Title

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Energy Technologies Area
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Disclaimer

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Abstract

Starting in 2026 Washington State building performance standards will come into effect that require commercial buildings larger than 50,000 sf to meet site energy use intensity targets. To support a state incentive program designed to encourage building owners to start complying early, we characterized the building stock energy use of 11 building types, analyzed 43 energy upgrade measures, and developed seven packages of energy upgrade measures using the ComStock energy analysis tool. Each energy upgrade package included from 4 to 17 energy measures consisting of lighting, HVAC, and envelope upgrades. Package savings were calculated for four priority building types using a sample of 35,000 buildings characterized by four building area bins, three climate zones, and two county types (urban and rural). Of the 28 package and building type combinations analyzed, 17 (61%) met or exceeded program energy savings targets and two packages met targets for all four building types.

Introduction

In 2019 Washington State (WA state) passed a building performance standard (BPS) (Washington State Legislature n.d.) that requires existing commercial buildings larger than 50,000 sf to meet site energy use intensity (EUI) targets based on ANSI/ASHRAE/IES Standard 100-2018 (ASHRAE 2018). The targets vary by building type and climate zone, and have adjustments for occupancy hours. The policy comes into effect in 2026 with buildings larger than 220,000 sf and smaller buildings phased in over the following two years.

WA state is developing an incentive program to encourage building owners to start complying with the BPS earlier. This will also provide valuable experience prior to the mandatory policy coming into effect. The incentive is structured as follows: buildings are eligible for an incentive if their current EUI is at least 15 kBtu/sf higher than the target for their building. The building receives an incentive payment of $0.85/sf for meeting or exceeding the target.

WA state is interested in developing a set of resources to support building owners. In particular, they are interested in resources for underserved sectors such as smaller buildings and rural areas and are interested in systems approaches to achieve deeper savings. The state was interested in receiving DOE support in this analysis, building on the “Beyond Widgets” project which developed systems packages for utility incentive programs (Regnier et al. 2020). The Northwest Energy Efficiency Alliance (NEEA) is supporting the state in their BPS efforts and was also engaged in informing this effort.

The goal of the analysis described in this report was to address three questions:

- What are the energy use characteristics of the WA building stock and which sectors should be prioritized?
- How do energy efficiency retrofit measure savings vary by building type and location?
- What packages of measures (systems solutions) would yield the savings required to meet the BPS targets?

We used the ComStock (Commercial building sector Stock model) tool (NREL n.d.) developed by the National Renewable Energy Laboratory (NREL) to conduct the analyses. ComStock provides detailed hourly energy simulation results for a stock of buildings. It should be noted that this was an iterative process and not strictly linear. Each of the following steps involved review and discussions with WA and NEEA.

1. We analyzed the overall stock energy use, broken out by building type, size, and location. This allowed us to prioritize sectors to focus on.
2. We defined a list of measures for consideration.
3. We reviewed the simulated measure savings and defined packages of measures based on level of savings and implementation considerations.
4. We simulated the energy savings for the packages of measures. We assessed the impact of these savings relative to the target EUI levels.

Modeling approach

ComStock

ComStock is a highly granular, bottom-up model that uses multiple data sources, statistical sampling methods, and EnergyPlus building energy simulations to estimate the annual energy consumption of commercial building stock across the United States. Lighting power densities in ComStock are currently code based; each building is sampled to have a year of construction, and each major building system (e.g. HVAC, lighting, walls) is assigned an effective turnover rate. The year of construction coupled with the turnover rate of the building system type produce an effective ASHRAE Standard 90.1 (ASHRAE 2019) code year, per state (since different states have different code requirements), that the building system will follow. Note that the version of ComStock used in this analysis predates major calibration implementations that were conducted subsequently. The northwest region Commercial Building Stock Assessment (CBSA) (NEEA n.d.) was not directly used for ComStock calibration, primarily due to its regional scope.

The ComStock data set results for this analysis are characterized by four principal parameters. Two are related to building characteristics (14 building types and four building area bins) and two are related to building location (three climate zones, and two county types - urban and rural). This results in 336 possible combinations, but not all combinations of these characteristics exist or are realistic and the final set simulated 73 unique building characteristics and location combinations for the analysis.

Building types

ComStock models 14 commercial building types based on the DOE prototype building models (DOE n.d.) (Mid-rise and High-rise Apartment are not simulated). Of these, three (Small Office, Quick Service Restaurant, and Full Service Restaurant) were not appropriate for this analysis because they only represent building types with less than 50,000 sf and are thus not part of the BPS. Table 1 summarizes the 11 modeled building types, along with the assumed EPA Portfolio

Manager occupancy type (ENERGY STAR n.d.), the mean stock EUI, and program EUI target set by the BPS.

Building area bins

Each building type is broken into four possible floor area bins:
- Less than 50,000 sf
- 50,000 to 90,000 sf
- 90,000 to 220,000 sf
- Greater than 220,000 sf

Only the top three bins are used in this analysis as buildings less than 50,000 sf are not in the BPS. Not all bins are used for all building types as for example none of the retail prototypes are assumed to have more than 220,000 sf.

Climate zones and county types

WA state contains three International Energy Conservation Code (IECC) climate zones (IECC 2018) as shown in Figure 1. These climate zones are characterized by heating degree days base 65°F (HDD65): Zone 4C is Mixed Marine (3,600 to 5,400 HDD65), 5B is Cool Dry (5,400 to 7,200 HDD65), and 6B is Cold Dry (7,200 to 9,000 HDD65). In addition, ComStock classifies counties as urban or rural. Zones 4C and 5B contain both urban and rural counties, but zone 6B contains only rural counties. For purposes of the BPS policy zone 6B is included in the 5B climate zone. Table 1 presents the stock and target EUIs for different building types.

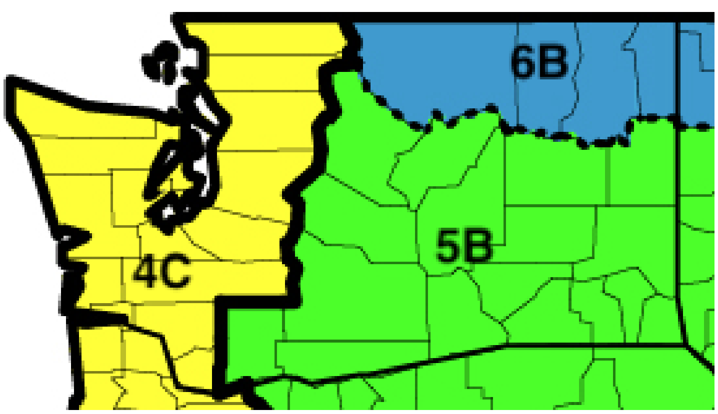

Figure 1: Washington State IECC Climate Zones

Table 1: Building Types, Stock EUIs, and Target EUIs

Comstock Type	Portfolio Manager Type			BPS Mean Stock EUI (kBtu/sf)		BPS Target EUI (kBtu/sf)	
	Type	Sub-type	Sub-type Detailed	4C	5B	4C	5B
Retail Standalone	Retail	Wholesale Club / Supercenter		80	88	68	75
Retail Strip Mall	Retail	Strip Mall		80	88	68	75
Primary School	Education	K-12 School	Middle school	57	59	49	50
Secondary School	Education	K-12 School	High school	57	58	48	49
Medium Office	Office	Other - Office		78	80	66	68
Large Office	Office	Other - Office		78	80	66	68
Small Hotel	Lodging / residential	Hotel	Hotel	87	90	74	77
Large Hotel	Lodging / residential	Hotel	Motel or Inn	80	84	68	72
Hospital	Healthcare	Hospital		226	226	196	196
Outpatient	Healthcare	Urgent Care / Clinic / Other Outpatient		106	113	90	96
Warehouse	Warehouse / storage	Non-Refrigerated Warehouse		42	52	36	44

Stock energy use

Figure 2 and Table 2 summarize the distribution of stock energy use from the ComStock simulations by building type, size, and location. Note that not all building types exist in all locations, with the fewest in the rural counties. More than 70% of the 45 TBtu of building energy use occurs in the urban counties of climate zone 4C, due to the large number of buildings in the Seattle area. Overall, primary schools use the most energy of all the building types, accounting for more than 20% of total building energy use, with large offices and hospitals using the second and third most. The sum of these top three building types makes up half of the total building energy use.

Table 2: Baseline Stock Energy Use (Site TBtu)

Climate Zone	4C						5B						6B		TOTAL
County Type	Rural			Urban			Rural			Urban			Rural		
Area Bin (1000s sf)	50 - 90	90 - 220	> 220	50 - 90	90 - 220	> 220	50 - 90	90 - 220	> 220	50 - 90	90 - 220	> 220	50 - 90	90 - 220	
Hospital		0.18		0.09	0.41	1.58	0.15	0.14	1.68			2.21			6.4
Large Hotel					0.63	0.97									1.6
Large Office				0.26	2.12	4.21				0.04	0.12				6.7
Medium Office				2.03			0.08			0.52					2.6
Outpatient	0.03			1.16	0.30					0.06					1.6
Primary School	0.28	0.31		4.01	1.94		0.51	0.94		0.55	0.53				9.1
Retail Standalone	0.13			1.68	0.24		0.11	0.07		0.33			0.02		2.6
Retail Stripmall	0.11			1.80	0.35		0.09			0.33	0.20				2.9
Secondary School	0.27	0.25		0.40	1.67	0.66	0.15	0.34	0.12	0.03	0.44		0.07	0.07	4.4
Small Hotel				0.96	0.82	0.61	0.16	0.20		0.23	0.10	0.36			3.4
Warehouse	0.06	0.03	0.02	1.17	1.26	0.20	0.10	0.10		0.20	0.05				3.2
TOTAL	1.7			31.5			4.9			6.3			0.1		44.6

Figure 2: ComStock modeled stock energy use by building type and location

A note on ComStock model calibration

We found a number of discrepancies between the Site EUIs generated by ComStock and the EUIs from ASHRAE Standard 100. ComStock median EUIs were significantly higher or lower than the Standard 100 targets for some building types. While NREL is continuously calibrating ComStock with empirical data as it becomes available, the versions of ComStock used over the course of this analysis were not able to fully reconcile these differences. For example, one of the changes was updated equipment power densities and equipment schedules based on metered end use data for plug loads. This caused a drop in the power densities in some building types, including offices. After reviewing comparisons to data sources such as the Commercial Building energy Consumption Survey (CBECS) (EIA n.d.) during calibration efforts, NREL has since reverted the power density values for offices back to their original higher values (while still keeping the new schedules derived from the metered data). They are also seeing that ComStock's office energy usage is generally low in these comparisons.

NREL has since implemented and tested other calibration model changes to increase energy usage in offices such as increasing the presence of data centers and removing nighttime setbacks in a portion of models for building parameters such as ventilation, fan operation, and thermostat setpoints/setbacks.

Given the above, we could not use the absolute EUIs from ComStock to compare to the Standard 100 EUIs. Instead, we used ComStock to calculate savings fractions for packages and then applied them to the EUIs from Standard 100.

Energy Efficiency Measures

ComStock has a predefined list of 72 efficiency upgrade measures in the existing ComStock V1 national run (referred to as the "Pre-run"), which had approximately 7,000 buildings in the sample for WA state. We reviewed and down-selected from this list, focusing on 37 measures that were commercially proven (not "bleeding edge") and relevant to WA state climate zones. Six additional measures that were not currently in ComStock were identified by LBNL and NEEA based on prior work demonstrating benefits and/or cost effectiveness, or were identified as strategic priority measures for the region. This small set of custom measures was simulated for just WA using ComStock for a larger sample of approximately 35,000 buildings (about 1 in 3 buildings in the state). This run is referred to as the "Custom run". Table 3 lists all 43 upgrade measures (Pre-run plus Custom) along with a short description. For more detail of how these measures are simulated, refer to the ComStock Public Datasets page[1].

[1] https://comstock.nrel.gov/page/datasets

Table 3: List of ComStock Upgrade Measures

Pre-run Measures	Description
Upgrade Roof Insulation	Upgrades all roof surfaces to an insulation level of R-30
Upgrade Wall Insulation	Upgrades all exterior wall surfaces to an insulation level of R-30
Add Window Film	Adds window film to existing windows. Assumes window film reduces SHGC by 54% and VLT by 53%.
Add Cool Roof	Upgrades all roof surfaces with current thermal emittance less than 0.75. Assumes reflectivity of 0.45 (accounting for degradation)
Add EIFS Wall Insulation	Adds R-30 polystyrene exterior insulation and finish systems (EIFS)
Upgrade Boilers	Upgrades boiler thermal efficiency to 0.94 AFUE
Enable Demand Control Ventilation	Upgrades all variable volume outdoor air systems to DCV
Upgrade Furnaces (0.92 AFUE)	Upgrades furnace thermal efficiency to 0.92 AFUE
Upgrade Furnaces (0.98 AFUE)	Upgrades furnace thermal efficiency to 0.98 AFUE
Add Heat Recovery	Adds a heat recovery system, which recovers residual heat in exhaust air
Upgrade Motors	Upgrades all motors to electronically commutated motors (ECM), except those used for service water heating or refrigeration
Add PTAC Controls	Adjusts the packaged terminal air conditioner (PTAC) operation schedules to follow the zone occupancy schedules
Upgrade PTHPs (Efficient)	Upgrades packaged terminal heat pump (PTHP) units to efficient levels (+5% - EER 10-12.5, COP 3.1-3.5)
Upgrade PTHPs (Highly Efficient)	Upgrades packaged terminal heat pump (PTHP) units to highly efficient levels (+10% - EER 10.5-13.1, COP 3.2-3.7)
Upgrade PTACs (Efficient)	Upgrades packaged terminal air conditioner (PTAC) units to efficient levels (+5% - EER 10-12.5)
Upgrade PTACs (Highly Efficient)	Upgrades packaged terminal air conditioner (PTAC) units to highly efficient levels (+10% - EER 10.5-13.1)
Upgrade RTU ASHP (15 IEER)	Upgrades rooftop unit (RTU) air-source heat pump (ASHP) efficiencies to 15.0 IEER
Upgrade RTU ASHP (16.5 IEER)	Upgrades rooftop unit (RTU) air-source heat pump (ASHP) efficiencies to 16.5 IEER
Upgrade RTU DX (15.5 IEER)	Upgrades rooftop unit (RTU) direct expansion (DX) efficiencies to 15.5 IEER
Upgrade RTU DX (17 IEER)	Upgrades rooftop unit (RTU) direct expansion (DX) efficiencies to 17.0 IEER
Upgrade Split System DX (16 SEER)	Upgrades split system direct expansion (DX) efficiencies to 16 SEER
Upgrade Split System DX (18 SEER)	Upgrades split system direct expansion (DX) efficiencies to 18 SEER
Upgrade Split System DX (20 SEER)	Upgrades split system direct expansion (DX) efficiencies to 20 SEER
Add Advanced Hybrid RTUs	Replaces packaged single zone systems with advanced hybrid rooftop units

	(RTU), which combine traditional DX cooling with indirect evaporative cooling and variable speed drive fans
Add Low Pressure Drop Air Filters	Reduces fan pressure drop by 0.5 inches of water for all constant and variable volume fans, excluding zone HVAC equipment and unitary equipment
Close Outdoor Air Dampers During Unoccupied Periods	Reduces minimum outdoor air flow to 0 cfm during periods of less than 5% occupancy

Table 3: List of ComStock Upgrade Measures (continued)

Pre-run Measures	Description
Add Cold Climate Heat Pumps	Replaces heating coil performance curves with those representing heating performance of cold climate air source heat pumps
Widen Thermostat Setpoints	Increases thermostat setpoint deadband by 1.5°F
Upgrade Compact Lighting	Replaces all compact lights with efficient 24W LED fixtures
Upgrade Linear Lighting	Replaces all linear lights with efficient 40W LED T8 troffers
Add Daylighting Controls	Adds daylighting controls as specified in ASHRAE 90.1-2013 to selected perimeter zones
Add PC Power Management	Reduces electric equipment schedules in all office space types by 25% during nighttime and weekend hours
Add Advanced Power Strips	Reduces electric equipment schedules in all office space types by 10% during nighttime and weekend hours
Upgrade Electric Water Heaters	Upgrades all small (<12kW, <50gal) electric non-heat pump water heater efficiencies to 0.93 EF
Upgrade to Heat Pump Water Heaters	Upgrades all small (<50gal) electric non-heat pump water heaters to a heat pump water heater with an EF of 3.5
Custom Measures	**Description**
Add Ceiling Fans	Adds ceiling fans to office spaces, classrooms and guest rooms. 4°F cooling setback when occupancy is over 5%.
Add Integrated Economizers	Upgrades all economizers to work in conjunction with the cooling coil
Raise Economizer High Temp Limit	Increases the economizer high temperature limit to 75°F for any economizer that originally had a limit below this value
Add Economizer Differential Controls	Changes economizer control to operate any time the outdoor air temperature is warmer than the return air temperature
Add Luminaire Level Lighting Controls	Adds occupancy sensors integrated in light fixtures to turn off individual light fixtures during periods of detected inoccupancy. Does not include daylighting controls.
Add Secondary Window Inserts	Adds secondary window inserts to existing windows. Assumes U-value is reduced by 70% and SHGC is reduced by 57%.

Systems Packages of Measures

Package selection

Packages of upgrade measures were developed for four of the eleven building types: Medium Office, Primary School, Secondary School, and Small Hotel. These four building types were selected based on their relative size and policy considerations and priorities. For each of these four building types we reviewed the upgrade measure savings and selected measures that had significant savings, were likely to be acceptable to building owners, and were cost effective (based on prior project efforts studying specific strategies). These sets of measures were then combined into packages based on the building trades involved in order to reduce job site coordination costs. These smaller packages were then combined into larger packages so that there was a range of package savings available for each building type.

A total of seven upgrade measure packages were developed for analysis and are listed in Table 4. Each package consists of from three to 17 upgrade measures. Packages one, two, and five are the smaller base packages with packages three, six and seven being the larger combination packages. Not all upgrade measures are applicable to every building type or location.

Table 4: Upgrade Package Descriptions

Package Number	Title	Description	Number of Measures
1	Lighting and controls	Lighting upgrades, lighting and plug load controls	5
2	HVAC controls	HVAC control changes	6
3	Lighting and HVAC controls	Package 1 + package 2	11
4	HVAC controls and equipment	Package 2 + equipment upgrades	9
5	Envelope	Wall and window upgrades	4
6	HVAC and envelope	Package 4 + package 5	12
7	HVAC, envelope, and lighting	Package 6 + package 1	17

Tables 5 - 11 show the fraction of buildings that have each upgrade measure applied for each package. There are three categories of applicability:

1. Always (indicated as 100%). For example, the “Upgrade Compact Lighting” measure is always applicable to all building types.
2. Likely to have already been adopted depending on building characteristics (indicated as less than 100%). For example, in Package 5 (see Table 9) the “Upgrade Roof Insulation” measure is not applicable to buildings that are assumed to already have the roof insulated. All schools are assumed to have no existing insulation, but 98% of medium offices and only 21% of small hotels are assumed to not be insulated.
3. Not applicable due to typical building envelope or system conditions (indicated by N/A). For example, in Package 2 (Table 6) the “Enable Demand Controlled Ventilation” measure is not assumed to be applicable to the medium office and small hotel building types.

Table 5: Package 1 applicability

Lighting and controls	Building Type			
Upgrade Measure	Medium Office	Primary School	Secondary School	Small Hotel
Add Advanced Power Strips	100%	100%	100%	100%
Add Luminaire Level Lighting Controls	100%	N/A	N/A	N/A
Add Daylighting Controls	100%	100%	100%	100%
Upgrade Compact Lighting	100%	100%	100%	100%
Upgrade Linear Lighting	100%	100%	100%	100%

Table 6: Package 2 applicability

HVAC controls	Building Type			
Upgrade Measure	Medium Office	Primary School	Secondary School	Small Hotel
Close Outdoor Air Dampers During Unoccupied Periods	31%	62%	63%	N/A
Enable Demand Control Ventilation	N/A	67%	79%	N/A
Add Economizer Differential Controls	N/A	N/A	N/A	37%
Raise Economizer High Temp Limit	44%	N/A	N/A	17%
Add PTAC Controls	2%	N/A	N/A	N/A
Widen Thermostat Setpoints	100%	100%	100%	100%

Table 7: Package 3 applicability

Lighting and HVAC controls	Building Type			
Upgrade Measure	Medium Office	Primary School	Secondary School	Small Hotel
Add Advanced Power Strips	100%	100%	100%	100%
Close Outdoor Air Dampers During Unoccupied Periods	31%	62%	63%	N/A
Enable Demand Control Ventilation	N/A	67%	79%	N/A
Add Economizer Differential Controls	N/A	N/A	N/A	37%
Raise Economizer High Temp Limit	44%	N/A	N/A	17%
Add PTAC Controls	2%	N/A	N/A	N/A
Add Luminaire Level Lighting Controls	100%	N/A	N/A	N/A
Add Daylighting Controls	100%	100%	100%	100%
Upgrade Compact Lighting	100%	100%	100%	100%
Upgrade Linear Lighting	100%	100%	100%	100%
Widen Thermostat Setpoints	100%	100%	100%	100%

Table 8: Package 4 applicability

HVAC controls and equipment	Building Type			
Upgrade Measure	Medium Office	Primary School	Secondary School	Small Hotel
Add Advanced Hybrid RTUs	42%	53%	46%	25%
Add Ceiling Fans	100%	100%	100%	100%
Close Outdoor Air Dampers During Unoccupied Periods	31%	61%	63%	N/A
Enable Demand Control Ventilation	N/A	66%	79%	N/A
Add Economizer Differential Controls	N/A	N/A	N/A	38%
Raise Economizer High Temp Limit	44%	N/A	N/A	18%
Add Heat Recovery	82%	67%	84%	38%
Add PTAC Controls	2%	N/A	N/A	N/A
Widen Thermostat Setpoints	100%	100%	100%	100%

Table 9: Package 5 applicability

Envelope	Building Type			
Upgrade Measure	Medium Office	Primary School	Secondary School	Small Hotel
Upgrade Roof Insulation	98%	100%	100%	21%
Add Secondary Window Inserts	83%	94%	97%	84%
Add Window Film	100%	100%	100%	100%

Table 10: Package 6 applicability

HVAC and envelope	Building Type			
Upgrade Measure	Medium Office	Primary School	Secondary School	Small Hotel
Add Advanced Hybrid RTUs	42%	53%	46%	25%
Add Ceiling Fans	100%	100%	100%	100%
Close Outdoor Air Dampers During Unoccupied Periods	31%	61%	63%	N/A
Upgrade Roof Insulation	98%	100%	100%	21%
Add Secondary Window Inserts	83%	94%	97%	85%
Add Window Film	100%	100%	100%	100%
Enable Demand Control Ventilation	N/A	66%	79%	N/A
Add Economizer Differential Controls	N/A	N/A	N/A	38%
Raise Economizer High Temp Limit	44%	N/A	N/A	18%
Add Heat Recovery	82%	67%	84%	38%
Add PTAC Controls	2%	N/A	N/A	N/A
Widen Thermostat Setpoints	100%	100%	100%	100%

Table 11: Package 7 applicability

HVAC, envelope, and lighting	Building Type			
Upgrade Measure	Medium Office	Primary School	Secondary School	Small Hotel
Add Advanced Hybrid RTUs	42%	53%	46%	25%
Add Advanced Power Strips	100%	100%	100%	100%
Add Ceiling Fans	100%	100%	100%	100%
Close Outdoor Air Dampers During Unoccupied Periods	31%	61%	63%	N/A
Upgrade Roof Insulation	98%	100%	100%	21%
Add Secondary Window Inserts	83%	94%	97%	84%
Add Window Film	100%	100%	100%	100%
Enable Demand Control Ventilation	N/A	66%	79%	N/A
Add Economizer Differential Controls	N/A	N/A	N/A	37%
Raise Economizer High Temp Limit	44%	N/A	N/A	17%
Add Heat Recovery	82%	67%	84%	37%
Add PTAC Controls	2%	N/A	N/A	N/A
Add Luminaire Level Lighting Controls	100%	N/A	N/A	N/A
Add Daylighting Controls	100%	100%	100%	100%
Upgrade Compact Lighting	100%	100%	100%	100%
Upgrade Linear Lighting	100%	100%	100%	100%
Widen Thermostat Setpoints	100%	100%	100%	100%

Package Savings

Once the packages had been developed and reviewed, they were simulated using the ComStock WA building sample of 35,000 buildings in order to account for any interactive effects between measures. Because of the calibration issue with ComStock median EUIs, we calculated package EUI energy savings by multiplying the package savings fraction times the the BPS Mean Stock EUI for the building type.

Median site EUI savings are summarized for each package by building type in Table 12, along with the target EUI savings (mean EUI - target EUI) for each building type. Median package savings that meet or exceed the target are colored blue, and median package savings that are less than required to meet the target are colored red. Figures 3, 5, 7, and 9 show the median package savings by location and size of building. The color of the symbol indicates the location of the building and the size of the symbol indicates the size of the building. Figures 4, 6, 8, and 10 show the distribution of package savings. The green bar indicates the median savings value, the blue box indicates the interquartile range (25th - 75th percentile), and the whiskers indicate the range of the data with a maximum of 1.5 times the interquartile range.

Package 1, the lighting and controls package, does not have median savings large enough to meet the target for any of the building types, though more than 25% of the medium office and small hotel buildings would meet the target. Package 2, the HVAC controls package, has median savings that easily meet the target for both school types, but are far from meeting the target for medium office and small hotel. When these two packages are combined in Package 3, the median savings exceeds the target for all building types with more than 75% of the buildings meeting the target for all building types except small hotel. Package 4 adds equipment improvements to package 2 and performs similarly to package 3, except in small hotel, where less than 25% of the buildings meet the target. Package 5, the envelope improvement package, has median savings that meet the target for only medium office, with less than 25% of school buildings meeting the target, and almost no savings for small hotel. Package 6, which combines packages 4 and 5, has median savings which meet the target for almost all of the buildings for all the building types except for small hotel, which has less than 25% of runs meeting the target. package 7 includes all the reviewed measures and meets the target for almost every building of every building type.

Table 12: Median site EUI savings (kBtu/sf). Blue = savings that meet or exceed target. Red = Savings that do not meet the target.

	Building Type			
Package	Medium Office	Primary School	Secondary School	Small Hotel
1: Lighting and controls	10.1	4.3	4.3	11.1
2: HVAC controls	6.3	10.6	10.6	2.4
3: Lighting and HVAC controls	17.6	16.1	16.3	13.8
4: HVAC controls and equipment	16.5	18.3	16.3	8.3
5: Envelope	13.4	5.9	4.3	0.9
6: HVAC and envelope	22.6	21.4	20.9	9.4
7: HVAC, envelope, and lighting	32.0	25.8	25.2	20.9
Target EUI Savings	12	8 / 9	9	13

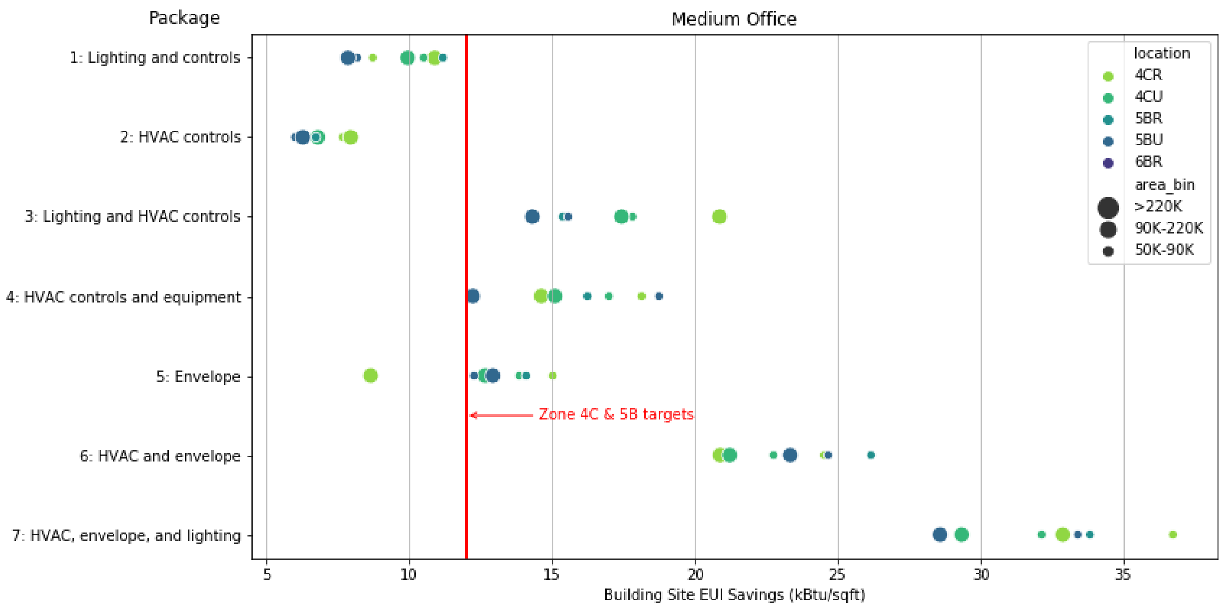

Figure 3: Medium office median package savings by location and size

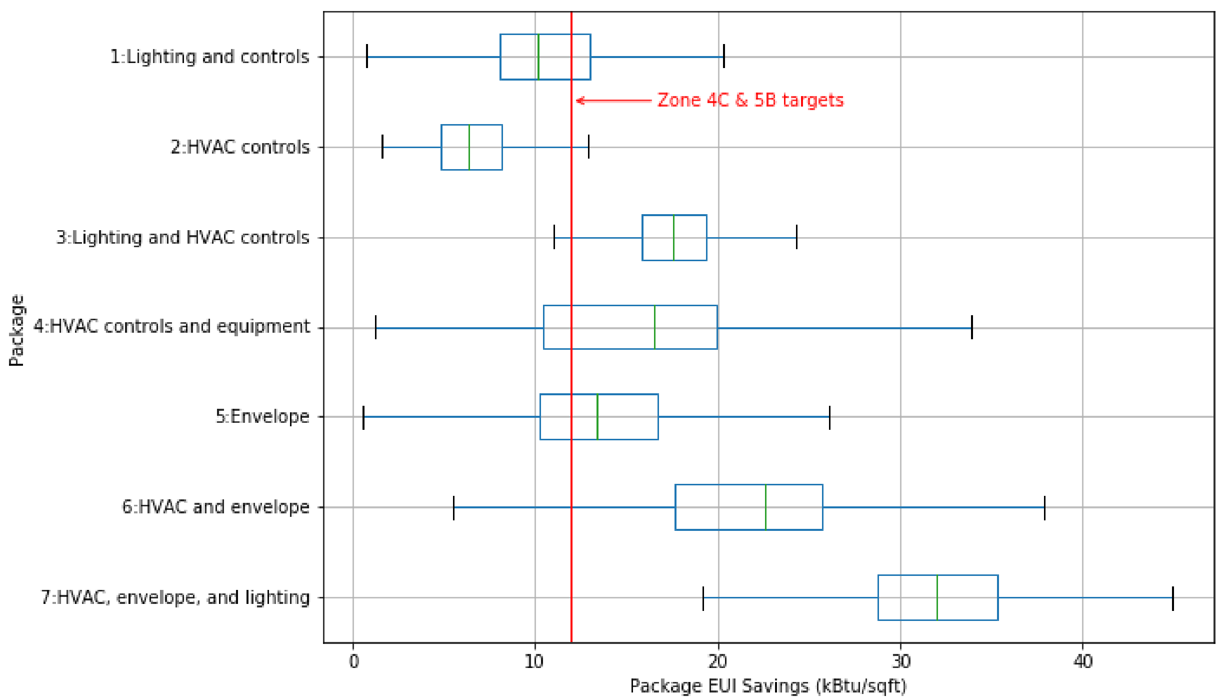

Figure 4: Medium office package savings distribution

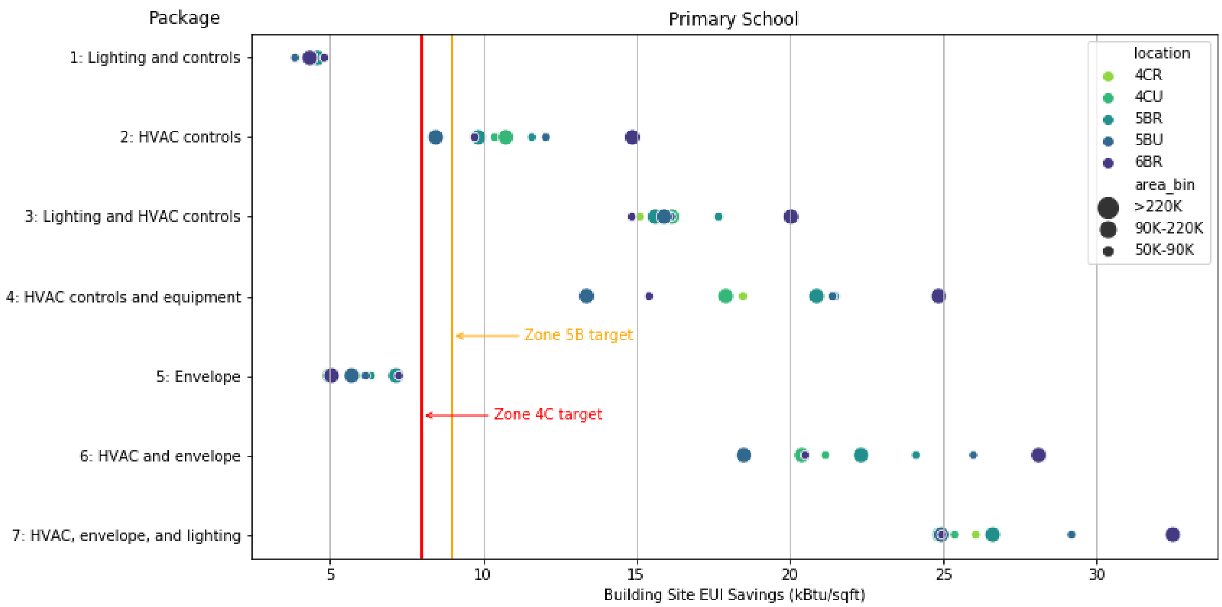

Figure 5: Primary school median package savings by location and building size

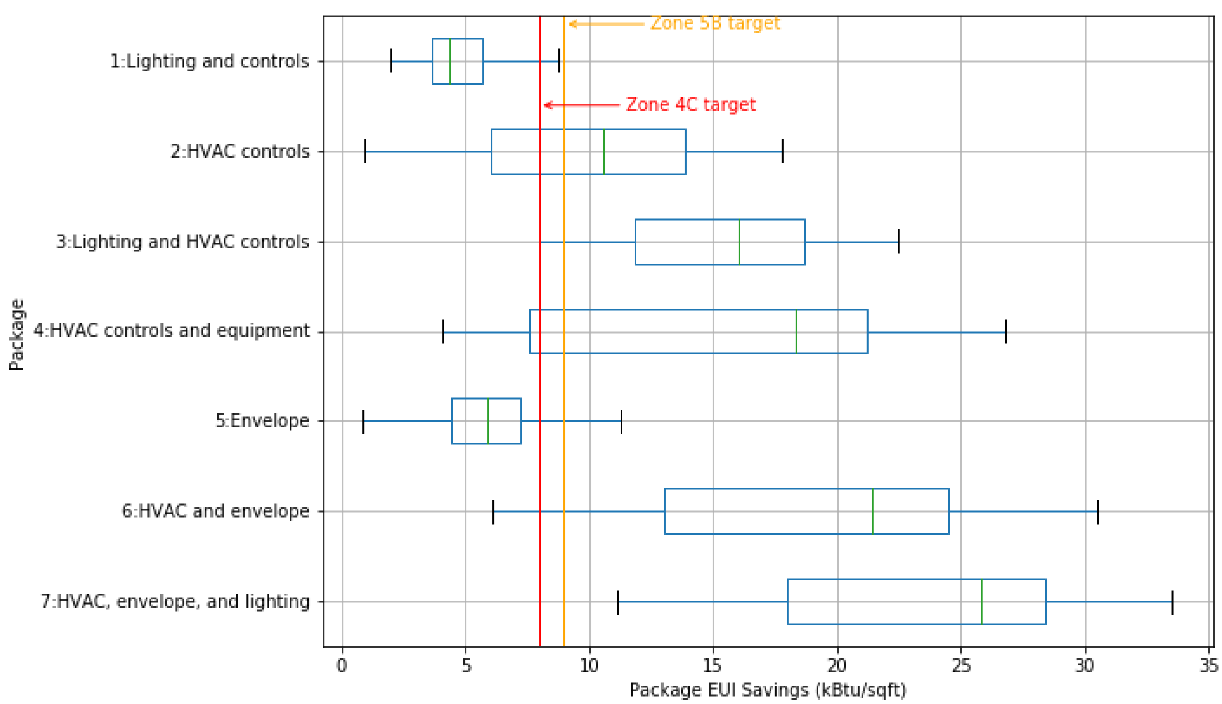

Figure 6: Primary school package savings distribution

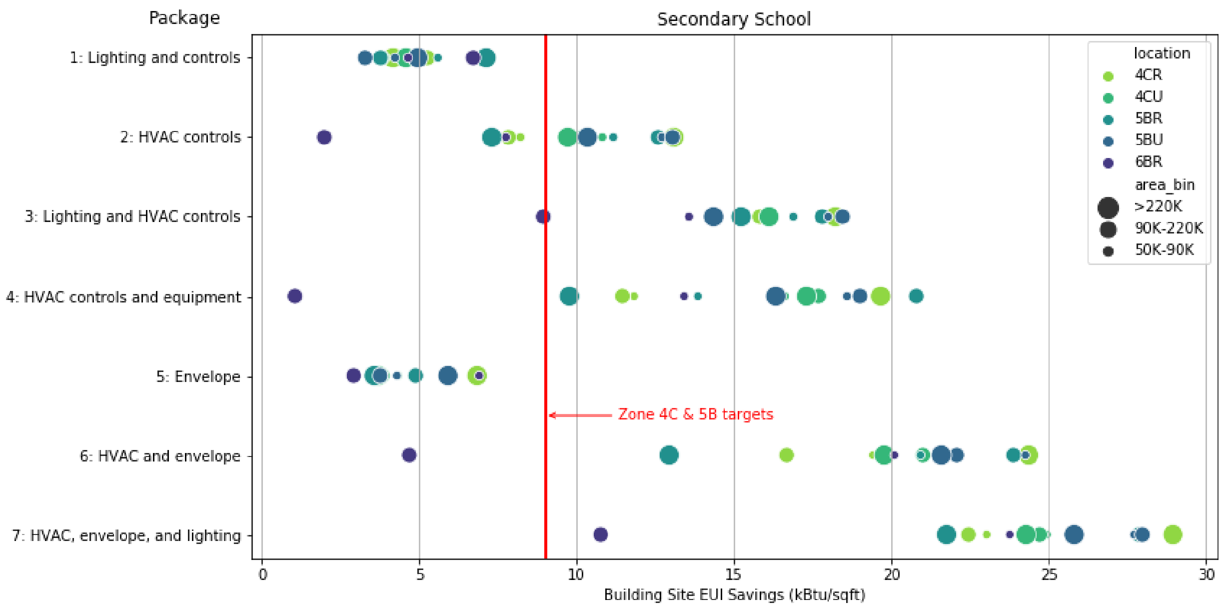

Figure 7: Secondary school median package savings by location and size

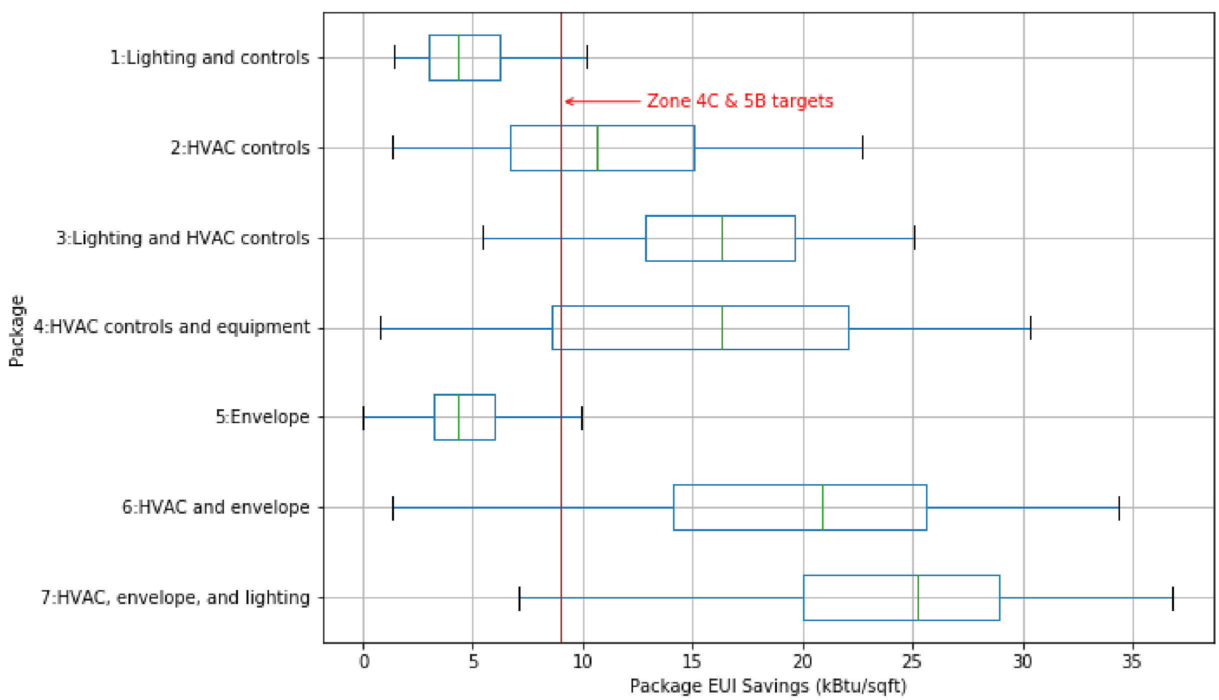

Figure 8: Secondary school package savings distribution

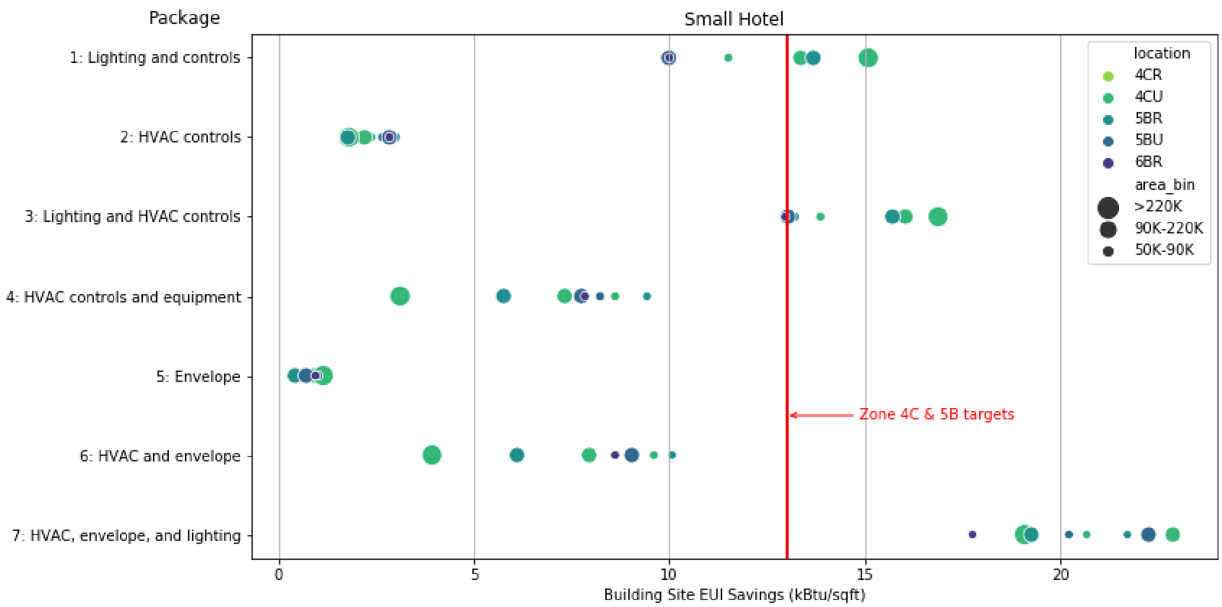

Figure 9: Small hotel median package savings by location and size

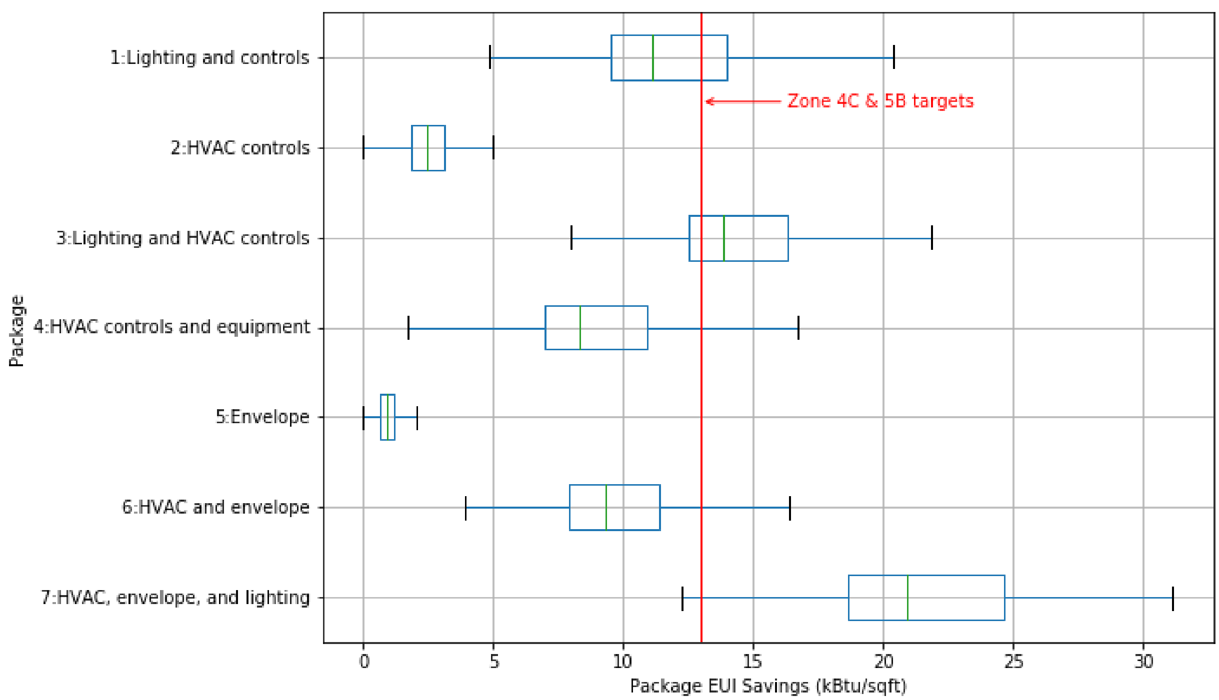

Figure 10: Small hotel package savings distribution

Conclusion

We used the ComStock stock modeling tool to analyze systems packages of energy efficiency measures. We reviewed savings results from a total of 43 measures to develop 7 packages of 17 measures. We analyzed the savings of these packages for four prioritized building types - medium office, primary and secondary schools, and small hotels. Package savings varied considerably for a given building type and size based on the applicability of individual measures given existing building conditions. The results clearly demonstrate the value of multi-system packages of measures. The lighting-only package does not meet the target in any of the building types for the median case. The envelope-only package meets the target only for medium office. The HVAC controls and equipment package sometimes meets the target. In most cases the HVAC and lighting controls package meets the target. The HVAC and envelope package and the HVAC, lighting and envelope package meet the target values for all building types.

This analysis is a first look at the potential savings of different packages in different locations. It can be extended to cover more building types, measures (such as very high efficiency DOAS) and packages (including different combinations of measures). Additionally, the model would benefit from additional calibration to improve accuracy, such as those implemented as part of the End Use Load Profiles calibration project. The analysis results can be used to inform the development of resources for building owners and service providers, tailored by building type, size and location.

References

ASHRAE. 2018. “ANSI/ASHRAE/IES Standard 100-2018 Energy Efficiency in Existing Buildings.” ASHRAE. https://blog.ansi.org/2018/04/ansi-ashrae-ies-standard-100-2018-building/.

———. 2019. “ASHRAE Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings.” https://www.ashrae.org/technical-resources/bookstore/standard-90-1.

DOE. n.d. “Prototype Building Models | Building Energy Codes Program.” Accessed October 18, 2021. https://www.energycodes.gov/prototype-building-models.

EIA. n.d. “Energy Information Administration (EIA)- Commercial Buildings Energy Consumption Survey (CBECS) Data.” Accessed September 14, 2020. https://www.eia.gov/consumption/commercial/data/2012/.

ENERGY STAR. n.d. “ENERGY STAR Portfolio Manager.” Accessed November 5, 2021. https://www.energystar.gov/buildings/benchmark.

IECC. 2018. “International Energy Conservation Code.” https://www.iccsafe.org/products-and-services/i-codes/2018-i-codes/iecc/.

NEEA. n.d. “Commercial Building Stock Assessments.” Northwest Energy Efficiency Alliance (NEEA). Accessed March 25, 2022. https://neea.org/data/commercial-building-stock-assessments.

NREL. n.d. “ComStock Analysis Tool.” Accessed March 25, 2022. https://www.nrel.gov/buildings/comstock.html.

Regnier, Cynthia, Paul A. Mathew, Alastair Robinson, Jordan Shackelford, and Travis Walter. 2020. “Systems Retrofit Trends in Commercial Buildings: Opening Up Opportunities for Deeper Savings.” Lawrence Berkeley National Laboratory. https://eta-publications.lbl.gov/sites/default/files/regnier_c_-_system_retrofit_trends_study_updated_5-8-20_final.pdf.

Washington State Legislature. n.d. “RCW 19.27A.210: State Energy Performance Standard.” Accessed September 16, 2020. https://app.leg.wa.gov/RCW/default.aspx?cite=19.27A.210.