End Use Load Profiles for the U.S. Building Stock

Elaina Present

Introducing End Use Load Profiles Study for the U.S. and Northeast

October 24, 2019

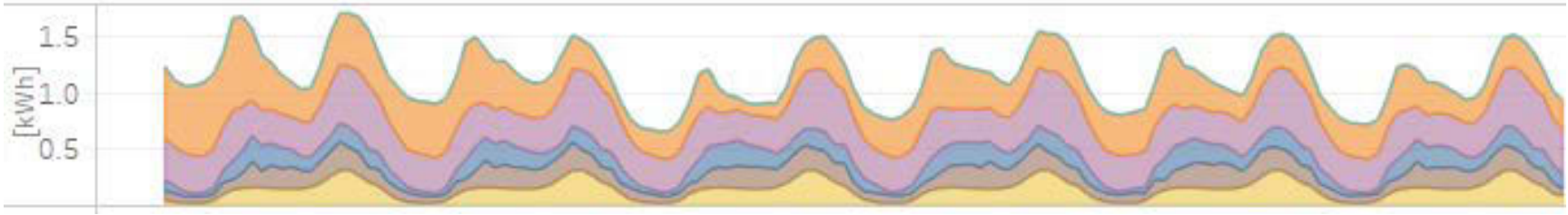
Agenda

- Part 1: Project overview
  - Project overview
    - What are end use load profiles?
    - Why create new ones?
    - Plan and approach
    - Timeline
  - This project and NEEP
  - Q&A
- Part 2: A few deeper dives
  - ComStock & ResStock
  - Stochastic occupancy modeling
  - Data requirements for use cases
  - Work progress
    - Data
    - Modeling & calibration
  - Where we are now
  - Q&A

What

End use load profiles describe ***how*** and ***when*** energy is used in buildings

They are the **most essential** data resource currently missing for Time-Sensitive Valuation of Energy Efficiency



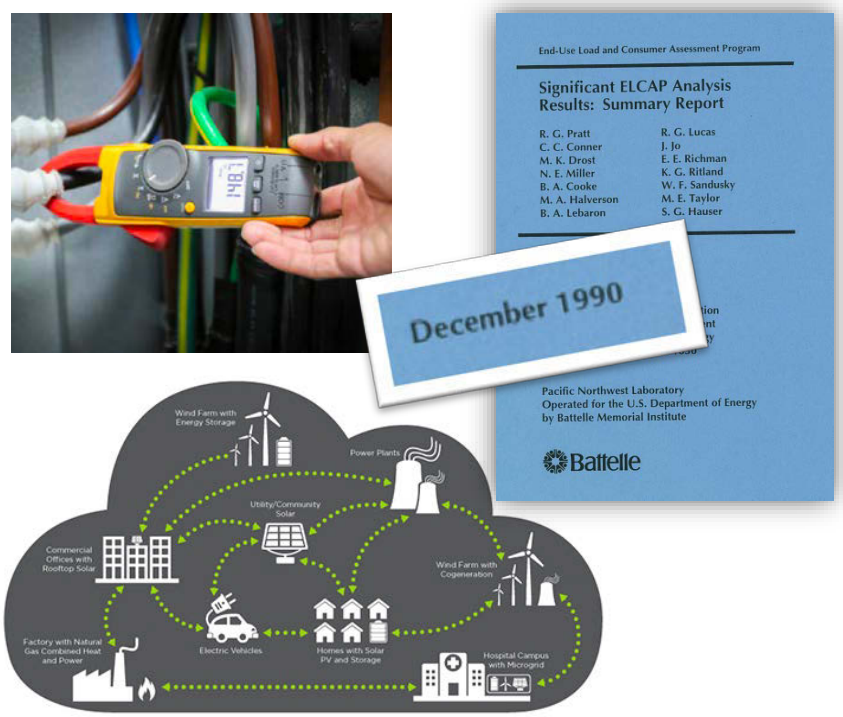
Why

Technical Advisory Group Respondents
0
10
20
30
Utility program design
Forecasting and resource planning
Distribution/Non-wires alternatives
Emerging technology evaluation
Codes/standards/policy analysis
Program implementation/targeting
Electrification impact analysis
Rate design & analysis
Valuation of grid services
EE/DR in electricity markets
Emissions reduction analysis
Regional/national energy planning
New building design/rating
Solar/storage economic analysis
Resilience analysis
Equity improvements

Why

Existing end-use load profiles

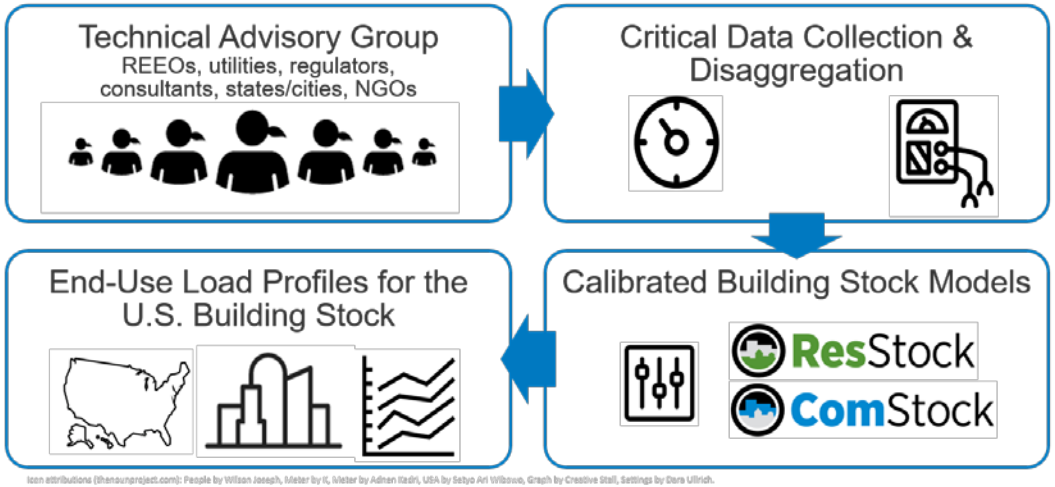
- outdated
- limited to certain regions and building types because of the **high cost** of traditional sub-metering
- insufficient for accurate evaluation of numerous **emerging use cases**



Source: Navigant

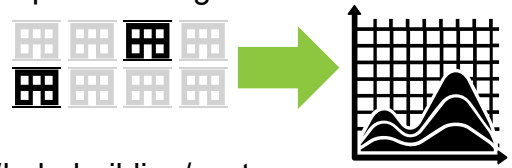
Our Plan:

Deliver a nationally-comprehensive dataset at a fraction of the historical cost



Our Approach

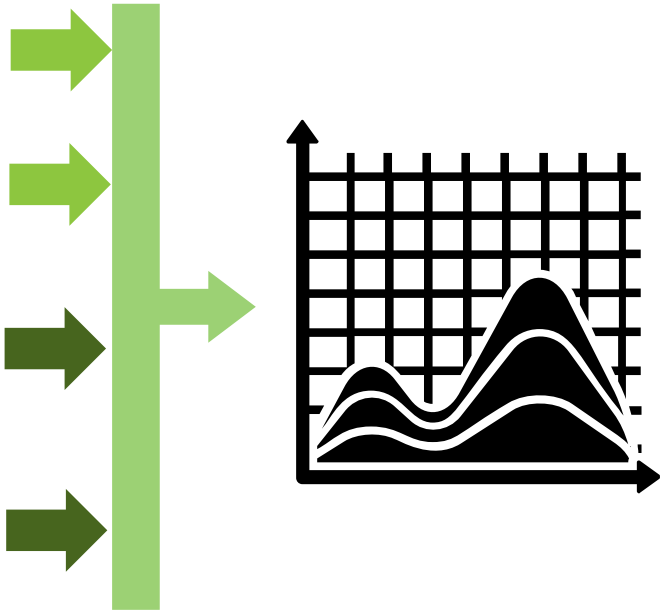
End-use data for sampled buildings



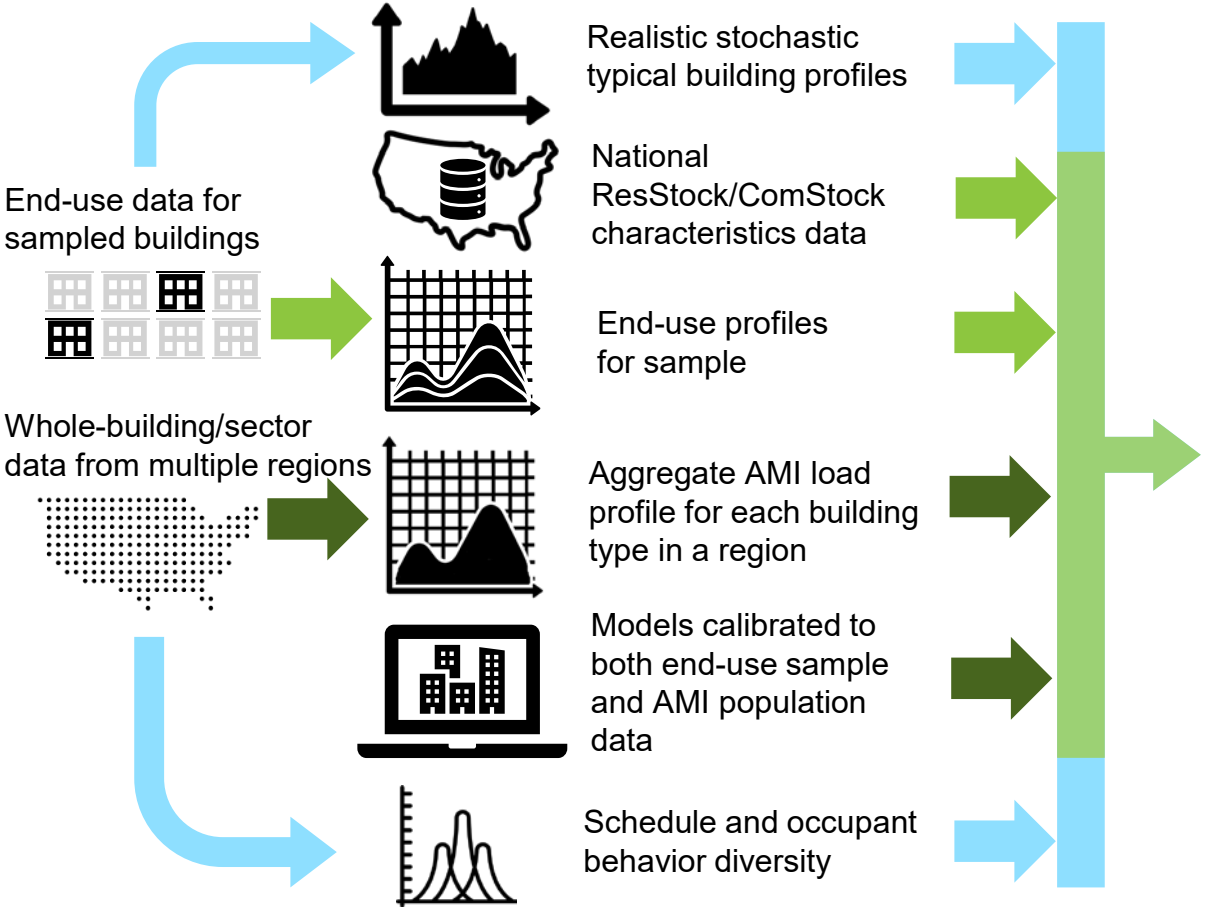
Whole-building/sector data from multiple regions

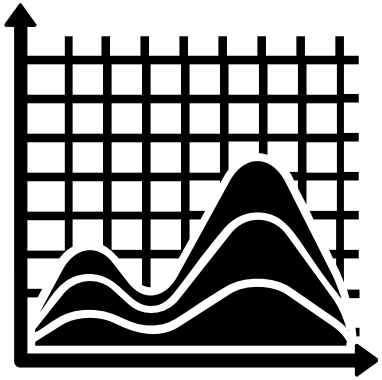
End-use profiles for sample

Aggregate AMI load profile for each building type in a region



Our Approach





- Validated at *both* the end use level and population level
- Validated diversity and individual typical building profiles as well (enables more use cases)

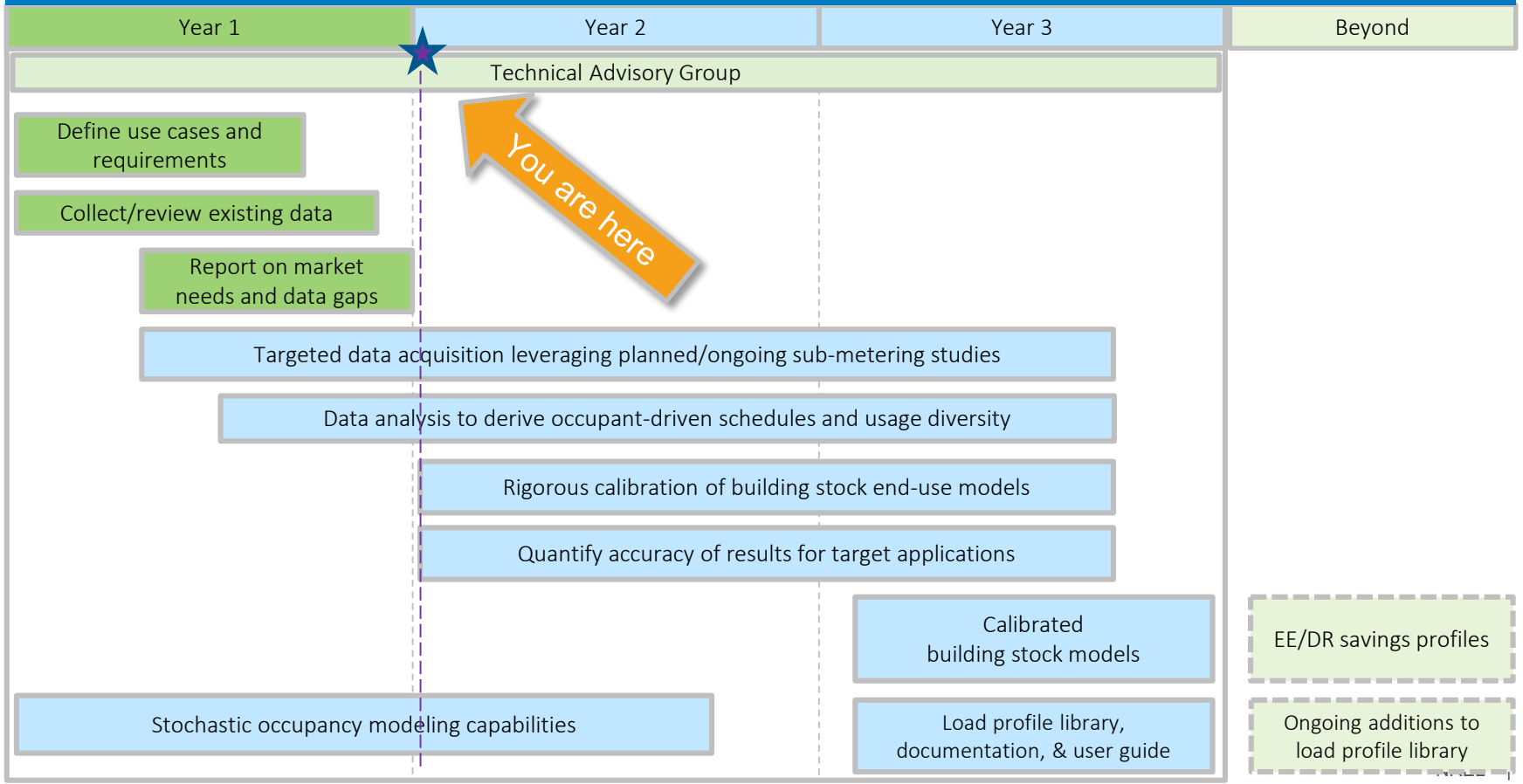
What … and When

The project will result in:

- **Validated end-use load profiles** for U.S. building stock at both aggregate and individual building scales
- **Calibrated building stock end use models** with ability to estimate EE/DR savings profiles for existing and emerging technologies
- **Documentation** of load profile use cases, critical gaps, model methodology, and user guide
- **Quantified uncertainty** of key outputs, by region and building type

All by October 2021.

Project Timeline

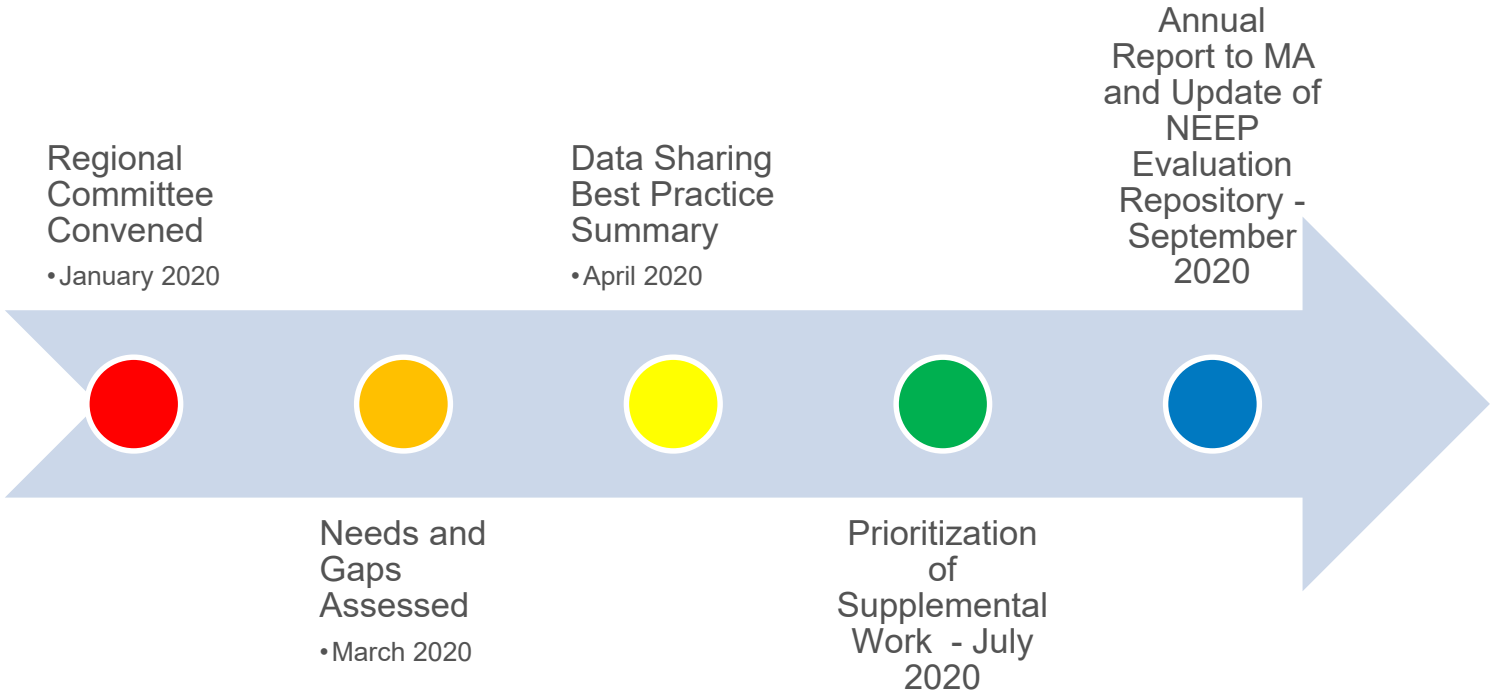


What this means for NEEP/Region

NEEP Technical Assistance Tasks Supported by Regional Funding (MA CEC, NYSERDA):

1. Participate in National Technical Advisory Group
2. Convene/Engage Regional Advisory Committee
3. Assess Regional Stakeholders' End-Use Loadshape Needs – Priorities & Gap Analysis
4. ID Best Practices for Source Data Sharing
5. Facilitate Supplemental Research for the Region

NEEP Project Timeline -Year 1



Some Future Benefits

1. Improved inputs to ISO EE Forecasts
2. Profiles available from an expanded set of building types
3. Opportunities to develop models of flexible loads, integrated resource use cases
4. Northeast region profiles more accurately portrayed in national reference materials
5. Leverage program funding by using available end use models/profiles and whole premise profiles for policy development, planning, etc.

You are Invited!

For more information and to get involved

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Q & A #1

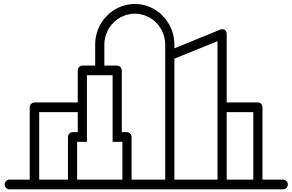
What aspects of this project are most important for the northeast?

ComStock and ResStock

Tool Overview

ComStock

ResStock



Building stock characteristics database

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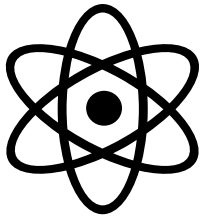

Physics-based computer modeling

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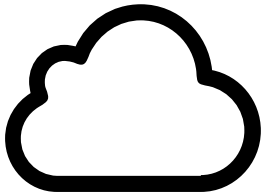


High-performance computing

Current Data Sources

ComStock

~280 high-level inputs

- CoStar (real estate database)
- EIA CBECS 2012, RECS 2009
- DOE Commercial Prototype Building Models
- DOE Commercial Reference Building Models
- ASHRAE Standard 90.1
- ASHRAE Handbooks
- Schedules primarily from ASHRAE 90.1 / Reference Buildings

ResStock

~370 high-level inputs

- U.S. Census American Community Survey (ACS)
- EIA Residential Energy Consumption Survey (RECS) 2009
- National Association of Home Builders surveys
- IECC Energy Codes
- Regional audit databases
- LBNL envelope leakage database
- Building America House Simulation Protocols
- Schedules primarily from ELCAP

Working list of End Uses

Commercial

- HVAC
  - Heating
  - Cooling
  - Fans
  - Pumps
  - Heat rejection
  - Humidification
  - Heat recovery
- Service water heating
- Refrigeration
- Plug and process loads
- Lighting
  - Interior
  - Exterior

Residential

- HVAC
  - Heating
  - Cooling
  - Furnace/Air-conditioning
  - Boiler pumps
  - Ventilation fans
- Domestic water heating
- Major appliances
  - Refrigerator
  - Clothes washer
  - Clothes dryer
  - Dishwasher
  - Cooking range
  - Pool/spa pumps & heaters
- Miscellaneous plug loads
- Lighting
  - Interior
  - Exterior

Working list of Building Types

Commercial

- Small Office
- Medium Office
- Large Office
- Stand-alone Retail
- Strip Mall
- Primary School
- Secondary School
- Outpatient Healthcare
- Hospital
- Small Hotel
- Large Hotel
- Warehouse (non-ref.)
- Quick Service Restaurant
- Full Service Restaurant
- Supermarket
- Mid-rise Apartment
- High-rise Apartment

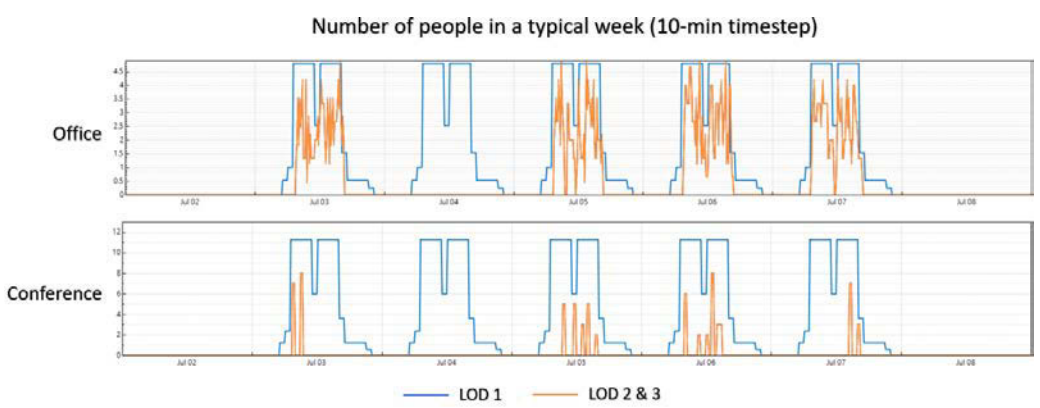
Residential

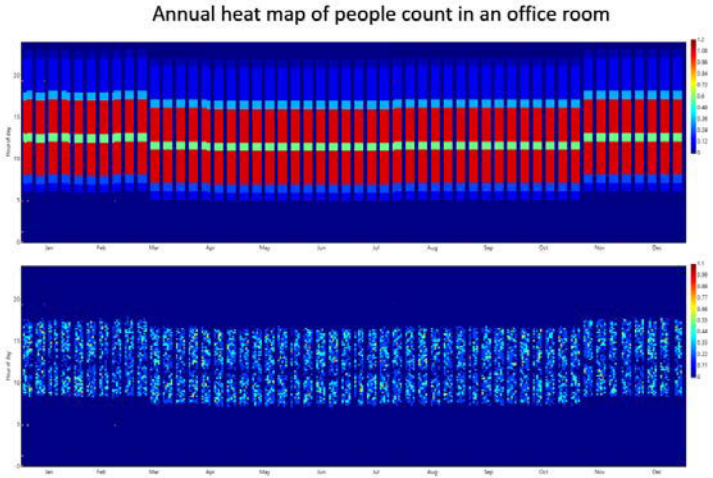
- Single-Family Detached
- Single-Family Attached
- Multifamily low-rise

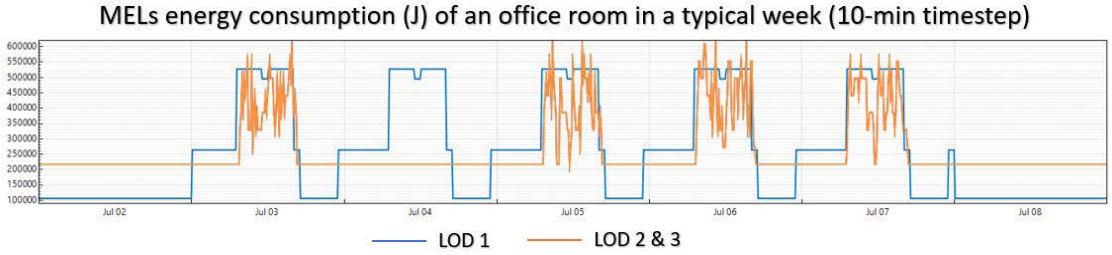
Stochastic Occupancy Modeling

Stochastic Occupancy Modeling

Examples for office buildings



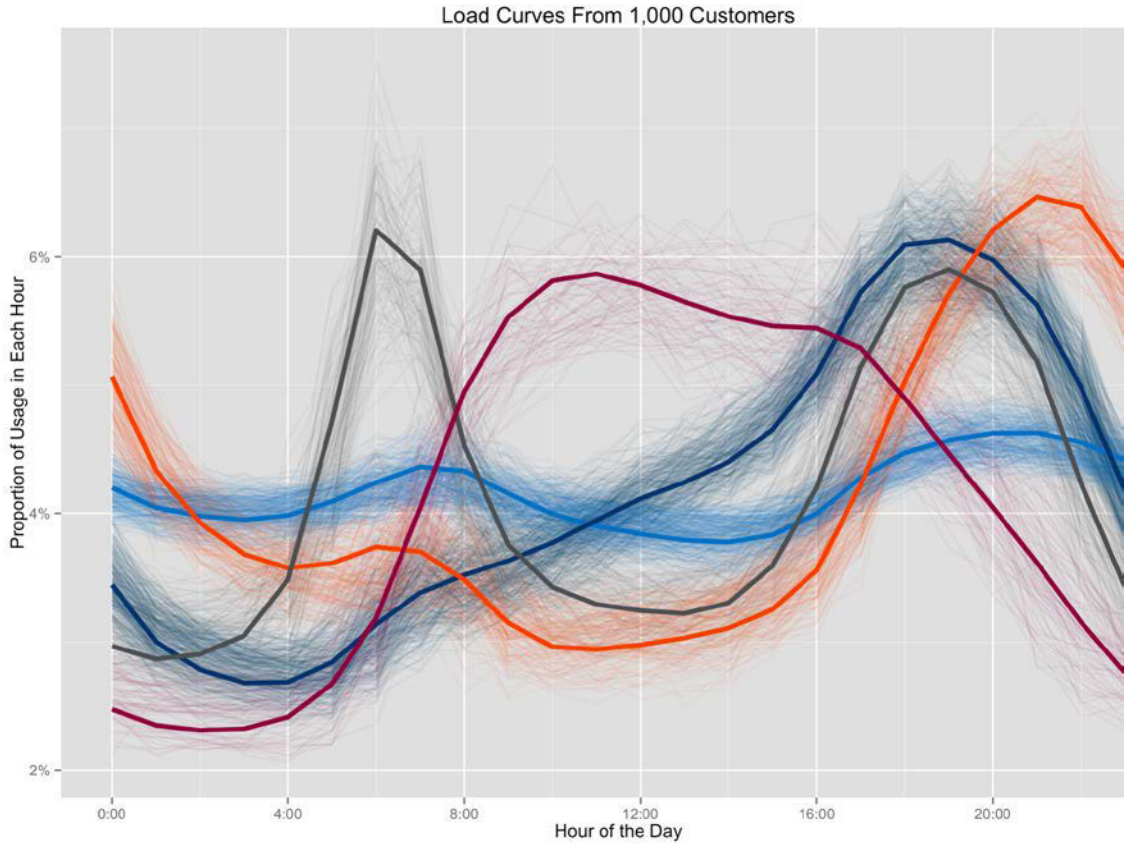




Occupant behavior diversity

Building or end use profiles could be clustered into similar patterns of occupancy

Right: Opower (now Oracle Utilities) clustered whole-building data to derive occupant "archetypes"



Source: Opower (2014)

Output Requirements

Top Use Case Data Requirements

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

= beyond status quo of available data

Data Requirements Driven by 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

Progress on obtaining data & addressing data gaps

Data Priorities

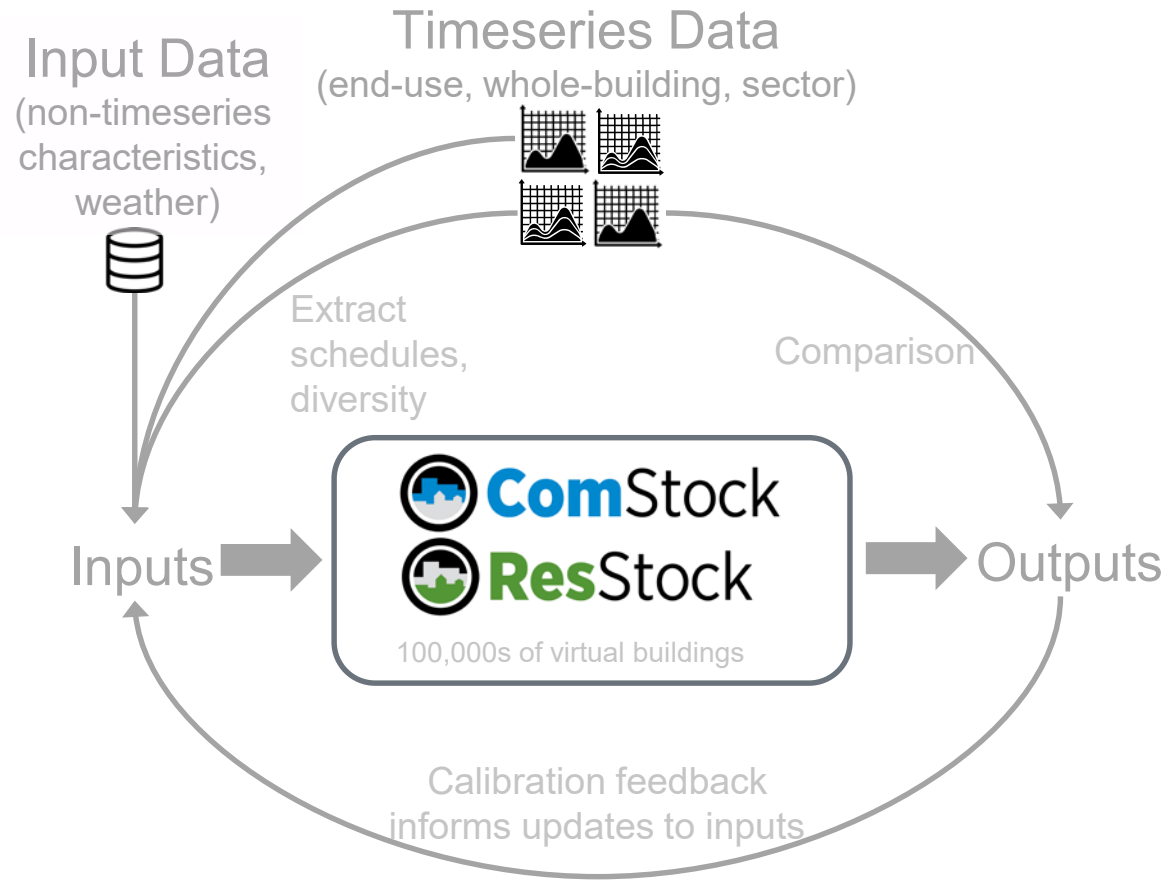
- Hierarchy of data needs:
  - Sub-building-level interval data

    Submetering data, BAS data, IoT data, other data logging or site metering
  - Sub-building-level interval data, aggregated per building type

    ideally: average, median, and quartile or quintile, number of samples
  - Load shapes at the individual building level

    e.g. AMI data
  - Load shapes aggregated per building type
  - Building characteristic distributions

How are we using data?



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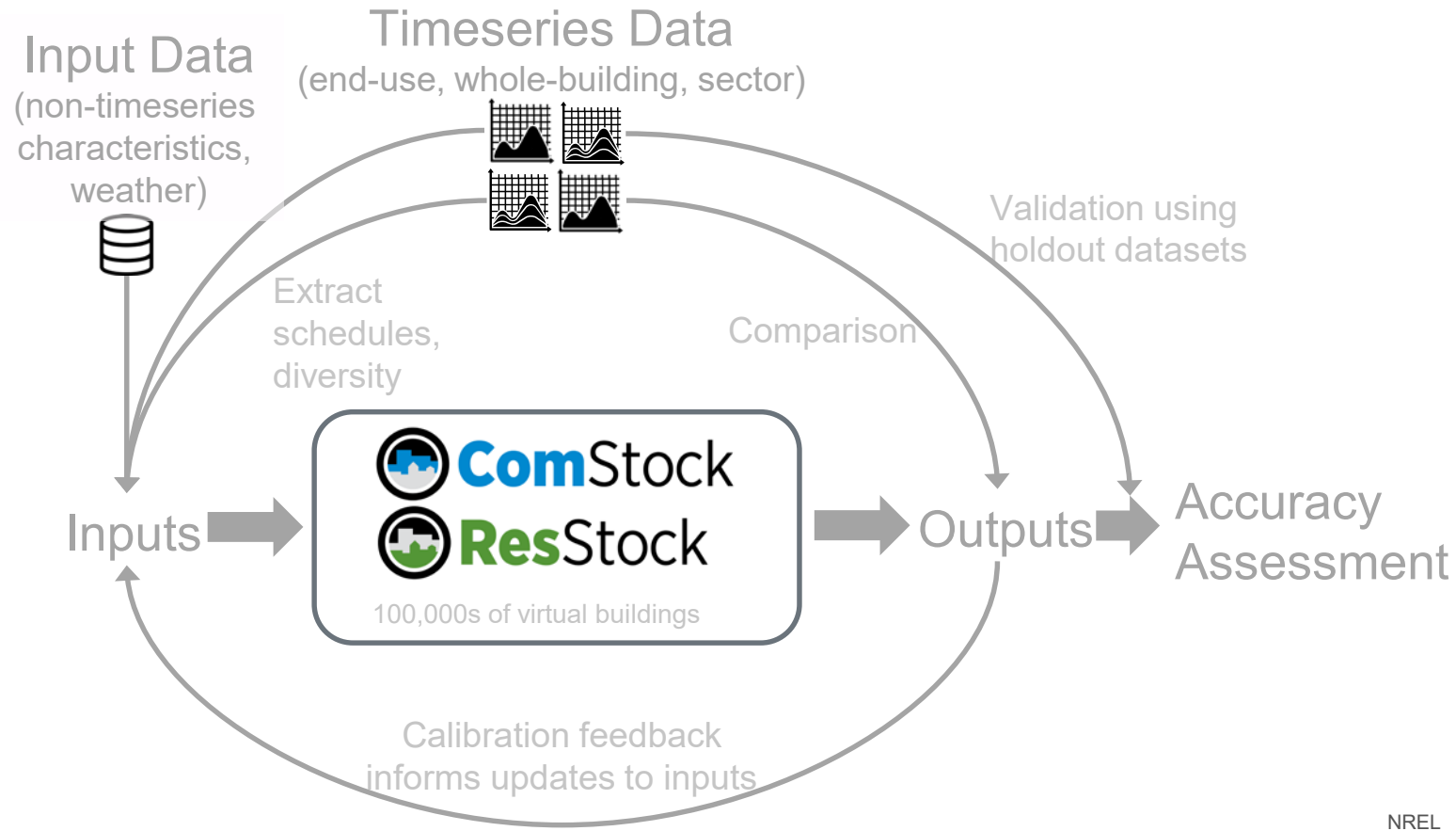
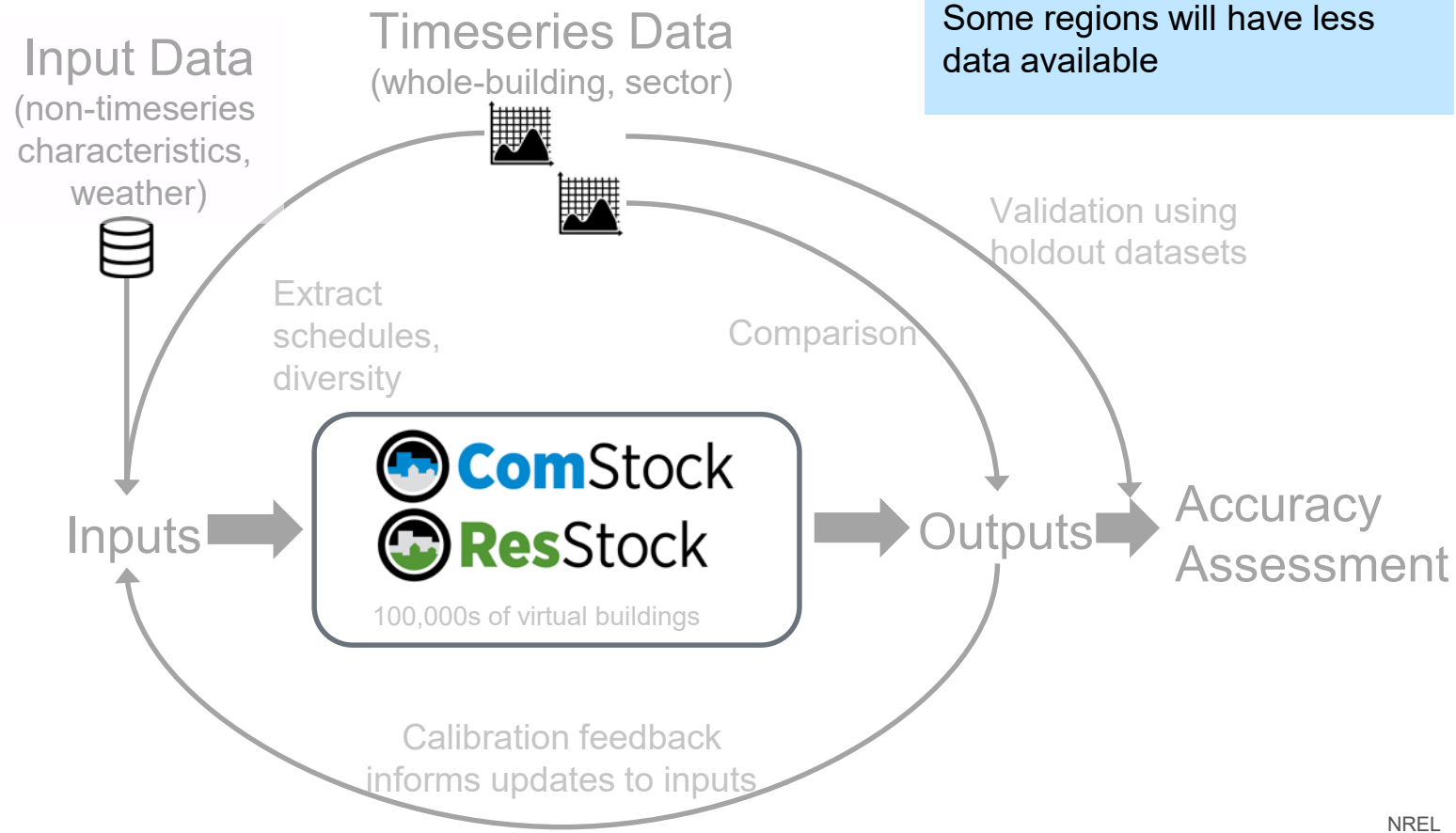


How are we using data?

Some regions will have less data available



Data Status Update: timeseries whole building

Timeseries whole building (i.e. AMI)

by utility territory dataset

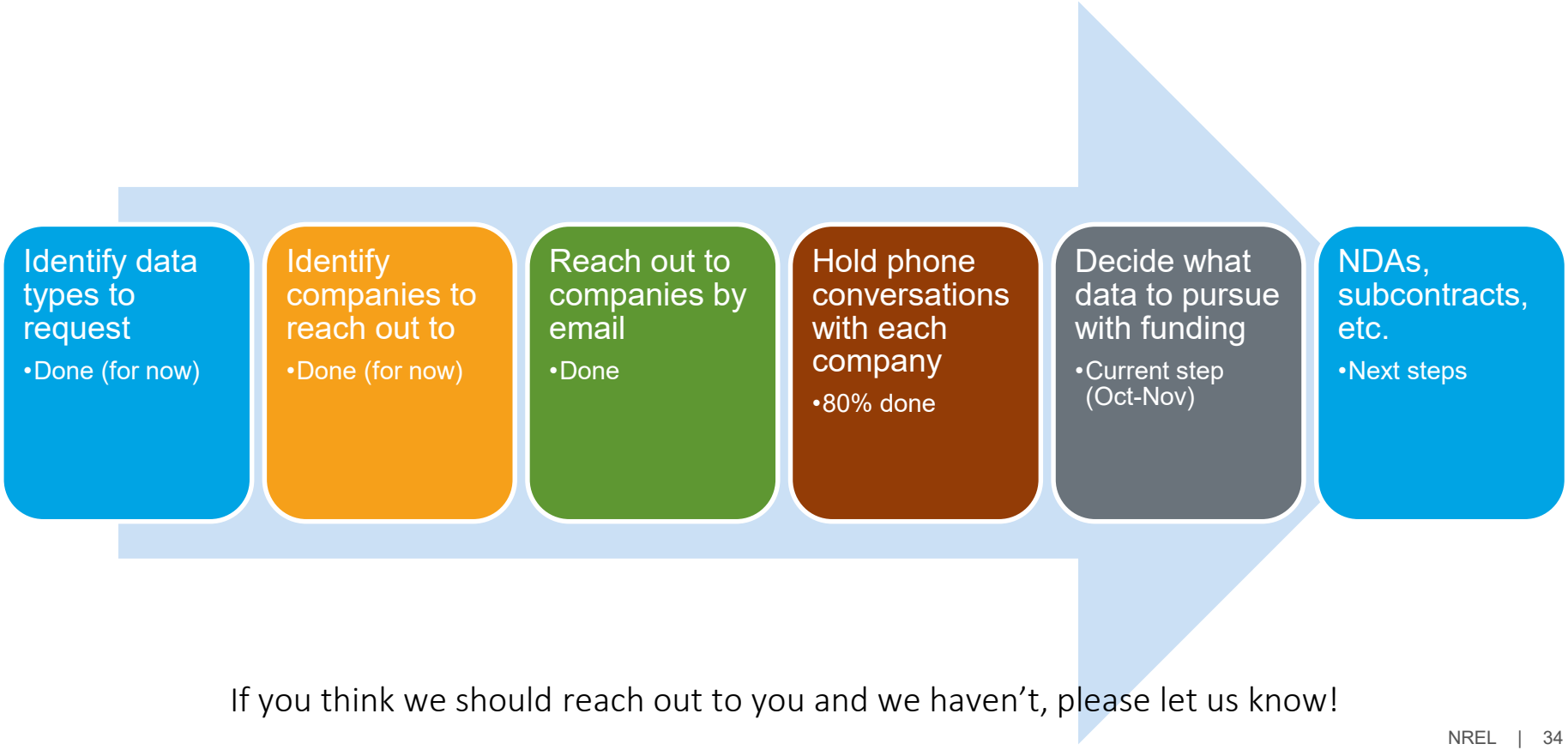
- 2 in hand
- 3 additional with NDAs in place, working on data transfer
- 3 with NDAs in process
- 6 additional in conversation

Data Status Update: submetering/end use

Timeseries sub-building/end use data

- Residential
  - Data from recent projects with submetering
    - Pecan Street, FSEC PDR, Southern Company's Smart Community, NEEA RBSAM, NEEA HEMS (in progress), etc.
    - Over 370 homes with a year or more of submetered data in hand currently
- Commercial
  - Currently conducting focused outreach to assess range of current data availability and prioritize funding

Market Research for Funding Prioritization



If you think we should reach out to you and we haven't, please let us know!

Data Status Update: Northeast U.S.

What we have:

- Massachusetts Load Study
  - Aggregate
  - Residential
- P72 shape savings tool
  - Individual buildings savings shapes
  - Some metadata

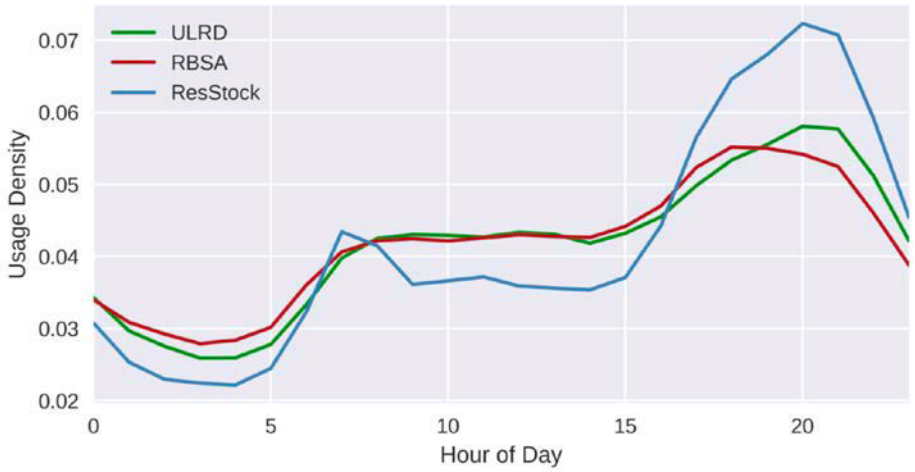
Currently in discussion:

- NEEP load savings tools
  - Tools are public
  - We're seeking underlying data or data aggregated by building type
- VEIC
- NYPA
- NYSERDA

Calibration Examples

Physics-based calibration: Non-weather loads

Before



Load research data (average of 8 profiles)

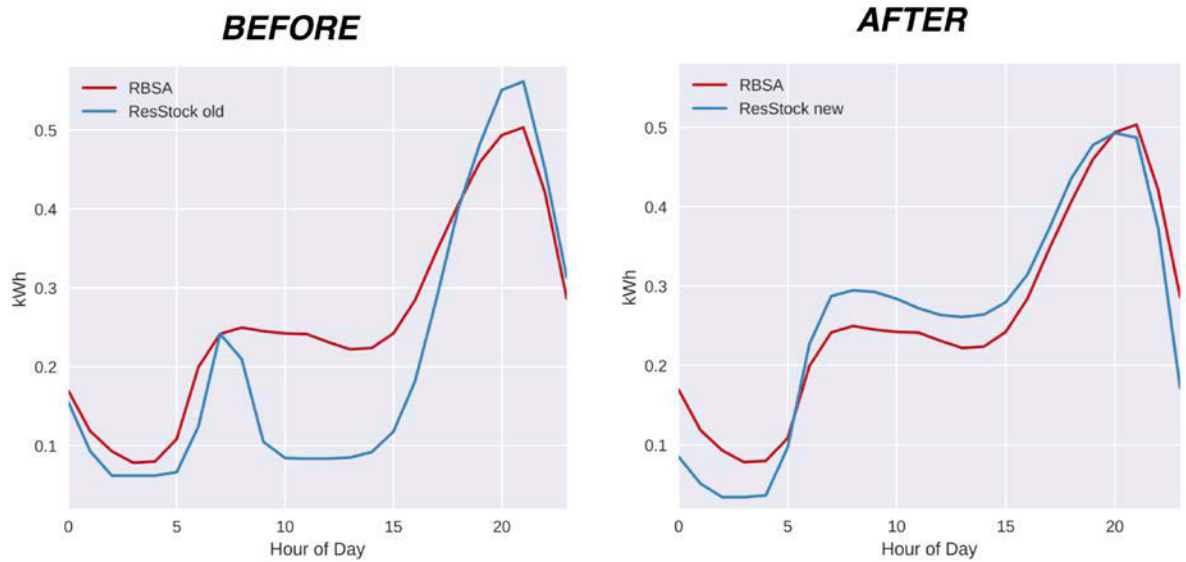
- agree with RBSA metering study (average of non-weather dependent end uses from 100 homes)

ResStock output

- overpredicts peak and nighttime low
- Has mid-day valley not present in measured data

Physics-based calibration: Non-weather loads

Lighting

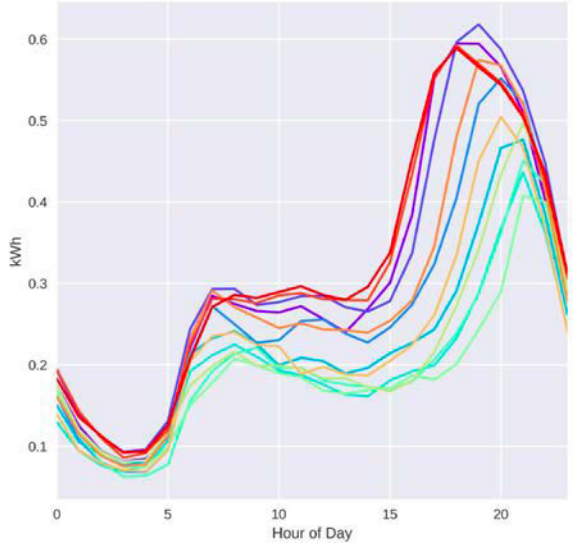


Modified ResStock/House Simulation Protocols latitude/longitude lighting algorithm to eliminate mid-day valley

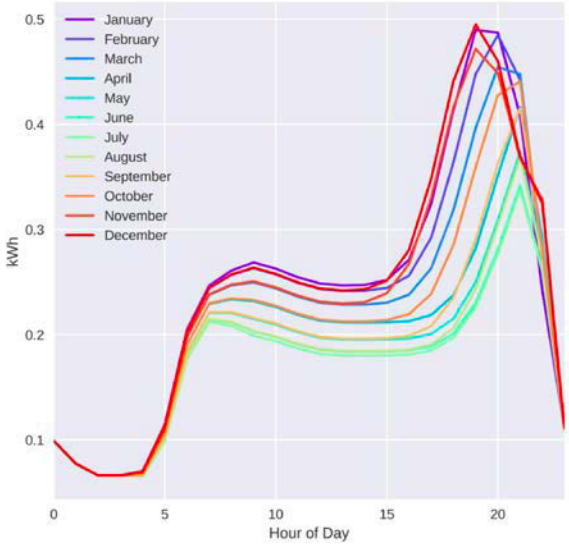
Physics-based calibration: Non-weather loads

Monthly lighting profile comparison

RBSA Metering Study



ResStock (PNW average)



Physics-based calibration: Non-weather loads

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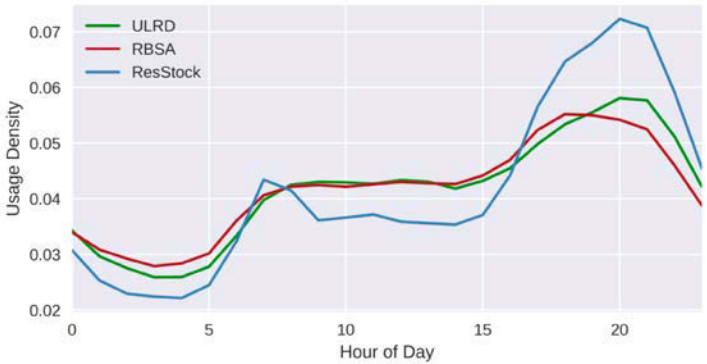
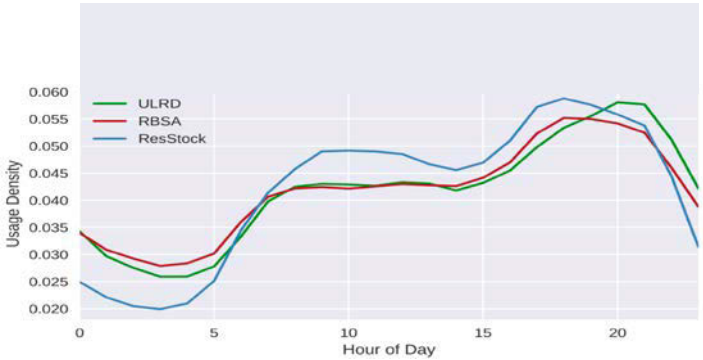


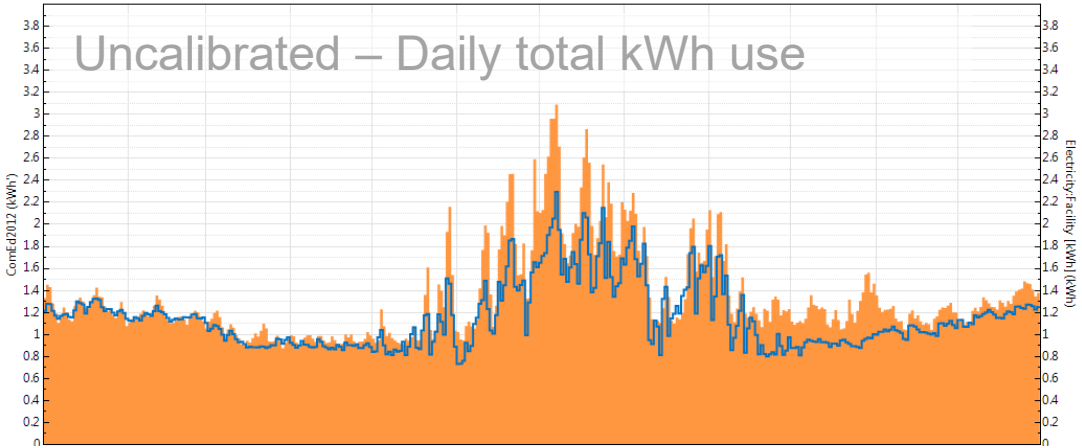
After



- Peak was reduced
- Filled mid-day valley

- Nighttime low still too low
- Afternoon peak too early

Calibration example 2: Weather loads

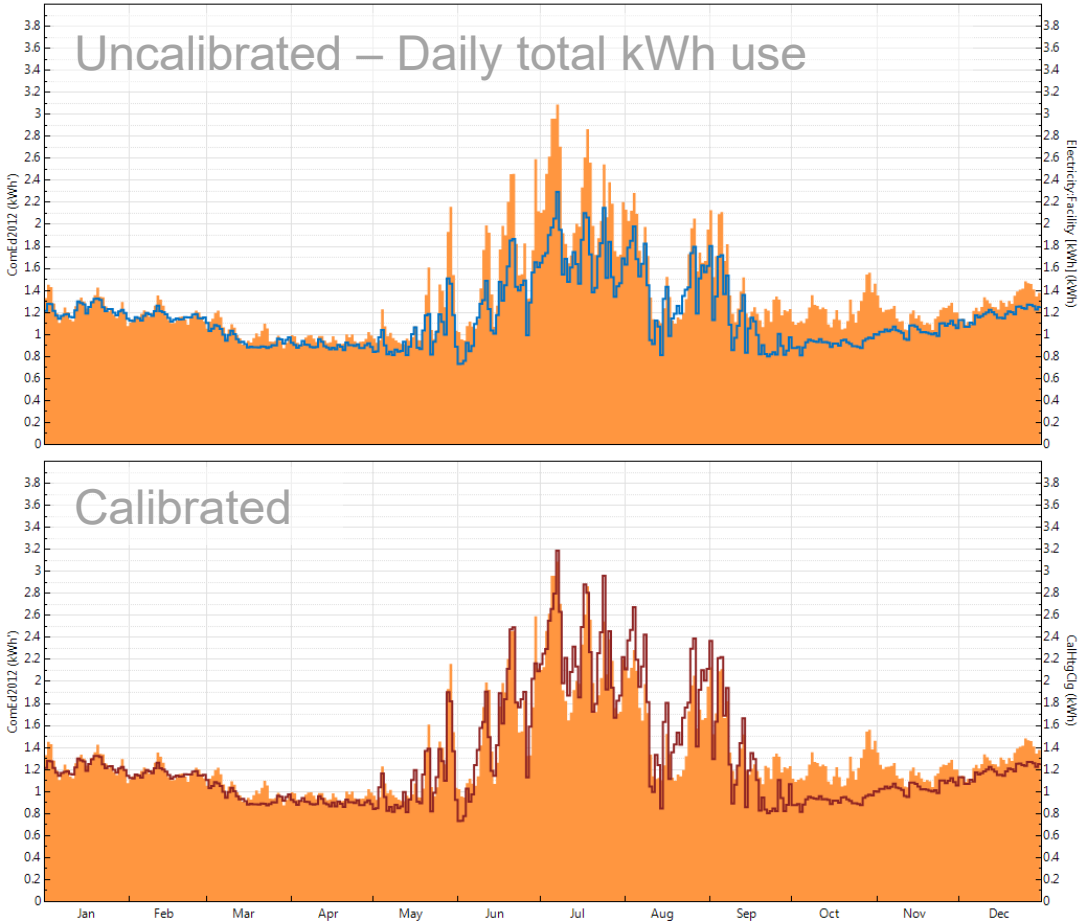


ComEd load research data

ResStock – Northern Illinois

- 2012 weather
- Single-family homes
- Customers **without** elec. heat

Calibration example 2: Weather loads



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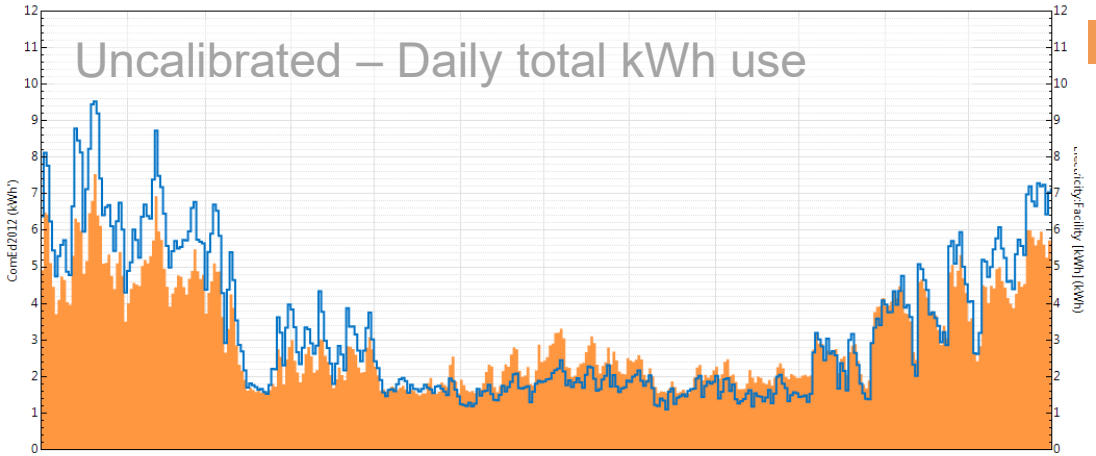
- Calibrated cooling energy with simple degree-day model
- October/November anomaly?

Calibration example 2: Weather loads



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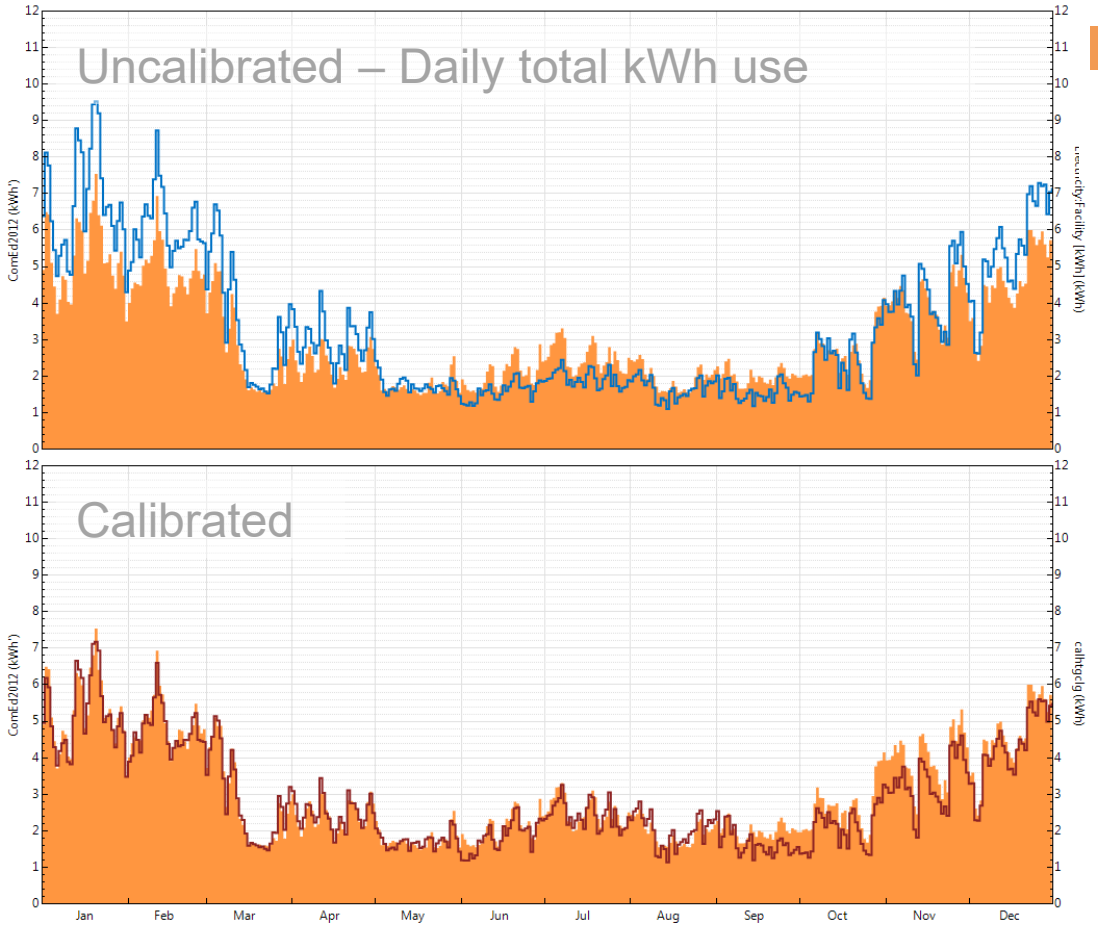


ComEd load research data

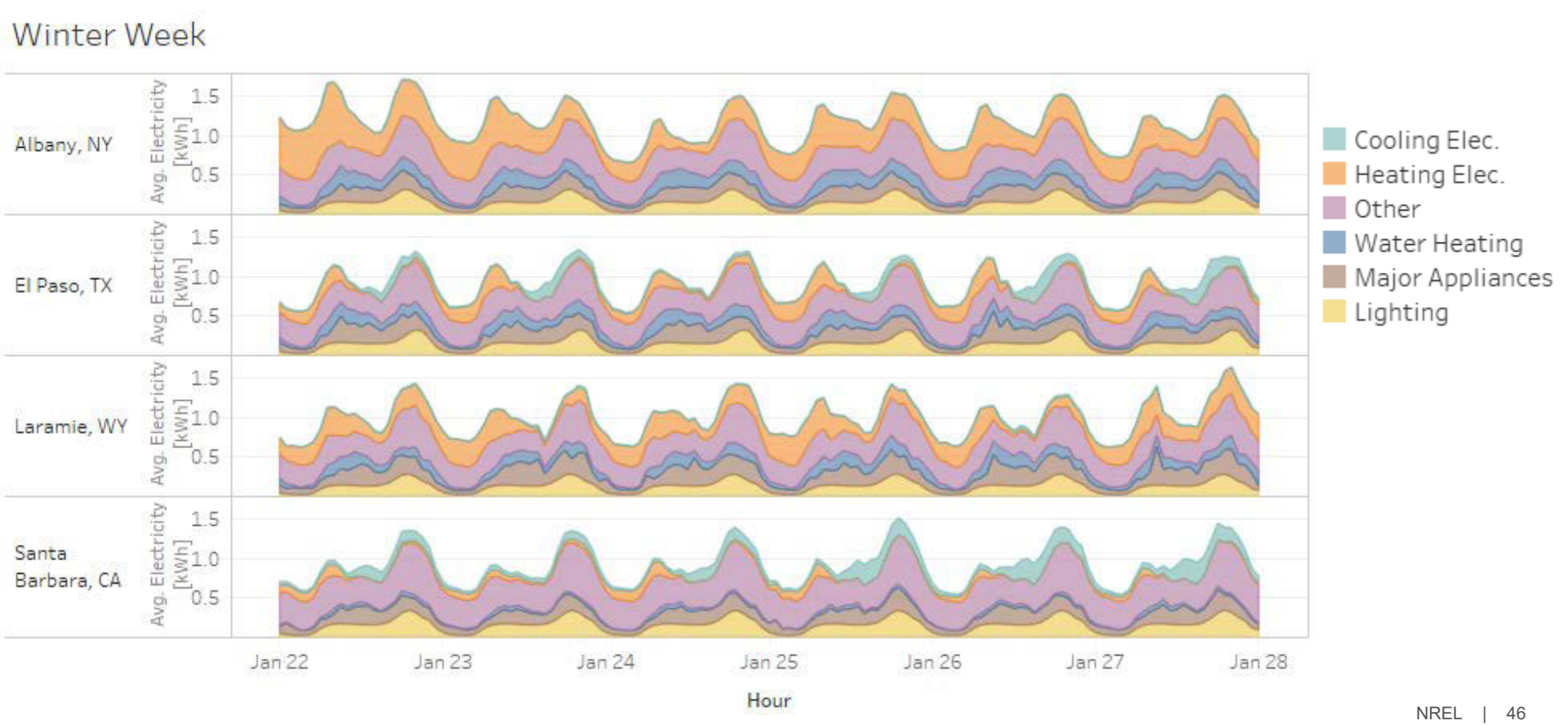
ResStock – Northern Illinois

- 2012 weather
- Single-family homes
- Customers **with** elec. heat

- Calibrated heating, cooling energy with simple degree-day model
- October/November anomaly?

Where we are now

Where we are now - winter



Where we are now - summer

Q & A #2

Thank you

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Sign up for the project mailing list at
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