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

Technical Advisory Group meeting #3
June 18, 2019

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Logistics

• Welcome back!

• Because of the large number of participants on the phone, everyone is in *listen-only* mode during presentations.

• **Please use the chat box to send us clarifying questions** during presentations. We will unmute lines after each topic for open dialogue.
Agenda

• Project background
• Technical advisory group use case priorities
• Data requirements
• Update: Modeling and calibration
• Progress on obtaining data & data gaps
• Next steps
• General discussion and Q&A
Project Background
Hybrid approach combines best-available ground-truth data—
• submetering studies,
• statistical disaggregation of whole-building interval meter data, and
• other emerging data sources
—with the reach, cost-effectiveness, and granularity of physics-based and data-driven building stock modeling capabilities

The novel approach delivers a nationally-comprehensive dataset at a fraction of the historical cost.
Project Timeline

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Beyond</th>
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</thead>
<tbody>
<tr>
<td>Collect/review existing data</td>
<td>Report on critical gaps</td>
<td>Targeted data collection through planned and ongoing sub-metering studies</td>
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<td></td>
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<td>Statistical disaggregation of certain end uses from existing AMI data¹</td>
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<td>Data analysis</td>
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<td></td>
<td></td>
<td>Occupancy and end-use schedules with diversity</td>
<td>Rigorous calibration of building stock end-use models</td>
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<td>Stochastic event modeling capabilities</td>
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<td>Calibrated building stock models</td>
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<td>Load profile library, documentation, &amp; user guide</td>
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<td>EE/DR savings profiles</td>
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<td></td>
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<td>Ongoing additions to load profile library</td>
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</table>

¹ For example, conditional demand analysis, or inverse (changepoint/degree day) models (KEMA 2009)
Key Milestones and Deliverables

2018 (December)  Establish TAG

2019 (Fall)  Publish Report on Market Needs, Use Cases and Data Gaps that discusses applications of end-use load profiles, use cases and identify gaps in existing data

2020  Complete models to represent stochastic behavior of discrete end-use events in building operation

Produce working but uncalibrated model of national residential and commercial building stocks that generates end-use load profiles

2021  Complete calibrated model of national residential and commercial building stocks that generates average and typical end-use load profiles

Publish dataset of end-use load profiles on one or more free, publicly accessible websites such as OpenEI.org, Data.gov, and the EPRI Load Shape Library

Publish Technical Project Documentation that describes technical details, assumptions and methodologies used to develop and calibrate the models and create end-use load profiles

Publish User’s Guide describes approach, results, and applications (e.g., load forecasting, resource planning, program, and policy design)
Technical Advisory Group Use Case Priorities
1. **Electricity resource planning**: Long range planning such as integrated resource planning or long range load or avoided cost forecasting.

2. **Energy efficiency planning**: Benefit-cost analysis, estimating potential, planning, design and implementation of energy efficiency programs.

3. **Policy and rate design**: Support for utility, local, state or federal policy decision-making. Examples include codes and standards development, electricity rate design including evaluating time-based rates and climate policy.

4. **Distribution system planning**: Assessing needed physical and operational changes to the distribution grid. Examples include non-wires alternatives.

5. **Energy efficiency program impacts**: Improving assumptions used in efficiency impact evaluations.
6. **New building design/modeling/rating**: Improving default assumptions at the building level for new building design and identifying major regional differences for multi-building modeling.

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

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

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

10. **Demand response planning**: Estimating potential, planning, design and implementation of demand response programs.
Top three use cases identified by TAG

Use Case Ranking

Energy Efficiency Planning 1st
Electricity Resource Planning 2nd
Policy & Rate Design 3rd
Electrification Planning
Distribution System Planning
Energy Efficiency Program Impacts 1st
Demand Response Planning 2nd
Improve Building Energy Modeling 3rd
Photovoltaic Planning
Emissions Analysis
Data Requirements
## Data requirements for top use cases

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

<table>
<thead>
<tr>
<th>Time Resolution</th>
<th>Geographic Resolution</th>
<th>Occupancy</th>
<th>Electrical Characteristics</th>
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</thead>
<tbody>
<tr>
<td><strong>15-minute</strong></td>
<td><strong>Utility territory</strong></td>
<td><strong>Stochastic</strong></td>
<td><strong>Real power</strong></td>
</tr>
<tr>
<td>• Highest impact cases require only hourly results</td>
<td>• Distribution System Planning requires feeder-level data</td>
<td>• This is a significant gap and will require new modeling techniques</td>
<td>• Some distribution system planning use cases might benefit from reactive power</td>
</tr>
<tr>
<td>• PV Planning is the only top use case that requires less than 15-minute data</td>
<td>• A “mix-and-match” approach from a bank of load profiles could help build specific utility and feeder level information</td>
<td></td>
<td>• Data requirements for some use cases are not well understood</td>
</tr>
</tbody>
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We are going to unmute all of the phone lines, so please mute yourself if you are not speaking.
Update: Modeling and Calibration
Data needs

Inputs → Data → Outputs

- Schedules, Probability distributions
- Calibration, Validation
- Calibration feedback

ComStock
ResStock

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Update: Modeling and Calibration

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

Example 2: Annual usage validation by building type

Data: Customer monthly billing data
Average annual electricity use by building type

How we use data for calibration

Example 2: Annual usage validation by building type

Data: Customer monthly billing data
Data-driven calibration approaches: Cooling Load Shape

How we use data for calibration

Example 2: Truing-up model residuals

Data:
Utility customer class hourly load data

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

- Cooling load shape shifted and scaled
- Total cooling load is conserved
- Fixes large diurnal swings
- Similar model for heating
Data-driven calibration approaches: Temperature Shift

Example 2: Truing-up model residuals

Data:
Utility customer class hourly load data

- Scales simulation data based on temperature
- Fixes errors on days with very high/low temps
Data-driven calibration approaches: Temperature Shift

How we use data for calibration

Example 2: Truing-up model residuals

Data:
Utility customer class hourly load data

- Scales simulation data based on temperature
- Fixes errors on days with very high/low temps
Example calibration results (work in progress)
After 30 iterations of input changes and truing-up residuals

2016 (Training Dataset)

Daily Total Load

Electric Consumption (GWh)

Day of Year

Daily

July

Electric Load (MWh)

Day

Hourly
Example calibration results (work in progress)
After 30 iterations of input changes and truing-up residuals
We are going to unmute all of the phone lines, so please mute yourself if you are not speaking.
Progress on obtaining data & data gaps
Examples of Data Sources

Acquired or actively pursuing 20 (and growing) data sources from around the U.S.
Calibration Data Sources (selected examples)

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

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

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

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

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

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

### High Priority Gaps, Limited Data

| **Commercial** | Computing (server) load  
Miscellaneous internal electric load  
Energy code compliance level  
Building component replacement rate  
Internal thermal mass |
| **Residential** | Well pumps  
Pools & hot tubs  
Appliance usage schedules  
Non-appliance plug load schedule  
Water heater type  
Internal thermal mass |
# Greatest Gaps in Modeling Inputs

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

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