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

Technical Advisory Group meeting #2

March 5 – 6, 2019

Introduction

Natalie Mims Frick, LBNL

Logistics

- We have ~40 people in Colorado and ~30 people on the phone.
- 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 during Q&A periods for open dialogue.
- If you are participating by phone, the agenda has your breakout group call-in information for today.
- We are taking notes and will distribute them to the TAG. We will not attribute specific remarks to participants.
- We will be recording the plenary sessions.

Agenda – March 5

12:15 – 12:30	Welcome, logistics, agenda, goals of meeting
12:30 – 12:50	Introductions
12:50 – 1:15	Project overview, deliverables, timeline
1:15 – 1:45	Partner Presentations
1:45 – 2:15	Presentation: Use Cases Introduction
2:15 – 2:30	Break 1
2:30 – 3:30	Breakout #1 - Use Cases Brainstorming
3:30 – 3:45	Break 2
3:45 – 4:45	Presentation: Data for Modeling and Calibration
4:45 – 5:00	Day 1 Wrap Up, Overview of Day 2
6 PM	Meet at Colorado Plus for dinner

TAG Responsibilities

- **Review materials provided in advance** of quarterly calls and annual meetings
- Be prepared to **contribute to thoughtful conversation** to guide review of technical choices and decision-making
- **Review three draft reports** and provide comments and feedback
- Help the project team produce **useful and industry-accepted** load profiles
- Help **disseminate results**

Goals of Today’s Meeting

- Meet the other TAG members and our team
- Share your knowledge with us
- Ask questions
- Identify and discuss:
  - traditional and novel use cases
  - data requirements for end-use load profiles
  - how to make the project’s results valuable to your regulators, stakeholders or clients

Grid-interactive Efficient Buildings

Monica Neukomm
Building Technologies Office, DOE
www.energy.gov/eere/buildings/geb

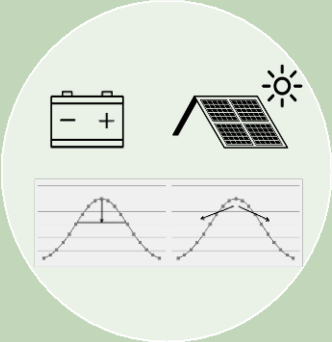
Key Aspects of a Grid-Interactive Efficient Building

Smart

Sensing, control, and analytics co-optimize efficiency, flexiblity, and occupant needs

Connected

Two-way communication with flexible technologies, the grid, and occupants



Flexible

Flexible loads and distributed generation/storage can be used to reduce, shift, or modulate grid-level energy use

Efficient

Persistent low energy use minimizes demand on grid resources and infrastructure

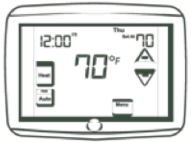
Grid Services Provided by GEB

Efficiency

- Reduced overall demand during high-cost periods
- Efficient appliances, insulated envelope
- **Grid Service: Reduce generation and T&D upgrade**

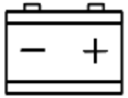
Shed Load

- Reduced demand during generation balancing annual peak demand
- Thermostat setpoints; IT equipment
- **Grid Service: Reduce generation capacity, T&D upgrade**



Shift Load

- Changes energy use to a different time
- Batteries, thermal mass and storage, smart appliances
- **Grid Service: Improve utilization of low-cost generation**



Modulate Load

- Modulates demand in response to a signal from grid
- SSLs, IT equipment, VFD equipment, batteries
- **Grid Service: Support frequency regulation**

BTO’s grid-interactive efficient buildings portfolio

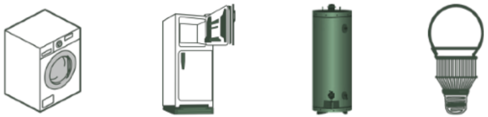
VALUATION

How do *<u>time & the interaction of flexibility options</u>* impact value?

Identify values to stakeholders, quantification of national value.

TECHNOLOGY OPTIONS

Which <u>end use technologies</u> provide solutions to specific grid needs?



Prioritize technologies / solutions based on grid services.

OPTIMIZATION

How to while maintaining or improving <u>optimize for flexibility</u> building operation?

Solutions that meet grid operator & building occupant needs.

VALIDATION

Do technologies <u>perform as predicted</u> and meet grid & occupant needs?

Verification of technologies / strategies, increasing confidence in the value of energy flexibility.

Joining By Phone

- Dan York, ACEEE
- Prasenjit Shil, Ameren
- Robert Weber, BPA
- Sami Khawaja, Cadmus
- Ayad Al-Al-Shaikh, CalTF
- Ross Macwhinney, City of New York
- Stephen Bird, Clarkson University
- Susan Powers, Clarkson University
- Griffin Reilly, ConEd
- Bob Ramirez, DNV-GL
- Chris Neme, Energy Futures Group
- Jamie Fine, Environmental Defense Fund
- Ron Domitrovic, EPRI
- Dave Parsons, HI PUC
- Erik Miller, IPL
- Henry Yoshimura, ISO-NE
- Brad Borum, IURC
- Bob Pauley, IURC
- Paulomi (Lucy) Nandy, MEEA
- Naomi Simpson, MI PSC
- Dave Walker, MI PSC
- Claire Miziolek, NEEP
- Elizabeth Titus, NEEP
- Mike Reed, NYSERDA
- Angela Long, PacifiCorp
- Scott Schuetter, Seventhwave
- Kenji Takahashi, Synapse
- Abhijeet Pande, TRC Solutions
- Robert Stephenson, VEIC
- JJ Vandette, VEIC

In the Room

- Jen Amman, ACEEE
- Steven Keates, ADM
- Kurtis Kolnowski, AEG
- Bob Willen, Ameren
- Phillip Kelsven, BPA
- Valerie von Schramm, CPS
- Curt Puckett, DNV-GL
- Craig Williamson, DNV-GL
- Ben King, DOE
- Monica Neukomm, DOE
- Rachel Scheu, Elevate Energy
- Adam Gerza, Energy Toolbox
- Krish Gomatom, EPRI
- Chris Holmes, EPRI
- Jamie Barber, GA PSC
- Matt Cox, Greenlink Group
- Ali Bozorgi, ICF
- Tom Eckman, LBNL
- Natalie Frick, LBNL
- Rodney Sobin, NASEO
- Mark Bielecki, Navigant
- Justin Spencer, Navigant
- Carlo Bianchi, NREL
- Jianli Chen, NREL
- Dane Christensen, NREL
- Matt Dahlhausen, NREL
- Lieko Earle, NREL
- Rawad El Kontar, NREL
- Anthony Fontanini, NREL
- Janghyun Kim, NREL
- Andrew Parker, NREL
- Ben Polly, NREL
- Marlena Praprost, NREL
- Elaina Present, NREL
- Janet Reyna, NREL
- David Roberts, NREL
- Eric Wilson, NREL
- Jessica Lin, Oracle
- Dan Patry, Oracle
- Ellen Franconi, PNNL
- Michael Bishop, SolarReviews
- Jim Leverette, Southern Company
- David Podorson, Xcel

Introductions – 30 Seconds

- Name
- Company
- Why you are interested in end-use load shapes

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

Project Overview, Deliverables, Timeline

Eric Wilson, NREL

Technical Advisory Group meeting #2

March 5–6, 2019

Project Team – Labs

NREL

Eric
Wilson (PI)

Andrew
Parker (Co-PI)

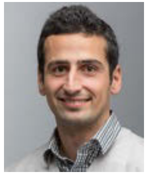
Dr. Rajendra
Adhikari

Dr. Jianli
Chen

Dr. Lieko
Earle

Rawad
El Kontar

Dr. Anthony
Fontanini



Dr. Sammy
Houssainy

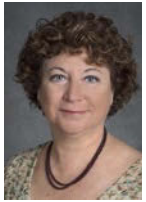
Dr. Janghyun
Kim

Elaina
Present

Dr. Janet
Reyna

LBNL

Natalie Mims
Frick (Co-PI)



Lisa
Schwartz

Dr. Tianzhen
Hong

Han Li

Argonne

Dr. Ralph
Muehleisen

Dr. Qi Li

Project Team – Industry

Northeast Energy Efficiency Partnerships (NEEP)

Elizabeth Titus

Claire Miziolek

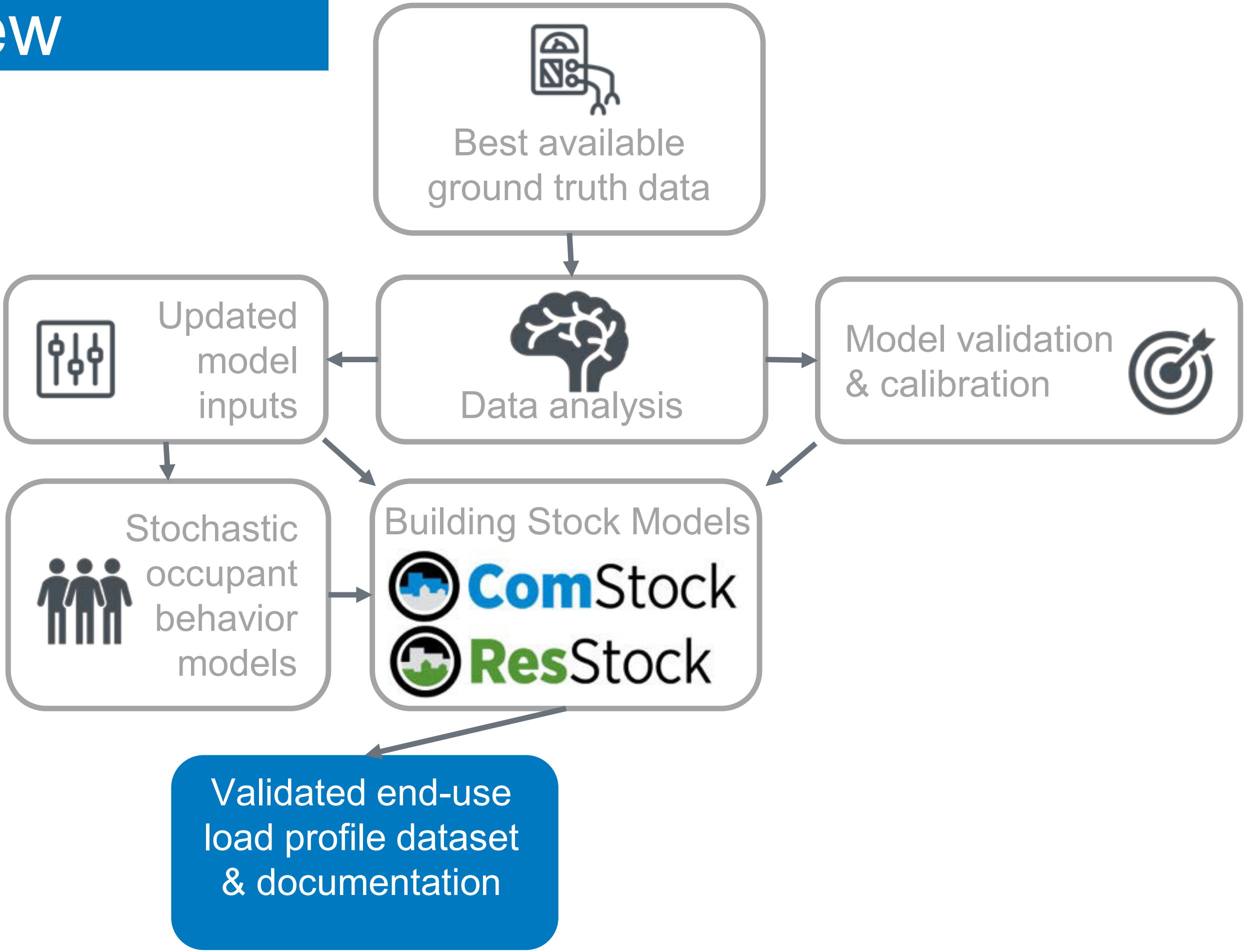
Electric Power Research Institute (EPRI)

Chris Holmes

Krish Gomatom

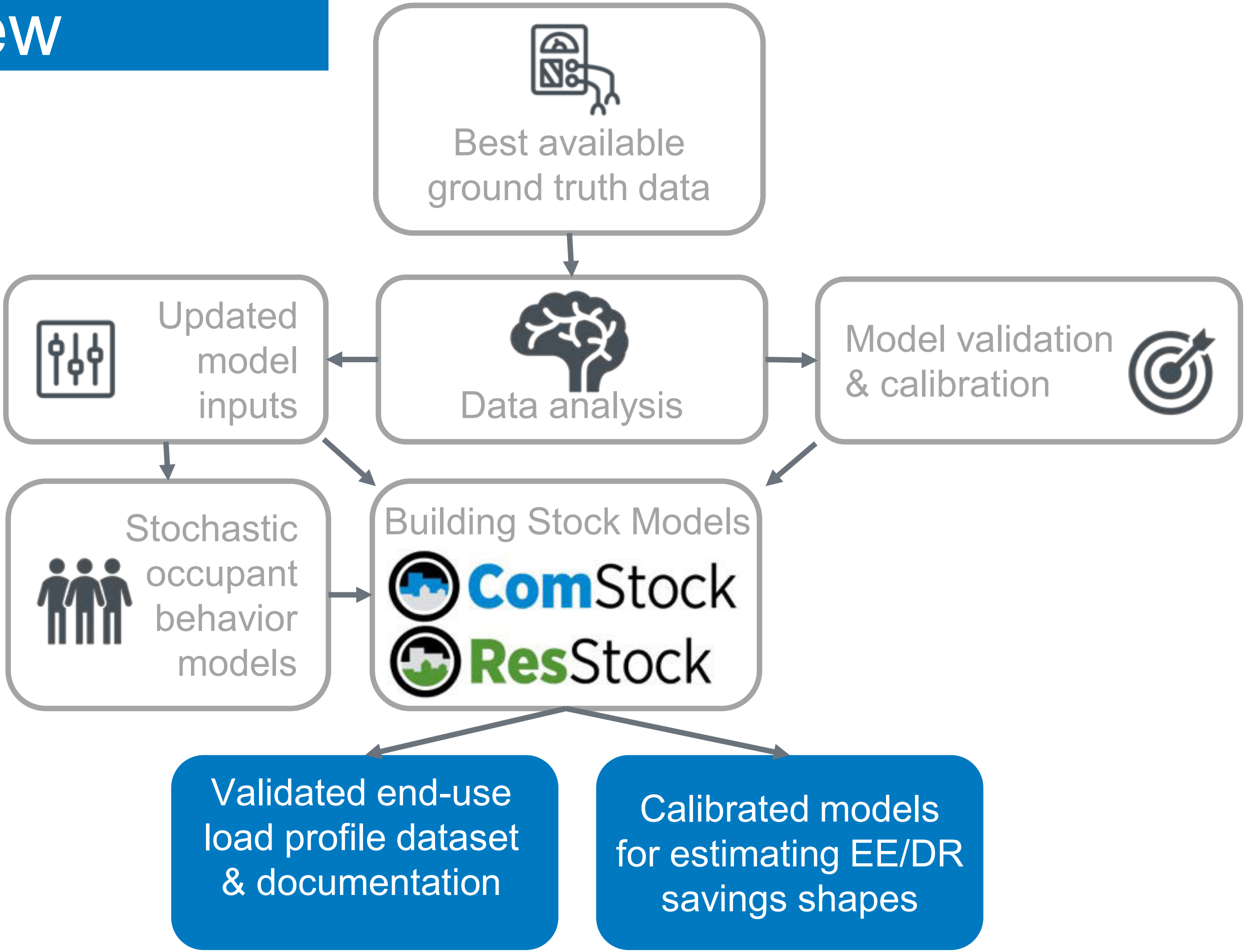
...and many others on the technical advisory group

Project Overview



Icon attributions (thenounproject.com): People by Wilson Joseph, Meter by K, USA by Setyo Ari Wibowo, Graph by Creative Stall, Settings by Dara Ullrich.

Project Overview



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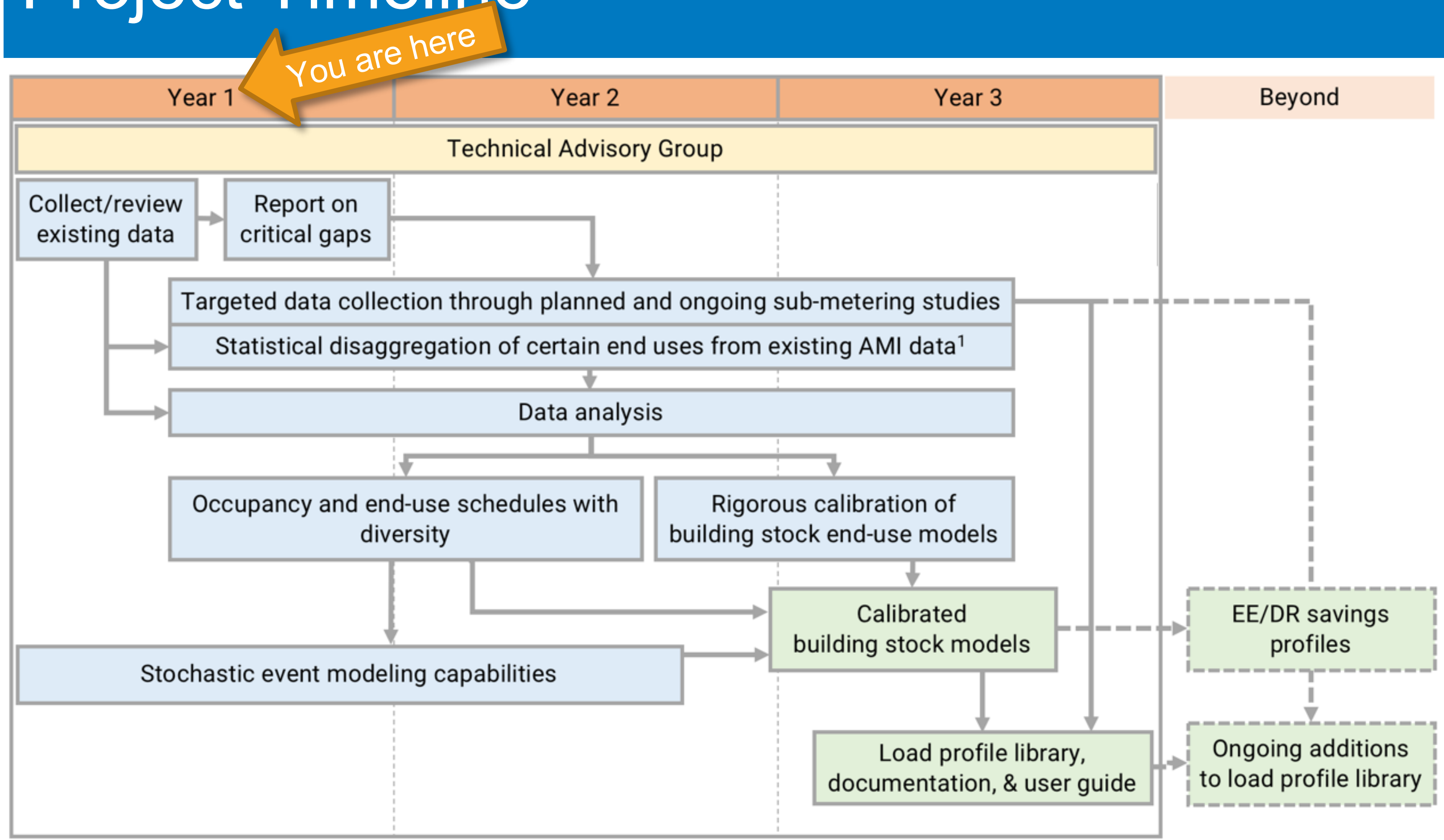
Project Timeline



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

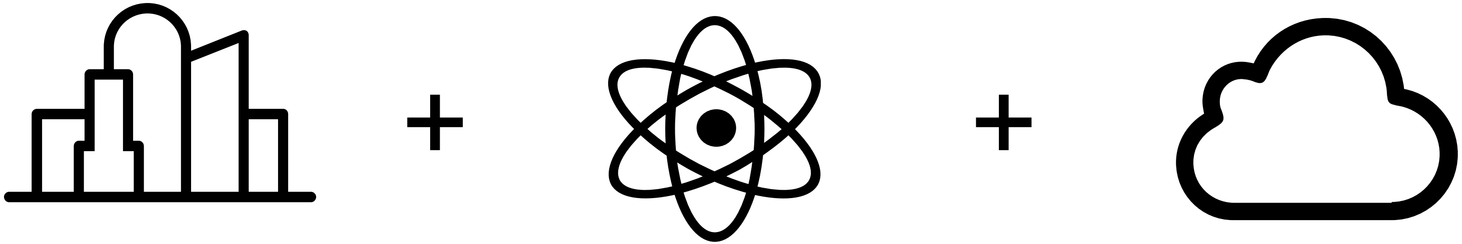
Key Milestones and Deliverables

2018 (December)	**Establish TAG**
2019 (Summer)	**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)

ResStock/ComStock Load Profile Modeling

Background: DOE Building Stock Models

ComStock ResStock

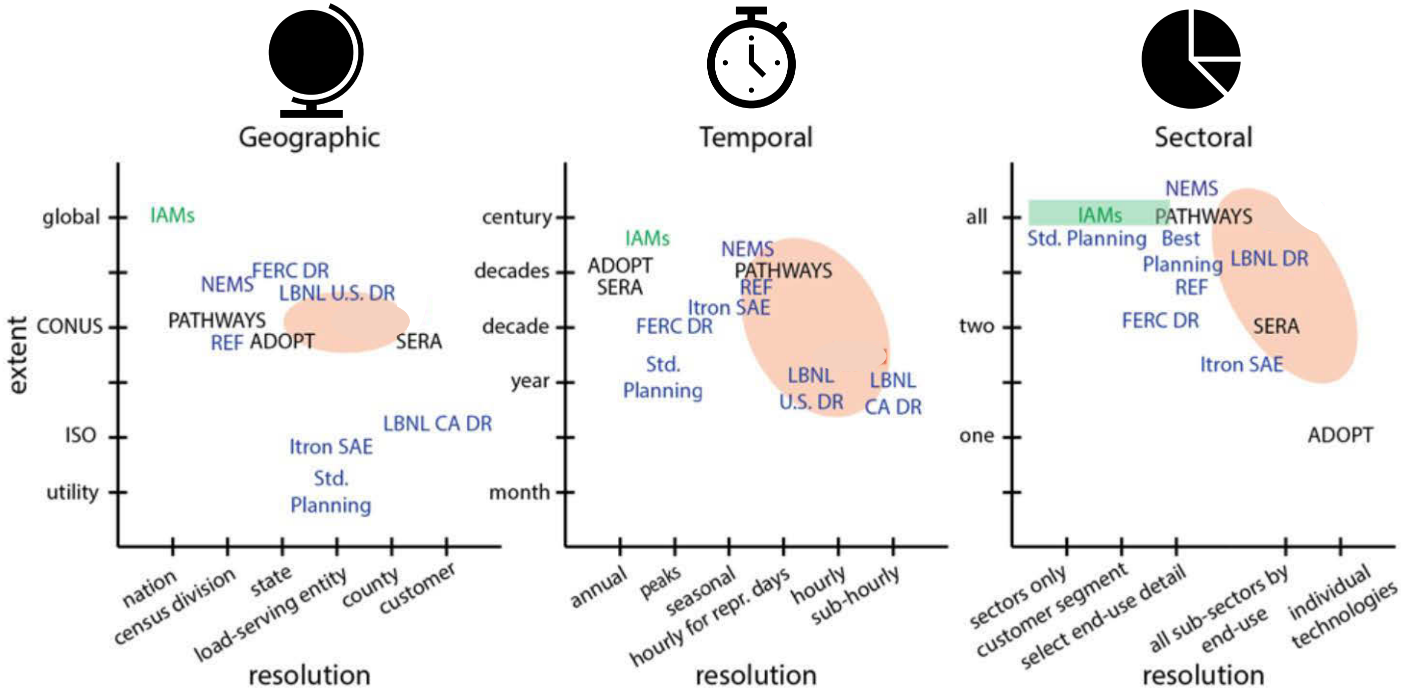


Building stock characteristics database + Physics-based computer modeling + High-performance computing

- DOE-funded, NREL-developed models of the U.S. building stock
- 100,000s of statistically representative physics-based building energy models (BEM)
- Use DOE’s flagship BEM tools OpenStudio and EnergyPlus
- Produce hourly load profiles, but calibration to-date has focused on annual energy consumption

For further details see: https://resstock.nrel.gov/page/publications

Comparing *extent* and *resolution* of load models



= ResStock/

ComStock

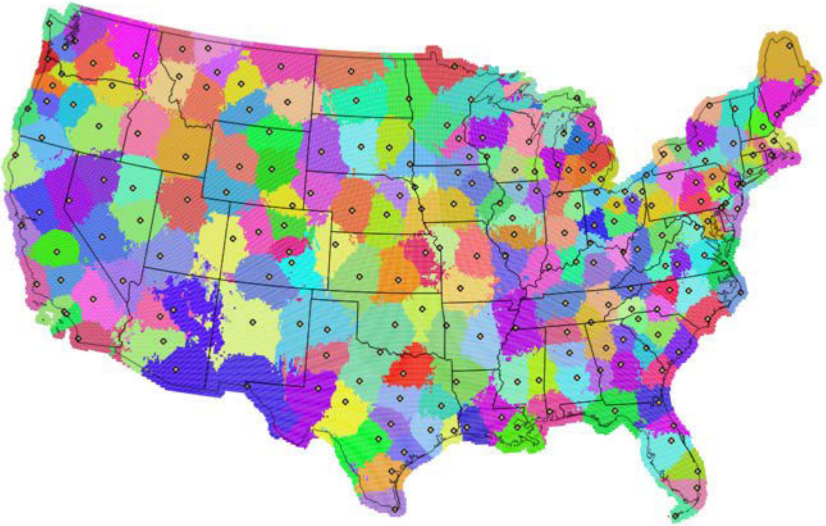
DR	Demand Response (Potential Studies)	**NEMS**	National Energy Modeling System
FERC	Federal Energy Regulatory Commission	**Planning**	Refers to utility/ISO/PUC planning efforts
IAM	Integrated Assessment Model	**REF**	Renewable Electricity Futures (Study)
LBNL	Lawrence Berkeley National Laboratory	**SAE**	Statistically Adjusted End-Use (Model)

This graphic only shows load model resolution. The modeling resolution for other energy system components (e.g., electricity supply) modeled by the referenced tools (e.g., IAMs or NEMS) may differ.

Graphic adapted from:
dsgrid model documentation
DOI 10.2172/1465659

Geographic Resolution (current)

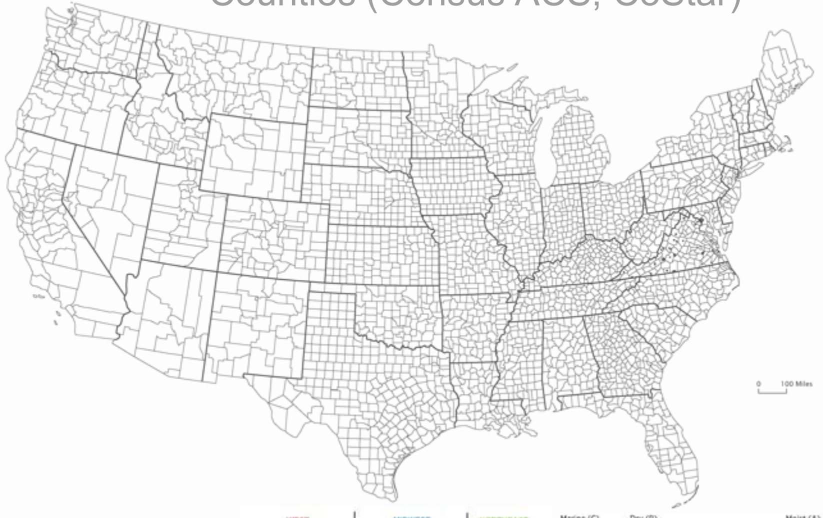
Weather



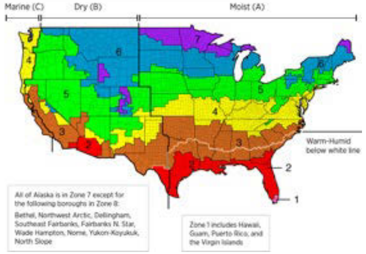
216 weather file locations

Building stock

Counties (Census ACS, CoStar)



Other data sources have coarser resolution



Temporal Resolution (current)

Model component	**Temporal resolution**	**Comments**
Weather (historical or typical)	60-minute	• Interpolated to simulation timestep
Occupant-related schedules	60-minute	• Interpolated/aggregated to simulation timestep • Finer resolution for some schedules (e.g., 1-min DHW draws)
Simulation timestep	Typically 15-minute	• Significantly affects simulation runtime • HVAC cycling not explicitly modeled
Timeseries output	Typically 60-minute	• Significantly affects timeseries output file size

Sectoral Resolution (current)

ComStock

Building Types

- 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

End-Uses

- Heating
- Cooling
- Interior Lighting
- Exterior Lighting
- Interior Equipment
- Exterior Equipment
- Fans
- Pumps
- Heat Rejection
- Humidification
- Heat Recovery
- Water Systems
- Refrigeration

ResStock

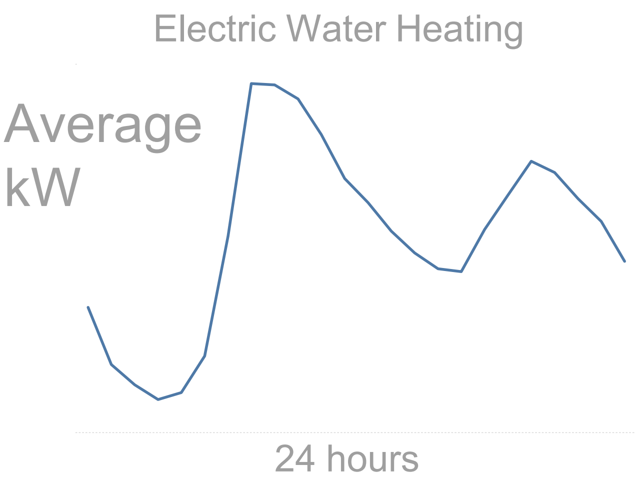
Building Types

- Single-Family Detached
- Multifamily (low-rise)
  - Single-Family Attached
  - 2–4 Units
  - 5+ Units

End-Uses:

- Heating
- Cooling
- Furnace/AC fan
- Boiler pumps
- Vent. fans
- Water heating
- Interior Lights
- Exterior Lights
- Misc. plug loads
- Refrigerator
- Clothes washer
- Clothes dryer
- Dishwasher
- Cooking Range

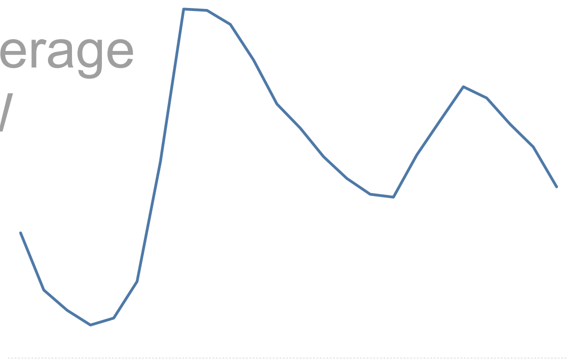
From *shapes*… …to *profiles*



From *shapes*…

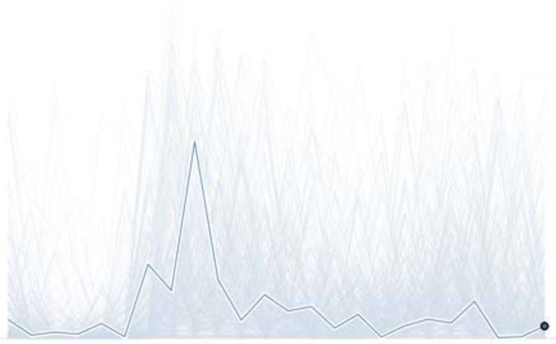
…to *profiles*

Electric Water Heating



Electric Water Heating
e.g., in County of Denver, CO

Aggregate
MW



Discussion and Q&A

Questions?

We are going to unmute all of the phone lines,

so please mute yourself if you are not speaking.

Partner Presentations

Electric Power Research Institute (EPRI)

Baseline End-Use Profile Development for National Building Stock

Utility Collaborative Leveraging Whole Premise Interval Data

Chris Holmes
Technical Lead, Principal
Krish Gomatom
Senior Engineer

Technical Advisory Group Meeting
NREL, Golden, CO
March 5-6, 2019

End-use Load Profile Development for Baseline Loads

Scope

- Baseline end-use load shape development for Residential & Commercial building stock
- Leverage utility meter data by region, to cover building types and climate zones.

Leverage

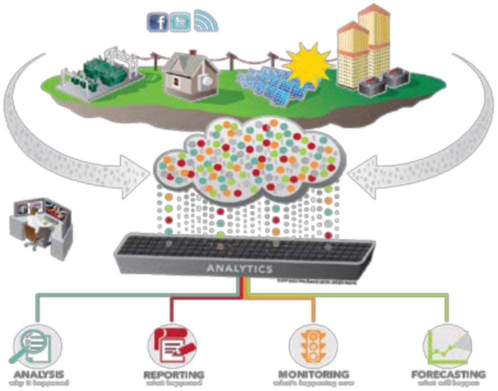
- Knowledge base, expertise under EPRI Load Research and Market Analytics
- EPRI Public Product: Load Shape Library loadshape.epri.com

Value

- Statistically significant, baseline end-use profile by building type
- Web accessible data and visualization
- Utility representation across the U.S

Proposed Approach

- Res.& Comm. end-use load shapes by climate zone, building type
- Leverage customer AMI data, customer survey information, building characteristics and other public data
- Statistical analysis: Better accuracy by class, building type
- Basic and enhanced project options
  - Additional sampling domains such as age and size of structures, occupancy, program participation, etc.
- Data made available through EPRI’s web product Load Shape Library: public database, user interface



Load Shape Development Options

Statistical: AMI and Survey Information

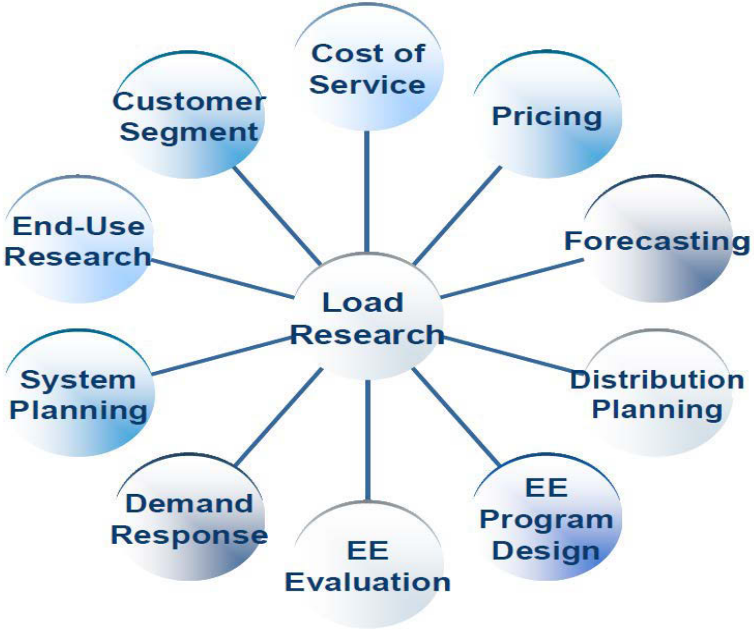
- Whole premise data by class X, building type X, appliance saturation X climate zone
- Lowest cost & low accuracy (function of data availability)
- Whole premise outputs that can still provide some end-use detail
- Currently being used in California

Hybrid: Engineering estimates plus limited metering

- Specific for sites without whole premise interval data
- Deploy select metering to calibrate site-specific engineering models
- Intermediate cost and moderate accuracy

Hourly CDA Approach: (Class) Diversified Load Shapes

- Relies on the *variation* of end-use appliance presence for statistically inferring the *components* of customers' hourly load profiles
- Modified Regression applied to hourly *load* data, using variables from *survey* information
- Conditioned on other causal variables to allocate total load to end uses
  - Comparing total loads of two identical houses, where only one has electric water heater; difference between loads is load of water heater
  - Regression analysis makes those comparisons across hundreds of customers & all included end uses
  - Result produces a "diversified end use load shape"
  - Cost to collect is far less than other methods

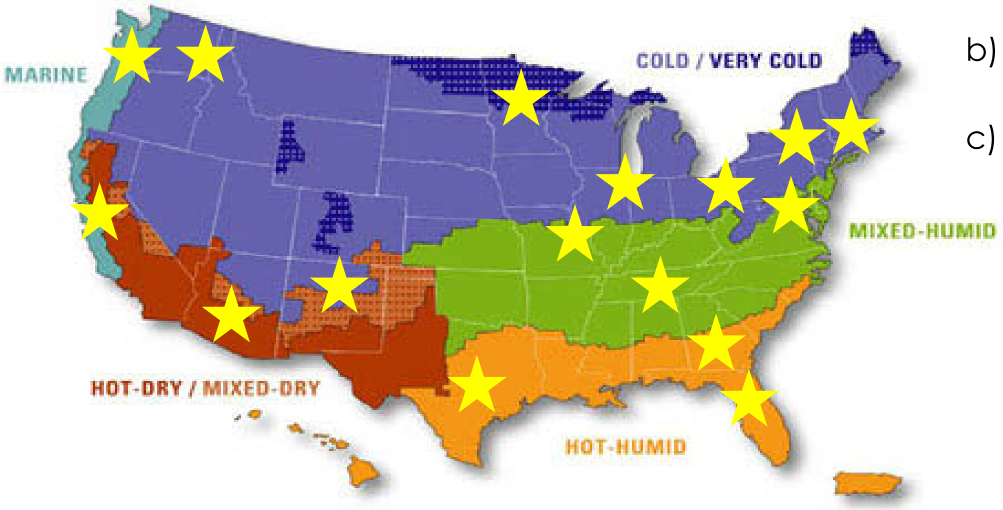


Current Landscape

- New efficient technologies, communication & control, AMI interval data
- Strategizing utility use cases for end-use and whole premise data
- Updating Load Data Repository (Load Shape Library)

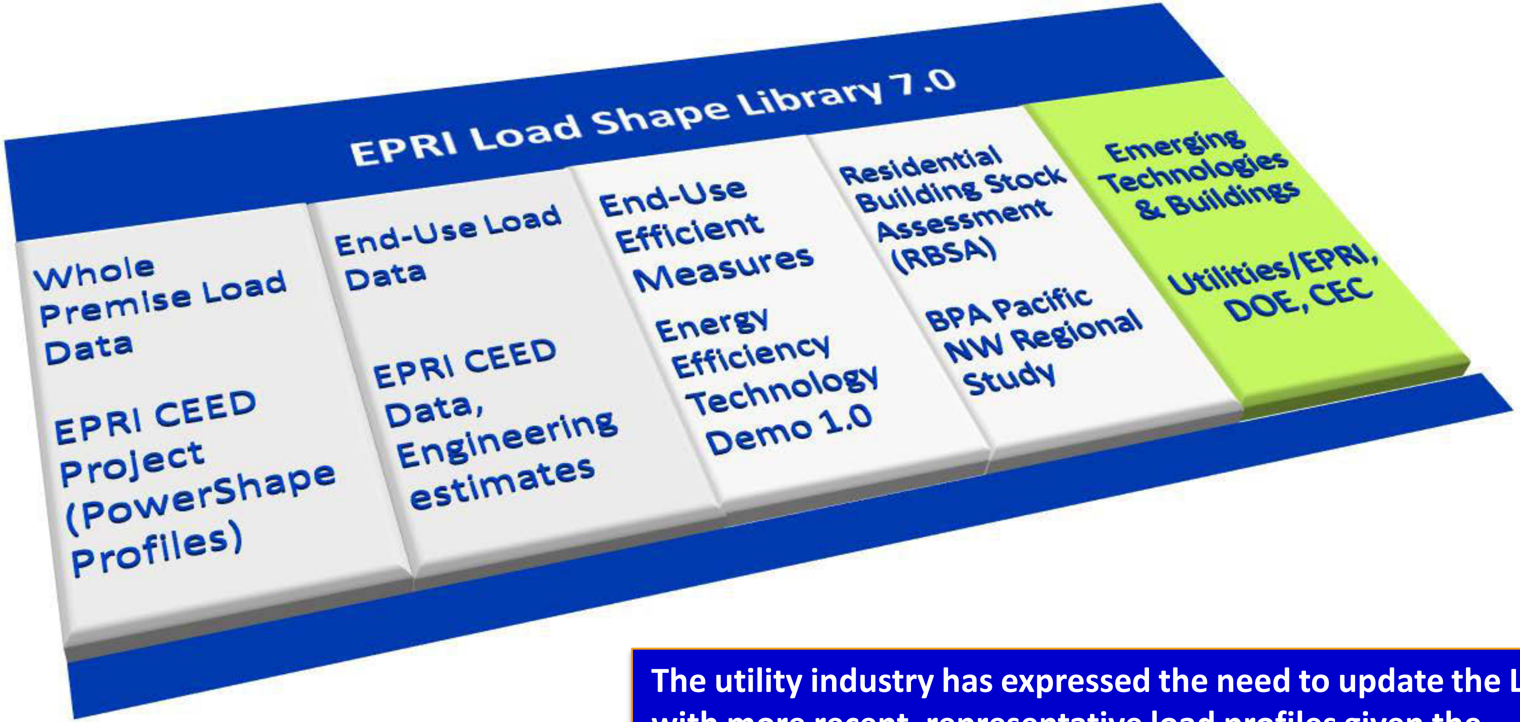
Leveraging AMI data for End Use Load Data Development & Analytics

Potential Utility Data Collection Sites – Residential & Commercial



a) Utilities with both interval data and metadata
b) Utilities will interval data but no metadata, and
c) Utilities with neither

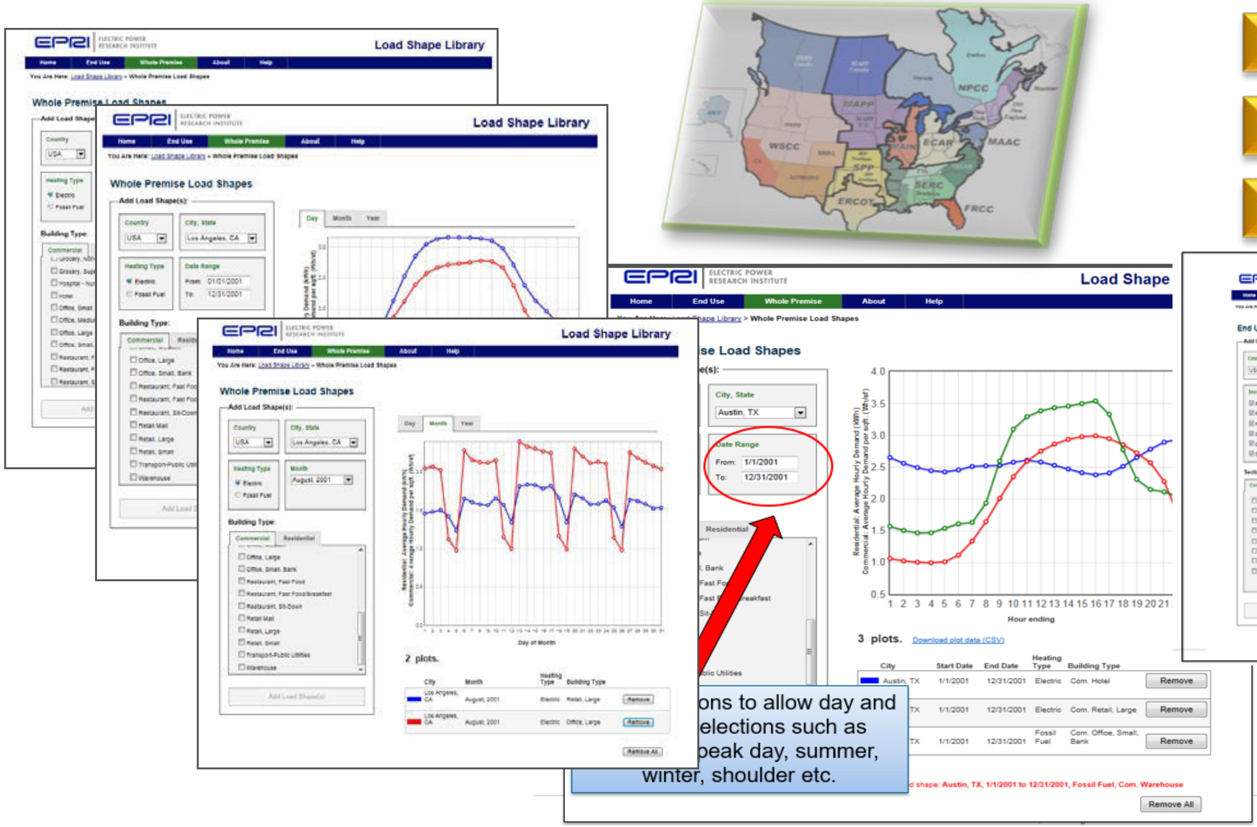
EPRI Public Product: Load Shape Library



The utility industry has expressed the need to update the Library with more recent, representative load profiles given the availability of AMI data

End-Use & Whole Premise Databases

(EPRI CEED PowerShape^{TM}, Model +Limited Field Validated)



2008 NERC Regional Distinctions

Sectors and End Uses

Unitized end use load shapes

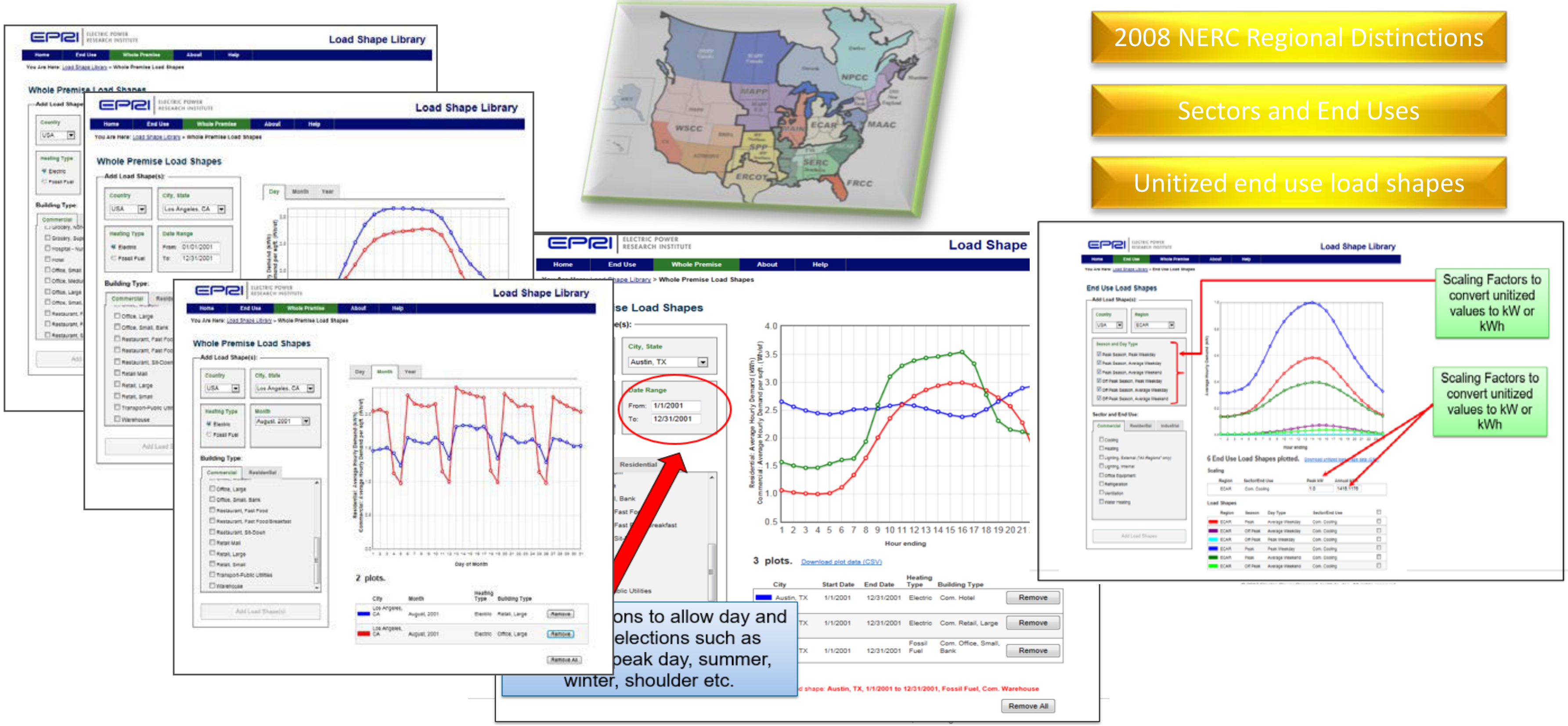
End-Use & Whole Premise Databases

(EPRI CEED PowerShape™, Model +Limited Field Validated)

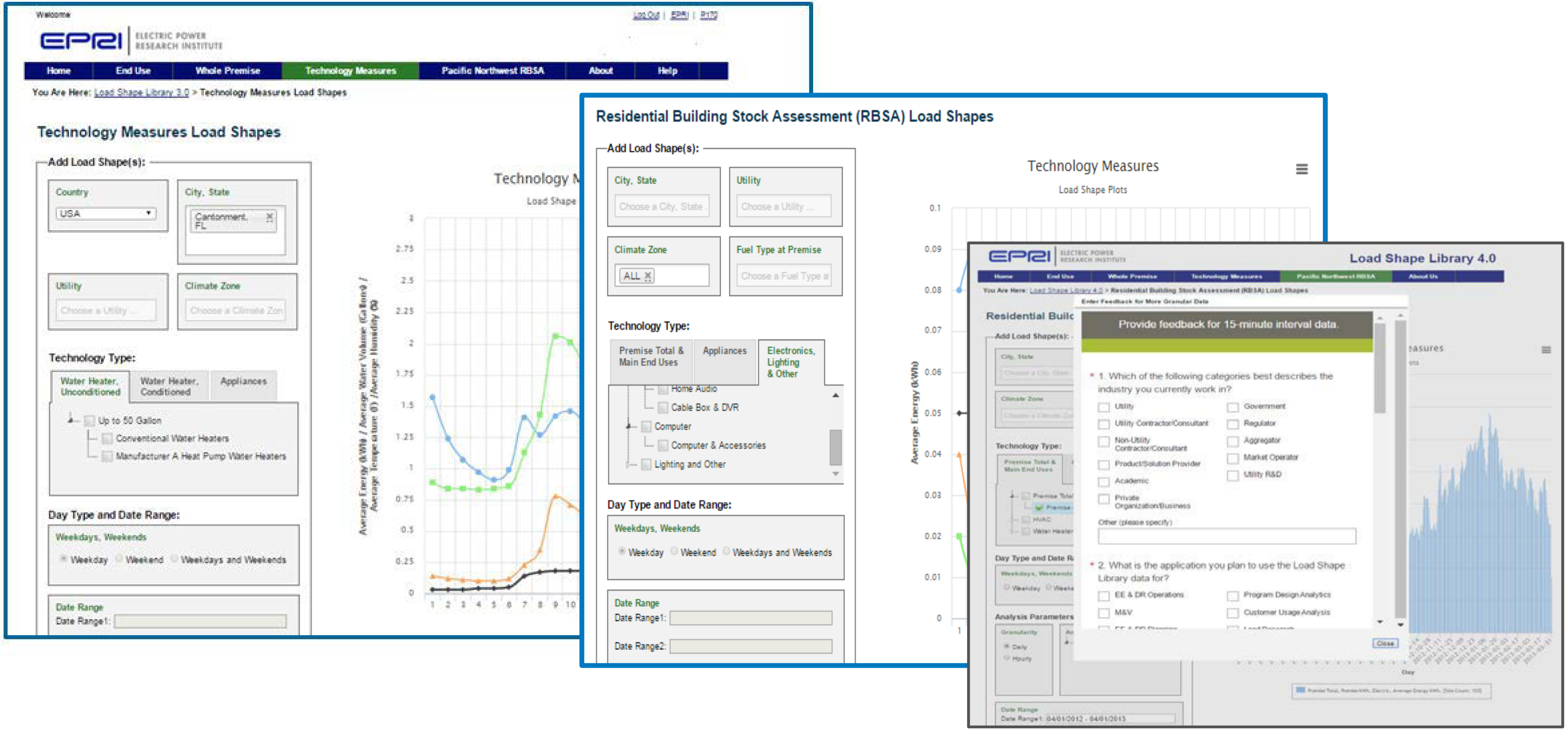
2008 NERC Regional Distinctions

Sectors and End Uses

Unitized end use load shapes



Technology Measures & RBSA Databases



Together…Shaping the Future of Electricity

Northeast Energy Efficiency Partnerships (NEEP)

End-Use Loadshape Project and NEEP

By: Elizabeth Titus

Northeast Energy Efficiency Partnerships

At: End-Use Loadshape Research Technical Advisory Group Meeting

NREL – March 5, 2019

About Northeast Energy Efficiency Partnerships

Mission

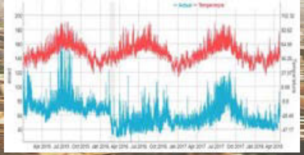
Vision

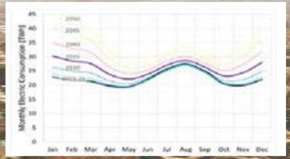
Approach

Northeast Energy Efficiency Partnerships

Study by NREL and LBL with regional participation
End-Use Load Profiles for the U.S. Building Stock
FROM THE MACRO PERSPECTIVE…

Loadshapes make the grid go round
Loadshapes make the grid go round
Somebody soon will measure you
If no one has so far
High in some silent sky
Loadshapes sing a silver song
Making the Earth whirl more cleanly
Loadshapes make the grid go round





Why Do We Care About Loadshapes in the Northeast – More Specifically

- Beneficial Electrification
- Non-Wires Alternatives
- Controllable measures and loads
- Dodging the duck curve
- Forward Capacity M&V

Electrification through Building Decarbonization 3 Key Elements Loadshape Needs

NEEP's analysis points to three critical elements to a strategic electrification pathway that benefits consumers, businesses and the environment. These are:

(Heat Pump Profiles) (Whole Building) (Flexible Loads)

ISO-NE Forward Capacity Market
Loadshapes for M&V

This may change.

What Is NEEP's Engagement ?

Task 1

Task 2

Task 3

Task 4

Task 5

Other NEEP Resources

Current

Existing

For more information:

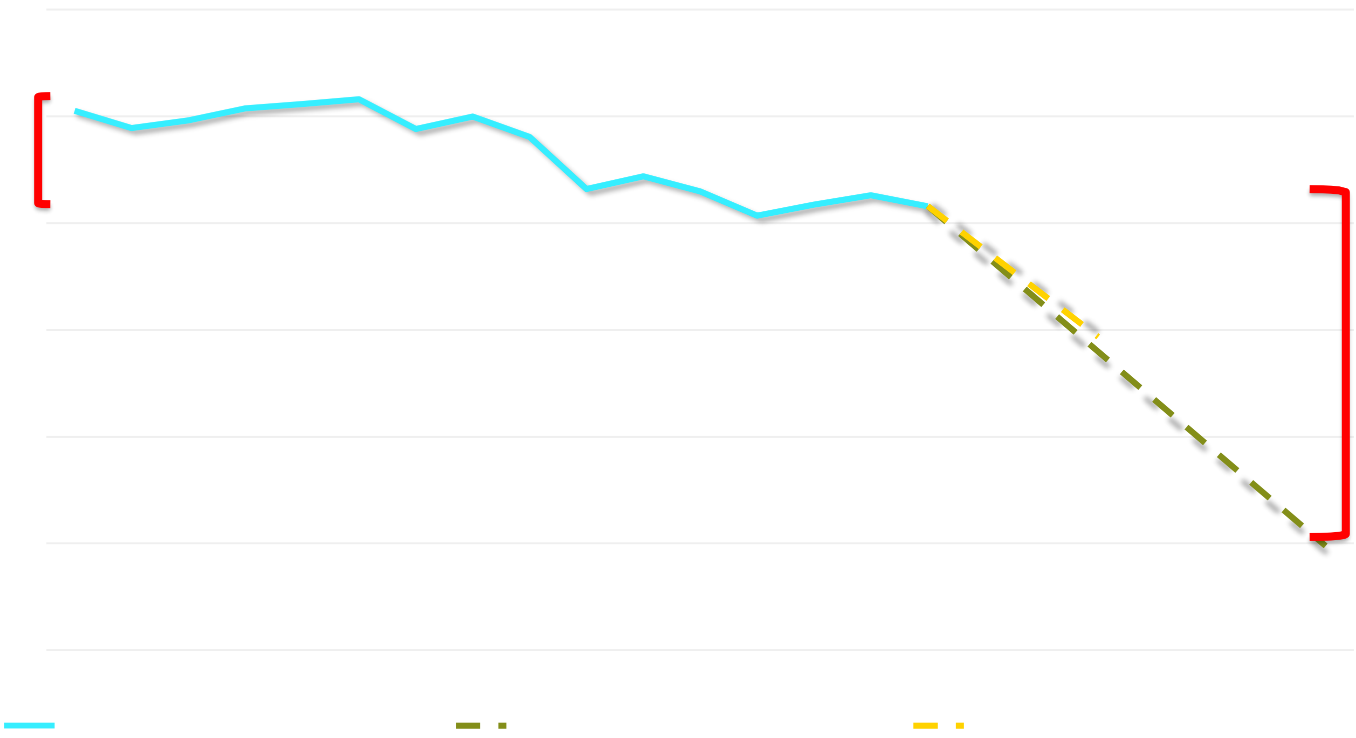
www.neep.org

scoakley@neep.org

etitus@neep.org

cmiziolek@neep.org

Are we on the path to 80% by 2050?: Understanding loadshapes can help



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Use Cases for Load Profiles

Technical Advisory Group meeting #2
March 5, 2019

Andrew Parker, NREL

What is a use case?

Something that the end-use load profiles will be used for

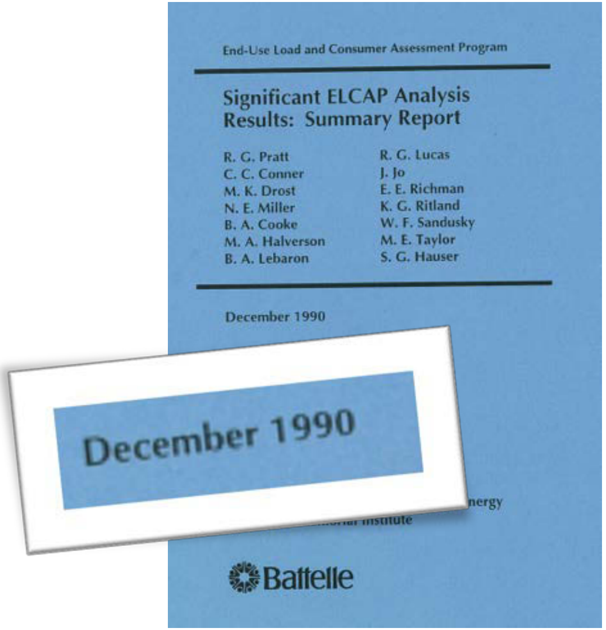
Example:

Energy efficiency resource planning:

Analyze profiles to see which end-uses have the biggest savings opportunities.

Why identify use cases?

- Complex, expensive project
  - Due diligence required
- Will likely be used for decades
  - We owe it to the future
- Plus, it's fun!



Technical dimensions

Time	Weekday Weekend Peak day	Sub-60hz
Space	Aggregate for USA	Every actual building in USA
Building	Building type	Building type, size, climate, vintage, hours, owner
Electrical	Power	Real power Reactive power Voltage Wave form

Non-technical dimensions

Buy-in	No involvement in project	TAG member guiding project
Documentation	No detail on method or validation	Raw data, method, validation, examples all available

What are we missing? (breakout)

Use case groups

Utility planning

Public policy analysis

Utility operations

Product development

PV / storage adoption

Research

Utility planning – traditional

Energy efficiency program planning

- Choose end-uses to target through EE programs

- Requirements
  - Time: weekday, weekend, peak day data
  - Space: service territory
  - Electrical: power
  - Buy-in: PUC
  - Documents: hold up to regulatory scrutiny

Utility planning – future?

Non-wires alternatives

- Use targeted EE to defer distribution system upgrades

- Requirements
  - Time: 15 minute
  - Space: distribution feeder
  - Electrical: real power, reactive power
  - Buy-in: distribution engineers
  - Documents: validation to make utility engineers believe

Public policy analysis – traditional

Energy efficiency program target setting

- Set targets for regulated utility EE programs

- Requirements
  - Time: 8760 hourly data
  - Space: service territory
  - Electrical: power
  - Buy-in: PUC
  - Documents: hold up to scrutiny

Public policy analysis – future?

Air quality impacts

- Use EE to reduce demand with the goal of improving air quality in some region

- Requirements
  - Time: hourly
  - Space: regional
  - Electrical: power
  - Buy-in: air quality regulators
  - Documents: hold up to scrutiny

Product development

Home energy management system design

- Design HEMS to control appliances to meet grid needs and customer needs

- Requirements
  - Time: sub-minute
  - Space: individual buildings with realistic diversity
  - Electrical: real power, reactive power
  - Buy-in: corporate R&D staff
  - Documents: validation to make R&D teams comfortable testing against

PV / storage adoption

Rooftop solar economics

- Determine economics of PV installations in a particular neighborhood / area of city

- Requirements
  - Time: minute to 15min, depends on net metering approach
  - Space: individual buildings with realistic diversity
  - Electrical: power
  - Buy-in: PV installers/analysts
  - Documents: validation approaches

Research

Anthropogenic waste heat

- How does heat rejected/injected to buildings influence temperatures in cities?

- Requirements
  - Time: 8760 hourly
  - Space: Aggregate
  - Electrical: power
  - Buy-in: researchers
  - Documents: accessible documentation so researchers find and use

Breakout questions

1. What dimensions are we missing?
2. What applications are you currently using EULPs for?
3. What challenges are associated with those applications?
4. What applications do you want/anticipate using EULPs for in the future?
5. What prevents you from using current EULPs for that now?
6. What requirements must be met for EULPs to be used for your use case?
7. What is the most off-the-wall, obscure use case you can think of?

If we had ~5 min data on a neighborhood scale we might be able to predict the impact that different HEMS system interventions would have on traffic in a city.

Onsite breakout groups – March 5

Location: Maxwell (B208)

Jen Amman, ACEEE
Jamie Barber, GA PSC
Mark Bielecki, Navigant
Michael Bishop, Solar Investments Inc
Ali Bozorgi, ICF
Matt Cox, Greenlink Group
Krish Gomatom, EPRI

Location: Edison (B211)

Ellen Franconi, PNNL
Adam Gerza, Energy Toolbox
Steven Keates, ADM
Phillip Kelsven, BPA
Ben King, DOE
Chris Holmes, EPRI
Jessica Lin, Oracle

Location: Faraday (B212)

Tom Eckman, LBNL
Kurtis Kolnowski, AEG
Jim Leverette, Southern Company
Monica Neukomm, DOE
Curt Puckett, DNV-GL
Dan Patry, Oracle
David Podorson, Xcel

Location: Tesla (B210)

Rachel Scheu, Elevate Energy
Rodney Sobin, NASEO
Justin Spencer, Navigant
Valerie von Schramm, CPS
Bob Willen, Ameren
Craig Williamson, DNV-GL

TAG member perspectives on data sharing

1. Rachel Scheu, Elevate Energy
2. Adam Gerza, Energy Toolbase
3. Jim Leverette, Southern Company

NATIONAL RENEWABLE ENERGY LABORATORY

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

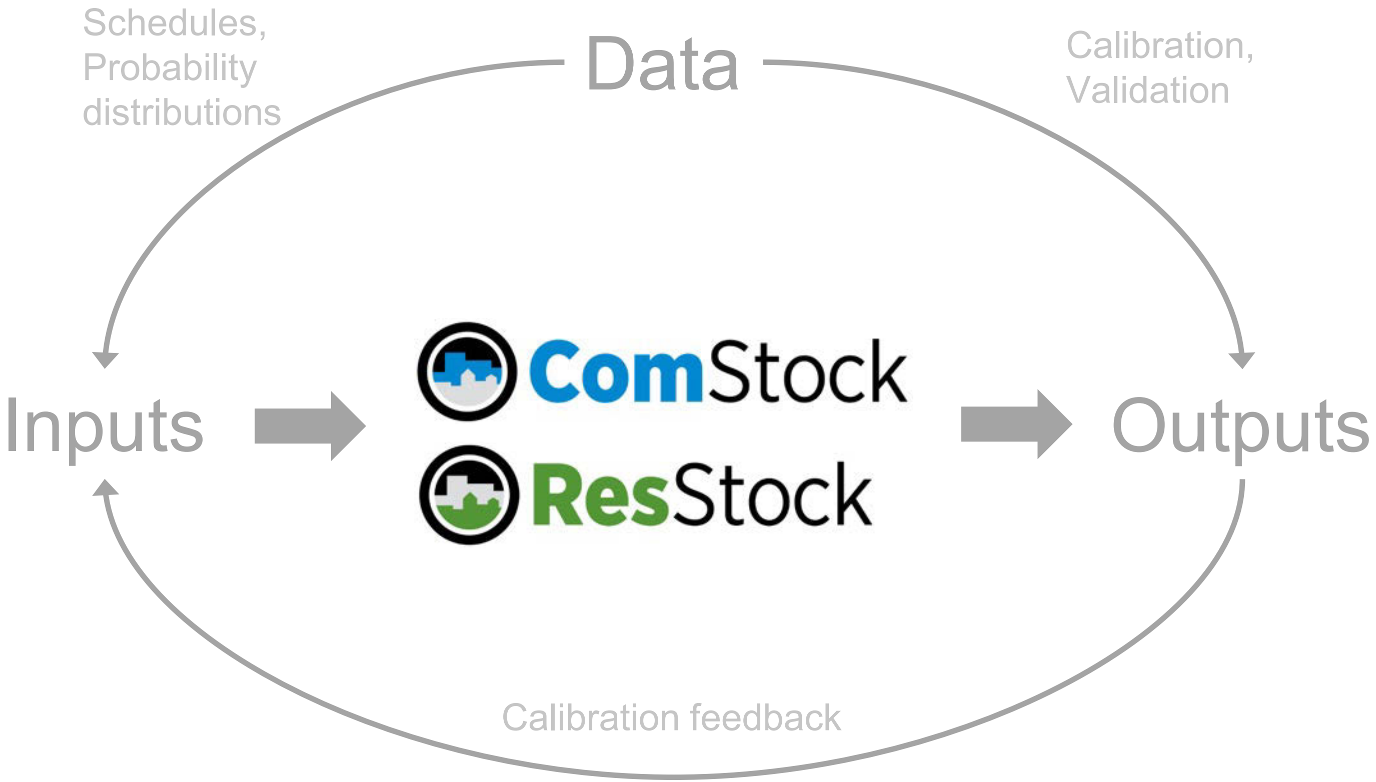
Eric Wilson, NREL

Technical Advisory Group Meeting #2

March 5–6, 2019

Data for Modeling and Calibration

Data needs


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

Existing data sources | **characteristics**

ComStock

<u>~280 high-level inputs</u>

- 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

ResStock

<u>~370 high-level inputs</u>

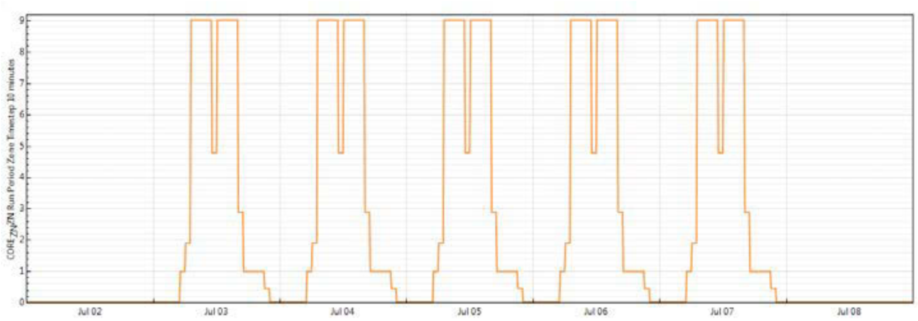
- U.S. Census American Community Survey (ACS)
- EIA Residential Energy Consumption Survey (RECS) 2009
- National Association of Home Builders surveys
- IECC Energy Codes
- Regional audit databases
- LBNL envelope leakage database
- Building America House Simulation Protocols

Existing data sources | **schedules**

ComStock

Schedules primarily from
ASHRAE 90.1 / Reference Buildings

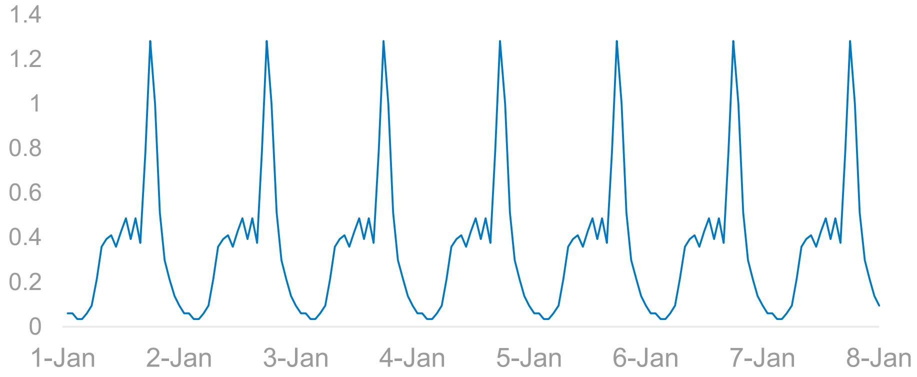
Medium Office Occupancy



ResStock

Schedules primarily from
ELCAP (Pratt et al., 1989)

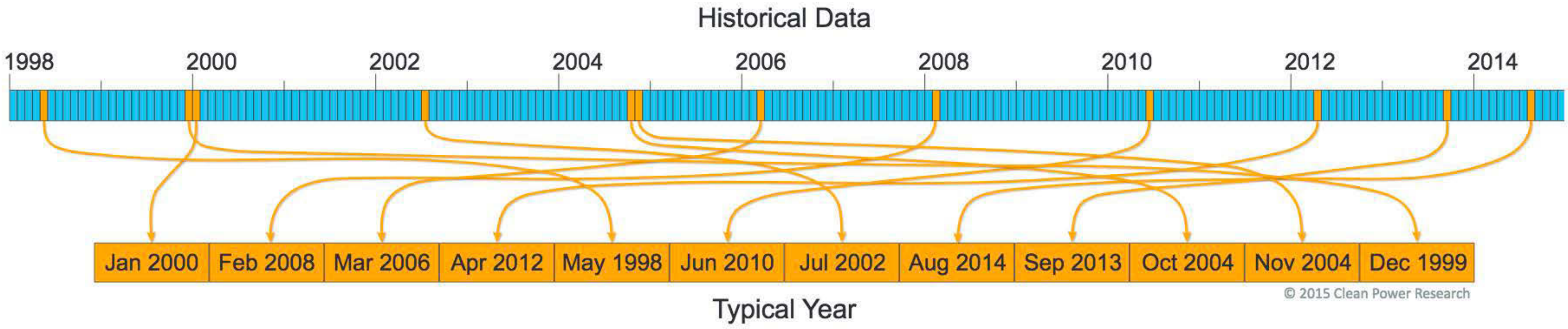
Cooking Stove/Oven



A word on weather data

Building energy simulations have traditionally used *Typical Meteorological Year (TMY)* weather data to drive energy calculations

Example of Generic TMY Dataset Construction



Graphic source: Clean Power Research whitepaper, http://www.cleanpower.com/wp-content/uploads/SA-TGY_Whitepaper_122915Final.pdf

A word on weather data

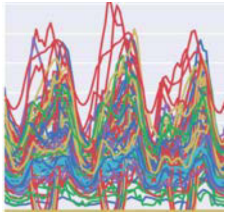
Actual Meteorological Year (TMY) weather data is important for applications involved building-grid interaction

Typical Meteorological Year (TMY)	Actual Meteorological Year (AMY)
Constructed from 30-years of historical weather	One year of historical weather
Average heating/cooling degree days	Particular year may have more or fewer heating/cooling degree days than average
Includes typical extreme periods	Particular year may have more or fewer extreme weather periods than is typical
Adjacent locations **might not have coincident extremes**	Adjacent locations **do have coincident extremes**
Available for ~1000 U.S. locations	Available for ~2000 U.S. locations

Spectrum of data sources

Level of detail	Sources	Pros	Cons
Sector or customer class	Load research data (aggregated AMI data or metered sample of customers)	Already exists for many utilities; good sector-total ground truth	Less useful for calibrating end uses and understanding diversity of individual building profiles
Whole building (interval)	AMI data (typ. 15-min, sometimes 1-min)	Already exists for many utilities; Some end use disaggregation possible using CDA or degree-day inverse modeling	Less useful for calibrating end uses (aside from CDA and disaggregation of weather dependent load); NILM for other end uses not reliable on 15-min AMI data
Whole building (monthly)	Monthly billing data	Useful for understanding monthly/seasonal patterns; gas data allows isolation of some end uses	Only useful for monthly/seasonal patterns
End uses	Circuit-level submeters, receptacle submeters, connected devices	Ground truth for individual building end uses; can also provide power parameters and high frequency (< 1 hz)	Expensive to collect using traditional methods
Savings shape	Circuit-level submeters, receptacle submeters	Ground truth for EE/DR savings	Expensive to collect using traditional methods; requires control group or modeled baseline

Example datasets



Load research data
192 customer class profiles from 30 utility companies
60-min interval data
E.g., residential w/o electric heat, large general service

ComEd
An Exelon Company

ComEd Anonymous Data Service
All ~4 million meters in northern Illinois
30-min interval data
Meters tagged with ZIP/ZIP+4 code and customer class

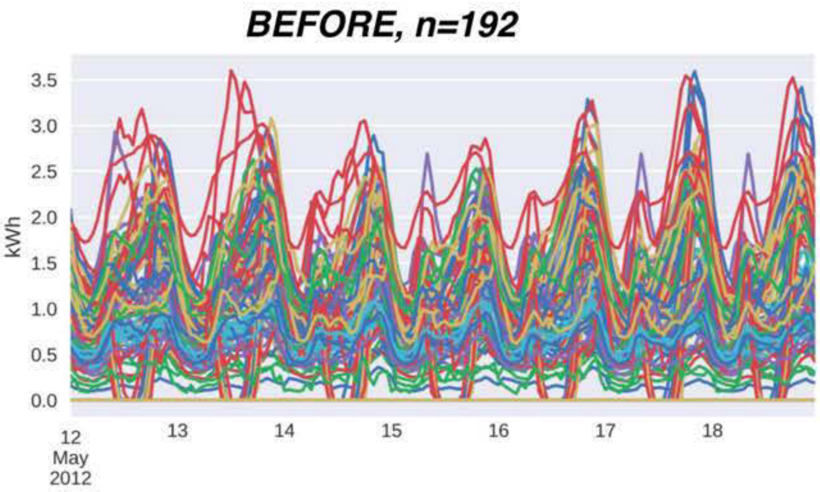
neea

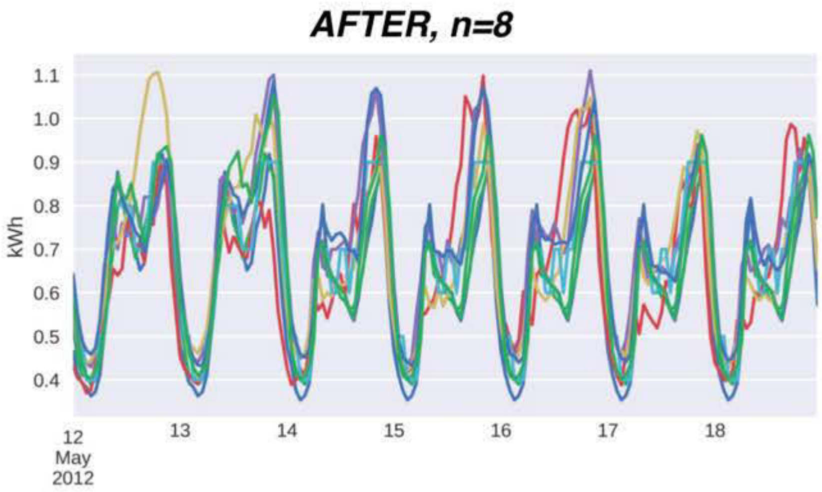
Residential Building Stock Assessment: Metering Study (2011)
100 homes in northwest U.S.
15-min submetered circuit-level data
Home audit data available from larger RBSA study

ResStock calibration examples

Calibration example 1: Non-weather loads

Using load research sample data from 30 utilities, we identified 8 “well-behaved” profiles to infer non-weather dependent load patterns for a mild weather week in May

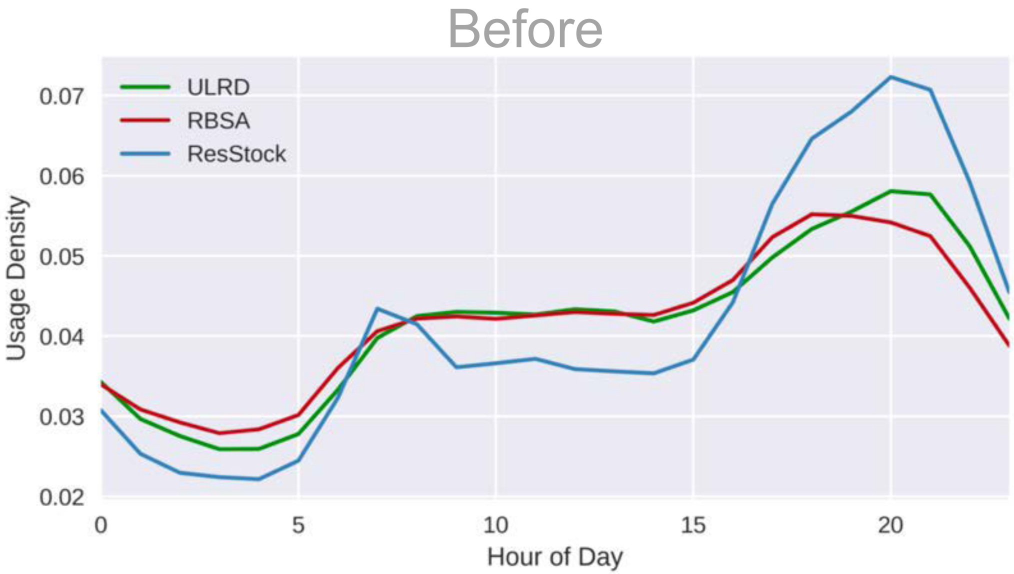




- Missing Data
- Scaling Issues
- High winter usage
- Non-Residential
- Multifamily only
- Time-of-use rates

- Low winter usage
- Single family majority
- Agreement between sets

Calibration example 1: Non-weather loads



Load research data (average of 8 profiles)

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

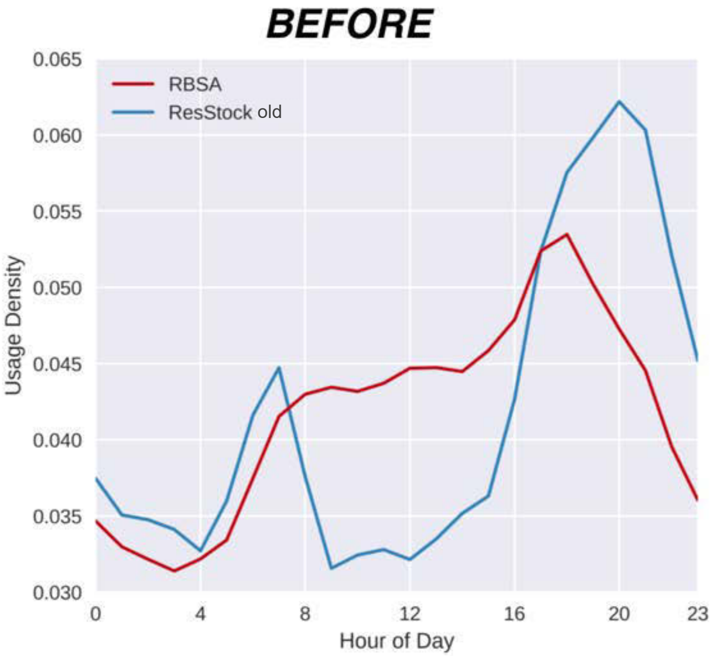
ResStock output

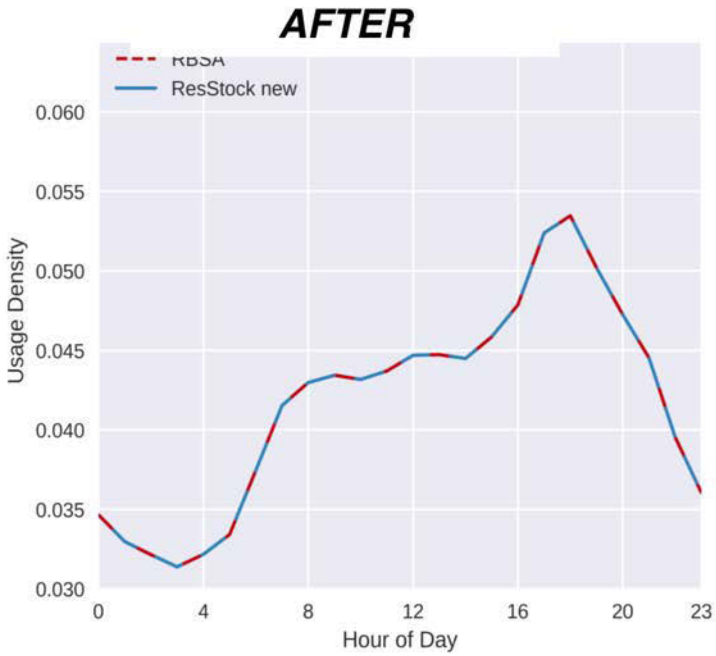
- overpredicts peak and nighttime low
- Has mid-day valley not present in measured data

Calibration example 1: Non-weather loads

Miscellaneous plug loads

Switched to using RBSA profile for misc. plug load for ResStock to eliminate mid-day valley

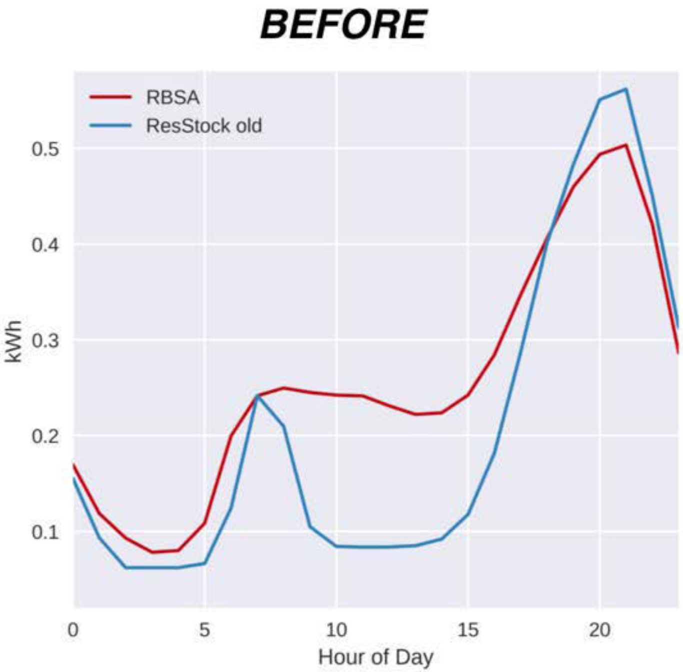


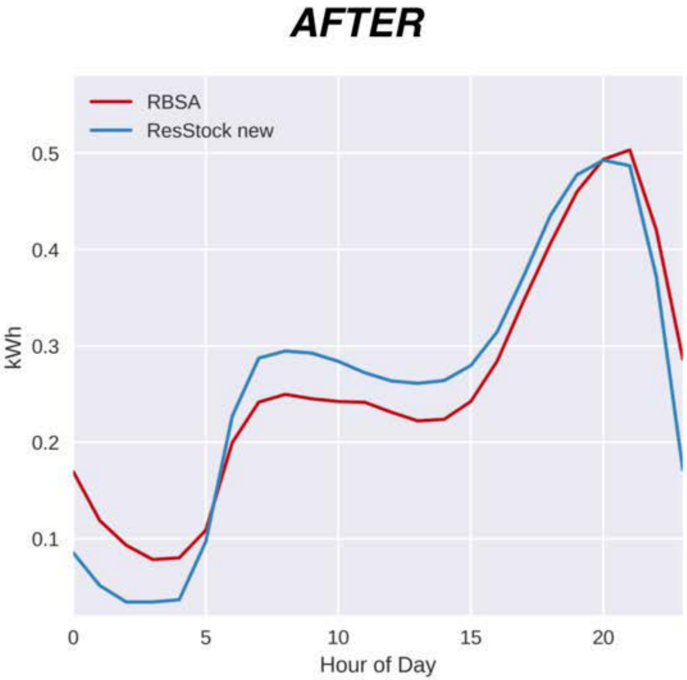


Calibration example 1: Non-weather loads

Lighting

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

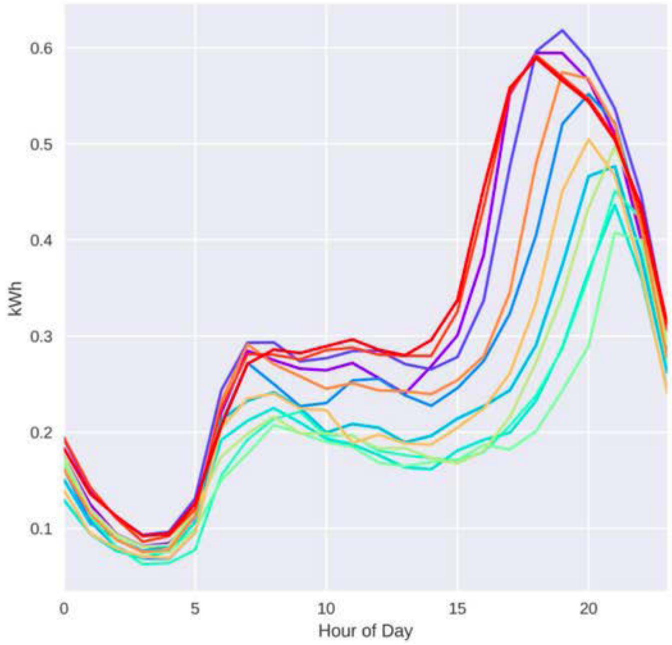




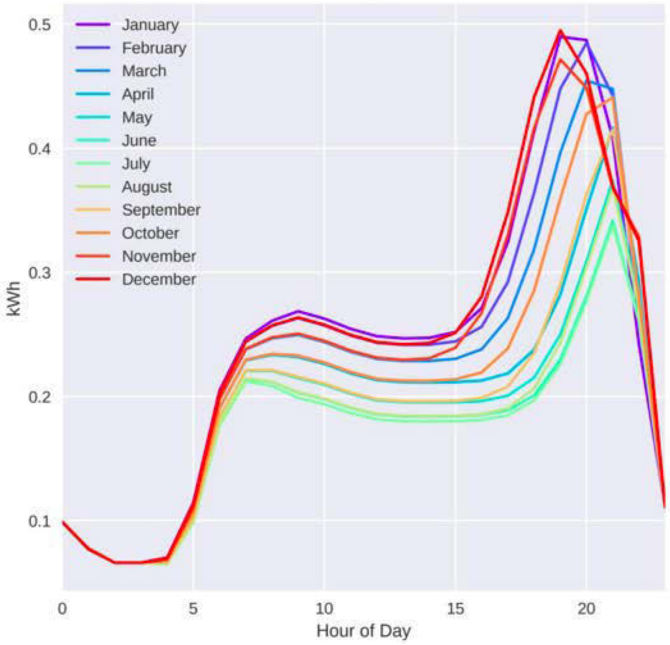
Calibration example 1: Non-weather loads

Monthly lighting profile comparison

RBSA Metering Study

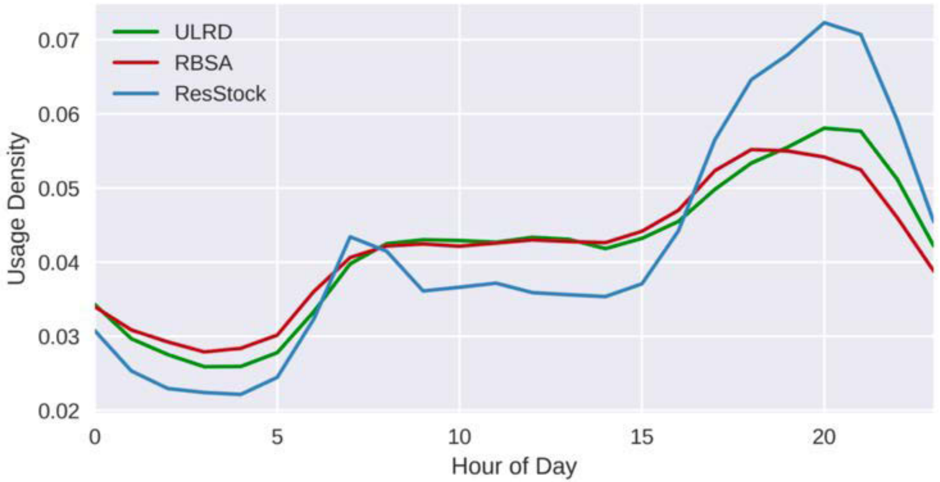


ResStock (PNW average)

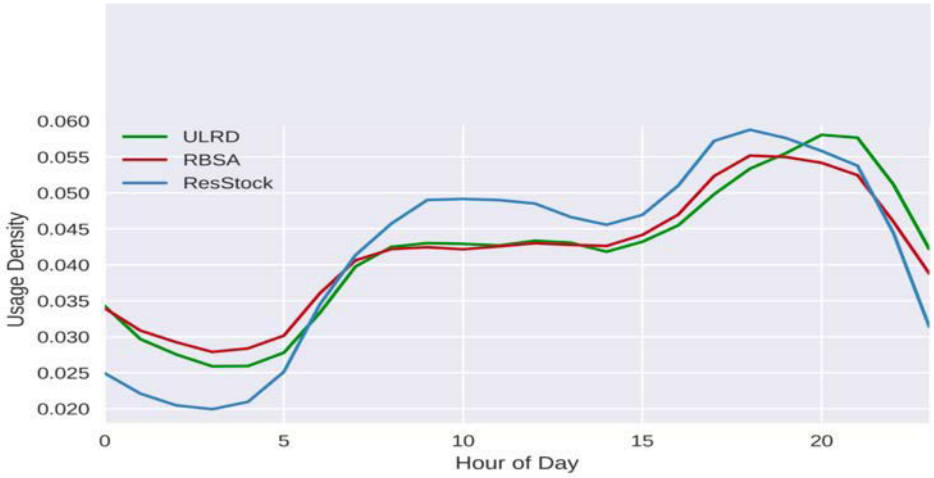


Calibration example 1: Non-weather loads

Before

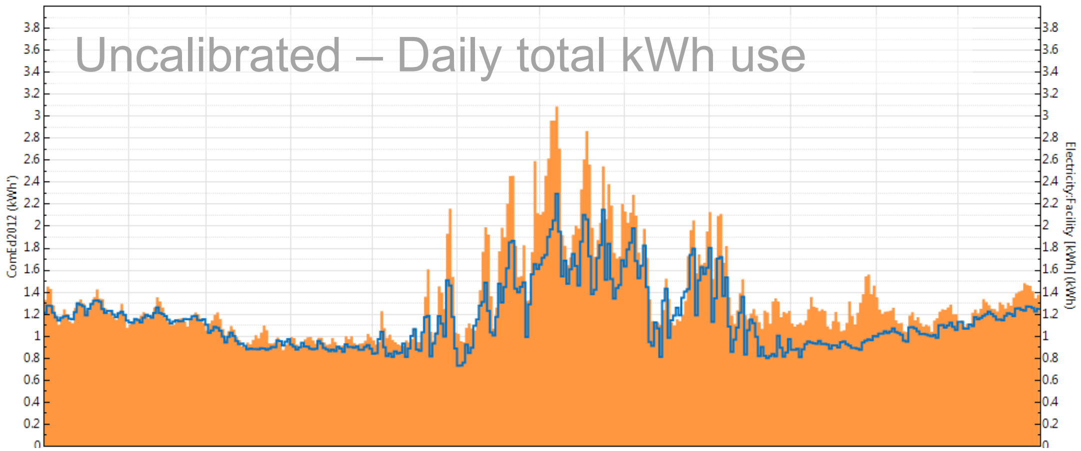


After



- Nighttime low still too low
- Afternoon peak too early

Calibration example 2: Weather loads

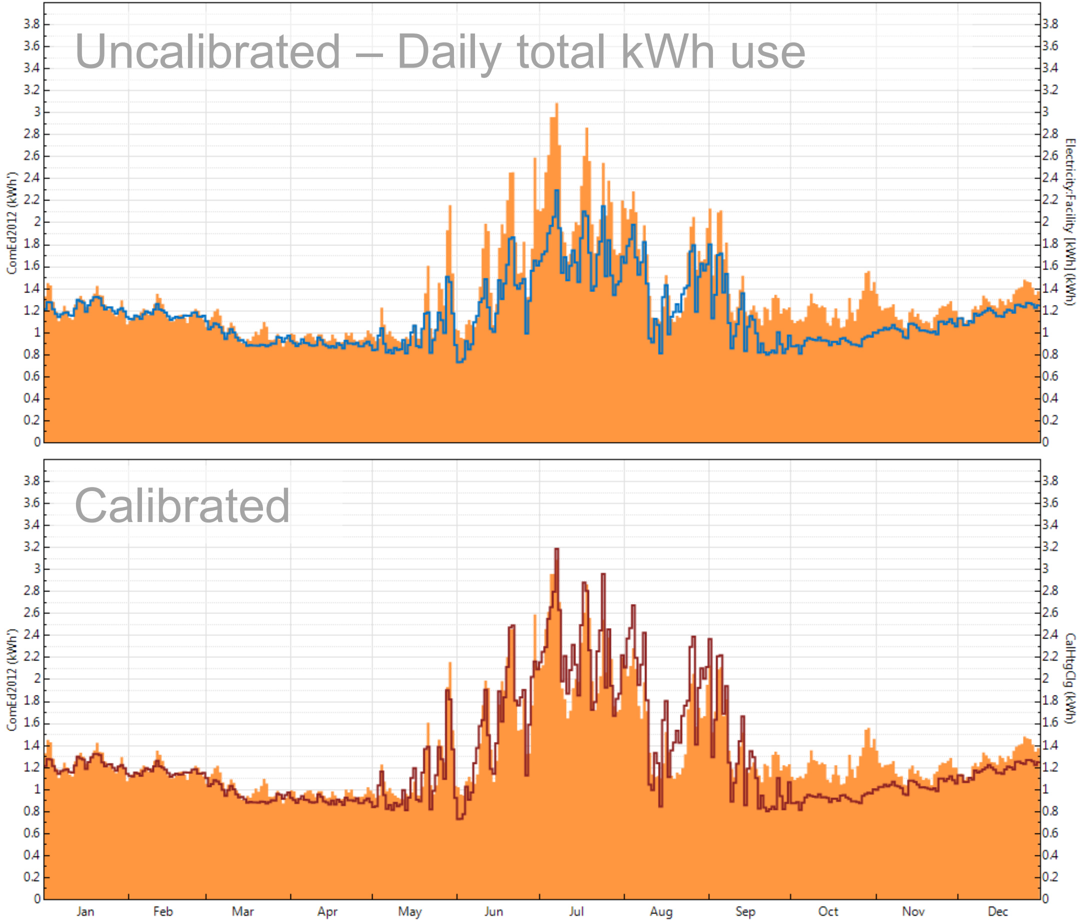


ComEd load research data

ResStock – Northern Illinois

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

Calibration example 2: Weather loads



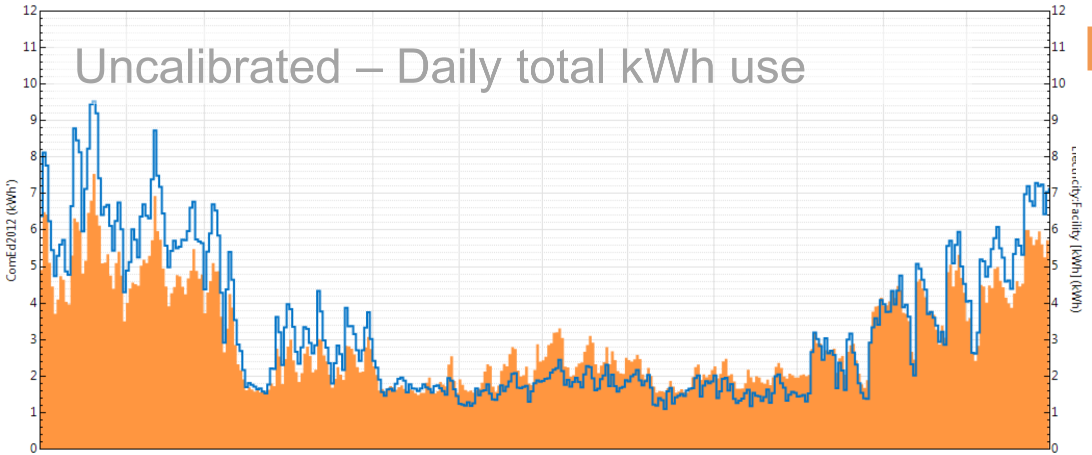
ComEd load research data

ResStock – Northern Illinois

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

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

Calibration example 2: Weather loads

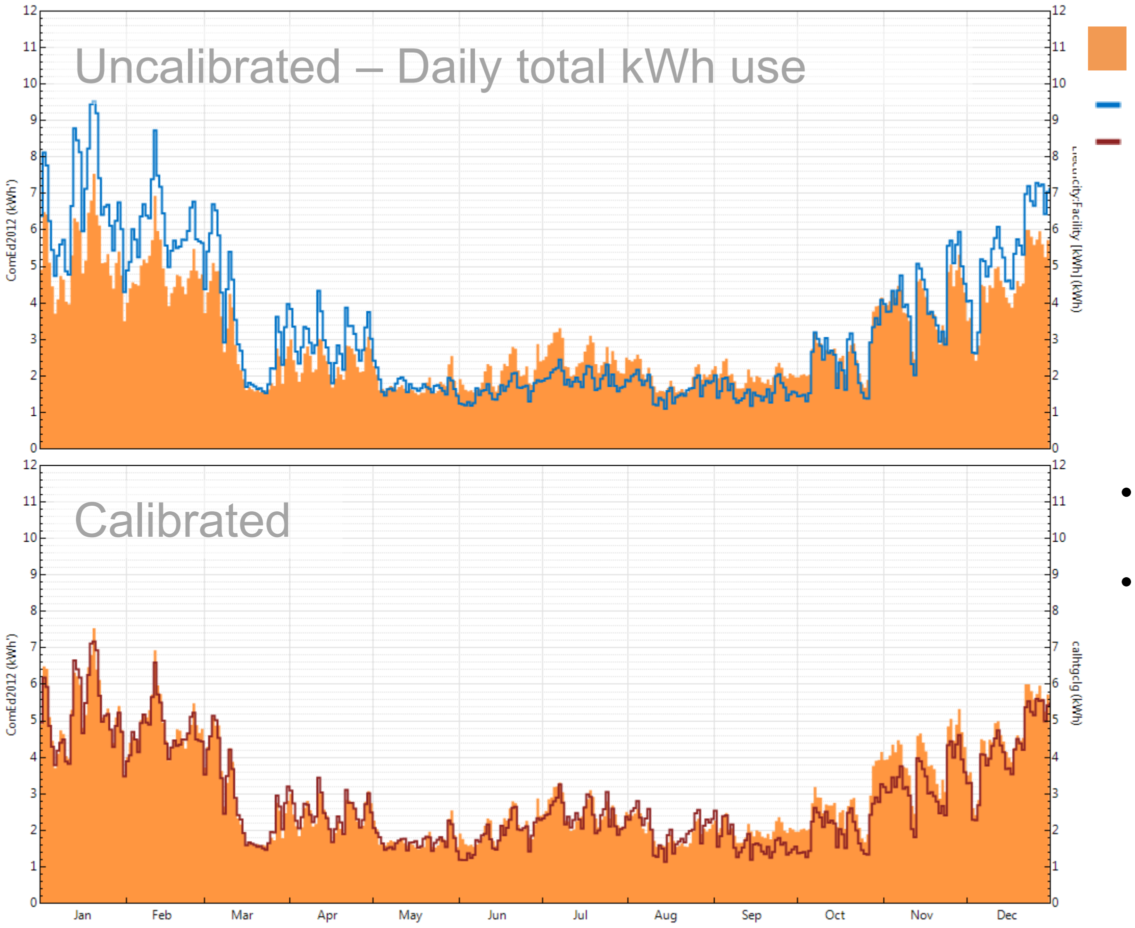


ComEd load research data

ResStock – Northern Illinois

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

Calibration example 2: Weather loads



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

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

Next Steps

Next steps

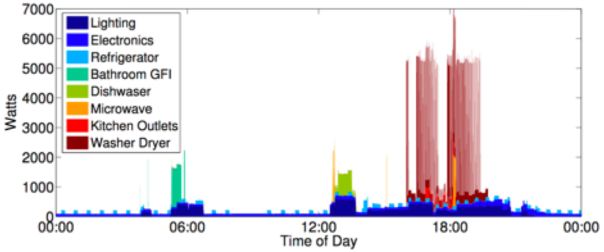
- Continue calibration process
- Collect and catalog data sources
- Add diversity in occupant patterns
- Develop stochastic occupant behavior models

Other potential data sources

ecobee

Northeast Energy Efficiency Partnerships
Load Shape Catalog

BUILDING DATA
Genome Project



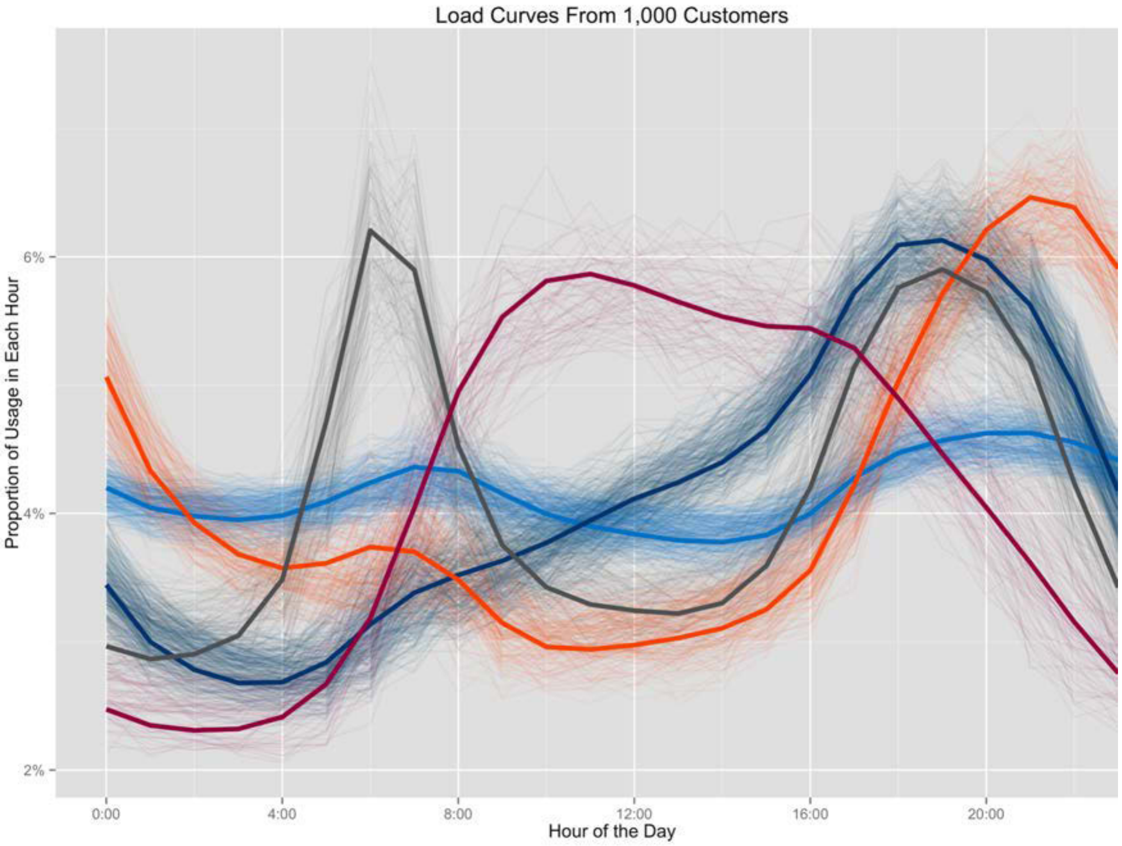
PECAN STREET

REDD: Reference Energy Disaggregation Dataset
(Kolter and Johnson 2011) and other similar datasets

Occupant behavior diversity

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

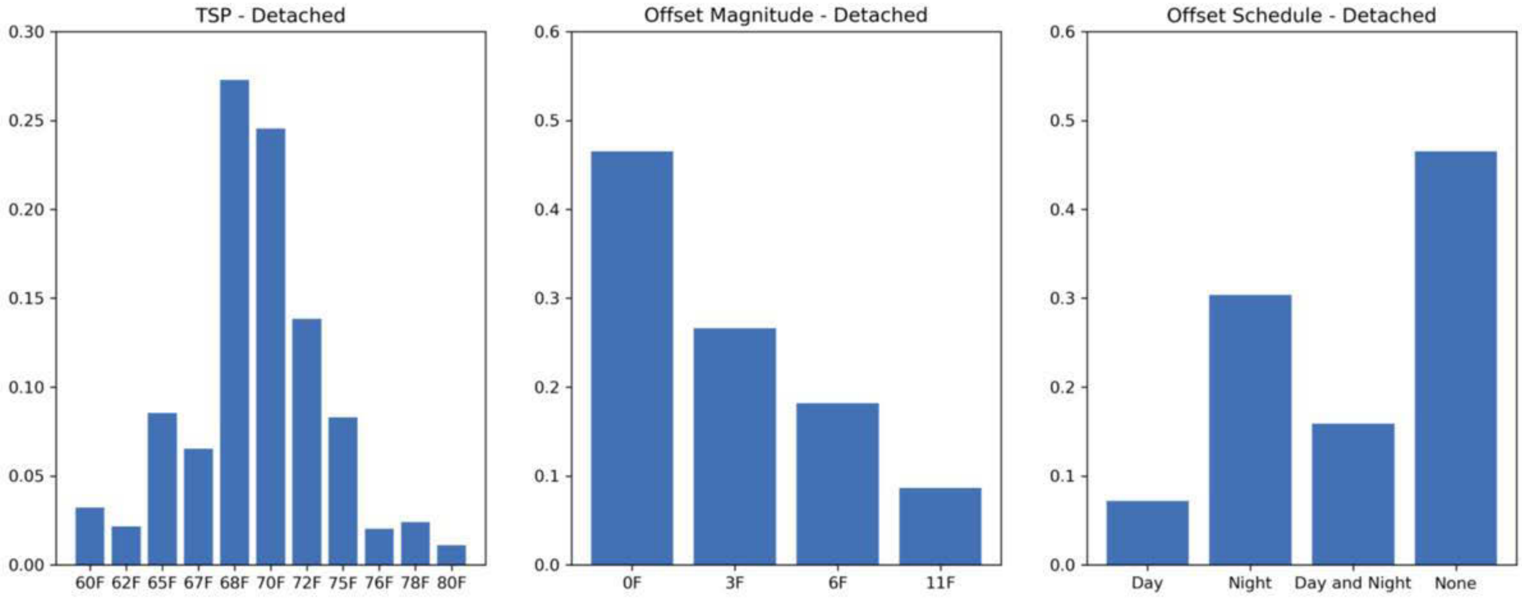
Right: Opower (now Oracle Utilities) clustered whole-building data to derive occupant "archetypes"



Source: Opower (2014)

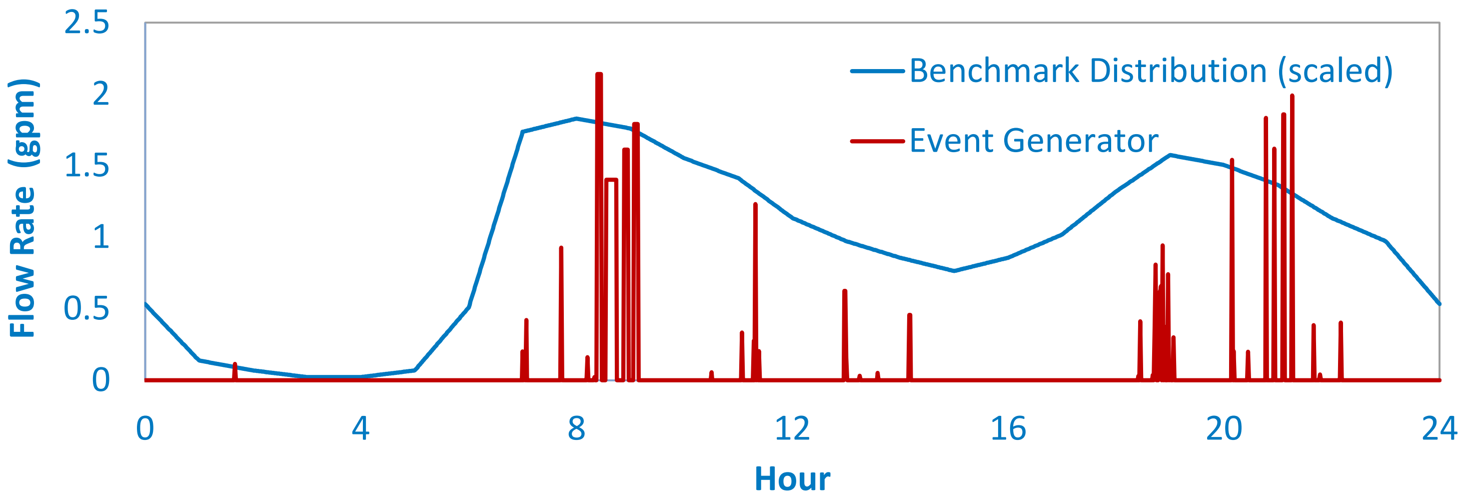
Occupant behavior diversity

Progress on adding diversity for residential thermostat setpoints
Data from EIA RECS 2009



Occupant Behavior Modeling | Residential

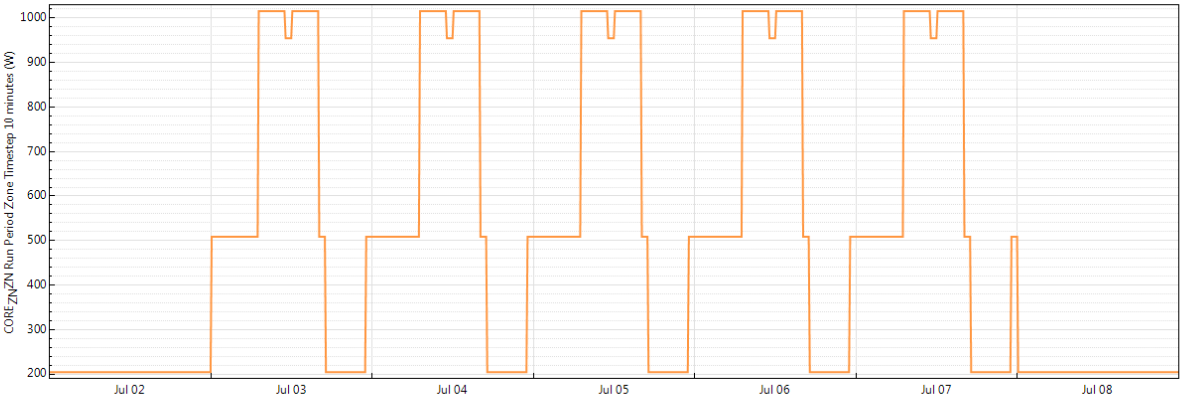
Discrete domestic hot water (DHW) draws were recently implemented for OpenStudio and ResStock



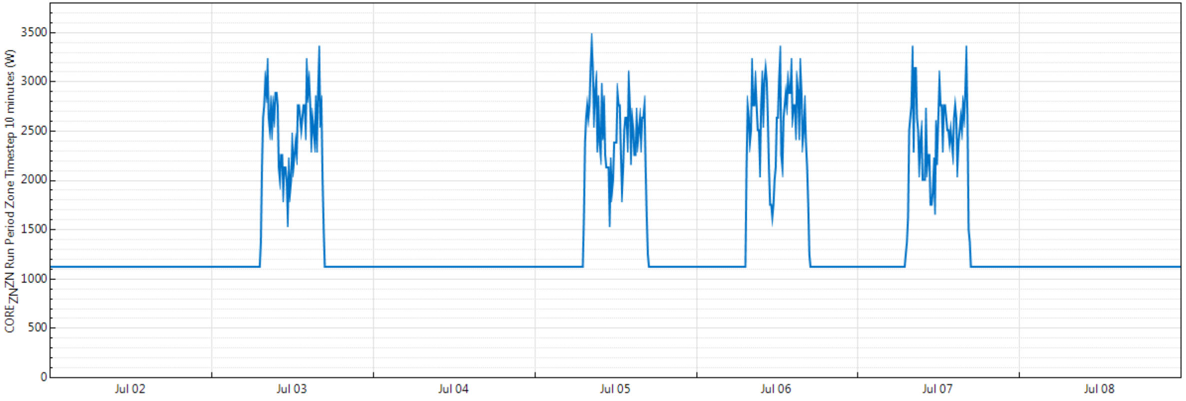
Occupant Behavior Modeling | Commercial

Office Misc. plug loads

Existing



With LBNL's stochastic Occupancy model



Discussion and Q&A

Questions?

We are going to unmute all of the phone lines,

so please mute yourself if you are not speaking.

TAG member perspectives on data sharing

1. Rachel Scheu, Elevate Energy
2. Adam Gerza, Energy Toolbase
3. Jim Leverette, Southern Company

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

Technical Advisory Group Meeting

Data for Modeling and Calibration

National Renewable Energy Laboratory

March 5, 2019

ELEVATE ENERGY
Smarter energy use for all

Our Mission: Smarter Energy Use for All

We give people the resources they need to make informed energy choices.

We design and implement efficiency programs that lower costs, and protect the environment.

We ensure the benefits of energy efficiency reach those who need them most.

Smart Grid Benefits and Dynamic Pricing

Helping households benefit from the smart grid

Dynamic electricity pricing for residential customers

- Ameren Illinois Power Smart Pricing
- Ameren Peak Time Rebate
- ComEd Residential Real-Time Pricing

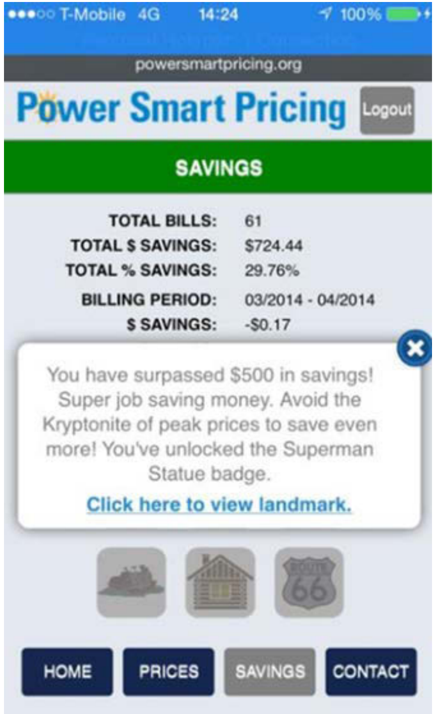
- Marketing and outreach
- Education and enrollment
- Customer service call center

Smart Grid Benefits and Dynamic Pricing

- More than 23,000 households enrolled in hourly pricing
- More than $22 million dollars saved
- Reduced peak demand for electricity

Data Makes Hourly Pricing Easy for Customers

- **Smart phone app** provides current prices, bill comparison data and ability to collect ‘savings badges’ for participants
- **Bill comparison tool** provides savings information to track success
- **Shadow bill marketing** showing individual potential for savings based on historical data



ComEd Anonymous Usage Data

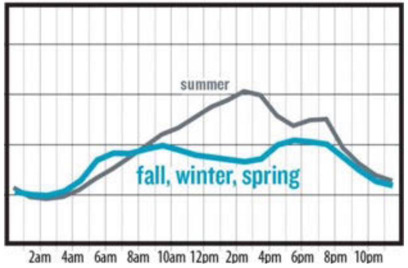
- Individual-level usage in ½ hour increments
- Anonymous customer IDs that change every month
- Delivery service class (single family vs. multifamily; electric vs non-electric spaceheat)
- Zip code, either 5-digit or 9-digit (zip+4)
- Downloadable as one file per month, per zip code

	A	B	C	D	E	F	G	H
1	#ZIP_CODE	DELIVERY_SERVICE_CLASS	DELIVERY_SERVICE_NAME	ACCOUNT_IDENTIFIER	INTERVAL_READING_DATE	INTERVAL_LENGTH	TOTAL_REGISTERED_ENERGY	INTERVAL_HR0030_ENERGY_QTY
2	60005	C23	RESIDENTIAL SINGLE	100061027962758000	1/1/2015	1800	64.3927	1.68
3	60005	C23	RESIDENTIAL SINGLE	100061027962758000	1/2/2015	1800	59.9403	1.245
4	60005	C23	RESIDENTIAL SINGLE	100061027962758000	1/3/2015	1800	49.9033	1.3025
5	60005	C23	RESIDENTIAL SINGLE	100061027962758000	1/4/2015	1800	49.9962	0.8325
6	60005	C23	RESIDENTIAL SINGLE	100061027962758000	1/5/2015	1800	62.6776	0.9875

Elevate Energy review of ComEd's Anonymous Data Service:
http://www.elevateenergy.org/wp/wp-content/uploads/Data-service-report-FINAL-31May2017.pdf

ComEd Anonymous Usage Data – Potential Uses

- Segmentation: Analysis of average daily load shape for broad customer groups (e.g. single-family versus multifamily customers and by housing type)
- Rates: estimate costs under time of use or other dynamic rates
- Disaggregation: weather-dependent versus other usage types; predict kWh savings for certain energy efficiency measures; electrification potential
- Geographic variation in energy consumption (zip codes); target programs to higher-use zip codes/demography (e.g. income-eligible programs)



Housing segmentation example

ComEd Anonymous Usage Data – Limitations

- Anonymous customer IDs change every month: seasonal or annual trends cannot be tracked for individual customers
  - Persistent anonymous IDs would enable: seasonal load shape analysis, longitudinal analysis over years, more reliable weather normalization

- Download process is arduous, due to separate files for each month and zip code
  - Jan 2016-Feb 2017: 2,954 files for 5-digit zip codes, and 314,248 files for 9-digit zip codes

Questions?

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(773) 269-4032

ElevateEnergy.org

@elevate_energy

Facebook/elevateenergy

LinkedIn

End-use Load Profiles technical advisory group

Energy Toolbase presentation
March 5, 2019

ENERGY TOOLBASE™

ENERGY TOOLBASE™

SaaS platform for modeling and proposing the economics of solar + storage projects

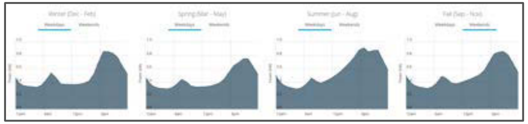
Accurate, objective, transparent: utility rate & avoided cost analysis

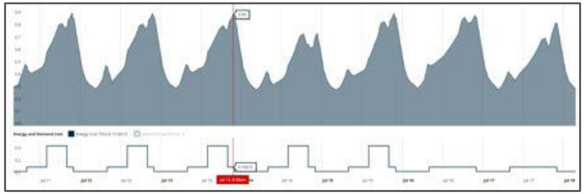
A few of our customers

SUNPOWER
enel x
EDF
Honeywell
THE POWER OF CONNECTED
Schneider Electric
ENERNOC
An Enel Group Company
AMERESCO
Green • Clean • Sustainable
Advanced Microgrid Solutions
ENGIE
stem
EDISON energy
OPTERRA
ENERGY SERVICES
sunworks
Solar Power
amazon
FOREFRONT POWER
nrg
REC SOLAR
PETERSENDEAN
Roofing & Solar Energy
SAMSUNG
RENEW FINANCIAL
BayWa r.e.
renewable energy
CLEANFUND
Commercial PACE Capital
Shell
vivint. solar
SOLSYSTEMS
BORREGO SOLAR
NEXTera ENERGY
Ygrene
BAKER ELECTRIC SOLAR
RGS ENERGY
SunGreen. SYSTEMS
current
powered by GE
Constellation.
onswitch
CanadianSolar
[e] enphase ENERGY

Benefits of interval meter data

- Energy usage data – high granularity data is best
- Dynamic utility rates – TOU, NEM 2.0, RTP
- Energy Storage – project modeling
- Simulate the reduction of demand charges
- Optimize combined technology system (PV+ESS+EE)
- Visualize the data





ENERGY TOOLBASE™

Why we need great reference datasets

- Green Button Data is great, but it's not ubiquitous
- Baselining against a reference file is the next best thing
- Consumer protection issue

Contact info

See a demo OR start a free trial:

www.energytoolbase.com

Adam Gerza
Energy Toolbase, COO
adam@energytoolbase.com
310-210-2392

ENERGY TOOLBASE™

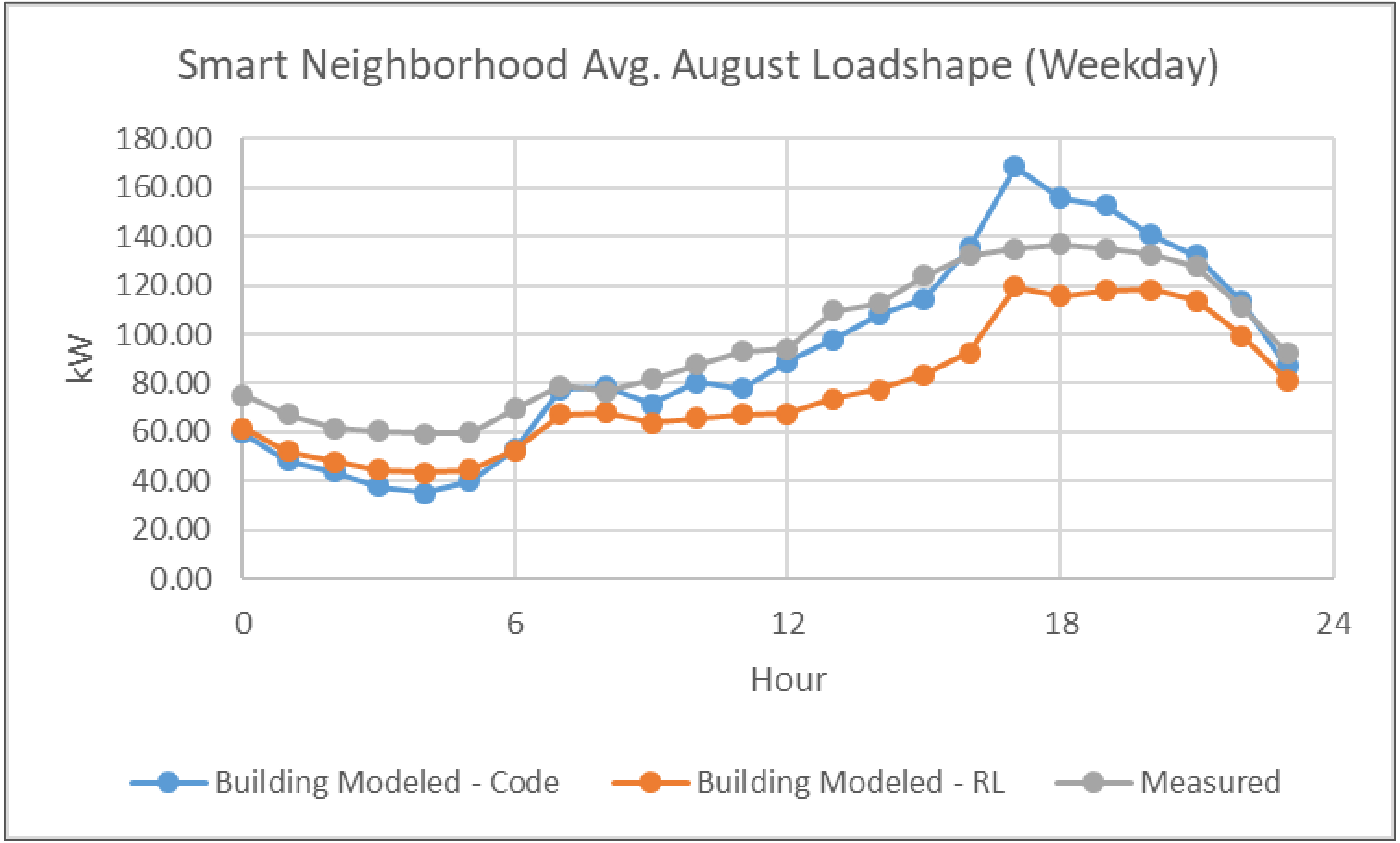
Modeled vs Measured – End Uses

Research & Development

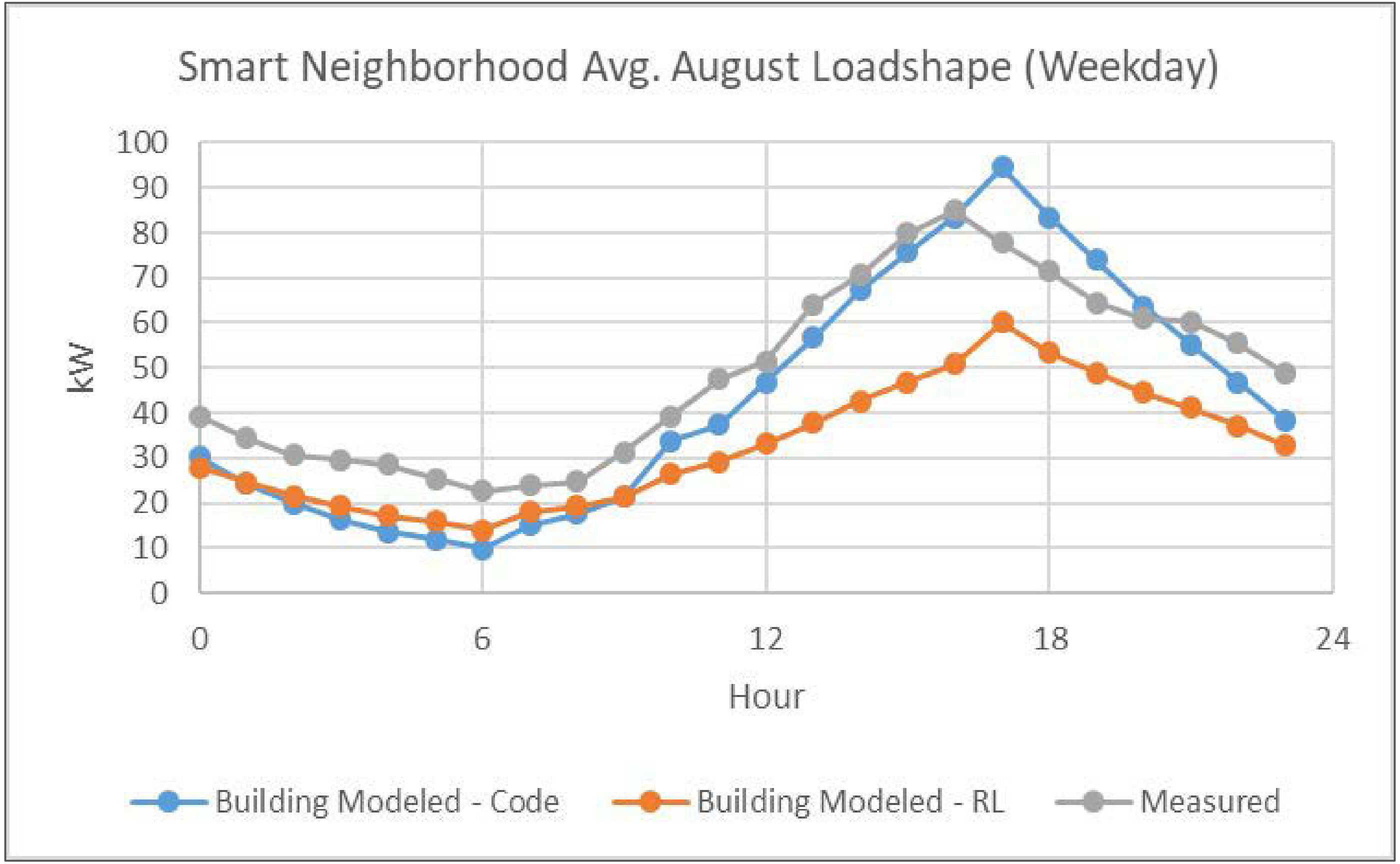
Jim Leverette

Senior Research Engineer

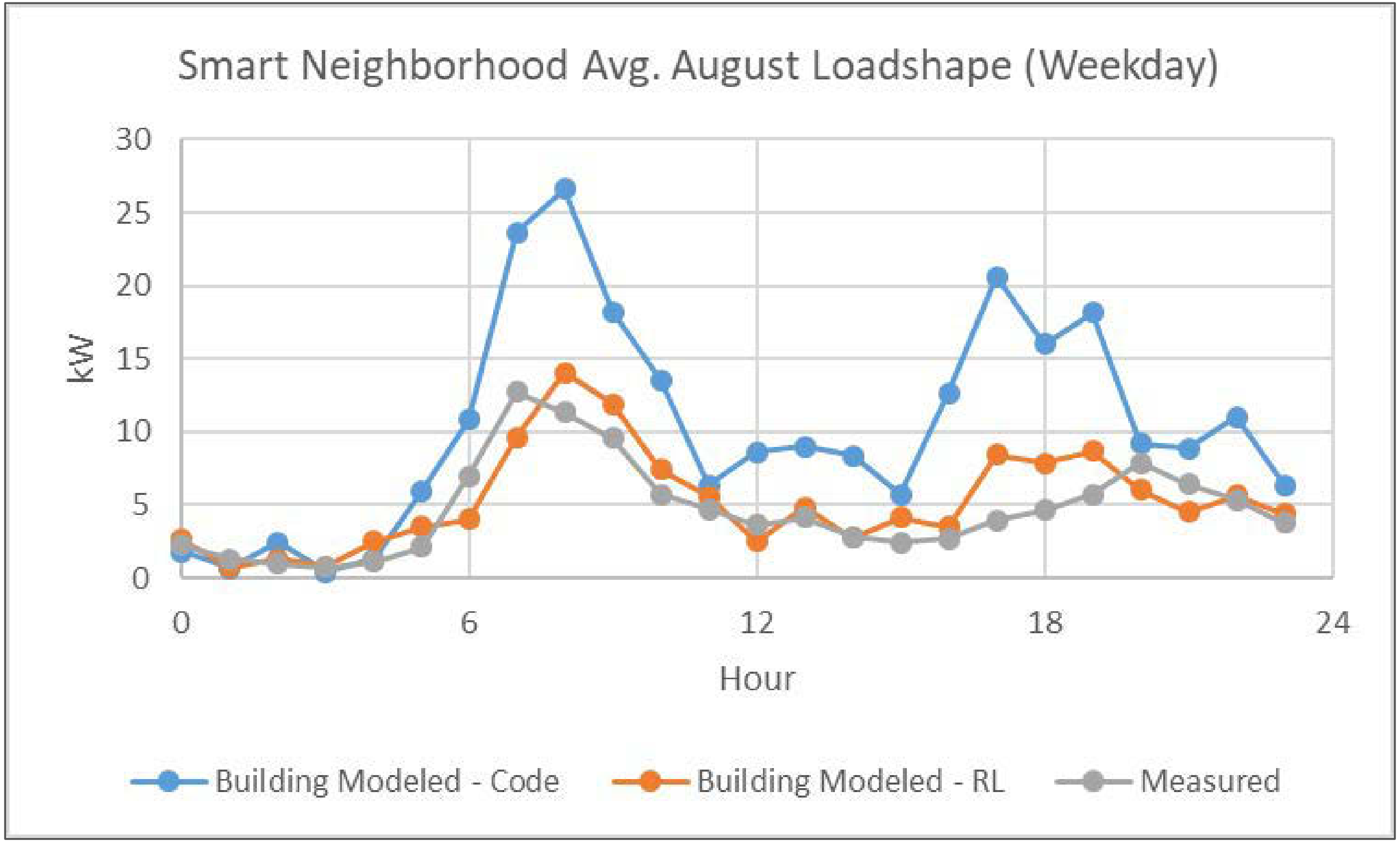
Community Loadshape



Community Loadshape



Community Loadshape



Backup Slides

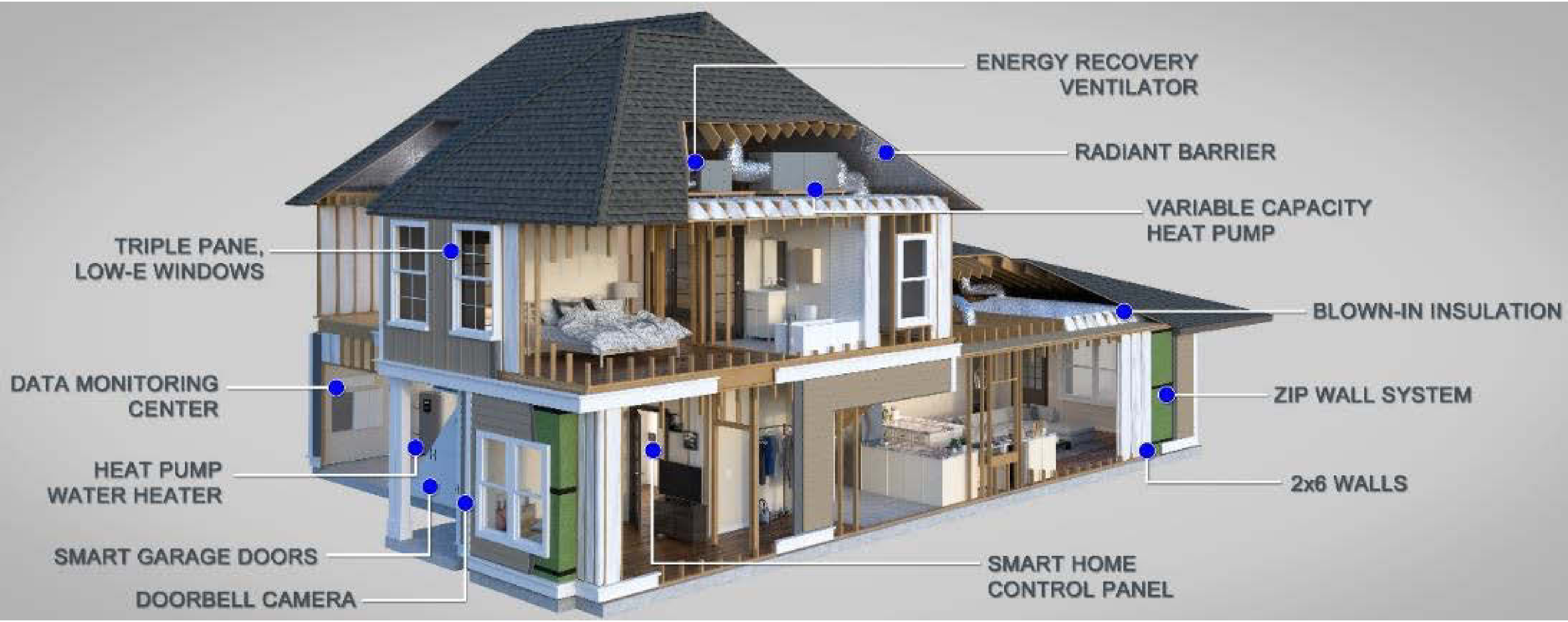
Alabama Power

SMART NEIGHBORHOOD®

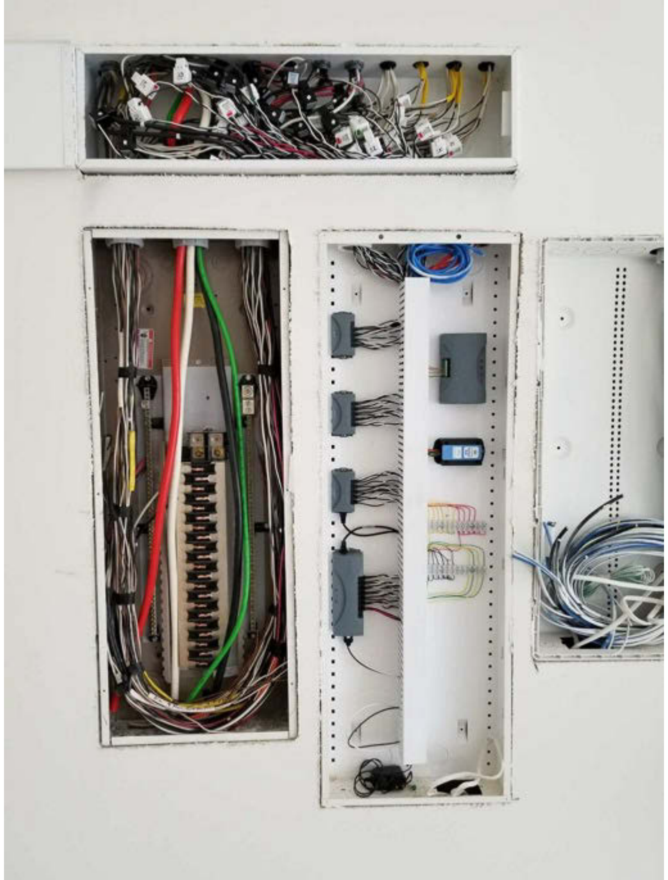
Objective:

Design and build a first-of-a-kind high-performance community and residential microgrid to learn how to better serve changing customer needs.

Demonstrate **62 high-performance homes** with connected home technologies providing an improved customer experience


ENERGY RECOVERY VENTILATOR
RADIANT BARRIER
VARIABLE CAPACITY HEAT PUMP
TRIPLE PANE, LOW-E WINDOWS
BLOWN-IN INSULATION
DATA MONITORING CENTER
ZIP WALL SYSTEM
HEAT PUMP WATER HEATER
2x6 WALLS
SMART GARAGE DOORS
SMART HOME CONTROL PANEL
DOORBELL CAMERA

Sensor Installation



Discussion and Q&A

Questions?

We are going to unmute all of the phone lines,

so please mute yourself if you are not speaking.

Agenda – March 6

8:00 – 9:00	Breakfast
9:00 – 9:20	Presentation: Use Cases – The Compiled List
9:20 – 10:00	Breakout Group: Use Cases Prioritization
10:00 – 10:15	Morning Break
10:15 – 10:45	Presentation: Data Gaps for Load Profile Development
10:45 – 11:30	Interactive Session: Data Gaps Prioritization and Brainstorming
11:30 – 12:15	Report Out and Final Discussion
12:15 – 1:00	Box Lunches
1:00 – 2:00	Tour of Energy Systems Integration Facility (Optional)

Thank you

Eric Wilson, eric.wilson@nrel.gov
Andrew Parker, andrew.parker@nrel.gov
Natalie Mims Frick, nfrick@lbl.gov

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NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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

Technical Advisory Group meeting #2

March 5 – 6, 2019

Introduction

Natalie Mims Frick, LBNL

Logistics

- We have ~40 people in Colorado and ~30 people on the phone.
- 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 during Q&A periods for open dialogue.
- If you are participating by phone, the agenda has your breakout group call-in information for today.
- We are taking notes and will distribute them to the TAG. We will not attribute specific remarks to participants.
- We will be recording the plenary sessions.

Agenda – March 6

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Joining By Phone

- Dan York, ACEEE
- Prasenjit Shil, Ameren
- Robert Weber, BPA
- Sami Khawaja, Cadmus
- Ayad Al-Al-Shaikh, CalTF
- Ross Macwhinney, City of New York
- Stephen Bird, Clarkson University
- Susan Powers, Clarkson University
- Griffin Reilly, ConEd
- Bob Ramirez, DNV-GL
- Chris Neme, Energy Futures Group
- Jamie Fine, Environmental Defense Fund
- Ron Domitrovic, EPRI
- Dave Parsons, HI PUC
- Erik Miller, IPL
- Henry Yoshimura, ISO-NE
- Brad Borum, IURC
- Bob Pauley, IURC
- Paulomi (Lucy) Nandy, MEEA
- Naomi Simpson, MI PSC
- Dave Walker, MI PSC
- Claire Miziolek, NEEP
- Elizabeth Titus, NEEP
- Mike Reed, NYSERDA
- Angela Long, PacifiCorp
- Scott Schuetter, Seventhwave
- Kenji Takahashi, Synapse
- Abhijeet Pande, TRC Solutions
- Robert Stephenson, VEIC
- JJ Vandette, VEIC

In the Room

- Jen Amman, ACEEE
- Steven Keates, ADM
- Kurtis Kolnowski, AEG
- Bob Willen, Ameren
- Phillip Kelsven, BPA
- Valerie von Schramm, CPS
- Curt Puckett, DNV-GL
- Craig Williamson, DNV-GL
- Ben King, DOE
- Monica Neukomm, DOE
- Rachel Scheu, Elevate Energy
- Adam Gerza, Energy Toolbox
- Krish Gomatom, EPRI
- Chris Holmes, EPRI
- Jamie Barber, GA PSC
- Matt Cox, Greenlink Group
- Ali Bozorgi, ICF
- Tom Eckman, LBNL
- Natalie Frick, LBNL
- Rodney Sobin, NASEO
- Mark Bielecki, Navigant
- Justin Spencer, Navigant
- Carlo Bianchi, NREL
- Jianli Chen, NREL
- Dane Christensen, NREL
- Matt Dahlhausen, NREL
- Lieko Earle, NREL
- Rawad El Kontar, NREL
- Anthony Fontanini, NREL
- Janghyun Kim, NREL
- Andrew Parker, NREL
- Ben Polly, NREL
- Marlena Praprost, NREL
- Elaina Present, NREL
- Janet Reyna, NREL
- David Roberts, NREL
- Eric Wilson, NREL
- Jessica Lin, Oracle
- Dan Patry, Oracle
- Ellen Franconi, PNNL
- Michael Bishop, Solar Investments Inc
- Jim Leverette, Southern Company
- David Podorson, Xcel

Use Case Breakout Review

Technical Advisory Group meeting #2
March 6, 2019

Andrew Parker, NREL

Currently, we use EULPs for (1 of 2)

- **DSM/EE program inputs**
- **IRP planning**
- PV calculations
- Codes & standards EE and DR for Com and Res
- distribution cost analysis for PV vs. non-PV customers
- City planning for clean energy targets
- Hourly avoided costs
- DR potential estimates
- Finding energy theft

Currently, we use EULPs for (2 of 2)

- Rate design
- ET analysis
- Informing modeling assumptions for new building design
- Policy analysis
- Resilience analysis
- Motivate behavioral changes
- Savings shapes would be useful
- Geotargeting of EE/DR programs
- Resource interactions
- Non-wires alternatives

Challenges (1 of 2)

- Quantifying the economic impact of bad load profiles data
- Lack of variation between weekend and weekday
- Lack of confidence that models match current reality
- Difficult/expensive to validate datasets before using them
- Too aggregated for a lot of uses
- Customers don’t have an incentive to give up individual data
- For most use cases, 15min is fine, but for microgrids and customer targeting, 1min is lower
- Heat island effect

Challenges (2 of 2)

- Behavior differs even within regions and within cities – include metadata to use for this
- Understanding the variance is important
- For IRP planning
- Need to include extreme weather events
- Need to include variance in addition to typical
- Need to account for customer behavior change when forecasting utility infrastructure
- Time more important for now, but location will be in future
- Hard to get utility operations to trust anything besides real-world data
- Hard to understand locational value

Requirements for EULPs

- **Show the calibration**
- Ensure that current state of building controls is included in load shapes
- Show what technologies are associated with each load shape in the database
- Need to understand demographic/income driven trends – important for future projection
- For future DR, need to be able to predict how much load shift probable

Obscure use cases

- Finding unreported PV behind the meter
- Peer-to-peer energy trading and settlement
- Look at gaming system consumption and use as predictor of overall media consumption changes
- Looking at worst-case scenario resilience – what does it really take to keep critical infrastructure running islanded
- Detect faults for preventative maintenance

Use cases from a different perspective

Dane Christensen

Breakout questions

1. Which of the use cases are most important to meet your needs?
2. Which of the use cases have the most potential impact? (however you define impact)
3. Which of the use cases would your stakeholders be most interested in
4. Which of the dimensions (time, segmentation, end use granularity, geography, buy-in, documentation, etc.) are most important overall?

Onsite breakout groups – March 6

Location: Maxwell (B208)
Mark Bielecki, Navigant
Ali Bozorgi, ICF
Steven Keates, ADM
Kurtis Kolnowski, AEG
Curt Puckett, DNV-GL
Rachel Scheu, Elevate Energy
Justin Spencer, Navigant
Craig Williamson, DNV-GL

Location: Faraday (B212)
Jen Amman, ACEEE
Jamie Barber, GA PSC
Tom Eckman, LBNL
Ellen Franconi, PNNL
Ben King, DOE
Rodney Sobin, NASEO

Location: Edison (B211)
Michael Bishop, Solar Investment Inc
Matt Cox, Greenlink Group
Adam Gerza, Energy Toolbox
Krish Gomatom, EPRI
Jessica Lin, Oracle
Dan Patry, Oracle

Location: Tesla (B210)
Chris Holmes, EPRI
Phillip Kelsven, BPA
Jim Leverette, Southern Company
David Podorson, Xcel
Valerie von Schramm, CPS
Bob Willen, Ameren

Load Profile Input Data Gaps

Technical Advisory Group meeting #2
March 6, 2019

Andrew Parker, NREL

Traditional approach – sample & meter

1. Sample the buildings in an area
   A. Each sample has a weight
2. Meter the end-uses (maybe)
3. Sum(sample * weight)

Get the WHAT (load shape) right; the WHY is a bonus

Our approach – bottom up model

Must get the WHY right in order to get the correct WHAT

1. Break each end use into different types of model inputs
   a) 280 commercial inputs, 370 residential inputs
2. Figure out data sources for each input
3. Combine all inputs, run model, check results

Example – commercial internal lighting

Model Input	**Input Type**	**Data Source Quality**
Power/Space-Floor-Area	Physical Properties	High
Schedule	Equipment Setting, Occupant Behavior	Medium
Occupancy Sensor	Occupant Behavior	High
Daylight Sensor	Weather Response	Low

Example – commercial PTACs

Model Input	Input Type	Data Source Quality
Capacity	Physical Properties	High
Efficiency	Physical Properties	High
Part Load Performance	Physical Properties	Medium
OAT-driven Performance	Physical Properties	Medium
Equipment Faults	Physical Properties	Low

Hard questions

1. How do you know your model isn't right for the wrong reason?
    a) e.g. high LPD plus high occupancy sensor reductions = same load profile.
2. How do you handle cascading impacts?
    a) e.g. envelope properties drive load, which drives cooling demand
3. How do

Prioritization approach

1. What has the biggest impact on load magnitude?
2. What has the biggest impact on peaks?
   a) May differ by region
3. What currently has the worst data?
4. What end-uses are likely targets of interventions?
   a) Try to think ahead about future technologies
5. What is most embarrassing to admit in a report?

Residential data gaps

Category	Subcategory	End Uses Impacted	Input Type
Geometry	Mass: Wall/Structure	Res: Heating & Cooling	Physical Properties
Geometry	Overhangs:Depth	Res: Heating & Cooling	Physical Properties
Hot Water	Water Heater:Schedule	Res: Water heating	Occupant Behavior
HVAC	Bath Exhaust Vent Flow Rate	Res: Heating & Cooling	Physical Properties
HVAC	Bathroom Spot Vent Hour	Res: Heating & Cooling	Occupant Behavior
HVAC	Cooling Setpoint	Res: Cooling	Occupant Behavior
HVAC	Cooling Setpoint:Seasonality	Res: Cooling	Occupant Behavior
HVAC	Cooling:RoomAC:Schedule, seasonality, partial cond.	Res: Cooling	Physical Properties
HVAC	Dehumidifier	Res: Heating & Cooling	Occupant Behavior
HVAC	Heating Setpoint	Res: Heating	Occupant Behavior
HVAC	Heating Setpoint Seasonality	Res: Heating	Occupant Behavior
HVAC	HVACCombined:ASHP:Min_Temp	Res: Heating & Cooling	Physical Properties
HVAC	Natural Ventilation:Days per week	Res: Cooling	Occupant Behavior
HVAC	Natural Ventilation:Portion of Year	Res: Cooling	Occupant Behavior
HVAC	Range Spot Vent Hour	Res: Misc. plug loads	Occupant Behavior
HVAC	Range Vent Flow Rate	Res: Misc. plug loads	Physical Properties
Internal Loads	Clothes Dryer: Schedule	Res: Clothes dryer	Occupant Behavior
Internal Loads	Clothes Washer: Schedule	Res: Clothes washer	Occupant Behavior
Internal Loads	Dishwasher: Schedule	Res: Dishwasher	Occupant Behavior
Internal Loads	Lighting: Schedule	Res: Interior Lights	Occupant Behavior
MELs/MGLs	Hot Tub Spa:Schedule	Res: MELs/MGLs	Occupant Behavior
MELs/MGLs	Plug Loads:Energy Usage	Res: MELs/MGLs	Occupant Behavior
MELs/MGLs	Plug Loads:Schedule	Res: MELs/MGLs	Occupant Behavior
MELs/MGLs	Pool: Schedule	Res: MELs/MGLs	Physical Properties
MELs/MGLs	Pool:Pump Schedule	Res: MELs/MGLs	Physical Properties
MELs/MGLs	Well Pump:Schedule	Res: MELs/MGLs	Occupant Behavior
Occupants	Occupancy	Res: Indirectly affects multiple end uses	Occupant Behavior
Occupants	Occupants:Number	Res: Indirectly affects multiple end uses	Occupant Behavior
Occupants	Occupants:Schedule	Res: Indirectly affects multiple end uses	Occupant Behavior
Occupants	Usage Level	Res: Indirectly affects multiple end uses	Occupant Behavior

Residential data gaps from 8th NWPP

- New construction baselines
- Hours of use for room cooling (room AC, ceiling fans)
- Lighting occupancy sensor
  - Reductions
  - Savings profile
- Hot water pipe insulation savings estimates

Commercial data gaps

Category	Subcategory	End Uses Impacted	Input Type
Building Stock	Energy Code Equivalency and Adoption Dates	Com: All	Physical Properties
Building Stock	Energy Code Compliance Levels	Com: All	Physical Properties
Building Stock	Building Component Replacement Rate	Com: All	Occupant Behavior
Geometry	Orientation	Com: Heating & Cooling	Physical Properties
Geometry	Illuminated Facade Areas	Com: Exterior Lighting	Physical Properties
Envelope	Air Leakage: Continuous Air Barrier Materials and Assemblies	Com: Heating & Cooling	Physical Properties
Internal Loads	IT Closet Equipment: Power/Space-Floor-Area	Com: Interior Equipment	Physical Properties
Internal Loads	OccupantLoad: Occupancy Schedule	Com: Heating & Cooling	Occupant Behavior
Internal Loads	Internal Mass: Surface Area	Com: Heating & Cooling	Physical Properties
HVAC&R	Decentralized: PackagedTerminalUnit: DXUnit: PartLoadPerformance	Com: Cooling	Physical Properties
HVAC&R	Decentralized: PackagedTerminalUnit: DXUnit: Fault	Com: Cooling	Physical Properties
HVAC&R	Decentralized: PackagedTerminalUnit: HeatPump: PartLoadPerformance	Com: Heating & Cooling	Physical Properties
HVAC&R	Decentralized: PackagedUnitarySystem: VAV: Economizer: Fault	Com: Heating & Cooling	Physical Properties

Commercial data gaps from 8th NWPP

- Food prep equipment
- Grocery refrigeration
- Advanced rooftop controller
- VRF

Questions for the group

1. What data gaps did we miss
2. What data sources are you aware of that can fill these gaps
   a) Think outside the box

Thank you!

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