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

Technical Advisory Group Meeting #4
September 20, 2019

Natalie Mims Frick, LBNL
Eric Wilson, NREL
Anthony Fontanini, NREL
Elaina Present, NREL

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
- Report Overview
- Update: Modeling and calibration
- Update: Progress on obtaining data
- Next steps
- General discussion and Q&A

Project Background

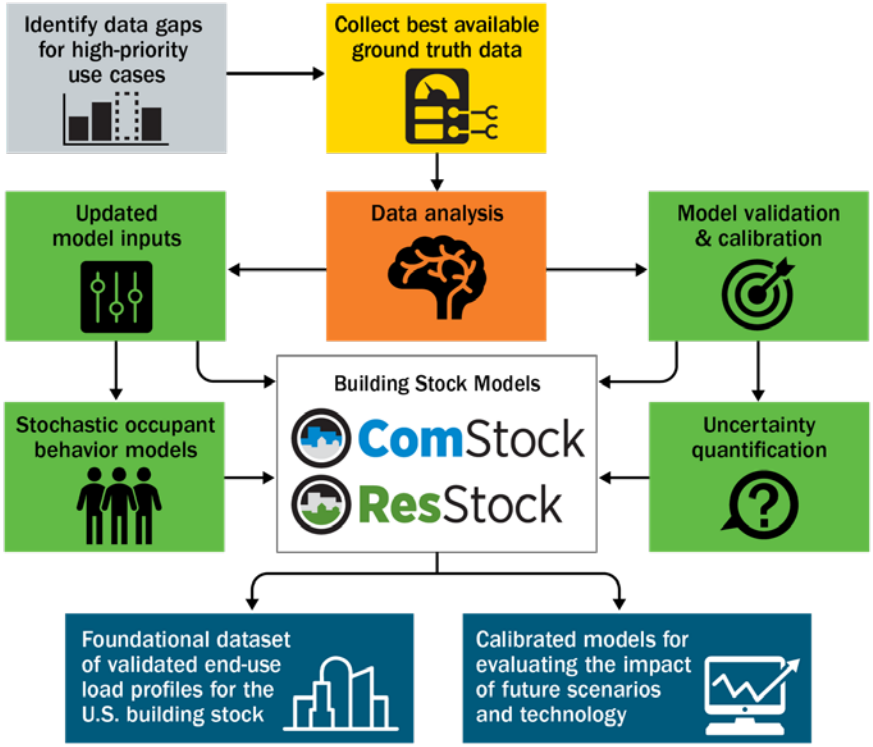
Project Overview

Hybrid approach combines best-available ground-truth data—

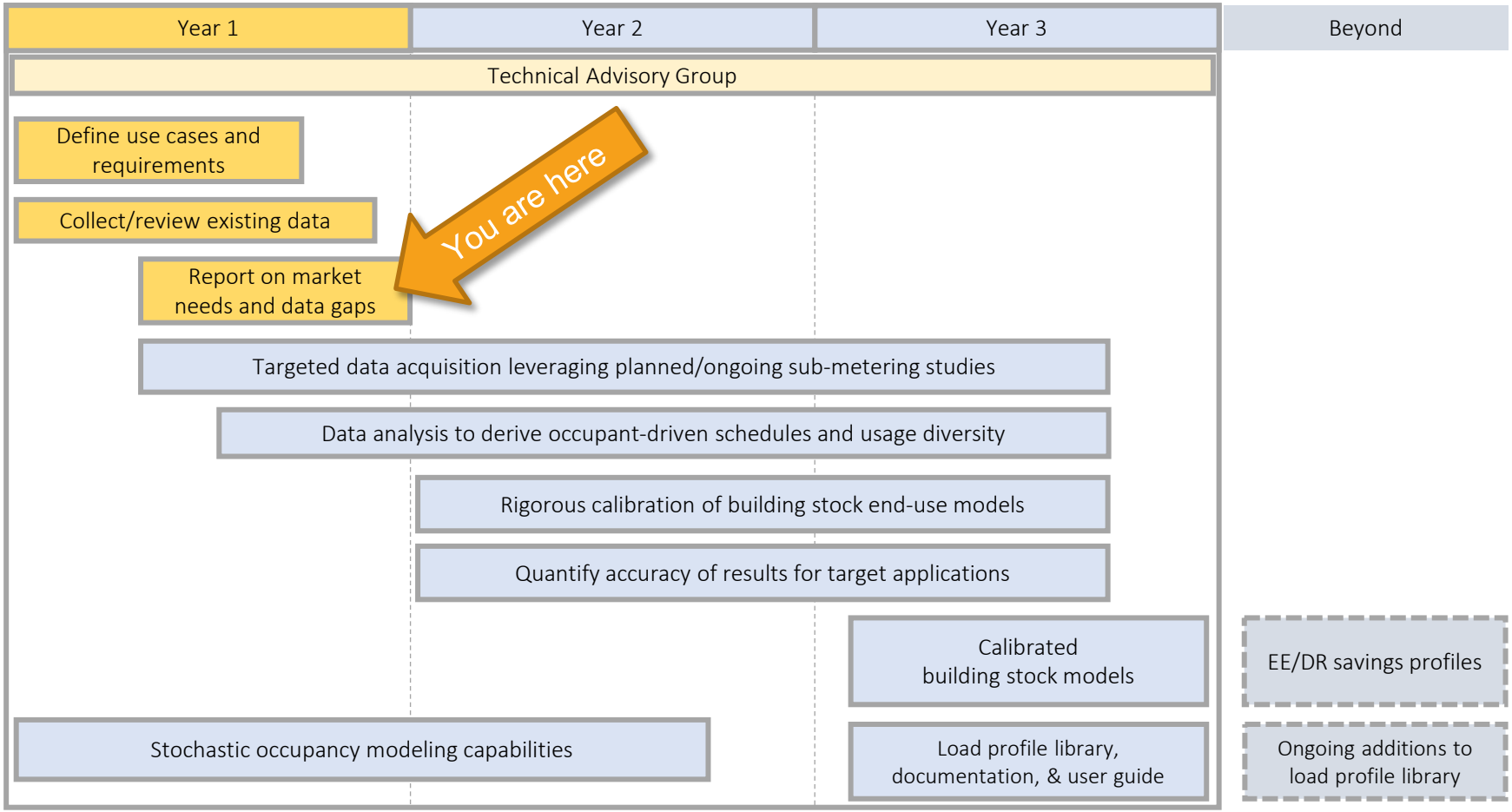
- submetering studies,
- whole-building interval meter data, and
- other emerging data sources

—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



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)

Report Overview

Draft Report Review

- End Use Load Profiles for the U.S. Building Stock: Market Needs, Use Cases and Data Gaps distributed to the TAG on September 9
- Please provide us with your comments by September 30

Report Contents

Project Overview

- What is an end-use load profile? What are energy savings load profiles? What is the purpose of the report?

Table 1. Working List of End Uses for This Project

Commercial Building End Uses	Residential Building End Uses
HVAC	HVAC
Heating	Heating
Cooling	Cooling
Fans	Furnace/AC fan
Pumps	Boiler pumps
Heat rejection	Ventilation fans
Humidification	Domestic water heating
Heat recovery	Major appliances
Service water heating	Refrigerator
Refrigeration	Clothes washer
Plug and process loads	Clothes dryer
Lighting	Dishwasher
Interior	Cooking range
Exterior	Pool/spa pumps, heaters
	Miscellaneous plug loads
	Lighting
	Interior
	Exterior

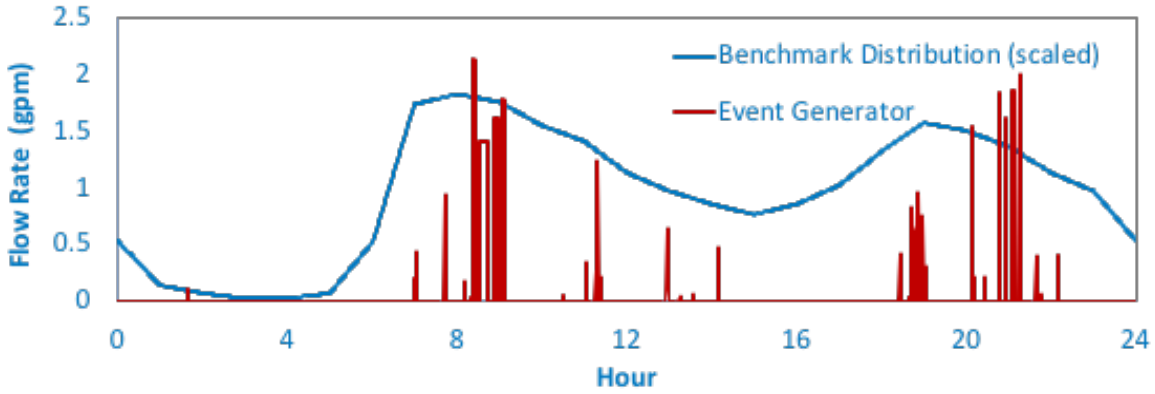


Figure 2. Example aggregate versus individual EULP concept demonstration using water draws

Market Needs and Use Cases

Market Needs | Existing Publicly Available End Use Load Profiles

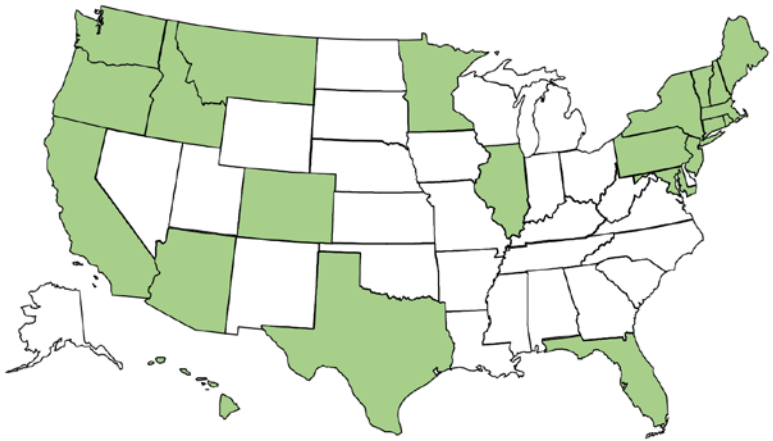


Figure 5. The quantity of data and number of EULPs that are available in each state vary greatly. See the EULP inventory for more information.

- We collaborated with E3 to develop an inventory of publicly available end-use load profiles
- We circulated a draft of the inventory to the TAG in July
- The inventory is now available on LBNL's website: https://emp.lbl.gov/publications/end-use-load-profile-inventory

Market Needs | Use Case Identification

Figure 4. Overview of Team Approach to Identifying Market Needs

- Use cases: type of process or analysis that utilize end-use load profiles
- 10 most mentioned use cases are presented in the report
- Use cases informed data requirements for modeling

Use Cases | Data Fidelity Requirements

Use Case Data Requirements

Use Case	Time Resolution	Geographic Resolution	Electrical Characteristics
Electricity Resource Planning	Hourly or peak day	Service territory	Real power
Energy Efficiency Planning	Hourly or peak day	Service territory	Real power
Policy and Rate Design	15 min to hourly	City, climate zone, or state	Depends on application
Transmission and Distribution System Planning	15 min or smaller	Distribution feeder	Real and reactive power
Program Impact Evaluation	Hourly	Service territory	Real power
Demand-Response Planning	15 min to hourly	Service territory	Real power
Improved Building Energy Modeling	15 min	Region	Real power
Electrification Planning	Hourly	Service territory or smaller	Real power
Emissions Analysis	Hourly	Service territory or larger	Real power
PV Planning	1 min	Weather station	Real power

Use Cases | Data Fidelity Requirements

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

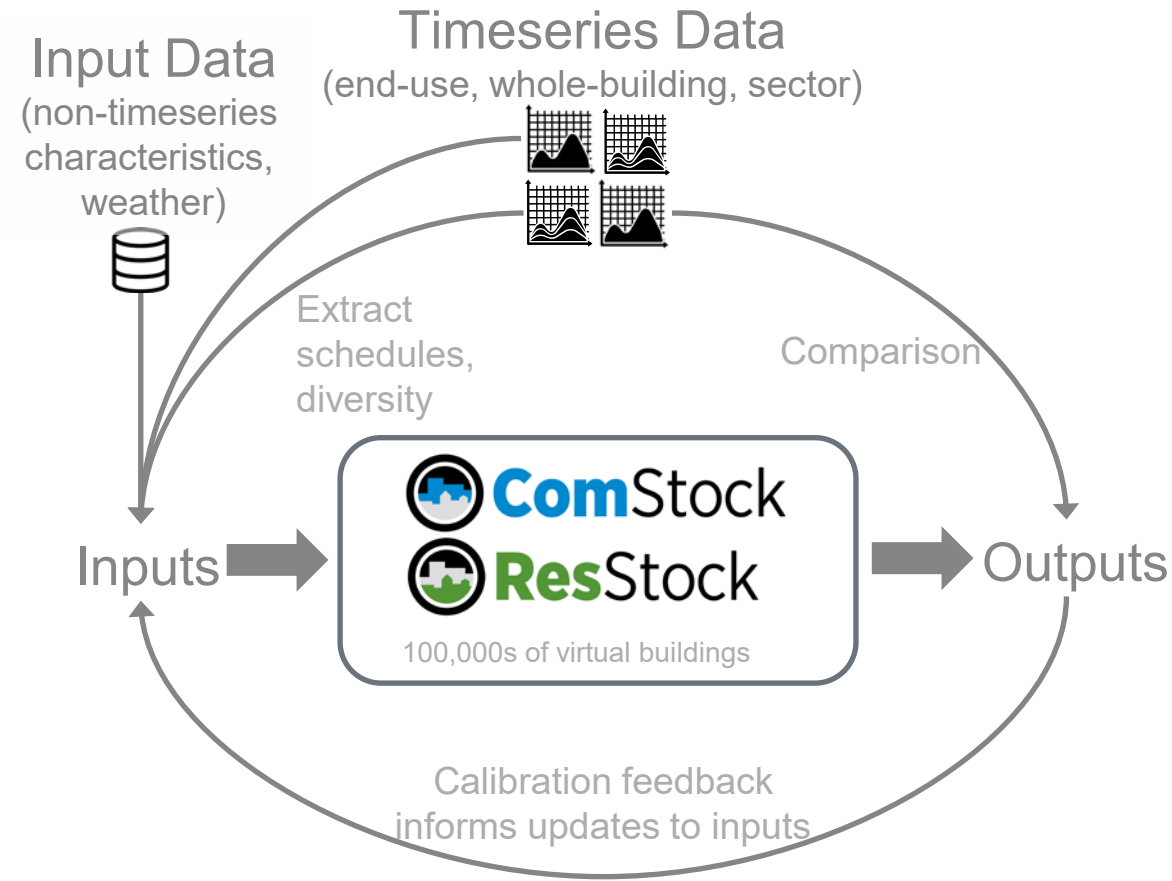
Electrical Characteristics

Real power

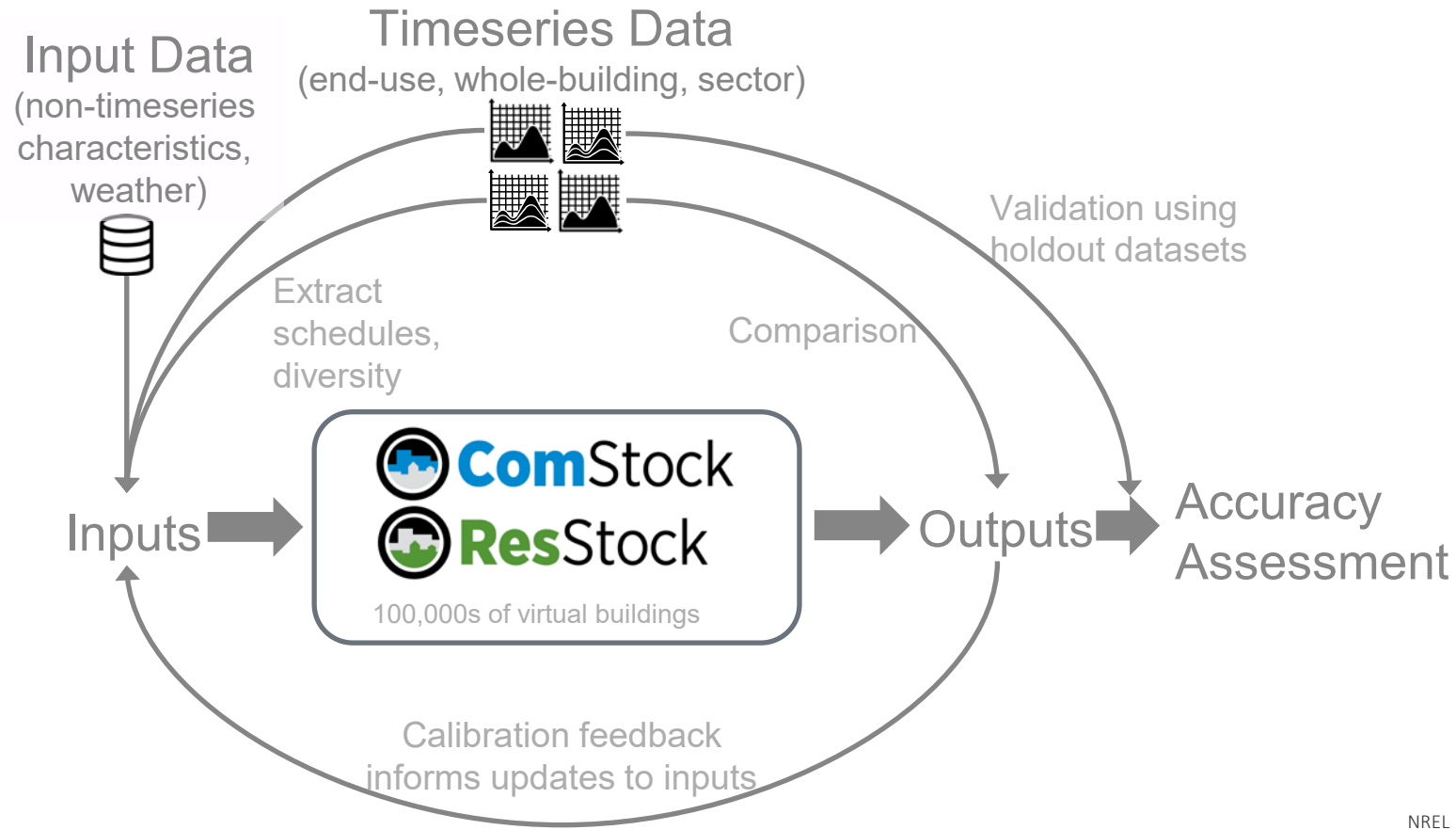
- Some distribution system planning use cases might benefit from reactive power
- Data requirements for some use cases are not well understood

Data Needs and Identified Gaps

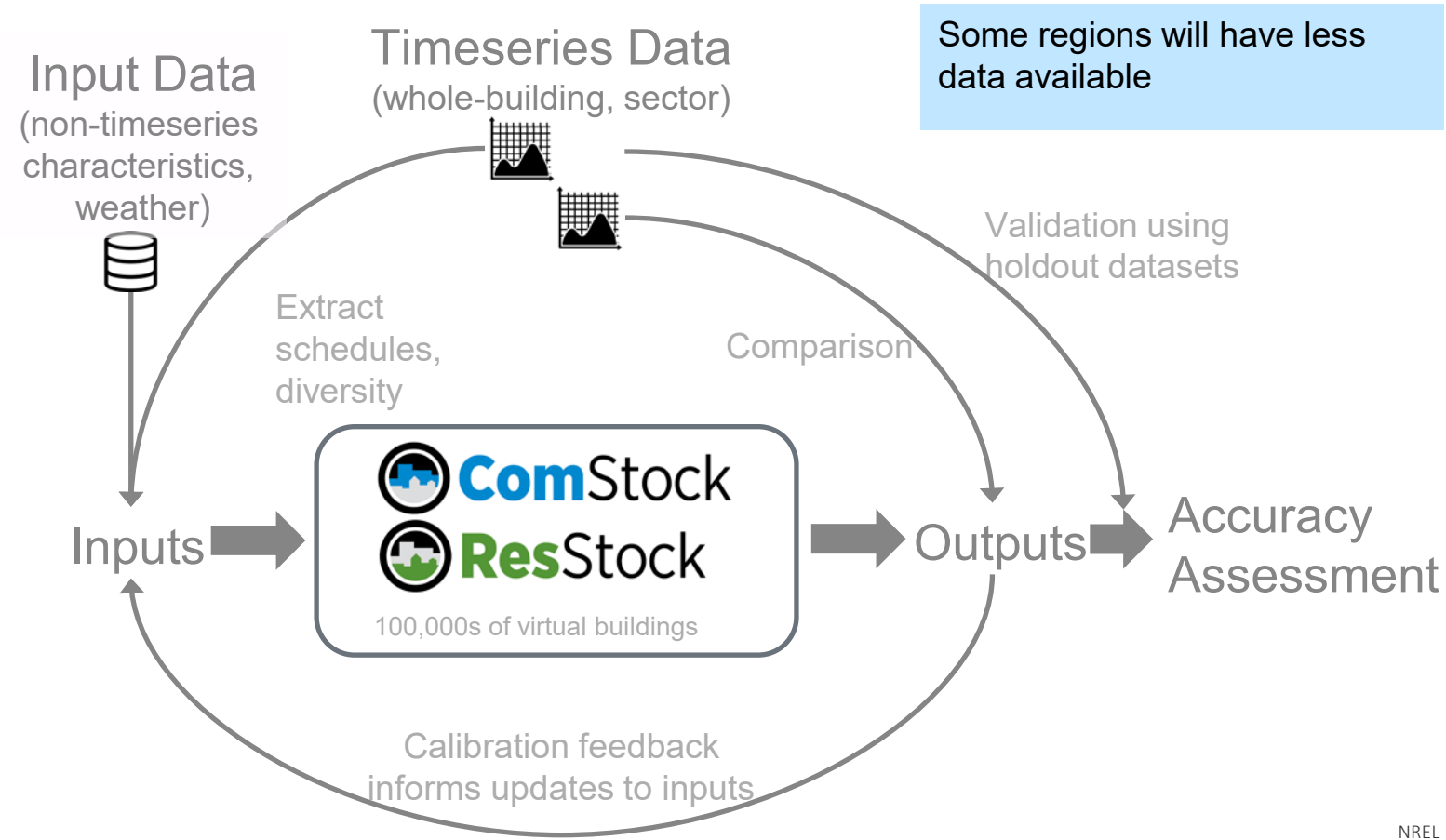
How are we using data?



How are we using data?



How are we using data?



Model Input Data (1)

- *Schedule-related inputs* (e.g., lighting on/off schedules)
  - Directly related to human behavior within the building
  - Includes variability and saturation of different behavior types across the building stock
  - Directly affect the timing of energy use
- *Characteristic inputs* (e.g., HVAC system cooling type)
  - Physical description of the building, its equipment, and the saturation of these components across the stock
  - Indirectly affect the magnitude and timing of energy use
- *Environmental inputs* (e.g., temperature)
  - External to the building.
  - Directly affect the timing and magnitude of energy use

Model Input Data (2)

The following process was used to identify improved model inputs for ResStock and ComStock:

1. **Identify and document existing inputs** to ResStock and ComStock, including data sources
2. **Prioritize existing inputs** based on their impact on peak power and energy consumption
3. Based on prioritized inputs, **identify gaps that require improved data**
4. **Identify new data sources** that fill these high-priority data gaps.

- Appendix D contains full list of prioritized input data gaps and identified data sources
- Sensitivity analyses and uncertainty quantification useful for prioritizing updates

Model Calibration Data

Table 4. Summary of Calibration Data Classes

Type of Calibration Data	Summary of Availability
Utility Sales: Annual sales/consumption data by sector by utility	Universally available from U.S. Energy Information Administration (EIA)
Load research data: Utility customer class aggregate load shapes	Acquired for ~20 utility companies and the Electric Reliability Council of Texas
Advanced metering infrastructure (AMI): Whole-building AMI data	Acquiring in multiple census divisions, via nondisclosure agreements with utility companies
AMI + Metadata: Building characteristic metadata joined with AMI data	Acquiring for a subset of the AMI data sets
Submetered: End-use metering data, including smart thermostat data	Multiple (3+) strong data sets available for residential; few data sets available for commercial buildings

Addressing Data Gaps

Largest identified gap is submetered data for commercial buildings

To address this gap, we are:

1. Conducting a targeted market research effort to identify data sets for potential purchase (BAS data, EM&V studies, etc.)
2. Studying transferability between building types and regions

Next Steps: Assessing Accuracy (1)

- The most important component of this project is the fidelity of the EULPs produced through our work. Therefore, it is crucial that we develop a robust process for quantifying model accuracy and uncertainty.
- Based on TAG and DOE feedback, we moved the Uncertainty Quantification work up into year 2 (in parallel with calibration)

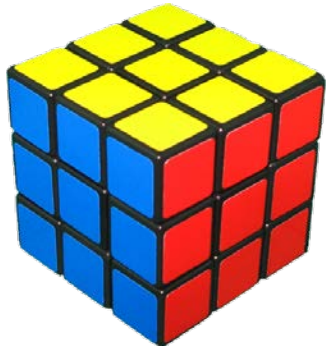
Next Steps: Assessing Accuracy (2)

Multifaceted Calibration

1. Annual – Whole-Building
2. Annual – End Uses
3. Annual – Diversity
4. Timeseries – Whole-Building
5. Timeseries – End Uses
6. Timeseries – Diversity

Each dimension has:

- metrics,
- visualizations,
- relevant data sources,
- relevant inputs to update



By calibrating six different dimensions, we can ensure accuracy by bounding errors and variability of results.

Report discussion

We are going to unmute all of the phone lines, so please mute yourself if you are not speaking.

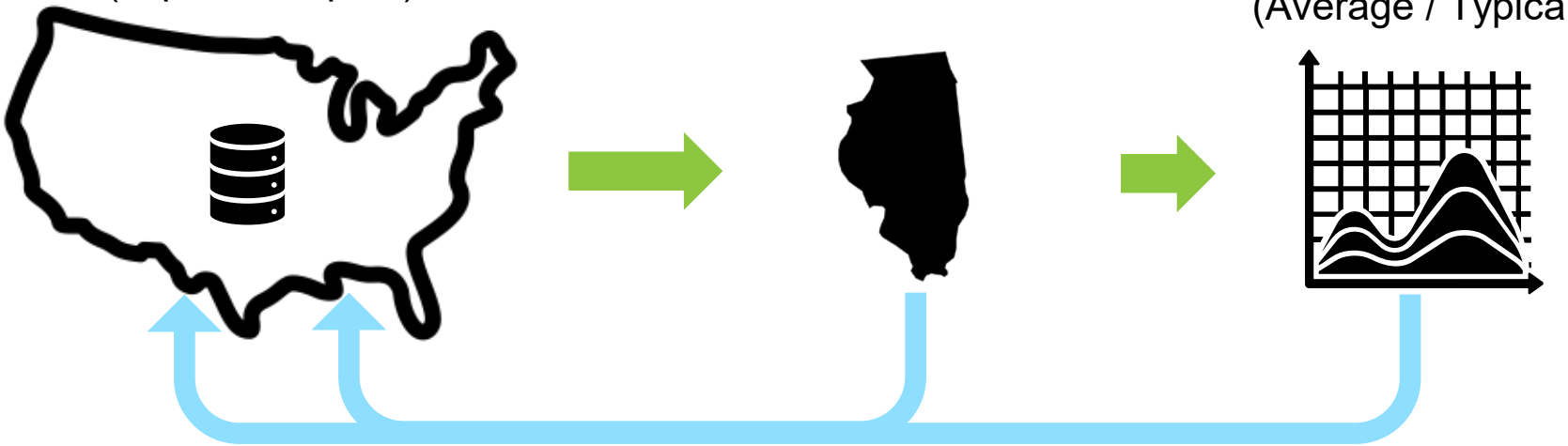
Update: Modeling and Calibration

General Modeling Plan (1)

National ResStock / ComStock (improved inputs)

Regional calibration (AMI, ISO, LRD, Submetered)

Regional Load Profiles & Occupancy Schedules (Average / Typical)



- Start with a region with high data coverage
- Update national model

Results from regional calibration improve national model and transfer to other regions (as appropriate)

General Modeling Plan (2)

Move region-by-region:

- Calibrating
- Quantifying uncertainty
- Improving inputs
- Identifying transferable end-uses

General Uncertainty Quantification Plan

Sensitivity Assessment

- Identify the parameters most important to outcomes
- Inform model improvements and/or data collection
- Region-by-region

Uncertainty Propagation

- Propagate uncertainty in input parameters to uncertainty in output parameters
- Improves confidence in results
- Region-by-region

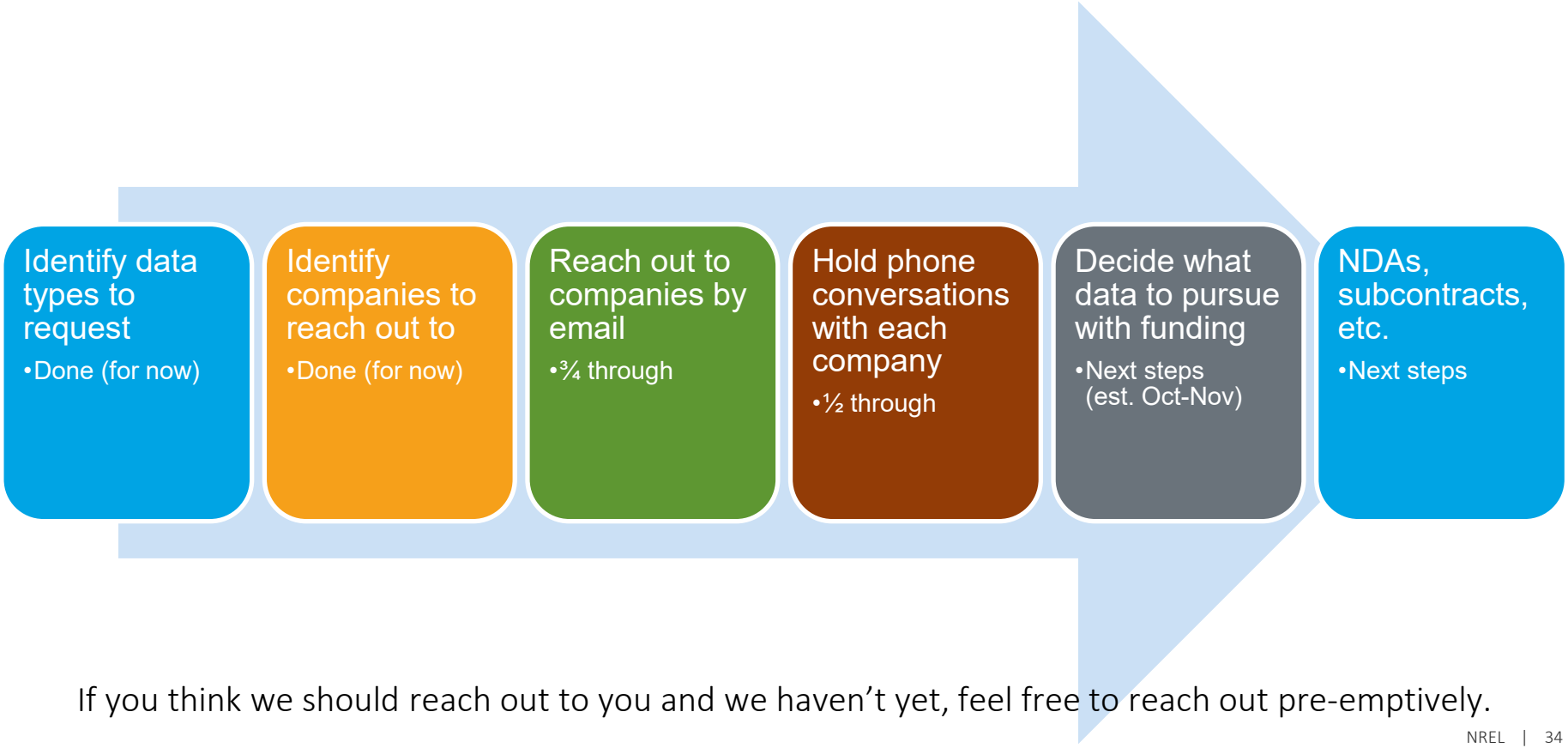
Update: Progress on obtaining data

Data Status Update

- Timeseries whole building (i.e. AMI) (by utility territory dataset)
  - 1 in hand
  - 3 additional with NDAs in place, working on data transfer
  - 3 with NDAs in process
  - 9 additional in conversation

- Timeseries sub-building/end use data
  - Focus: market research for funding prioritization, assessing range of existing data availability

Market Research for Funding Prioritization



If you think we should reach out to you and we haven't yet, feel free to reach out pre-emptively.

Next Steps

Next steps

- *End Use Load Profiles for the U.S. Building Stock: Market Needs, Use Cases and Data Gaps* draft report review. Comments due September 30.
- Next technical advisory group meeting via webinar in December.
- Continue work on
  - Market research on data procurement options
  - Residential and commercial occupancy modeling
  - Residential calibration work
- Talk to us at upcoming conferences:
  - 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

Natalie Mims Frick, nfrick@lbl.gov
Eric Wilson, eric.wilson@nrel.gov
Anthony Fontanini, anthony.fontanini@nrel.gov
Elaina Present, elaina.present@nrel.gov

www.nrel.gov

NREL/PR-5500-79099

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Building Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY