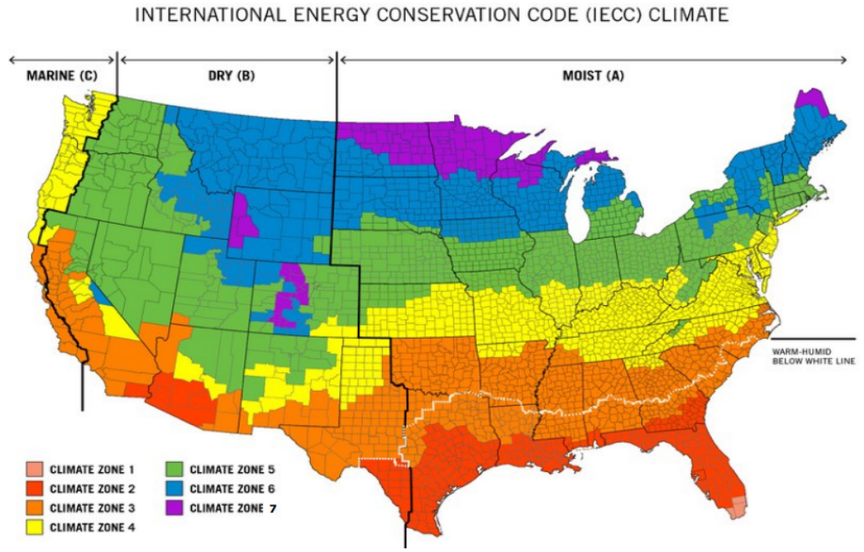




Significant Calibration Data Gaps

1. Commercial end-use data
   - Current sources:
     - ELCAP – 30 years old
     - Illinois TRM – only lighting and only in aggregate

2. Cold climate data
   - No strong leads on individual building data (residential or commercial) in IECC climate zones 6A, 7A, 7B



Input Data Coverage

Primary Current Sources

ASHRAE 90.1 · CoStar · CBECS 2003/2012 · RECS 2009 · ACS 2011-2015 · AHS 2013 · RBSA · ENERGY STAR · ELCAP · IECC · Manufacturer Literature · ACCA Manual J · BAFDR · NAHB/Home Innovation Research Labs Survey 80s/90s/2000s · ClimateMaster · Home Energy Saver · LBNL Residential Diagnostics Database · NREL Modeling and Testing Reports 2013/2014 · DOE Prototype Buildings

Selected Prospective Sources

RECS 2015 · RBSA II · Building Performance Database · CBSA · Nexant C&I · CEUS · MS Building Footprint Database · CEC Title 24 · BCL Fault Models · ecobee · ASHRAE service life database · Building Code Status Maps · ATUS · Pecan Street · RBSAM · MA Baseline Load Study

Greatest Gaps in Modeling Inputs

	High Priority Gaps, Limited Data
Commercial	Computing (server) load
	Miscellaneous internal electric load
	Energy code compliance level
	Building component replacement rate
	Internal thermal mass
Residential	Well pumps
	Pools & hot tubs
	Appliance usage schedules
	Non-appliance plug load schedule
	Water heater type
	Internal thermal mass

Greatest Gaps in Modeling Inputs

	High Priority Gaps, Limited Data	Negligible Data
Commercial	Computing (server) load	Cooking
	Miscellaneous internal electric load	HVAC faults
	Energy code compliance level	
	Building component replacement rate	
	Internal thermal mass	
Residential	Well pumps	Kitchen & bath mechanical ventilation
	Pools & hot tubs	Hot water recirculation type for multifamily
	Appliance usage schedules	ASHP minimum operation temperature
	Non-appliance plug load schedule	Depth of overhangs
	Water heater type	
	Internal thermal mass	

Inputs and calibration data gaps discussion

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Next Steps

Next steps

- *End Use Load Profiles for the U.S. Building Stock: Market Needs, Use Cases and Data Gaps* **draft report review** in **August/September**
- Next **technical advisory group** meeting via webinar in **September** (tentative topic: stochastic occupancy modeling)
- **Continue work** on data collection/gap-filling, calibration, occupancy modeling
- Talk to us at upcoming conferences:
  - **NASUCA**, June 21, 2019, Portland, OR
  - **Better Buildings 2019 Summit**, July 10–11, Arlington, VA
  - **IEPEC**, August 20–22, Denver, CO
  - **ASHRAE Building Performance Analysis Conference**, Sept. 25–27, Denver, CO
  - **ACEEE Energy Efficiency as a Resource**, October 15–17, Minneapolis, MN

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

Thank you

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