Project Overview and Deliverables
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- outdated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
**Project Timeline**

- **FY19** (ends 9/30/2019)
  - Define use cases and requirements
  - Collect/review existing data
  - Stochastic occupancy modeling capabilities

- **FY20** (ends 9/30/2020)
  - Targeted data acquisition leveraging planned/ongoing sub-metering studies
  - Data analysis to derive occupant-driven schedules and usage diversity
  - Rigorous calibration of building stock end-use model
  - Quantify accuracy of results for target applications

- **FY21** (ends 9/30/2021)
  - Calibrated building stock models
  - Load profile library, documentation, & user guide

- **Beyond**
  - Ongoing additions to load profile library

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**You are here**

Com: 2 of 4 calibration regions complete
Res: 4 of 5 calibration regions complete

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- Ongoing additions to load profile library
Major Efforts so Far

Overarching
• Year one report *End Use Load Profiles for the U.S. Building Stock: Market Needs, Use Cases and Data Gaps*
• Uncertainty quantification framework, defining “Quantities of Interest”

Residential
• End use transferability study
• Stochastic occupant behavior model
• 4 of 5 calibration regions

Commercial
• End use data sourcing
• AMI processing/outlier detection
• 2 of 4 calibration regions
# Publication Plan

## Public Datasets
- Published by Sept 30, 2021
- Web data viewer
- Pre-aggregated load profiles
- Raw individual building load profiles
- Raw individual building models
- Data access instructions

## Public Webinar
- Conducted by Sept 30, 2021
- Presents project outcomes to technical advisory group and other stakeholders

## Methodology and Results Report
- Published by Dec 31, 2021
- Detailed description of model improvements, validation, and uncertainty of results
- NREL lead

## Applications and Opportunities Report
- Published by Dec 31, 2021
- Example applications and opportunities for using the dataset
- LBNL lead

To sign up for our mailing list and get occasional updates on all the above: [https://www.nrel.gov/buildings/end-use-load-profiles.html](https://www.nrel.gov/buildings/end-use-load-profiles.html)
Resources

**Publications**
- Li et al. Characterizing Patterns and Variability of Building Electric Load Profiles in Time and Frequency Domain
- Bianchi et al. 2020. Modeling occupancy-driven building loads for large and diversified building stocks through the use of parametric schedules
- Parker et al. 2020. Framework for Extracting and Characterizing Load Profile Variability Based on a Comparative Study of Different Wavelet Functions
- Present et al. 2020. Putting our Industry’s Data to Work: A Case Study of Large Scale Data Aggregation
- N. Frick. 2019. End Use Load Profile Inventory

**Presentations and Slides**
- Technical Advisory Group slides — LBNL and NREL site
- E. Wilson. 2020. EFX webinar
- E. Wilson. 2019. Peer Review presentation

**Software**
- OpenStudio Occupant Variability Gem and Non Routine Variability Gem (more info at IBPSA newsletter)

**Data**
- First year of 15-min NEEA HEMS data available: https://neea.org/data/end-use-load-research/energy-metering-study-data
A Few Details
Project Outcomes | Calibrated Building Stock Models

- 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 BEM tools OpenStudio and EnergyPlus
- Produce hourly load profiles, but previous calibration has focused on annual energy consumption
Guiding Principles

• We want to get the “why” right so we can ask questions about changes to the stock (i.e., savings load shapes)
• Make changes that are supported by data and domain experience, not simply to get a better fit
• Report out accuracy and uncertainty so users can decide if they want to use
Then and Now: ERCOT Residential Load Profile Comparisons

Before End Use Load Profiles Project

Current
Same Data, Multiple Scales

Added Filters
- in_building_type: Hospital
- in_building_type: MediumOffice

Filters
- in.sqft
- in.rotation
- in.applicable
- in.aspect_ratio
- in.climate_zone
- in.building_type
- in.code_when_built
- in.weather_station
- in.hvac_system_type
- in.current_hvac_code
- in.number_of_stories
- in.walls_common_fuel

Filter Options
- FullServiceRestaurant
- Hospital
- LargeHospital
- LargeOffice
- MediumOffice
- Outpatient
- PrimarySchool

Real data will be spikier
Pre-aggregated Load Profiles

**Pre-aggregated EULPs by building type for:**
- U.S. States (contiguous)
- ASHRAE Climate Zones
- DOE Building America Climate Zones
- Electric System ISOs
- U.S. Census Public Use Microdata Area*
- U.S. Counties

**Format:**
- CSV files

**Additional Data:**
- Count of models included per aggregation
- List of model IDs per aggregation
- Model characteristics by ID
- Timeseries mean, stdev, and range

*PUMA is an area with ~200k people; ~2,400 in U.S.*
Web Viewer Interface

- View End Use Load Profiles
- View distributions of building characteristics
- Filter by building characteristic
- Filter by geography
- Select time window
- Download CSV of results
Individual Building End Use Load Profiles

• ~450,000 residential
• ~350,000 commercial
• Full dataset will be 10’s of terabytes
• Plan to include high-level instructions for loading this dataset using one cloud-based big-data analysis tool

Additional Data:

• Model characteristics by ID
• Model in OpenStudio (.osm) format

Format:

• Folders with a series of Apache parquet* files
  • Likely 1 file per building, with IDs in names
• In Amazon S3 bucket or similar

*https://parquet.apache.org/
Questions?

www.nrel.gov

Supplemental Slides
Summary of Residential AMI Calibration Regions

Using AMI data from over 2.3 million meters (res. + com.)

Background colors are DOE Building America Climate Regions
Summary of Residential Submeter Datasets

Background colors are DOE Building America Climate Regions.
Residential Calibration

• Significant improvements seen across all truth data comparisons
• Remaining areas of focus include electric heating and heating/cooling behavior during shoulder seasons
• Our research found that appliance and plug load shapes are highly transferrable between regions
  – But the magnitudes are not; we incorporated data on how these end use magnitudes vary by region
• Region 5 of 5 to finish in July 2021
Summary of Commercial AMI Calibration Regions

Using AMI data from over 2.3 million meters (res. + com.)

Critical for Commercial:
- Customer metadata (building type, floor area)
- Detection of misclassification and outliers

Background colors are DOE Building America Climate Regions
Commercial Calibration

- Getting an accurate ground truth to use for calibration is challenging and critical
  - Submeter data not readily available, eventually procured from a range of companies
  - AMI data is only useful if you know building type and size; had to develop ways to assign metadata that avoid privacy concerns
  - Developed process for removing outliers (e.g., misclassified building types, missing meters)
  - AMI sample size can be small – can't rely on AMI alone
  - Will be adding comparisons to additional data sources (e.g. CBECs)
- Making model improvements in parallel, much work still to do
- Region 3 of 4 to finish in May 2021, Region 4 of 4 to finish in August 2021
2 Sets of Weather Data = 2 Sets of EULPs

Typical Meteorological Year (TMY3)
- Widely accepted/expected by utilities, regulators, etc.
- Weather is not coordinated across regions

<table>
<thead>
<tr>
<th>Month</th>
<th>Denver, CO</th>
<th>Boulder, CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1995</td>
<td>1987</td>
</tr>
<tr>
<td>February</td>
<td>1994</td>
<td>1990</td>
</tr>
<tr>
<td>March</td>
<td>1991</td>
<td>1981</td>
</tr>
<tr>
<td>April</td>
<td>1999</td>
<td>1986</td>
</tr>
</tbody>
</table>

Actual Meteorological Year (AMY)
- Using 2018 NOAA data

Format:
- CSV timeseries data for each location used
  - Dry bulb temperature
  - Relative humidity
  - Solar direct normal irradiation
  - Solar diffuse horizontal irradiation
  - Wind speed
  - Building characteristics
- Location used for each Model

2 locations 40 miles apart use data from different years for the same month
Project Outcomes | 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
### Project Outcomes | Working List of Building Types

<table>
<thead>
<tr>
<th>Commercial</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Small Office</td>
<td>• Single-Family Detached</td>
</tr>
<tr>
<td>• Medium Office</td>
<td>• Single-Family Attached</td>
</tr>
<tr>
<td>• Large Office</td>
<td>• Multifamily Low-Rise</td>
</tr>
<tr>
<td>• Stand-alone Retail</td>
<td>• Multifamily Mid-Rise</td>
</tr>
<tr>
<td>• Strip Mall</td>
<td>• Multifamily High-Rise</td>
</tr>
<tr>
<td>• Primary School</td>
<td></td>
</tr>
<tr>
<td>• Secondary School</td>
<td></td>
</tr>
<tr>
<td>• Outpatient Healthcare</td>
<td></td>
</tr>
<tr>
<td>• Hospital</td>
<td></td>
</tr>
<tr>
<td>• Small Hotel</td>
<td></td>
</tr>
<tr>
<td>• Large Hotel</td>
<td></td>
</tr>
<tr>
<td>• Warehouse (non-ref.)</td>
<td></td>
</tr>
<tr>
<td>• Quick Service Restaurant</td>
<td></td>
</tr>
<tr>
<td>• Full Service Restaurant</td>
<td></td>
</tr>
</tbody>
</table>
Example aggregate versus individual EULP concept demonstration using water draws
Use Cases | Data Fidelity Requirements

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

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

**Electrical Characteristics**
- Real power
  - Some distribution system planning use cases might benefit from reactive power
  - Data requirements for some use cases are not well understood
Commercial Calibration Dimensions

AMI data from (likely)
Horry County, SC;
Chattanooga TN;
Tallahassee, FL

AMI data from Vermont;
Maine; Cherryland, MI

AMI data (aggregated by building type) from
Seattle City Light, WA and
Portland General Electric, OR

AMI data from Fort Collins
municipal service territory (CO)

Region 4 AMI data
EIA 861m electricity, natural gas

EIA CBECs
Submetered end-uses

Sub-metered end-use load data (10 datasets)

Load duration curves and seasonal load shapes of ~16 utilities around U.S.

Region 3 AMI data

Region 2 AMI data

Region 1 AMI data

Utility load research data (LRD)

Com. Calibration

Annual and monthly electricity and natural gas consumption by state, sector

Annual gas and electricity EUIs by building type
Residential end-use transferability study
Residential end use transferability

Question: Are residential end use patterns the same across regions?

- Navigant Massachusetts Residential Baseline Study (Mass Res 1)
  - 356 sites, metered between May 2017 and April 2018
  - Massachusetts, representative sample
- NEEA Residential Building Stock Assessment: Metering Study (RBSAM)
  - 101 homes, metered from 2012-04-01 to 2014-07-31
  - Pacific Northwest, representative sample
- Florida Solar Energy Center - Phased Deep Retrofit Study (FSEC)
  - 56 homes, metered from 2012 to 2016
  - Central Florida, biased sample
- Pecan Street Dataport (Pecan Street)
  - 998 homes, metered between 2011 to 2014
  - Texas (97%), biased sample
- American Time Use Survey (ATUS)
  - ~55,000 respondents from 2013–2017 (one day of activities per respondent)
  - National, representative sample
Comparing ATUS to end-use datasets