End-Use Savings Shapes
Public Data Set Release: Commercial 2023 Release 2

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NREL Webinar

October 5, 2023
Logistics

• We are recording the webinar.

• Because of the large number of participants, everyone is muted.

• Please use the Q&A box to send us questions at any time during the presentation.

• The webinar slides and webinar recording will be available in ~1 week. The data set is available now.
Acknowledgments

This work is the culmination of several years of research efforts.

We would like to thank the following for helping make this possible:

• ComStock™ and ResStock™ teams
• OpenStudio® and EnergyPlus® teams
• Lawrence Berkeley National Laboratory
• Argonne National Laboratory
• Pacific Northwest National Laboratory
1. End-Use Savings Shapes: Background
2. Our Approach to Stock Modeling with ComStock
3. End-Use Savings Shapes: 2023 Release 2
4. Accessing the Data Set
5. Next Steps
6. Q&A
Project Background
A lack of credible and relevant information results in confusion and inaction by cities, states, utilities, and other major stakeholders.

Will electrification of buildings...
• Reduce carbon emissions in my city?
• Be feasible in my building stock?
• Overload the grid?
• The **End-Use Load Profiles** (EULP) project:
  – Created a public data set for calibrated energy models of the U.S. commercial and residential building stock using ComStock and ResStock.

• The **End-Use Savings Shapes** (EUSS) follow-on project:
  – Adds the impact of several energy efficiency and electrification “what-if” scenarios (“measures”) to the baseline stock models.
  – [Residential EUSS Release 1](#) was presented September 2022.
  – [Commercial EUSS 2023 Release 1](#) was presented March 2023.
  – This presentation is for **Commercial EUSS 2023 Release 2**.
End-Use Load Profiles (EULP)

Describe how and when energy is used in buildings **today**.

*Public database of 350,000 individual building models and their energy end-use load profiles.*

End-Use Savings Shapes (EUSS)

Describe how and when energy is used in **“what-if” scenarios**.

*Adds measure impact profiles for energy efficiency and electrification packages versus the ComStock baseline.*

**EUSS 2023 Commercial Release 2 Data Set** represents the building stock circa 2018 using 2018 actual meteorological year (AMY) weather.
**Alignment and Impact**

*We are putting information in the hands of decision makers.*
This effort supports DOE’s goals to increase building energy efficiency, accelerate building electrification, and to do so in ways that prioritize equity, affordability, and resilience.

<table>
<thead>
<tr>
<th><strong>What the Data Sets Provide</strong></th>
<th><strong>How the Information Is Used</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Building stock characterization</td>
<td>• Electrification planning</td>
</tr>
<tr>
<td>• How, where, and when buildings use energy</td>
<td>• Emissions analysis</td>
</tr>
<tr>
<td>• Potential impacts of energy efficiency</td>
<td>• Decarbonization decision-making</td>
</tr>
<tr>
<td>• Information on time-sensitive value of energy resources</td>
<td>• Utility-integrated resource plans and load forecasts</td>
</tr>
<tr>
<td>• Potential impacts of building electrification.</td>
<td>• Policy and rate design.</td>
</tr>
</tbody>
</table>
Public Data Sets Are Intended To Serve a Broad Set of Use Cases and Audiences
Our Approach to Stock Modeling
The Making of the Data Sets:

- Describe the U.S. building stock quantitatively using best-available public data
- Sample the description
- Model the samples
- Apply “what-if” scenarios to models—energy efficiency, electrification, etc. [EUSS only]
- Publish description, samples, models, results, aggregations, visualizations, and documentation.

Building stock characteristics database

- Variation in building type; size; location; vintage; heating, ventilating, and air conditioning (HVAC) system; etc.
- Over 80 probability distributions of various attributes.

Physics-based computer modeling

- Representative set of 350K OpenStudio energy models.

High-performance computing

- Simulate models
- Process and publish data
- Apply scaling factors.
**What Does ComStock Model?**

### All Buildings in the Commercial Buildings Energy Consumption Survey (CBECS)

- **36%**

### Not in ComStock

- **9%**

### Building Types

- **Other (not modeled in ComStock)**
- **Retail strip mall**
- **Hospital**
- **Large office**
- **Full service restaurant**
- **Medium office**
- **Warehouse**
- **Primary school**
- **Retail standalone**
- **Large hotel**
- **Small office**
- **Secondary school**
- **Outpatient**
- **Quick service restaurant**
- **Small hotel**

*Includes other public order and safety, convenience store with gas station, other classroom education, vacant, fire station/police station, courthouse/probation office, vehicle dealership/showroom, other lodging, preschool/daycare, repair shop, post office/postal center, other food service, other food sales.*
ComStock Baseline Updates Since Release 1

**Continuous Improvements:**
- Updated HVAC system and fuel type distributions
- Established technology baseline for commercial cooking equipment
- Implemented baseline economizer fault prevalence
- Enhanced infiltration methodology
- Updated to OpenStudio 3.4.0 to 3.6.1.

**Future:**
- Improve gas calibration (ComStock is low relative to other data sources)
- And more...

**Graphs:**
- Release 1 Baseline
- Release 2 Baseline

**Legend:**
- Heat Rejection, Electricity
- Heat Recovery, Electricity
- Pumps, Electricity
- Refrigeration, Electricity
- Exterior Lighting, Electricity
- Water Systems, Other Fuel
- Water Systems, District Heating
- Water Systems, Natural Gas
- Water Systems, Electricity
- Heating, Other Fuel
- Heating, District Heating
- Heating, Natural Gas
- Heating, Electricity
- Interior Lighting, Electricity
- Cooling, District Cooling
- Cooling, Electricity
- Fans, Electricity
- Interior Equipment, Natural Gas
- Interior Equipment, Electricity
ComStock documentation is now public.

This document serves as a guide and resource to the methodology and assumptions behind ComStock.

Links

ComStock Documentation
Introduction to ComStock slides
# Greenhouse Gas Emissions

## Electricity
- Three grid electricity scenarios compared today; more included in published data set.
- This work does not imply a preference for any grid emission scenario.

<table>
<thead>
<tr>
<th>Electricity Grid Scenario</th>
<th>Start Year</th>
<th>Levelization Period (3% discount rate)</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRMER High RE Cost*</td>
<td>2022</td>
<td>15 years</td>
<td>NREL Cambium [1]</td>
</tr>
<tr>
<td>LRMER Low RE Cost</td>
<td>2022</td>
<td>15 years</td>
<td>NREL Cambium [1]</td>
</tr>
<tr>
<td>eGRID*</td>
<td>2021</td>
<td>N/A</td>
<td>EPA eGRID [2]</td>
</tr>
</tbody>
</table>

## On-Site Combustion Fuels
- Values from Table 7.1.2(1) of draft ANSI/RESNET/ICCC 301 [3]

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Emissions (lb/mmbtu, kg/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>147.3 lb/mmbtu (228.0 kg/MWh)</td>
</tr>
<tr>
<td>Propane</td>
<td>177.8 lb/mmbtu (182.3 kg/MWh)</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>195.9 lb/mmbtu (303.2 kg/MWh)</td>
</tr>
</tbody>
</table>

* LRMER = Long Run Marginal Emissions Rate; RE = renewable energy; eGRID = Emissions & Generation Resource Integrated Database

Greenhouse gas emissions in data set represent equivalent CO₂ emissions.
Please Note

• The ComStock model is **continuously updated** with new information, methods, and improved quality assurance/quality control procedures. Data sets are released in 6-month increments.

• Measures are **not intended to be comprehensive** of a given technology. As additional data becomes available, measure results may be updated.

• The measure result summaries in this presentation are intended to be **high-level observations** to introduce the data set. For more detailed conclusions, please watch for updates on the **publications section** of our website or explore the data set.
End-Use Savings Shapes: Commercial 2023 Release 2

Technology modeling, results observations, and discussion
EUSS Release 2: What is the new data set?

- **Updated ComStock Baseline**
  - Improvements since Release 1

- **EUSS Release 1 Measures**
  - Nine existing measures, re-simulated with updated ComStock baseline

- **EUSS Release 2 Measures**
  - Eight new measures/packages

Commercial EUSS Release 1 data set will remain available.
Comprehensive documentation is available for each measure.

Describes the modeling methodology, assumptions, limitations, relevant ComStock baseline features, and observations from results.

Access at: ComStock Documentation Site
<table>
<thead>
<tr>
<th>Measure Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump Rooftop Unit (HP-RTU) With Electric Resistance Backup</td>
<td>Replace gas and electric RTUs with HP-RTU.</td>
</tr>
<tr>
<td>Rooftop Ventilator + HP Split System</td>
<td>Replace gas and electric RTUs with rooftop ventilator + HP split system in small commercial buildings (&lt;20,000 sq ft).</td>
</tr>
<tr>
<td>Air to Water HP Boiler Retrofit With Electric Backup</td>
<td>Replace gas boilers with heat pump boilers. Electric resistance boiler used for backup heat source.</td>
</tr>
<tr>
<td>LED Lighting</td>
<td>Upgrade all lighting to LED.</td>
</tr>
<tr>
<td>Exterior Wall Insulation</td>
<td>Add exterior wall insulation panels.</td>
</tr>
<tr>
<td>Secondary Windows</td>
<td>Add secondary windows.</td>
</tr>
<tr>
<td>Window Replacement</td>
<td>Replace windows.</td>
</tr>
<tr>
<td>Window Film</td>
<td>Add window film to windows.</td>
</tr>
<tr>
<td>Roof Insulation</td>
<td>Add roof insulation.</td>
</tr>
</tbody>
</table>

Included in Release 2 data set; not discussed in this presentation.
# New EUSS 2023 Release 2 Measures

<table>
<thead>
<tr>
<th>Measure Name</th>
<th>Description</th>
<th>% of Stock Floor Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump Rooftop Unit (HP-RTU) With Original Fuel Backup</td>
<td>Replace gas and electric RTUs with HP-RTU. Backup heat source matches fuel type of the original system.</td>
<td>36%</td>
</tr>
<tr>
<td>Air to Water HP Boiler Retrofit With Gas Backup</td>
<td>Replace gas boilers with heat pump boilers. Gas boiler used for backup heat source.</td>
<td>33%</td>
</tr>
<tr>
<td>Variable Refrigerant Flow (VRF) With Dedicated Outdoor Air System (DOAS)</td>
<td>Replaces air handling units (AHUs) with a VRF DOAS.</td>
<td>53%</td>
</tr>
<tr>
<td>Demand Control Ventilation (DCV)</td>
<td>Adds DCV to AHUs that do not have them.</td>
<td>73%</td>
</tr>
<tr>
<td>Energy Recovery</td>
<td>Adds heat or energy recovery to AHUs that do not have them.</td>
<td>70%</td>
</tr>
<tr>
<td>Package 1: Envelope</td>
<td>Combines wall insulation, roof insulation, and new windows measures.</td>
<td>100%</td>
</tr>
<tr>
<td>Package 2: Lighting + HVAC</td>
<td>Combines LED lighting and HP-RTU or HP-boiler measures.</td>
<td>89%</td>
</tr>
<tr>
<td>Package 3: Envelope + Lighting + HVAC</td>
<td>Combines packages 1 and 2.</td>
<td>100%</td>
</tr>
</tbody>
</table>
Note on Heat Pump Modeling

• **Limited comprehensive heat pump performance maps exist**, which are required for detailed energy modeling. This limits our understanding of heat pump performance and operation in this work.

• **Heat pump modeling is sensitive** to performance assumptions due to the strong relationship between efficiency and capacity with outdoor air temperature. This impacts both annual energy consumption and peak demand.

• This work attempts to use the most informative data available and makes documented assumptions about heat pump operation and performance. These will notably impact results. Please consider these assumptions.

• The assumptions used for the measures **represent one of multiple possible approaches**. They are intended to be reasonable but not necessarily optimal. Assumptions can be modified as our understanding of the technologies improves.
**Stock Energy Savings**

Represents energy-weighted savings across the stock, not just applicable buildings.

*Does not represent the average savings that a building would experience for a measure.*

*For individual building savings, use the raw data to perform your analysis on specific building samples.*

**Site Energy Savings**

Represents energy savings for resources used on site.

*Does not necessarily translate proportionally to savings for source energy, operational cost, or avoided greenhouse gas emissions. These factors should also be considered where appropriate, especially for electrification measures that change the heating fuel type of buildings.*
Heat Pump Rooftop Unit (HP-RTU) With Original Fuel Backup Heating
Heat Pump Rooftop Units (HP-RTUs) With Original Fuel Backup

Measure Concept
- Replace gas and electric RTUs with HP-RTUs
- Variable speed, high efficiency

HP-RTU Performance
- **Sizing:** Compressor sized to design cooling load; backup heat sized for remainder
- **Backup Heat:** Original heating fuel type
- **Compressor Lockout:** 0°F
- **Defrost:** Reverse cycle
- **Performance Data Source:** Mix of lab testing and manufacturer performance data

Applicability
- Buildings w/ gas or electric resistance RTUs
- ~36% of stock floor area, varies regionally
  - 28% gas RTU; 8% electric RTU

Backup Heat Scheme

Existing system
- Gas RTU
- Electric RTU

New system
- HP-RTU with **gas** backup
- HP-RTU with **electric** backup
For original fuel (OF) backup scenario:

- 27% stock heating gas savings (226 TBtu)
- −22% stock heating electricity savings (−43 TBtu)
- 11% stock cooling electricity savings (81 TBtu)
- 19% stock fan electricity savings (112 TBtu)

- Cooling and fan savings could also be attributed to high-performance non-HP-RTUs.
- Savings are associated with premium units.
- Electric backup scenario shows higher electricity and lower natural gas consumption compared to original fuel scenario.

**Electric Backup Scenario:** Less gas heat, more electric heat
Heat Pump Rooftop Units (HP-RTUs) With Original Fuel Backup

- Emissions avoided across all presented grid scenarios.
- Electricity emissions avoided despite electrifying furnaces from cooling and fan end uses; also from replacing electric resistance RTUs with HP-RTUs.
HP-RTU: Electric vs. Original Fuel Backup Load Profile for Winter Peak

Sample Location: Boston, MA (Suffolk County)
Time step: 15 minutes

Scope: Total commercial stock
Fuel: Electricity

Note that load profiles are heavily influenced by assumptions for heat pump sizing routine, lockout temperature, and performance curves.
Air to Water Heat Pump Boiler With Gas Backup Heating
Heat Pump Boiler With Gas Backup

**Measure Concept**
- Replace natural gas boilers for HVAC application with air source heat pump boilers
- Natural gas boiler backup
- 140°F supply temperature

**Applicability**
- Applicable to 33% of stock floor area
- Doesn’t apply to natural gas boilers serving condenser water loops

**Heat Pump Boiler Performance**
- **Sizing:** Meet loads down to 17°F
- **Compressor Lockout:** −5°F
- **Defrost:** Integrated into performance curves
- **Performance Data Source:** Manufacturer data

**Stock Boiler Prevalence**
For Gas Backup Scenario:
• **61.9%** stock **heating gas** savings (512 TBtu)
• **83.2%** stock **heating electricity** increase (164 TBtu)
• Large reduction in stock natural gas heating and increase in electric heating from electrifying boilers
• Gas backup shows slightly higher gas consumption and lower electricity consumption.

**Stock Site Energy by Fuel and End Use**

Electric Backup Scenario: Less gas heat, more electric heat
Heat Pump Boiler With Gas Backup

- Increased electricity emissions from electrifying gas boilers
- Decreased natural gas emissions from electrifying natural gas boilers
- Net emissions avoided for all comprehensive scenarios shown despite increased electricity emissions.
Variable Refrigerant Flow (VRF) With Dedicated Outdoor Air System (DOAS)
VRF With DOAS

Measure Concept
- Replace RTUs/variable air volumes (VAVs) with VRF with DOAS
- Cold climate VRF technology (rated to −22°F)
- Outdoor ventilation air provided by heat/energy recovery DOAS with electric heat and DX cooling
- Decoupled ventilation

VRF Performance
- Sizing: Based on design cooling load
- Supplemental heat: Electric resistance
- Compressor lockout: −22°F
- Performance Data Source: Manufacturer data

Applicability
- Buildings with RTUs/VAVs (with limitations)
  - Limitations = building/space type, size, indoor unit count, or original fuel type (i.e., district).
  - Applicable to 53% of stock floor area

VRF DOAS Applicability (%)
VRF With DOAS

- VRF design heating performance
- $\text{COP}_{\text{comp&fan,design}}$
  - Only accounts for compressor and outdoor unit fan power
  - Reflects design conditions (and not operating conditions)

**Performance maps from manufacturer data tables.**
VRF With DOAS

- **53%** stock heating **natural gas** savings (438 TBtu)
- **−24%** stock heating **electricity** savings (−48 TBtu)
- **18%** stock cooling **electricity** savings (128 TBtu)
- **30%** stock **fan electricity** savings (178 TBtu).
- Heat/energy recovery reduces heating and cooling loads
- High-performance VRF system saves cooling energy
- Decoupled ventilation and high-efficiency motors saves fan energy.
VRF With DOAS

- Net emissions avoided across all comprehensive grid scenarios and fuel types presented

- Electricity savings from fans, cooling, and heat/energy recovery savings outweigh heating electricity increase, resulting in net electricity emissions avoided
# VRF With DOAS

## Building Annual Average Heating COPs

<table>
<thead>
<tr>
<th>Region</th>
<th>COP_comp&amp;fan,design</th>
<th>COP_system,operating</th>
<th>Fraction of backup heating against heat pump heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subarctic</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Very Cold</td>
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<td></td>
<td></td>
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<tr>
<td>Cold</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed-Humid</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mixed-Dry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot-Humid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot-Dry</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-Varies based on system capacity

-Alternative sizing routines can reduce backup heating

Includes backup heating electricity and other operational factors
VRF With DOAS: Summer vs. Winter Peak

**Location:** Boston, MA (Suffolk County)  
**Time step:** 15 minutes

**Scope:** Total commercial stock  
**Fuel:** Electricity

Note that load profiles are heavily influenced by assumptions for heat pump sizing routine, lockout temperature, and performance curves.
Demand Control Ventilation (DCV)
Demand Control Ventilation

Measure Concept

• DCV reduces outdoor ventilation air during periods of detected low occupancy.
• Measure adds DCV to air handling units (AHUs) that do not already contain it.

Applicability

• Applicable to 73% of stock floor area.
• Applies to air handling units.
• Not applicable to:
  • Hotels and restaurants
  • Space types where ventilation is not occupancy-driven (e.g., operating rooms)
  • Models with DOAS, or non-AHU system types.
Demand Control Ventilation

- **8.8%** stock heating gas savings (73 TBTu)
- **9.3%** stock heating electricity savings (18 TBTu)
- **2.1%** stock cooling electricity savings (15 TBTu)
- Generally decreases heating and cooling loads
- Some increased cooling loads in models without economizers

Mean Site Energy Percent Savings by Climate Zone

- Highest site % energy savings in colder climates

Stock Site Energy by Fuel and End Use

Mean Site Energy Percent Savings by Climate Zone

- Highest site % energy savings in colder climates

Mean Site Energy Percent Savings by Climate Zone

- Highest site % energy savings in colder climates

Mean Site Energy Percent Savings by Climate Zone

- Highest site % energy savings in colder climates
Demand Control Ventilation

Emissions avoided across presented grid scenarios and on-site combustion fuels.
Exhaust Air Heat/Energy Recovery
Exhaust Air Heat/Energy Recovery (H/ER)

Measure Concept
- Adds E/HR to existing air handlers
- Recovers energy from exhaust air stream to pretreat ventilation air
- 90% return air assumed
- Fan static pressure increased

Applicability
- Added to air handlers without existing H/ER
- Not added to food service space types
- Applicable to ~70% of stock floor area

Technology Specifications

Humid Climates
- Membrane fixed-plate energy recovery
- Sensible and latent recovery
- Includes bypass

All Other Climates
- Aluminum fixed-plate heat recovery
- Sensible-only recovery
- Includes bypass
Exhaust Air Heat/Energy Recovery

- **23%** stock **heating** savings (268 TBtu)
- **10%** stock **cooling** savings (82 TBtu)
- **−8%** stock combined **fan** and **heat recovery** penalty (−46 TBtu)
- Heating and cooling savings are from reduced ventilation loads.
- Heat recovery end use represents added fan energy for E/HR system.
Exhaust Air Heat/Energy Recovery

- Emissions avoided across presented grid scenarios.
- Reduced ventilation loads yield avoided emissions.

Savings from cooling and electric heat

Savings from on-site combustion fuel heat

Annual GHG Emissions (MMT CO2e)
Package 1: Envelope Upgrades
**Package 1: Envelope Upgrades**

**Package Concept:**
Combination of three measures from 2023 Release 1:
- Window Replacement
- Exterior Wall Insulation
- Roof Insulation

**Applicability**
- Package 1 is applicable to **100%** of stock for at least one measure.
- Window Replacement: All non-triple-pane windows (>99%)
- Exterior Wall Insulation: All buildings not already meeting R-value targets (98%)
- Roof Insulation: All buildings not already meeting R-value targets (>99%)

**Applicability: % Floor Area per Measure Combination**

- The full package is applicable to ~98% of the stock area
- Partially applicable to ~2% of the stock area
Package 1: Envelope Upgrades

- 23% stock site heating electricity savings (146 TBtu)
- 18% stock site heating gas savings (44 TBtu)
- 12% stock site electricity cooling energy savings (85 TBtu)
- 4% stock site electricity fan energy (21 TBtu)
- Reduced heating and cooling load from envelope measures.

Average Site % Savings* by Measure Applicability

*Note that site energy savings do not necessarily translate proportionally to savings for source energy, operational cost, or avoided greenhouse gas emissions.
Package 1: Envelope Upgrades

Emissions avoided across all presented grid scenarios and on-site combustion fuels due to HVAC load reductions from improved thermal properties of windows, walls, and roofs.
Package 2: Lighting Upgrades and HP-Boiler or HP-RTU
Package 2: Lighting Upgrades and HP-Boiler or HP-RTU

**Package Concept:**
Combination of three measures from 2023 Release 1: LED Lighting, HP-RTU, and HP-Boiler

**Applicability**
- Package 2 is applicable to **89%** of stock for at least one measure.
- **LED Lighting:** Buildings without LED interior lighting (65% stock applicability)
- **HP-RTU, Electric Backup:** Buildings with gas or electric resistance RTUs (36% stock applicability)
- **HP-Boiler, Electric Backup:** Buildings with natural gas boiler for space heating (33% stock applicability)

**Applicability: % Floor Area per Measure Combination**

- Not Applicable
- HP-Boiler Only
- HP-RTU Only
- LED Only
- HP-Boiler+LED
- HP-RTU+LED

HP-RTU and HP-Boiler measures are mutually exclusive.
Package 2: Lighting Upgrades and HP-Boiler or HP-RTU

- 94% stock heating gas savings (779 TBtu)
- −132% stock heating electricity savings (−261 TBtu)
- 37% stock interior lighting electricity savings (164.9 TBtu)
- 20% stock fan electricity savings (119 TBtu)
- 14% stock cooling electricity savings (104 TBtu)

Average Site % Savings* by Measure Applicability

*Note that site energy savings do not necessarily translate proportionally to savings for source energy, operational cost, or avoided greenhouse gas emissions.
Package 2: Lighting Upgrades and HP-Boiler or HP-RTU

- Net emissions avoided despite increased electricity emissions.
- Increased electricity emissions from electrifying gas boilers.
- Electricity emissions avoided are from cooling and fan end uses; also from replacing electric resistance RTUs with HP-RTUs and LED lighting installation.
Package 3: Combine Package 1 and 2
Package 3: Combine Package 1 and 2

Package Concept:
Combination of six measures from 2023 Release 1:
- Window Replacement
- Exterior Wall Insulation
- Roof Insulation
- LED Lighting
- HP-RTU
- HP-Boiler

Applicability
- Package 3 is applicable to 100% of stock for at least one measure.

Applicability: % Floor Area per Measure Combination

E.g., “22.6% of stock floor area is applicable to the HP-RTU, LED, window, wall, and roof measures.”
Package 3: Combine Package 1 and 2

- **96.3%** stock heating gas savings (795.6 TBtu)
- **−88.4%** stock heating electricity savings (−174.7 TBtu)
- **36.5%** stock interior lighting electricity savings (164.9 TBtu)
- **25.2%** stock fan electricity savings (148.5 TBtu)
- **24.9%** stock cooling electricity savings (180.4 TBtu)

**Average Site % Savings* by Measure Applicability**

*Note that site energy savings do not necessarily translate proportionally to savings for source energy, operational cost, or avoided greenhouse gas emissions.
Package 3: Combine Package 1 and 2

- Emissions avoided across all grid scenarios and combustion fuels presented.

- Electricity emission reductions include interior lighting and fan and cooling end uses, as well as the increase in electricity from electrifying gas furnace and boiler systems.

<table>
<thead>
<tr>
<th>Electricity Grid Scenarios: Choose 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual GHG Emissions (MMT CO2e)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Electricity: eGRID 2021</td>
</tr>
<tr>
<td>Electricity: LRMER High RE Cost 15</td>
</tr>
<tr>
<td>Electricity: LRMER Low RE Cost 15</td>
</tr>
<tr>
<td>Natural Gas</td>
</tr>
<tr>
<td>Fuel Oil</td>
</tr>
<tr>
<td>Propane</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>Package 3</td>
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<tr>
<td></td>
</tr>
<tr>
<td>336.6</td>
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<td>304.1</td>
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<td>231.0</td>
</tr>
<tr>
<td>-10.0</td>
</tr>
<tr>
<td>-53.2</td>
</tr>
<tr>
<td>-1.3 (27.1%)</td>
</tr>
<tr>
<td>-1.2 (60%)</td>
</tr>
<tr>
<td>99 (34%)</td>
</tr>
<tr>
<td>83.6</td>
</tr>
<tr>
<td>30.4</td>
</tr>
<tr>
<td>4.8</td>
</tr>
<tr>
<td>3.5</td>
</tr>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>0.8</td>
</tr>
</tbody>
</table>

Large decrease in natural gas emissions due to electrification of RTUs and boiler systems.
Package 3: Summer vs. Winter Peak

**Location:** Boston, MA (Suffolk County)

**Time step:** 15 minutes

**Scope:** Total commercial stock

**Fuel:** Electricity

Note that load profiles are **heavily influenced** by assumptions for heat pump sizing routine, lockout temperature, and performance curves.
Accessing the Data Set
# Accessing the Data

<table>
<thead>
<tr>
<th>Metadata</th>
<th>Individual Load Profiles</th>
<th>Aggregate Load Profiles</th>
<th>Data Viewer</th>
<th>Full Database</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data Format</strong></td>
<td>.csv and .parquet files</td>
<td>.csv and .parquet files</td>
<td>.csv and .parquet files</td>
<td>Dashboard with .csv exports</td>
</tr>
<tr>
<td><strong>Time Scale</strong></td>
<td>Annual</td>
<td>15-minute intervals</td>
<td>15-minute intervals</td>
<td>Customizable</td>
</tr>
<tr>
<td><strong>Grouped by</strong></td>
<td>Individual building ID</td>
<td>Individual building ID</td>
<td>Geographies: climate zone, ISO/RTO region, state</td>
<td>Customizable</td>
</tr>
<tr>
<td><strong>Fields by</strong></td>
<td>Building input characteristics</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>Energy consumption</td>
<td>Energy consumption</td>
<td>Energy consumption</td>
<td>Energy consumption</td>
</tr>
<tr>
<td>Energy savings</td>
<td>Energy savings</td>
<td>Energy savings</td>
<td>Energy savings</td>
<td>Energy savings</td>
</tr>
<tr>
<td>Emissions</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Calculated fields</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Accessed via</strong></td>
<td>OEDI</td>
<td>OEDI</td>
<td>OEDI</td>
<td>ComStock.nrel.gov</td>
</tr>
</tbody>
</table>

OEDI = Open Energy Data Initiative
## Field Naming Convention

<table>
<thead>
<tr>
<th>Prefix or Name</th>
<th>Count</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>64</td>
<td>Inputs of building characteristics and geospatial codes</td>
<td>in.window_type</td>
</tr>
<tr>
<td>out.</td>
<td>352</td>
<td>Simulation outputs</td>
<td>out.electricity.refrigeration.energy_consumption</td>
</tr>
<tr>
<td>calc.</td>
<td>159</td>
<td>Calculated values such as totals and % savings</td>
<td>calc.weighted.electricity.cooling.energy_consumption..tbtu</td>
</tr>
<tr>
<td>weight</td>
<td>1</td>
<td>Value for scaling single model results to national scale</td>
<td>4.8960474</td>
</tr>
<tr>
<td>bldg_id</td>
<td>1</td>
<td>Unique ID of the building model</td>
<td>3324</td>
</tr>
<tr>
<td>upgrade</td>
<td>1</td>
<td>Unique ID number for upgrade</td>
<td>5</td>
</tr>
<tr>
<td>model_count</td>
<td>1</td>
<td>Number of models aggregated (time-series files)</td>
<td>5334</td>
</tr>
<tr>
<td>applicability</td>
<td>12</td>
<td>Upgrade names</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

**Second Level**

| out.[fuel type] | 6     | Fuel type: electricity, natural gas, etc. | out.natural_gas.water_systems.energy_consumption |
| out.emissions   | 20    | Emission values | out.emissions.electricity.egrid..co2e_kg |
| out.params      | 197   | Model parameters and summary statistics | out.params.dx_cooling_average_cop..cop |
| out.qoi         | 15    | Quantities of interest such as peak demand | out.qoi.maximum_daily_use_summer_kw..kw |
| out.site_energy | 4     | Total of all end uses, site energy | out.site_energy.total.energy_consumption |

**Third Level**

| out.[fuel type].[end use] | 136   | End uses: heating, cooling, lighting, water systems, etc. | out.electricity.heating.energy_consumption |

**Units**

| ..foo | - | ".." denotes the start of the unit name | ..kWh_per_ft2 |

Data dictionary available at [OEDI](https://www.energy.gov/oedi)
Open Energy Data Initiative (OEDI) Folder Structure

Access at: OEDI

- **Metadata** files with annual usage, building characteristics, equipment size and performance, etc.
- **Time-series** data by fuel type and end use; various pre-aggregations
- **CSV weather files**
- **Dictionary of available data fields with definitions**
- **Dictionary of upgrade IDs and names**
### Example Metadata File

<table>
<thead>
<tr>
<th>Building ID</th>
<th>County</th>
<th>Building Type</th>
<th>Building Area (unweighted)</th>
<th>Annual Electricity Peak kW (unweighted)</th>
<th>Annual Natural Gas Consumption (unweighted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>Outpatient</td>
<td>Double - No LowE</td>
<td>37500</td>
<td>8.75</td>
<td>288.54417</td>
</tr>
<tr>
<td>324</td>
<td>Hospital</td>
<td>Single - No LowE</td>
<td>35000</td>
<td>8.5</td>
<td>2537.623</td>
</tr>
<tr>
<td>457</td>
<td>Hospital</td>
<td>Double - LowE - CNA</td>
<td>15000</td>
<td>8.75</td>
<td>1510.74817</td>
</tr>
<tr>
<td>496</td>
<td>Hospital</td>
<td>LowE - CNA</td>
<td>15000</td>
<td>8.75</td>
<td>96659.167</td>
</tr>
<tr>
<td>758</td>
<td>Hospital</td>
<td>LowE - CNA</td>
<td>37500</td>
<td>8.25</td>
<td>6125.3224</td>
</tr>
<tr>
<td>769</td>
<td>Hospital</td>
<td>LowE - CNA</td>
<td>37500</td>
<td>8.75</td>
<td>292.54247</td>
</tr>
<tr>
<td>1122</td>
<td>Hospital</td>
<td>Single - No LowE</td>
<td>15000</td>
<td>9.7</td>
<td>1264.01005</td>
</tr>
<tr>
<td>1934</td>
<td>Hospital</td>
<td>LowE - CNA</td>
<td>100000</td>
<td>7.5</td>
<td>6813.14901</td>
</tr>
<tr>
<td>2357</td>
<td>Hospital</td>
<td>Single - No LowE</td>
<td>75000</td>
<td>9.5</td>
<td>374.63398</td>
</tr>
<tr>
<td>3324</td>
<td>Hospital</td>
<td>Single - No LowE</td>
<td>35000</td>
<td>7.5</td>
<td>252.96659</td>
</tr>
<tr>
<td>3640</td>
<td>Hospital</td>
<td>Double - LowE - CNA</td>
<td>35000</td>
<td>8.25</td>
<td>2544.36643</td>
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<tr>
<td>3801</td>
<td>Hospital</td>
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<td>8.75</td>
<td>489.49215</td>
</tr>
<tr>
<td>5764</td>
<td>Hospital</td>
<td>Single - No LowE</td>
<td>75000</td>
<td>8</td>
<td>329.3614</td>
</tr>
<tr>
<td>6058</td>
<td>Hospital</td>
<td>Double - No LowE</td>
<td>35000</td>
<td>8.25</td>
<td>294.87621</td>
</tr>
<tr>
<td>6194</td>
<td>Hospital</td>
<td>Single - No LowE</td>
<td>75000</td>
<td>8.25</td>
<td>600.52446</td>
</tr>
<tr>
<td>6647</td>
<td>Hospital</td>
<td>LowE - CNA</td>
<td>17500</td>
<td>6.5</td>
<td>99.54277</td>
</tr>
<tr>
<td>6752</td>
<td>Hospital</td>
<td>LowE - CNA</td>
<td>37500</td>
<td>7</td>
<td>209.44043</td>
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<td>7153</td>
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<td>Double - No LowE</td>
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<td>7.75</td>
<td>310.28772</td>
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<tr>
<td>7500</td>
<td>Hospital</td>
<td>Single - No LowE</td>
<td>37500</td>
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<tr>
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<td>Hospital</td>
<td>Single - No LowE</td>
<td>17500</td>
<td>7</td>
<td>283.39981</td>
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<tr>
<td>7535</td>
<td>Hospital</td>
<td>Double - No LowE</td>
<td>17500</td>
<td>9</td>
<td>122.88107</td>
</tr>
<tr>
<td>7662</td>
<td>Hospital</td>
<td>Single - No LowE</td>
<td>75000</td>
<td>10.25</td>
<td>592.7709</td>
</tr>
</tbody>
</table>

---

**Notes:**
- Building ID refers to a unique identifier for each building.
- County indicates the geographical location of the building.
- Building Type describes the style or category of the building.
- Building Area (unweighted) is the total square footage of the building.
- Annual Electricity Peak kW (unweighted) indicates the peak electrical usage of the building in kilowatts.
- Annual Natural Gas Consumption (unweighted) represents the total amount of natural gas consumed by the building.
## Example Time-Series File

<table>
<thead>
<tr>
<th>Building ID</th>
<th>Timestamp</th>
<th>Exterior Lighting Consumption (kWh)</th>
<th>Interior Lighting Consumption (kWh)</th>
<th>Gas Heating Consumption (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5324</td>
<td>1/1/2018:01:15</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:01:20</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:01:25</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:01:30</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:01:35</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:01:40</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:01:45</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:00</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:05</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:10</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:15</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:20</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:25</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:30</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:35</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:40</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5324</td>
<td>1/1/2018:02:45</td>
<td>3.499</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

NREL | 67
ComStock Data Viewer

- Visualize data
- Export to csv

Access at: ComStock.nrel.gov
Summary of Data Set Links

Access at: ComStock.nrel.gov and ComStock Documentation Site
A Few Reminders

• All time stamps are time-period-ending and are in EST.

• Annual metadata files provide weighting factors for national scaling. Columns with “weighted” in the title already have this factor applied.

• Check your sample sizes on custom aggregations—too few samples can increase uncertainty.

• All “out.” columns without units denoted are in kWh.

(This is driven by current limitations with the data viewer.)
Next Steps
## Proposed List for Commercial EUSS 2024 Release 1; Expected March 2024

<table>
<thead>
<tr>
<th>Measure Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP-RTU, Standard Performance</td>
<td>Replaces gas and electric resistance RTUs with standard efficiency HP-RTUs.</td>
</tr>
<tr>
<td>HP-RTU With Heat/Energy Recovery</td>
<td>Adds heat/energy recovery to HP-RTUs.</td>
</tr>
<tr>
<td>Single-Zone VAV RTUs</td>
<td>Retrofits existing constant air volume RTUs to single-zone variable air volume RTUs.</td>
</tr>
<tr>
<td>Economizers</td>
<td>Adds economizers to air handling units (non-DOAS) that do not already have them.</td>
</tr>
<tr>
<td>Electric Cooking Equipment</td>
<td>Replaces major gas cooking equipment (ranges, ovens, etc.) with electric equipment.</td>
</tr>
<tr>
<td>VRF With 25% Upsizing Allowance</td>
<td>Allows VRF to size up to 25% beyond cooling design for heating as needed.</td>
</tr>
<tr>
<td>No Outdoor Air During Unoccupied Times</td>
<td>Closes outdoor air dampers during unoccupied periods for buildings not already doing so.</td>
</tr>
<tr>
<td>Package 2: Max Tech HVAC</td>
<td>Applies HP-RTU or HP-Boiler along with economizers, heat/energy recovery, and demand control ventilation.</td>
</tr>
<tr>
<td>Others</td>
<td>Geothermal heat pumps; demand flexibility.</td>
</tr>
</tbody>
</table>

Email us with measure/package requests for future releases!
Citation and Attribution Guidance

