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Energy Savings Analysis of the Proposed NYStretch-Energy Code 2018

January 2018

Bing Liu
Jian Zhang
Yan Chen
Jim Edelson
Mark Lyles

U.S. DEPARTMENT OF ENERGY
Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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[1] New Buildings Institute, Portland, Oregon.

Acronyms and Abbreviations

ACEEE	American Council for an Energy-Efficient Economy
CAV	constant air volume
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
DOAS	dedicated outdoor air system
DOE	U.S. Department of Energy
DX	direct expansion
EEM	energy-efficiency measure
ERV	energy recovery ventilator
HVAC	heating, ventilating, and air conditioning
IALD	International Association of Lighting Designers
IECC	International Energy Conservation Code
LPD	lighting power density
NBI	New Buildings Institute
NYSESRDA	New York State Energy Research and Development Authority
PNNL	Pacific Northwest National Laboratory
SHGC	solar heat gain coefficient
SWH	service water heating
VAV	variable air volume
WSHP	water source heat pump
WWR	window-to-wall ratio

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1.0 Introduction

This study was conducted by the Pacific Northwest National Laboratory (PNNL) in support of the stretch energy code development led by the New York State Energy Research and Development Authority (NYSERDA). In 2017 NYSERDA developed its 2016 Stretch Code Supplement to the 2016 New York State Energy Conservation Construction Code (hereinafter referred to as "NYStretch-Energy"). NYStretch-Energy is intended as a model energy code for statewide voluntary adoption that anticipates other code advancements culminating in the goal of a statewide Net Zero Energy Code by 2028. Since then, NYSERDA continues to develop the NYStretch-Energy Code 2018 edition. To support the effort, PNNL conducted energy simulation analysis to quantify the energy savings of proposed commercial provisions of the NYStretch-Energy Code (2018) in New York.

The focus of this project is the 20% improvement over existing commercial model energy codes. A key requirement of the proposed stretch code is that it be 'adoptable' as an energy code, meaning that it must align with current code scope and limitations, and primarily impact building components that are currently regulated by local building departments. It is largely limited to prescriptive measures, which are what most building departments and design projects are most familiar with.

This report describes a set of energy-efficiency measures (EEMs) that demonstrate 20% energy savings over ANSI/ASHRAE/IES Standard 90.1-2013 (ASHRAE 2013) across a broad range of commercial building types and all three climate zones in New York. In collaboration with New Building Institute, the EEMs were developed from national model codes and standards, high-performance building codes and standards, regional energy codes, and measures being proposed as part of the on-going code development process. PNNL analyzed these measures using whole building energy models for selected prototype commercial buildings and multifamily buildings representing buildings in New York.

Section 2 of this report describes the analysis methodology, including the building types and construction area weights update for this analysis, the baseline, and the method to conduct the energy saving analysis. Section 3 provides detailed specifications of the EEMs and bundles. Section 4 summarizes the results of individual EEMs and EEM bundles by building type, energy end-use and climate zone. Appendix A documents detailed descriptions of the selected prototype buildings. Appendix B provides energy end-use breakdown results by building type for both the baseline code and stretch code in all climate zones.

2.0 Methodology

Analysis of the EEMs was conducted using DOE's Commercial Prototype Building Models[1] (Thornton et al. 2011) that were developed using DOE's EnergyPlus software (DOE 2013). These are whole building energy models representing the national building stock in the United States. This section describes the selected prototypes and climate zones representing the commercial and multifamily buildings in New York. The baseline code for the analysis is ASHRAE Standard 90.1-2013 and the target code is the commercial provisions of NYStretch-Energy (2018), the stretch code.

2.1 Building Prototypes

DOE, PNNL and other national labs developed standard or reference energy models for 16 commercial building types, which represent approximately two-thirds of the commercial building stock nationally. PNNL also developed construction weighting factors for the 16 DOE Commercial Prototype Building Models (Jarnagin and Bandyopadhyay 2010). Table 1 shows the 16 building types and the construction weights of the building types in each of the three climate zones in New York. Five building types, i.e., Large Office, Standalone Retail, Secondary School, Large Hotel, and High-Rise Apartment, bolded in the table, represent approximately 63% of commercial building stock in New York.

As shown in Table 1, multifamily high-rise buildings represent a significant percentage of the new construction activity in New York State. Based on Dodge McGraw Hill New Construction data for the past 5 years, 97% of the multifamily high-rise new construction is in New York City (Bronx, Kings, New York, Queens, and Richmond counties). While just over half of the activity is well-represented by the DOE High-Rise Apartment prototype, the other half is for buildings more than 20 stories in height, where the construction methods and building systems differ. PNNL collected feedback from the multifamily stakeholder working group, NYSERDA and New York City, made major changes to the existing 10-story multifamily apartment and developed a new 20+ story multifamily apartment building prototype. These adjustments are necessary to more accurately represent high-rise apartment building stocks and typical designs and construction in New York City.

New York City gathered building permit data about New York City multifamily building construction that provided key information for PNNL to adjust and develop high-rise apartment building models. Data was derived from approved construction drawings for multifamily new construction between January 2016 to June 2017. Data was then grouped into the two categories (10-20 stories and 20+ stories) and the results are shown in Table 2.

[1] https://www.energycodes.gov/development/commercial/prototype_models

Table 1. Original Construction Area Weights in New York State

	4A	5A	6A	Weights by Building Type
Small Office	1.1%	1.4%	0.2%	2.7%
Medium Office	1.6%	1.7%	0.4%	3.7%
Large Office	**5.5%**	**0.7%**	**0.2%**	**6.4%**
Standalone Retail	**3.6%**	**5.2%**	**1.9%**	**10.6%**
Strip Mall	2.0%	1.2%	0.2%	3.3%
Primary School	0.7%	0.6%	0.1%	1.4%
Secondary School	**3.7%**	**2.7%**	**0.8%**	**7.2%**
Outpatient Healthcare	1.5%	1.8%	0.7%	4.1%
Hospital	1.3%	0.7%	0.2%	2.2%
Small Hotel	0.6%	0.7%	0.6%	1.9%
Large Hotel	**2.6%**	**1.8%**	**1.3%**	**5.7%**
Warehouse	1.8%	2.8%	0.9%	5.5%
Quick-Service Restaurant	0.1%	0.3%	0.0%	0.4%
Full-Service Restaurant	0.1%	0.2%	0.1%	0.4%
Mid-Rise Apartment	9.8%	1.2%	0.1%	11.1%
High-Rise Apartment	**33.3%**	**0.1%**	**0.1%**	**33.5%**
Sum of the Weights for Selected 5	**48.7%**	**10.5%**	**4.1%**	**63.3%**
Sum of the Weights for All 16	69.4%	22.9%	7.7%	100.0%
The selected five building types are highlighted in bold				

Table 2. Multifamily New Construction in New York City

	Multifamily New Construction in NYC (Jan 2016 – June 2017)	
	10-20 Stories	20+ Stories
Number of projects	85	30
Avg. Floor Area (ft²)	136,716	360,162
Avg. # of floors	13	39
Mixed Use	68%	67%
WWR	27%	45%
Typical HVAC	PTAC with Boiler	Water-Source Heat Pump (WSHP)

The selected six prototypes are summarized in Appendix A, including the revised 10-story and newly developed 20-story multifamily apartment buildings.

Reviews of energy end use of the selected commercial prototype models from the commercial working group resulted in a revision of the energy consumption in the data center of the large office building. PNNL added the data center and IT closet in the large office building as part of major enhancement efforts of DOE's Commercial Prototype Building Models (Goel et al. 2014). The equipment peak design loads used are as follows:

- Core data center: 45 W/ft^2 of IT load
- IT closets: 20 W/ft^2

Previously we assumed the data center and IT closet equipment always operates at the peak design load, which might overestimate the energy consumption from the data center. The working group suggested following the guidance from ASHRAE Standard 90.1 Appendix G computer room schedule, which models a constant fraction of the peak design load per the following monthly schedule:

Month 1, 5, 9 – 25%; Month 2, 6, 10 – 50%; Month 3, 7, 11 – 75%; Month 4, 8, 12 – 100%

The enhanced model for this work has implemented this schedule change.

2.2 Construction Area Weights Update

From the data in Table 2, PNNL calculated the construction area weights as 52% for the 10-20 stories and 48% for the 20+ stories apartment by combining the number of projects and average floor area. This split of construction weights in high-rise apartments was further applied to Table 1. Table 3 shows the updated construction area weights for all six selected prototype buildings representing New York commercial construction and multifamily building sector.

Table 3. Updated Construction Area Weights in New York State

	Climate Zone 4A	Climate Zone 5A	Climate Zone 6A	Weights by Building Type
Large Office	8.69%	1.11%	0.32%	10.1%
Standalone Retail	5.69%	8.21%	3.00%	16.9%
Secondary School	5.85%	4.27%	1.26%	11.4%
Large Hotel	4.11%	2.84%	2.05%	9.0%
20-story High-Rise Apartment	25.35%	0.00%	0.00%	25.3%
10-story High-Rise Apartment	27.26%	0.16%	0.16%	27.6%
Sum of the Weights for Selected 6 Prototypes	76.9%	16.6%	6.8%	100.0%

2.3 Baseline

At the time the NYStretch-Energy 2018 effort was conceived, Standard 90.1-2013 was the most recent version of the standard and it was also the official national model energy code (as determined by the U.S. Department of Energy). In addition, PNNL had conducted an analysis demonstrating it was cost-effective

compared to Standard 90.1-2010 (Hart et al. 2015, ASHRAE 2010). Being the most advanced commercial building standard available at the time that was also determined to be cost-effective, it was chosen as the baseline against which performance improvements would be measured. The prototype models meeting the minimum requirements from Standard 90.1-2013 were used as the starting point for this analysis.

2.4 Energy Efficiency Measures (EEMs) Development

The stretch code measures were developed by PNNL, NBI and NYSERDA with several rounds of feedback discussions with the stretch code advisory group, commercial working group, and multifamily working group members. Several sources contributed to the compilation of the EEM list, including ASHRAE Standard 90.1-2016 (ASHRAE 2016), 2018 International Energy Conservation Code (IECC), ASHRAE Standard 189.1-2017, NBI's *Multifamily Guide* (NBI 2017), NBI's *New Construction Guide* (NBI 2015) and PNNL's recently published report *City Reach Code Technical Support Document* targeting the 20% energy saving goal (Athalye et al. 2017). Recommended EEMs are shown in Table 3. Detailed EEM descriptions and modeling assumptions are documented in Section 3 of this report.

2.5 Energy Saving Analysis

PNNL analyzed the differences between the baseline (90.1-2013) and the stretch code in six prototype building models covering all three climate zones (4A, 5A and 6A) in New York. The approach results in a total of 36 building models, consisting of 18 models each for ASHRAE 90.1-2013 and the stretch code. The resulting energy use from the simulation runs was converted to site energy, source energy and energy cost by the energy end-use and aggregated at the state level across building types and climate zones based on construction weights in New York (Table 3).

The analysis builds on previous PNNL work that assessed the energy performance of ASHRAE Standard 90.1-2016, NYStretch-Energy Code (2016) and City Reach Code. PNNL conducted two rounds of parametric analysis on a list of EEMs with the goal of reaching at least 20% better than ASHRAE 90.1-2013, applied to the buildings to determine their sensitivities to energy consumption. For both rounds of analysis, the results include the following:

- a list of modeled measures;
- key assumptions and analysis results by building prototype, measure, and climate zone, expressed in site EUI for each case and overall; and
- overall results expressed in site EUI for the baseline and stretch codes.

Section 4 in this report presents the final energy saving analysis results for site, source and energy costs.

3.0 Measure and Package Descriptions

The NYStretch-Energy (2018) analysis include 16 EEMs using ASHRAE Standard 90.1-2013 as the baseline. This section describes the individual EEMs in detail and specifies the modeling strategies used to estimate savings in the selected 6 prototype models. Each measure and some combinations were simulated in the analysis as described below. All individual EEMs were then grouped into the efficiency packages (referred to NYStretch) and additional packages with optional EEMs. The efficiency packages determine the total savings while accounting for interactive effects. Table 4 summarizes the EEMs and their applicable prototype buildings.

Table 4. Summary of EEMs and Optional Efficiency Measures

EEM #	Measure Description	Hotel	Office	School	Retail	10-story Apt	20-story Apt
1	Enhanced insulation for roofs and walls	yes	yes	yes	Yes	yes	yes
2	Enhanced windows	yes	yes	yes	Yes	yes	yes
3	Air leakage testing for large buildings	yes	yes	yes	NA	yes	yes
4	Reduced LPD for interior lighting and high efficacy lights in dwelling units	yes	yes	yes	Yes	yes	yes
5	Occupancy sensors and automatic lighting controls including egress lighting	yes	yes	yes	Yes	yes	yes
6	Exterior lighting control	yes	yes	yes	Yes	NA	NA
7	Fan power limit: 0.8 W/cfm VAV and 0.65 W/cfm CAV	yes	yes	yes	Yes	NA	yes
8	High efficiency cooling towers in CZ 5 & 6	NA	yes	NA	NA	NA	NA
9	Hotel guestroom HVAC vacancy control	yes	NA	NA	NA	NA	NA
10	SWH waste heat recovery	yes	NA	NA	NA	yes	yes
11	Plug load reduction	yes	yes	yes	NA	NA	NA
12	Thermal bridging reduction	yes	NA	NA	NA	yes	NA
13	Exterior lighting power reduction	yes	yes	yes	Yes	NA	NA
14	Efficient elevator	yes	yes	NA	NA	yes	yes
15	ERV for apartment makeup air units	NA	NA	NA	NA	yes	yes
16	Demand-based recirculated DHW controls	NA	yes	yes	NA	yes	yes
Optional Measures							
OPTION 1	HVAC equipment efficiency (DX and boiler)	yes	yes	yes	Yes	yes	yes
OPTION 2	Reduced LPD (10%)	yes	yes	yes	Yes	yes	yes
OPTION 3	Enhanced envelope performance (10%)	yes	yes	yes	Yes	yes	yes

OPTION 4	Reduced infiltration (0.25 cfm/sf)	yes	yes	yes	NA	yes	yes
OPTION 4	DOAS	Not modeled					
OPTION 5	Onsite renewable energy	Not modeled					
Efficiency Packages							
NYStretch	All EEMs (1-16)	yes	yes	yes	yes	yes	yes
NYStretch + Option 1	NYStretch with HVAC equipment efficiency option	yes	yes	yes	yes	yes	yes
NYStretch + Option 2	NYStretch with reduced LPD	yes	yes	yes	yes	yes	yes
NYStretch + Option 3	Enhanced envelope performance (10%)	yes	yes	yes	yes	yes	yes
NYStretch + Option 4	NYStretch with reduced infiltration (0.25 cfm/sf)	yes	yes	yes	NA	yes	yes

3.1 EEM Descriptions

EEM01 Enhanced insulation for roofs and walls

EEM01 increases the insulation requirement for opaque envelopes (i.e., roof and above grade wall). The specific insulation values in EEM01 and applicable building types are given below in Table 5 and Table 6.

Affected Prototypes: All

Source of EEM data: 189.1-2017

Table 5. U-factors for Above-Grade Walls (Btu/hr-ft^2-F)

		90.1-2013		Proposed 2018 NYStretch	
Climate Zones	**Opaque Elements**	**Non-Residential**	**Residential**	**Non-Residential**	**Residential**
4A	Mass	0.104	0.090	0.099	0.086
	Metal Building	0.060	0.050	0.057	0.048
	Steel-Framed	0.064	0.064	0.061	0.061
	Wood-Framed and Other	0.064	0.064	0.061	0.061
5A	Mass	0.090	0.080	0.086	0.076
	Metal Building	0.050	0.050	0.048	0.048
	Steel-Framed	0.055	0.055	0.052	0.052
	Wood-Framed and Other	0.051	0.051	0.048	0.048
6A	Mass	0.080	0.071	0.076	0.067
	Metal Building	0.050	0.050	0.048	0.048
	Steel-Framed	0.049	0.049	0.047	0.044
	Wood-Framed and Other	0.051	0.051	0.048	0.046

Table 6. U-factors for Roofs (Btu/hr- ft^2-F)

		90.1-2013		Proposed 2018 NYStretch	
Climate Zone	**Opaque Elements**	**Non-Residential**	**Residential**	**Non-Residential**	**Residential**
4A	Insulation Entirely above Deck	0.032	0.032	0.030	0.030
	Metal Building	0.037	0.037	0.035	0.035
	Attic and Other	0.021	0.021	0.020	0.020
5A	Insulation Entirely above Deck	0.032	0.032	0.030	0.030
	Metal Building	0.037	0.037	0.035	0.035
	Attic and Other	0.021	0.021	0.020	0.020
6A	Insulation Entirely above Deck	0.032	0.032	0.029	0.029
	Metal Building	0.031	0.029	0.028	0.026
	Attic and Other	0.021	0.021	0.019	0.019

EEM02 Enhanced Windows

EEM02 requires more stringent fenestration U-factor and SHGC than 90.1-2013. Improved values are proposed for both windows and skylights as shown in Table 7. Skylight changes are only applicable to the Standalone Retail and Secondary School prototypes.

Affected Prototypes: All

Source of EEM data: 189.1-2017 for skylights and NBI's Multifamily Buildings Guide for windows.

Table 7. Fenestration Properties

		90.1-2013					Proposed 2018 NYStretch				
Climate Zones	**Fenestration Elements**	**Fenestration Types**	**Non-Res (U-factor)**	**Non-Res (SHGC)**	**Res (U-factor)**	**Res (SHGC)**	**Fenestration Types**	**Non-Res (U-factor)**	**Non-Res (SHGC)**	**Res (U-factor)**	**Res (SHGC)**
4A	**Vertical Fenestration WWR 0-40%**	Nonmetal Framing	0.35	0.40	0.35	0.40	Non AW fenestration	0.30	0.35	0.30	0.35
		Metal Framing, Fixed	0.42		0.42		Class AW, Fixed window	0.36		0.36	
		Metal Framing, Operable	0.50		0.50		Class AW, Operable window	0.43		0.43	
		Metal Framing, Entrance Door	0.77		0.68						
	Skylights, 0-3%	All types	0.50	0.40	0.50	0.40	All types	0.48	0.38	0.48	0.38
5A	**Vertical Fenestration WWR 0-40%**	Nonmetal Framing	0.32	0.40	0.32		Non AW fenestration	0.27	0.35	0.27	0.35
		Metal Framing, Fixed	0.42		0.42		Class AW, Fixed Window	0.36		0.36	
		Metal Framing, Operable	0.50		0.50		Class AW, Operable	0.43		0.43	
		Metal Framing, Entrance Door	0.77		0.68						
	Skylights, 0-3%	All types	0.50	0.40	0.50	0.40	All types	0.48	0.38	0.48	0.38
6A	**Vertical Fenestration WWR 0-40%**	Nonmetal Framing	0.32	0.40	0.32	0.40	Non AW fenestration	0.27	0.35	0.27	0.35
		Metal Framing, Fixed	0.42		0.42		Class AW, Fixed Window	0.34		0.34	
		Metal Framing, Operable	0.50		0.50		Class AW, Operable	0.41		0.41	
		Metal Framing, Entrance Door	0.77		0.68						
	Skylights, 0-3%	All types	0.50	0.40	0.50	0.40	All types	0.48	0.38	0.48	0.38

EEM03 Air Leakage Testing for Large Buildings

EEM03 adds air leakage testing as a requirement and is based on DOE/PNNL's proposal CE105 developed for the 2018 IECC. Air leakage testing is required for large buildings and the threshold for different climate zones is listed in Table 8 below. The tested buildings need to meet an air leakage rate of 0.40 cfm/ ft^2 at 75 Pa or less. The baseline (90.1-2013) infiltration rate has been modeled as 1.00 cfm/ ft^2 and this EEM reduces the infiltration rate to 0.40 cfm/ft^2. Standalone Retail prototype is not affected by this EEM because its floor area doesn't meet the thresholds.

Affected Prototypes: All except Standalone Retail

Source of EEM data: literature review from PNNL and NBI supports use of 1.00 cfm/sf as baseline input.

Table 8. Minimum Building Size Requiring Air Leakage Testing

Climate Zones	Residential	Non-Residential
4A	9,000	75,000
5A	6,000	40,000
6A	6,000	40,000

EEM04 Reduced LPD for Interior Lighting

EEM04 reduces the interior LPD. This measure is based on space-by-space LPD requirements in ASHRAE Standard 189.1-2017, which is primarily based on LED sources in luminaires with high optical efficiency and with luminance distributions that are appropriate for the spaces they are serving. The prototype models use a space-by-space method for LPD inputs. For a detailed list of LPDs in 189.1-2017, see Addendum AV (with 2nd public review drafts) to 189.1-2004.
Table 9 and Table 10 list the LPD values for both 90.1-2013 and EEM04.

For the dwelling units in the 10- and 20-story high-rise apartment buildings, use 90% high-efficacy; 65 LPW lamps; 45 LPW luminaires. This is the recommendation from IALD proposal EC128.

Affected Prototypes: All (including display lighting for retail spaces in 20-story apartment building)

Source of EEM data: 189.1-2017

Table 9. Interior LPD values comparison between 90.1-2013 and EEM04

PNNL Prototype	Space Type	Method	90.1-2013 (W/ft^2)	EEM04 (W/ft^2)
10-story Apartment	Office – enclosed	Common Space Type	1.11	0.85
	Corridor – all other corridor	Common Space Type	0.79@	0.58
	Stairwell	Common Space Type	0.69	0.5
	Electrical/Mechanical Room	Common Space Type	0.95	0.89
20-story Apartment	Office – enclosed	Common Space Type	1.11	0.85
	Corridor – all other corridor	Common Space Type	0.79@	0.58
	Stairwell	Common Space Type	0.69	0.5
	Electrical/Mechanical Room	Common Space Type	0.95	0.89
	Sales Area – Retail Area	Area weighted LPD	1.25	0.91
	Display Lighting – Retail Area Type 3	Area weighted LPD	0.88	0.65
	Display Lighting – Retail Area Type 2	Area weighted LPD	0.68	0.50
Large Hotel	Office	Building Area Method	0.82	0.69
	Retail	Building Area Method	1.26	0.91
	Electrical/Mechanical Room	Common Space Type	0.95	0.89
	Storage Room – all other storage rooms	Common Space Type	0.63	0.43
	Laundry/Washing Area	Common Space Type	0.60	0.43
	Dining Area – in family dining	Common Space Type	0.89	0.62
	Lobby – in a hotel	Common Space Type	1.06	0.68
	Guest Room	Common Space Type	0.91	0.75
	Corridor – all other corridor	Common Space Type	0.66	0.58
	Food Preparation Area	Common Space Type	1.21	0.92
Large Office	Office	Building Area Method	0.82	0.69
Stand-alone Retail	Back pace (combination of active storage, enclosed office, and restrooms)	Area weighted LPD	0.70	0.50
	Sales Area	Common Space Type	1.44	1.06
	Lobby – all other lobbies	Common Space Type	0.90	0.86
	Display Lighting – Combination of Retail Area Type 1, 2, and 3	Area weighted LPD	0.46	0.32
Secondary School	Classroom/Lecture Hall /Training Room – all other	Common Space Type	1.24	0.74
	Corridor – all other corridors	Common Space Type	0.66	0.58
	Lobby – all other lobbies	Common Space Type	0.90	0.86
	Electrical/Mechanical Room	Common Space Type	0.95	0.89
	Restroom – all other restrooms	Common Space Type	0.98	0.75
	Office – enclosed	Common Space Type	1.11	0.85
	Gymnasium/Fitness Center – in an exercise room	Building Specific Space Type	0.72	0.50
	Food Preparation	Common Space Type	1.21	0.92
	Dining Area – in cafeteria or fast food dining	Common Space Type	0.65	0.53
	Library	Building Area Method	1.19	0.72
	Audience Seating Area – in an auditorium	Common Space Type	0.63	0.63

@ In corridors, the extra lighting power density allowance is permitted when the width of the corridor is less than 8 feet and is not based on the RCR.

Table 10. Display lighting allowance comparison between 90.1-2013 and EEM04

Retail Area[(a)]	90.1-2013 (W/ft^2)	EEM04 (W/ft^2)
Retail Area 1	0.6	0.4
Retail Area 2	0.6	0.4
Retail Area 3	1.4	1.0
Retail Area 4	2.5	1.5

(a) Retail area is defined in 90.1-2013 Section 9.6.2.

EEM05 Occupancy sensors and automatic lighting controls

EEM05 expands the use of occupancy sensors and automatic lighting controls to independently shut off building lighting in all spaces with a few exceptions. ASHRAE 90.1-2013 already covers many spaces under the occupancy sensor requirements. To simulate the savings of this EEM, additional occupancy sensors are modeled in the following spaces:

- Office-open Plan
- Corridor/transition
- Stairway
- Dining Area
- Storage >50 sf and <1000 sf
- Locker Room
- Playing Area
- Auditorium Seating Area

Time clock light reduction in Egress Areas for unoccupied hours: Lighting load does not exceed 0.02 W/ft^2 multiplied by the gross lighted area of the building. Feedback from ASHRAE 90.1 lighting subcommittee indicates that 0.02 W/ft^2 of the entire floor area should be sufficient for egress in typical buildings to maintain light level of 1 fc minimum requirement.

Affected Prototypes: All

Source of EEM data: NYStretch-Energy Code (2018) Commercial Working Group

EEM06 Exterior Lighting Control

EEM06 is based on ASHRAE Standard 90.1-2016. This EEM requires outdoor parking area luminaires mounted 24' or less above the ground to be controlled to automatically reduce the power of each luminaire by a minimum of 50% when no activity has been detected for at least 15 minutes. Because most constructions in climate zone 4A are in New York City and have no or limited area of parking lot, the savings of this measure are only analyzed for climate zones 5A and 6A. Because most high-rise apartment buildings are in New York City, we consider this measure not applicable to high-rise apartments.

EEM06 also reduces other controlled exterior lighting under Section 9.4.1.4b of 90.1-2013 from 30% reduction at night hours (when business is closed) to 50%. Because Large Hotel is open for business 24 hours a day, the savings are not analyzed for Large Hotel prototype.

Affected Prototypes:

Parking lot lighting: Large Office, Standalone Retail, Secondary School, and Large Hotel in climate zone 5A and 6A.

Other exterior lighting: Large Office, Standalone Retail, and Secondary School in all climate zones.

Source of EEM data: ASHRAE Standard 90.1-2016

EEM07 Fan Power Limit

EEM07 limits the fan energy used by HVAC equipment. It requires that variable air volume systems use no more than 0.80 W/cfm and constant air volume systems use no more than 0.65 W/cfm for fan power. These limits are used for fan motors larger than 5 nameplate horsepower to compute the new static pressure for fans based on the fan power limitation rules established previously in the development of the prototype models. The baseline fan power is approximately 0.92 W/cfm for variable air volume fans, and 0.68 W/cfm for constant volume fans.

A system based efficiency metric kW/RT was also proposed for NYStretch but it is not included in the analysis.

Affected Prototypes: All (only central exhaust fans and outdoor air makeup units in 20-story high-rise apartments)

Source of EEM data: NBI's New Construction Guide

EEM08 Cooing Tower Efficiency

EEM08 specifies a cooling tower efficiency of 80 gpm/hp for systems with 900 gpm and larger and chiller plants over 300 tons. The cooling tower gpm/hp is captured as reduced fan power for the cooling tower. For ASHRAE Standard 90.1-2013 baseline, the cooling tower efficiency is 40.2 gpm/hp.

Affected Prototypes: Large Office. Only applicable in climate zones 5A and 6A as a way to address concerns about the potential structural impacts if cooling towers are installed on the roof in New York City (climate zone 4A).

Source of EEM data: CEC Codes and Standards Enhancement (CASE) Initiative[1]

EEM09 Hotel Guestroom HVAC Vacancy Control

EEM09 reduces guestroom energy usage in hotels by resetting the temperature setpoint during the period when a guestroom is unoccupied or unrented. This measure is also in ASHRAE Standard 90.1-2016. The measure requires the guestroom thermostat setpoint to be automatically raised by at least 4°F in the cooling mode and lowered by at least 4°F in the heating mode within 30 minutes of all occupants leaving the guestroom. When the guestroom is unrented and unoccupied, HVAC setpoints are required to be automatically reset to 80°F or higher in the cooling mode and to 60°F or lower in the heating mode. These changes are implemented by changing the thermostat setpoint schedules for unrented guestrooms and for rented guestrooms during unoccupied hours.

[1] Study can be found at: http://title24stakeholders.com/wp-content/uploads/2017/06/2019-T24-CASE-Report-_Cooling-Towers_Draft-April-2017.pdf

Affected Prototype: Large Hotel

Source of EEM data: ASHRAE 90.1-2016

EEM10 Service Water Heating Waste Heat Recovery

EEM10 proposes that 40% of hot water loads be met by waste heat recovery (from service water heating [SWH], heat-recovery chiller, building equipment, process equipment or a combined heat and power system) or solar thermal water heating systems or a combination of both. To implement this EEM, the SWH consumption is reduced by 40% through post-processing.

EEM10 specifies that 40% of hot water needs are met either through drain water waste heat recovery or using a solar thermal water heating system or a combination of both. PNNL researched various methods through which drain water waste heat recovery can be accomplished and the typical returns achieved using drain water waste heat recovery.

- Using a direct heat exchanger on the drain water return provides about 30% recovery.
- Collecting greywater from the building into a single tank and using a water-source heat pump to extract heat from the greywater to provide all the SWH results in more than 75% recovery[2].
- Various other research papers indicate 30-60% savings from drain waste heat recovery for multifamily buildings[3].
- Up to 50% of the hot water load could be covered using solar water heating even in cold climates (Aldrich and Williamson 2016).

Thus, it was found that 40% waste heat recovery from SWH is possible and was used for this measure.

Affected Prototypes: Large Hotel, 10-story and 20-story High-rise Apartment.

Source of EEM data: Ecotope and study from ACEEE Hot Water Forum 2017

EEM11 Plug Load Reduction

EEM11 reduces plug load energy usage. This measure has two parts: 1) upgrade major commercial kitchen appliances to ENERGY STAR®, and 2) use Centralized Computer power management to turn off computers and monitors at night. The computer power management requirement is based on California's Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24).

Affected Prototypes: Large Office, Secondary School, and Large Hotel

Source of EEM data: 189.1-2017 for commercial kitchen and Title 24 for computer power management

[2] Source: Email correspondence with Ecotope on SWH waste heat recovery systems.
[3] Source: ACEEE Hot Water Forum 2017: http://aceee.org/conferences/2017/hwf#presentations

EEM12 Thermal Bridging

EEM12 captures the impact of thermal bridging of wall assemblies. Using the Building Envelope Thermal Bridging Guide[4], U-factors are developed for exterior walls assuming thermal bridging from balconies for the Large Hotel and High-rise Apartments prototypes. A second set of U-factors is developed for improved assemblies that attempt to mitigate thermal bridging. NBI developed and provided PNNL the U-factors for the baseline and advanced cases as shown in Table 11.

Table 11. U-factors for the exterior wall (Btu/hr-ft^2-F)

Prototype	Condition	CZ 4A	CZ 5A	CZ 6A
10-story Apartment (Steel-framed residential)	90.1-2013	0.064	0.055	0.049
	Calculated assembly with Thermal Bridging (broken baseline)	0.141	0.132	0.126
	Calculated improved assembly (EEM12)	0.102	0.110	0.104
Large Hotel (Mass non-residential)	90.1-2013	0.104	0.090	0.080
	Calculated assembly with Thermal Bridging (broken baseline)	0.162	0.148	0.138
	Calculated improved assembly (EEM12)	0.145	0.131	0.121
Large Hotel (Mass residential)	90.1-2013	0.090	0.080	0.071
	Calculated assembly with Thermal Bridging (broken baseline)	0.148	0.138	0.129
	Calculated improved assembly (EEM12)	0.131	0.121	0.112

It should be noted that this measure is simulated using a separate baseline, i.e., other measures or the EEM bundles are not affected by the base U-factors developed for this measure.

Affected Prototypes: Large Hotel and 10-story High-rise Apartment

Source of EEM data: NBI research. NBI's Multifamily Building Guide

EEM13 Exterior Lighting Power Reduction

The proposed lighting power requirement is derived from ASHRAE Standard 189.1-2017, which affects the power of exterior lighting for parking lot, entrance, and façade (Table 12). Because most buildings in New York City (climate zone 4A) do not have parking lots, the savings to parking lighting are applied to climate zones 5A and 6A only. Because most high-rise apartment buildings are in New York City and have no or limited exterior lighting, the savings of this measure are not analyzed for high-rise apartments.

Affected Prototypes: Large Hotel, Large Office, Standalone Retail, and Secondary School. Façade and entrance lighting savings are captured in all climate zones. Parking lighting savings are captured in climate zones 5A and 6A. No parking lot exterior lighting power in 4A (New York City).

Source of EEM data: 189.1-2017

[4] https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/power-smart/builders-developers/building-envelope-thermal-bridging-guide-1.1.pdf

Table 12. Exterior lighting power density requirements

Lighting Zone[(a)]	Parking Lots (W/ft^2)		Building Façade (W/ft^2)		Doors (W/linear foot of door opening)			
					90.1-2013		EEM13	
	90.1-2013	EEM13	90.1-2013	EEM13	Main Doors	Other Doors	Main Doors	Other Doors
0	0.00	0.00	0.00	0.0000	0	0	0.00	0.00
1	0.04	0.03	0.00	0.0000	20	20	12.60	12.60
2	0.06	0.03	0.10	0.0950	20	20	12.60	12.60
3	0.10	0.05	0.15	0.1425	30	20	19.95	19.95
4	0.13	0.05	0.20	0.1900	30	20	19.95	19.95

(a) Lighting zone is defined in 90.1-2013 Table 9.4.2-1.

EEM14 Efficient Elevator

This measure is similar to Section 609.2.1.2.3 in the 2015 IECC (ICC 2015), which requires elevator systems to recover the potential energy released during motion. Based on NBI's literature review, regenerative drive can potentially reduce average elevator energy consumption per day by about 5% for tall buildings.

Affected Prototype: Large Hotel, Large Office, 10-story High-rise Apartment, and 20-story High-rise Apartment.

Source of EEM Data: 2015 IECC and NBI

EEM15 Energy Recovery Ventilator for Apartment Makeup Air Units

Section 6.5.6.1 in ASHRAE Standard 90.1-2013 provides an ERV exception to fan systems where the largest source of air exhausted at a single location is less than 70% of the design outdoor airflow rate. High-rise apartment buildings often have more than two rooftop central exhaust fans. This EEM modifies the exception to require ERV for those exhausts unless they are far from each other (more than 30 feet). The analysis adds ERVs to the makeup air roof-top units supplying ventilation air to the corridors and they recover latent and sensible heat from the building exhaust to ventilation air intake. The baseline 90.1-2013 models in the two apartment buildings do not have ERV. Considering in practice it might be difficult to recover all exhaust air from the ERV, we only assume 70% of exhaust air to be covered by ERV.

Affected Prototype: 10-story High-rise Apartment, and 20-story High-rise Apartment.

Source of EEM data: 2016 NYCECC and 90.1-2016

EEM16 Demand-based Controls for Recirculated Service Water Heating Systems

This measure is the same as Section C404.6.1 in the 2015 IECC, which requires buildings with recirculated SWH systems to automatically turn off the circulation pumps when the water temperature in the circulation loop is either at or above the desired setpoint or when there is no hot water demand.

A recirculated SWH system provides more instant hot water at the water taps but energy losses are greater through pipe thermal losses and pump energy losses than a non-recirculated system. For prototypes that use recirculated SWH systems, PNNL assumed that the SWH pumps in the 90.1-2013 prototypes are always on at constant speed and the SWH temperatures are always maintained at their design setpoint. To estimate the energy savings impacts of the EEM, reductions to the pipe heat loss inputs and recirculation pump power inputs were applied based on the baseline inputs in the 90.1-2013 prototypes. PNNL estimated the savings based on assumed SWH demand profiles in these prototypes.

Although Large Hotel uses recirculated SWH systems, we did not quantify the impacts of the new requirements on them because we assumed the occupants in these building always have SWH demand.

Affected Prototype: Large Office, Secondary School, and 10-story and 20-story High-rise Apartment.

Source of EEM data: 2015 IECC

3.2 Optional EEM and Efficiency Packages

Option 1 HVAC Equipment Efficiency

DX Equipment Efficiency

This EEM improves the efficiency of DX equipment by specifying Tier 2 equipment for unitary AC units from the CEE specifications. CEE Tier 1 criteria for water source heat pump are also used. For PTAC, the 189.1-2017 requirements are used. Table 13 shows the CEE specifications compared with those in ASHRAE Standard 90.1-2013.

Affected Prototypes: Standalone Retail, Secondary School, 10-story High-rise Apartment and 20-story High-rise Apartment.

Source of EEM data: CEE Tiers and 189.1-2017

Boiler Efficiency

This EEM specifies condensing boilers (94.5% efficiency) and in ASHRAE Standard 90.1-2013 baseline the maximum boiler efficiency is 81.25%.

Affected Prototypes: Large Office, Secondary School, Large Hotel, 10-story High-rise Apartment and 20-story High-rise Apartment

Source of EEM data: NBI Multifamily Guide

Option 2 Reduced lighting power density system

Exceed Stretch Code LPDs by 10%

Affected Prototypes: All prototypes

Option 3 Enhanced envelope performance

Exceed Stretch Code of building thermal envelope to be 10% more efficient than the U-factor requirements of the opaque and fenestration components.

Affected Prototypes: All prototypes

Table 13. CEE Tier 1 and Tier 2 equipment efficiency specifications

Unitary AC	Capacity	<65 kBtu/h	65 <--> 135 kBtu/h	135 <--> 240 kBtu/h	240 <--> 760 kBtu/h	> 760 kBtu/h
	Specification	SEER	EER	EER	EER	EER
	IECC2015	14.0	11.0	10.8	9.8	9.5
	90.1-2013	14.0	11.0	10.8	9.8	9.5
	90.1-2016	14.0	11.0	10.8	9.8	9.5
	189.1-2017 (bh)	15.0	12.0	12.0	10.6	10.2
	CEE Tier 1	15.0	11.5	11.5	10.3	9.7
	CEE Tier 2	16.0	12.0	12.0	10.6	10.2
Water to Air HP Cooling Mode	Capacity	<17 kBtu/h	17 <--> 65 kBtu/h	65 <--> 135 kBtu/h		
	Specification	EER	EER	EER		
	IECC2015	12.2	13.0	13.0		
	90.1-2013	12.2	13.0	13.0		
	90.1-2016	12.2	13.0	13.0		
	189.1-2017(bu)	14.0	14.0	14.0		
	CEE Tier 1	14.0	14.0	14.0		
	CEE Tier 2	NA	NA	NA		
Water to Air HP Heating Mode	Capacity	<17 kBtu/h	17 <--> 65 kBtu/h	65 <--> 135 kBtu/h		
	Specification	COP	COP	COP		
	IECC2015	4.3	4.3	4.3		
	90.1-2013	4.3	4.3	4.3		
	90.1-2016	4.3	4.3	4.3		
	189.1-2017(bu)	4.6	4.6	4.6		
	CEE Tier 1	4.6	4.6	4.6		
	CEE Tier 2	NA	NA	NA		
PTAC (Standard Size)	Capacity	All Capacities				
	Specification	EER, As of 1/1/2015	EER, Before 1/1/2015			
	90.1-2016	14.0 - (0.300*Cap/1000)	13.8-(0.300*Cap/1000)			
	189.1-2017(bw)	14.4 - (0.300*Cap/1000)				

Option 4 Reduced air infiltration

This EEM requires measured air leakage to not exceed 0.25 cfm/ft^2 of the building thermal envelope area at a pressure differential of 75 Pa.

Affected Prototypes: All except Standalone Retail

Option 5 Liquid distribution and dedicated outdoor air system

This optional EEM requires the use of radiant heating and cooling together with a dedicated outdoor air system (DOAS) with energy recovery to replace the VAV systems in the baseline of large office buildings. PNNL conducted the energy analysis of this system change measure as part of the City Reach Code study (Athalye et al. 2017).

Option 6 On-site supply of renewable energy

This measure provides at least 6.0 kBtu/ft^2 for single-story buildings and at least 10 kBtu/ft^2 times the gross roof area for all other buildings. This measure is derived from ASHRAE Standard 189.1-2014 (ASHRAE 2014).

3.3 EEM Bundle Description

After analyzing and modeling each measure individually, EEMs were combined to determine the total savings including interactive effects. For example, when improved opaque U-factors are combined with higher heating equipment efficiency, it will result in less savings than if the individual savings from improved U-factors and heating efficiency were summed. This is because the improved U-factors will reduce heating load, thereby reducing the potential for savings from the improved heating efficiency.

The following EEM bundles were created:

- **NYStretch**: All EEMs (EEM01 to EEM16) were combined for this first bundle, except EEM12 (thermal bridging).
- **NYStretch + Option 1**: Includes all EEMs in NYStretch bundle and adds Option 1 HVAC equipment efficiency.
- **NYStretch + Option 2**: Includes all EEMs in NYStretch bundle and replaces the interior LPDs with Option 2 values.
- **NYStretch + Option 3**: Includes all EEMs in NYStretch bundle and enhances the EEM01 and EEM02 (envelope requirements) values by 10% as shown in Option 3.
- **NYStretch + Option 4**: Includes all EEMs in NYStretch bundle and replaces the air leakage rate of 0.40 cfm/ft^2 in EEM03 with a tighter air leakage rate of 0.25 cfm/ft^2.

EEM12 (thermal bridging) was not included in any of the bundles because it required the creation of a separate baseline as well as modified U-factors for the EEM. It would have been difficult to discern the interactive impact of adding this particular EEM with all the other EEMs.

4.0 Results

4.1 Individual Measure Savings

Table 14 through Table 19 show whole building site energy savings results by prototype for each EEM in all the climate zones. If an EEM was not applicable to a given prototype or climate zone, the percent savings value is replaced with "NA".

Table 14. Individual EEM savings for 10-story apartment building

EEM #	Energy Design Measures	10-story Apartment		
		4A	5A	6A
		Site EUI Saving %		
1	Enhanced insulation for roofs and walls	0.3%	0.3%	0.5%
2	Enhanced windows	1.0%	0.8%	1.4%
3	Air leakage testing for large buildings	4.9%	5.2%	5.4%
4	Reduced LPD for interior lighting and high efficacy lights in dwelling units	2.2%	1.9%	1.8%
5	Occupancy sensors and automatic lighting controls including egress lighting	0.2%	0.2%	0.2%
6	Exterior lighting control	NA	NA	NA
7	Fan power limit: 0.8 W/cfm VAV and 0.65 W/cfm CAV	NA	NA	NA
8	Cooling towers in CZ 5 & 6	NA	NA	NA
9	Hotel guestroom HVAC vacancy control	NA	NA	NA
10	SWH waste heat recovery	13.1%	12.5%	13.1%
11	Plug load reduction	NA	NA	NA
12	Thermal bridging	2.7%	1.7%	1.8%
13	Exterior lighting power	NA	NA	NA
14	Elevator	0.2%	0.2%	0.2%
15	ERV for Apartment makeup air units	8.8%	10.9%	10.7%
16	Demand-based recirculated DHW controls	1.1%	1.0%	1.0%

Table 15. Individual EEM savings for 20-story apartment building

EEM #	Energy Design Measures	20-story Apartment		
		4A	5A	6A
		Site EUI Saving %		
1	Enhanced insulation for roofs and walls	0.2%	0.2%	0.3%
2	Enhanced windows	1.5%	1.2%	2.0%
3	Air leakage testing for large buildings	4.6%	5.0%	5.1%
4	Reduced LPD for interior lighting and high efficacy lights in dwelling units	2.7%	2.3%	2.2%
5	Occupancy sensors and automatic lighting controls including egress lighting	0.2%	0.2%	0.2%
6	Exterior lighting control	NA	NA	NA
7	Fan power limit: 0.8 W/cfm VAV and 0.65 W/cfm CAV	0.03%	0.01%	0.01%
8	Cooling towers in CZ 5 & 6	NA	NA	NA
9	Hotel guestroom HVAC vacancy control	NA	NA	NA
10	SWH waste heat recovery	12.4%	11.9%	12.5%
11	Plug load reduction	NA	NA	NA
12	Thermal bridging	NA	NA	NA
13	Exterior lighting power	NA	NA	NA
14	Elevator	0.2%	0.2%	0.2%
15	ERV for Apartment makeup air units	8.3%	10.2%	10.1%
16	Demand-based recirculated DHW controls	1.0%	0.9%	0.9%

Table 16. Individual EEM savings for office building

EEM #	Energy Design Measures	Large Office		
		4A	5A	6A
		Site EUI Saving %		
1	Enhanced insulation for roofs and walls	0.1%	0.1%	-0.1%
2	Enhanced windows	0.9%	1.0%	1.3%
3	Air leakage testing for large buildings	1.2%	1.2%	1.2%
4	Reduced LPD for interior lighting and high efficacy lights in dwelling units	1.5%	1.5%	1.1%
5	Occupancy sensors and automatic lighting controls including egress lighting	1.0%	0.9%	0.9%
6	Exterior lighting control	0.01%	0.6%	0.6%
7	Fan power limit: 0.8 W/cfm VAV and 0.65 W/cfm CAV	0.4%	0.4%	0.4%
8	Cooling towers in CZ 5 & 6	NA	0.2%	0.1%
9	Hotel guestroom HVAC vacancy control	NA	NA	NA
10	SWH waste heat recovery	NA	NA	NA
11	Plug load reduction	0.4%	0.4%	0.3%
12	Thermal bridging	NA	NA	NA
13	Exterior lighting power	0.02%	1.0%	1.1%
14	Elevator	0.3%	0.3%	0.3%
15	ERV for Apartment makeup air units	NA	NA	NA
16	Demand-based recirculated DHW controls	0.1%	0.1%	0.1%

Table 17. Individual EEM savings for retail building

EEM #	Energy Design Measures	Standalone Retail		
		4A	5A	6A
		Site EUI Saving %		
1	Enhanced insulation for roofs and walls	0.2%	0.6%	0.7%
2	Enhanced windows	0.2%	1.0%	1.0%
3	Air leakage testing for large buildings	NA	NA	NA
4	Reduced LPD for interior lighting and high efficacy lights in dwelling units	11.8%	10.2%	11.1%
5	Occupancy sensors and automatic lighting controls including egress lighting	1.7%	1.5%	1.5%
6	Exterior lighting control	0.2%	0.5%	0.5%
7	Fan power limit: 0.8 W/cfm VAV and 0.65 W/cfm CAV	0.4%	0.4%	0.4%
8	Cooling towers in CZ 5 & 6	NA	NA	NA
9	Hotel guestroom HVAC vacancy control	NA	NA	NA
10	SWH waste heat recovery	NA	NA	NA
11	Plug load reduction	NA	NA	NA
12	Thermal bridging	NA	NA	NA
13	Exterior lighting power	0.3%	1.8%	1.7%
14	Elevator	NA	NA	NA
15	ERV for Apartment makeup air units	NA	NA	NA
16	Demand-based recirculated DHW controls	NA	NA	NA

Table 18. Individual EEM savings for school building

EEM #	Energy Design Measures	Secondary School		
		4A	5A	6A
		Site EUI Saving %		
1	Enhanced insulation for roofs and walls	0.2%	0.4%	0.4%
2	Enhanced windows	1.4%	1.5%	1.5%
3	Air leakage testing for large buildings	0.4%	0.7%	0.7%
4	Reduced LPD for interior lighting and high efficacy lights in dwelling units	5.0%	4.5%	4.7%
5	Occupancy sensors and automatic lighting controls including egress lighting	8.0%	7.0%	7.2%
6	Exterior lighting control	0.1%	0.2%	0.3%
7	Fan power limit: 0.8 W/cfm VAV and 0.65 W/cfm CAV	1.0%	0.9%	1.0%
8	Cooling towers in CZ 5 & 6	NA	NA	NA
9	Hotel guestroom HVAC vacancy control	NA	NA	NA
10	SWH waste heat recovery	NA	NA	NA
11	Plug load reduction	3.7%	3.4%	3.5%
12	Thermal bridging	NA	NA	NA
13	Exterior lighting power	0.2%	0.5%	0.5%
14	Elevator	NA	NA	NA
15	ERV for Apartment makeup air units	NA	NA	NA
16	Demand-based recirculated DHW controls	0.0%	0.0%	0.0%

Table 19. Individual EEM savings for hotel building

EEM #	Energy Design Measures	Large Hotel		
		4A	5A	6A
		Site EUI Saving %		
1	Enhanced insulation for roofs and walls	0.2%	0.2%	0.3%
2	Enhanced windows	0.9%	0.7%	1.3%
3	Air leakage testing for large buildings	1.1%	1.4%	1.4%
4	Reduced LPD for interior lighting and high efficacy lights in dwelling units	1.8%	1.2%	1.5%
5	Occupancy sensors and automatic lighting controls including egress lighting	0.2%	0.1%	0.1%
6	Exterior lighting control	NA	0.3%	0.3%
7	Fan power limit: 0.8 W/cfm VAV and 0.65 W/cfm CAV	0.6%	0.5%	0.5%
8	Cooling towers in CZ 5 & 6	NA	NA	NA
9	Hotel guestroom HVAC vacancy control	3.0%	3.9%	4.0%
10	SWH waste heat recovery	8.0%	7.9%	8.2%
11	Plug load reduction	3.7%	3.4%	3.4%
12	Thermal bridging	0.4%	0.6%	0.6%
13	Exterior lighting power	0.04%	0.8%	0.8%
14	Elevator	0.4%	0.4%	0.4%
15	ERV for Apartment makeup air units	NA	NA	NA
16	Demand-based recirculated DHW controls	NA	NA	NA

4.2 NYStretch Package Energy Savings

Table 20 through Table 22 show the NYStretch package analysis results for site energy, source and energy cost for the NYStretch package and 90.1-2013, respectively. The results were aggregated across all three climate zones in the state for each building type and further aggregated across all building types to calculate the weighted-average energy use and percentage of savings.

In these tables, site energy refers to the energy consumed at the building site, source energy (or primary energy) refers to the energy required to generate and deliver energy to the site. To calculate source energy, conversion factors were applied to the electricity and natural gas consumption. Electricity generation conversion factor of 8,697 Btu/kWh was used based on guidance from NYSERDA. The conversion factor was calculated based on a three-year state weighted average heat rate for fossil-fueled power plants[1].

Energy cost index was calculated by using the electricity and natural gas prices as shown below.

- $0.161 per kWh of electricity
- $0.808 per therm of natural gas

The energy rates for New York are state average annual prices from the United States Energy Information Administration (EIA) Electricity Power Monthly (EIA 2015a) and Natural Gas Monthly (EIA 2015b).

A more detailed energy end-use breakdown by fuel type for both NYStretch package and 90.1-2013 are documented in Appendix B.

Table 20. Annual site energy usage for NYStretch compared to 90.1-2013

Building Type	**Prototype**	**Construction Weight [%]**	**Site Energy (kBtu/ft²/yr)**		**% Energy Savings**
			90.1-2013	**NYStretch**	**NYStretch vs. 90.1-2013**
Office	Large office	**10.1%**	60.91	57.25	6.0%
Retail	Standalone retail	**16.9%**	49.23	41.86	15.0%
Education	Secondary school	**11.4%**	39.87	32.73	17.9%
Lodging	Large hotel	**9.0%**	87.68	69.84	20.3%
Apartment	20-story apartment	**25.3%**	53.04	36.57	31.0%
	10-story apartment	**27.6%**	51.35	35.04	31.8%
Weighted Average (across all climate zones in NY)		**100.0%**	**54.51**	**41.81**	**23.3%**

[1] NYSERDA Patterns and Trends report – October 2017. https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Patterns-and-Trends

Table 21. Annual source energy usage for NYStretch compared to 90.1-2013

Building Type	Prototype	Construction Weight [%]	Source Energy (kBtu/ft²/yr)		% Energy Savings
			90.1-2013	NYStretch	NYStretch vs. 90.1-2013
Office	Large office	**10.1%**	141.07	132.80	5.9%
Retail	Standalone retail	**16.9%**	111.55	92.03	17.5%
Education	Secondary school	**11.4%**	87.76	71.37	18.7%
Lodging	Large hotel	**9.0%**	161.22	133.93	16.9%
Apartment	20-story apartment	**25.3%**	94.43	72.53	23.2%
	10-story apartment	**27.6%**	87.41	67.20	23.1%
Weighted Average (across all climate zones in NY)		**100.0%**	**105.66**	**86.08**	**18.5%**

Table 22. Annual energy cost for NYStretch compared to 90.1-2013

Building Type	Prototype	Construction Weight [%]	Energy Cost Index ($/ft²/yr)		% Energy Savings
			90.1-2013	NYStretch	NYStretch vs. 90.1-2013
Office	Large office	**10.1%**	$2.49	$2.35	5.8%
Retail	Standalone retail	**16.9%**	$1.95	$1.58	18.8%
Education	Secondary school	**11.4%**	$1.51	$1.22	19.1%
Lodging	Large hotel	**9.0%**	$2.47	$2.12	14.4%
Apartment	20-story apartment	**25.3%**	$1.41	$1.17	17.0%
	10-story apartment	**27.6%**	$1.26	$1.06	15.7%
Weighted Average (across all climate zones in NY)		**100.0%**	**$1.68**	**$1.42**	**15.3%**

4.3 Optional Efficiency Packages Savings

Figure 1 through Figure 6 illustrate the end-use comparisons for baseline, NYStretch and the other four efficiency packages with optional measures.

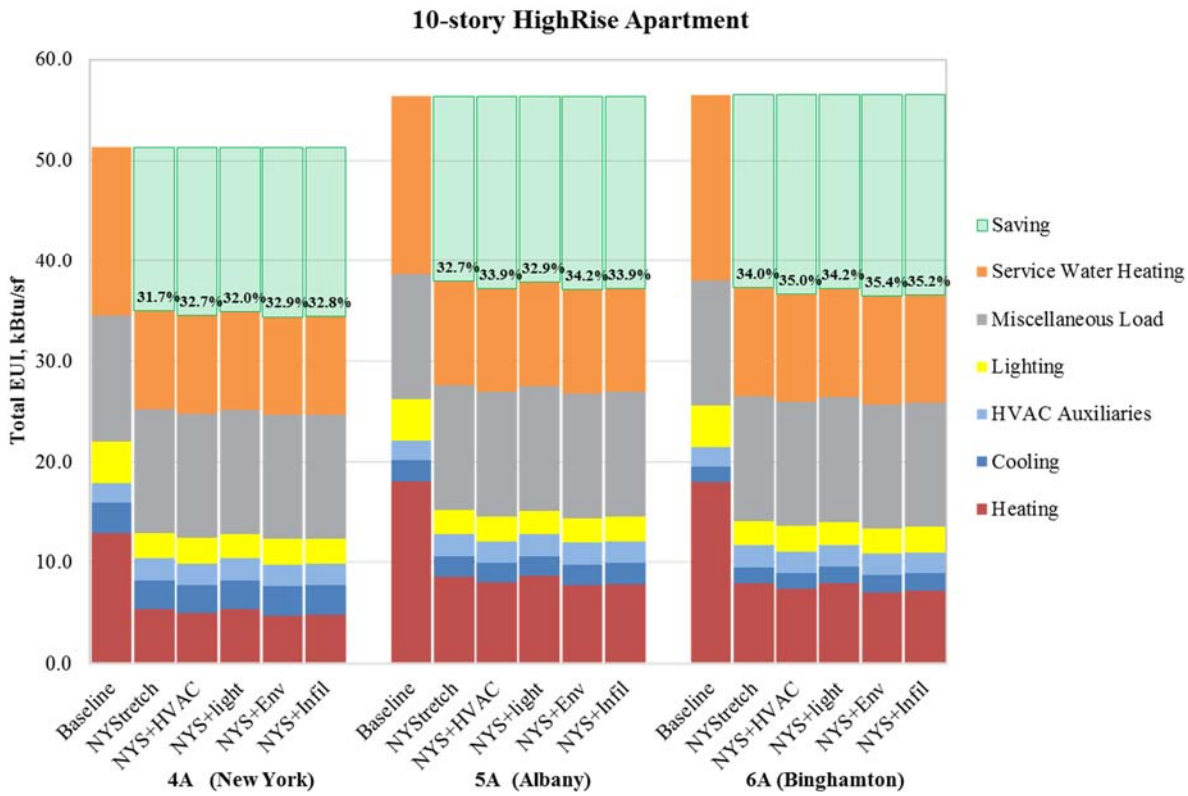

Figure 1. End-use comparison for 10-story high-rise apartment

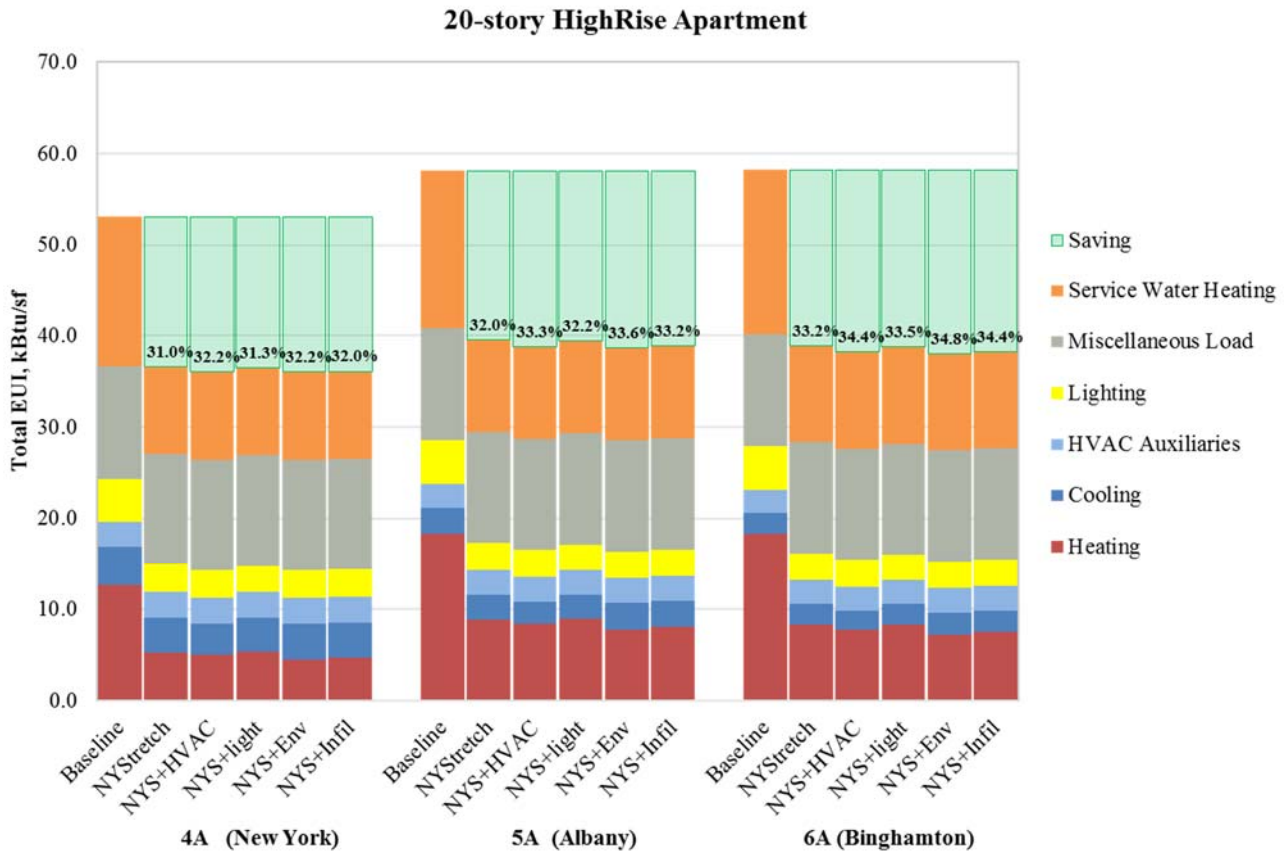

Figure 2. End-use comparison for 20-story high-rise apartment

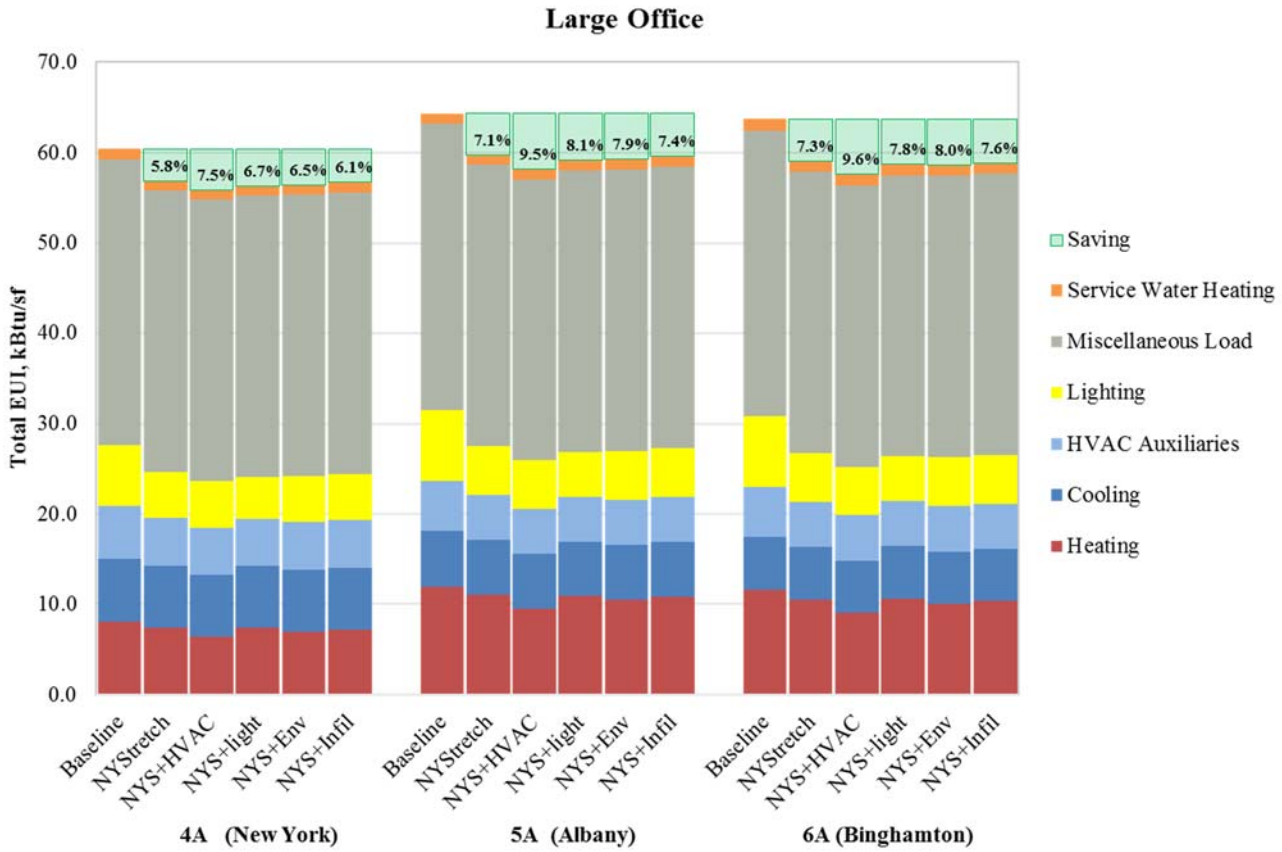

Figure 3. End-use comparison for large office

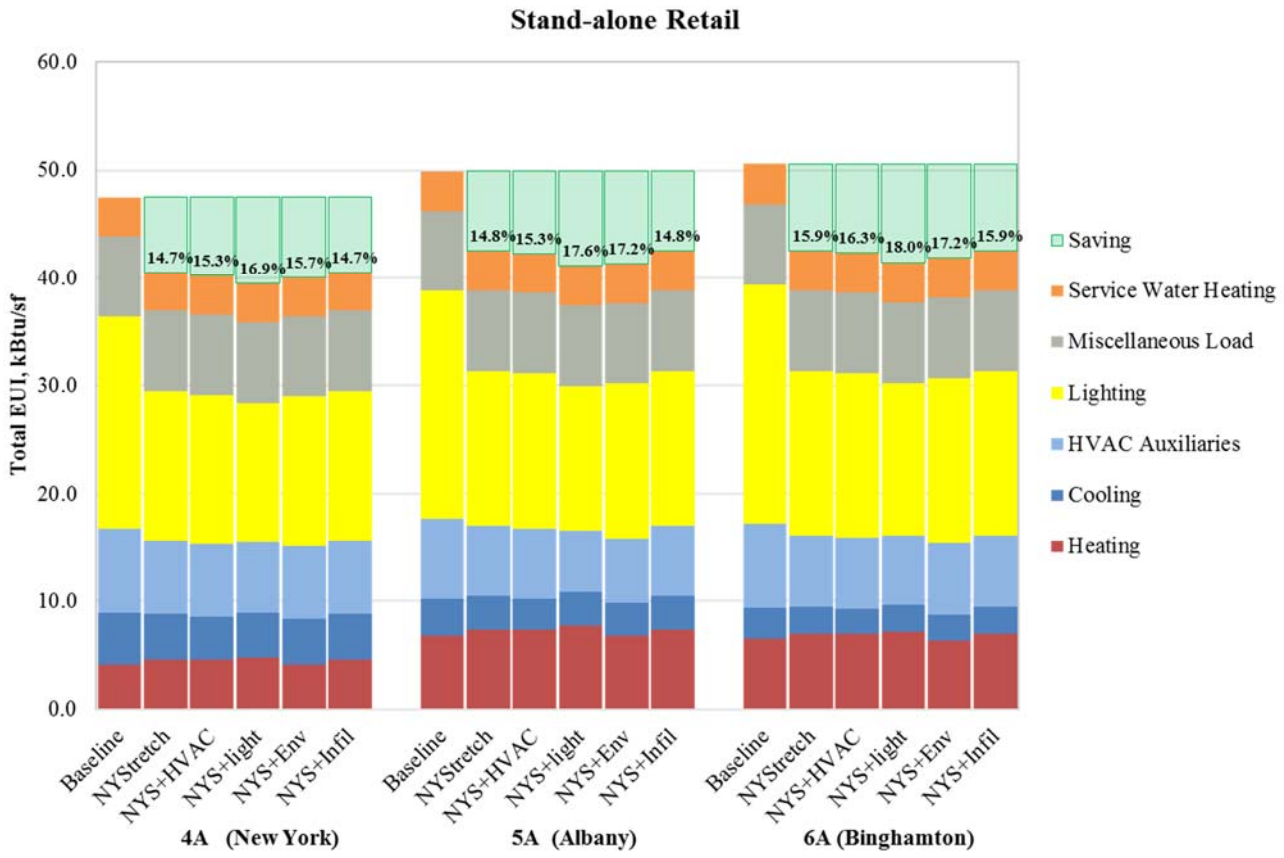

Figure 4. End-use comparison for standalone retail

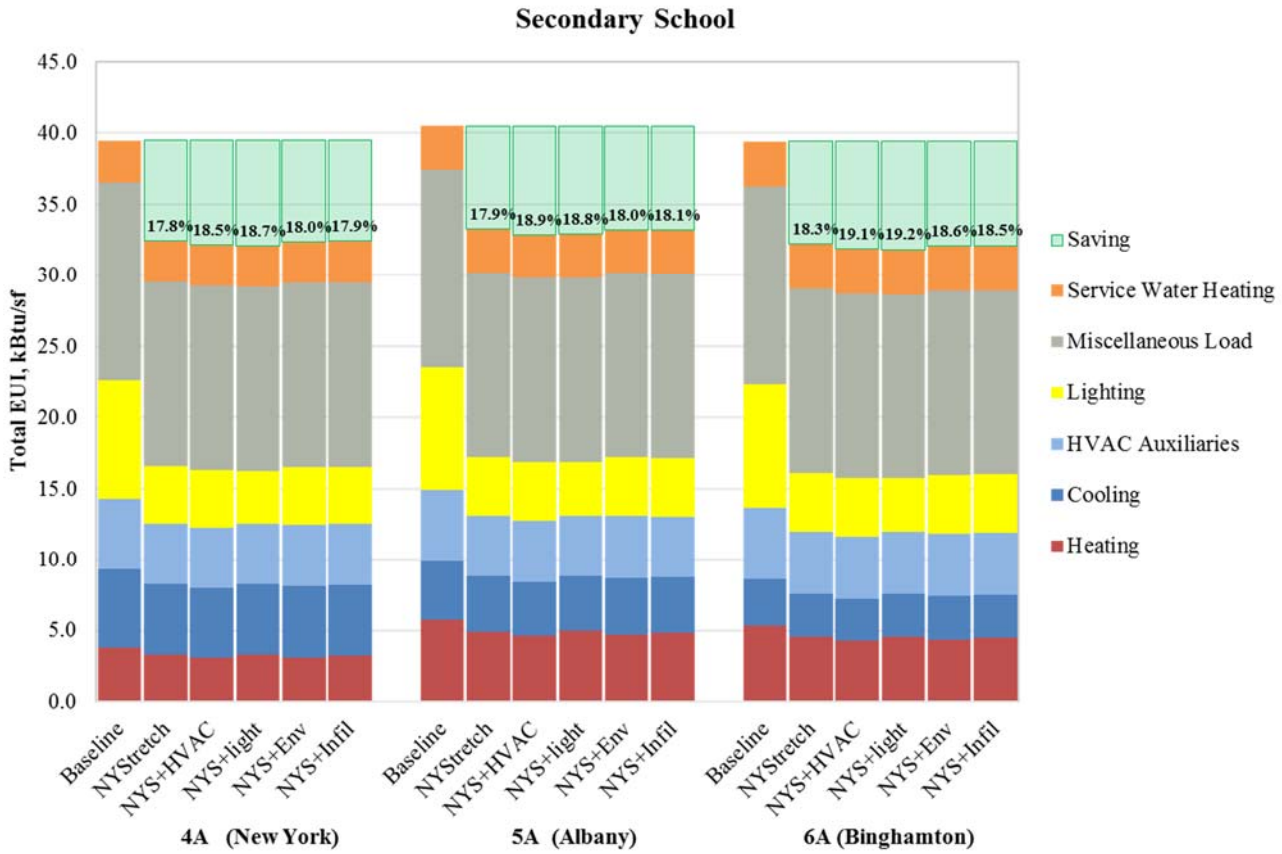

Figure 5. End-use comparison for secondary school

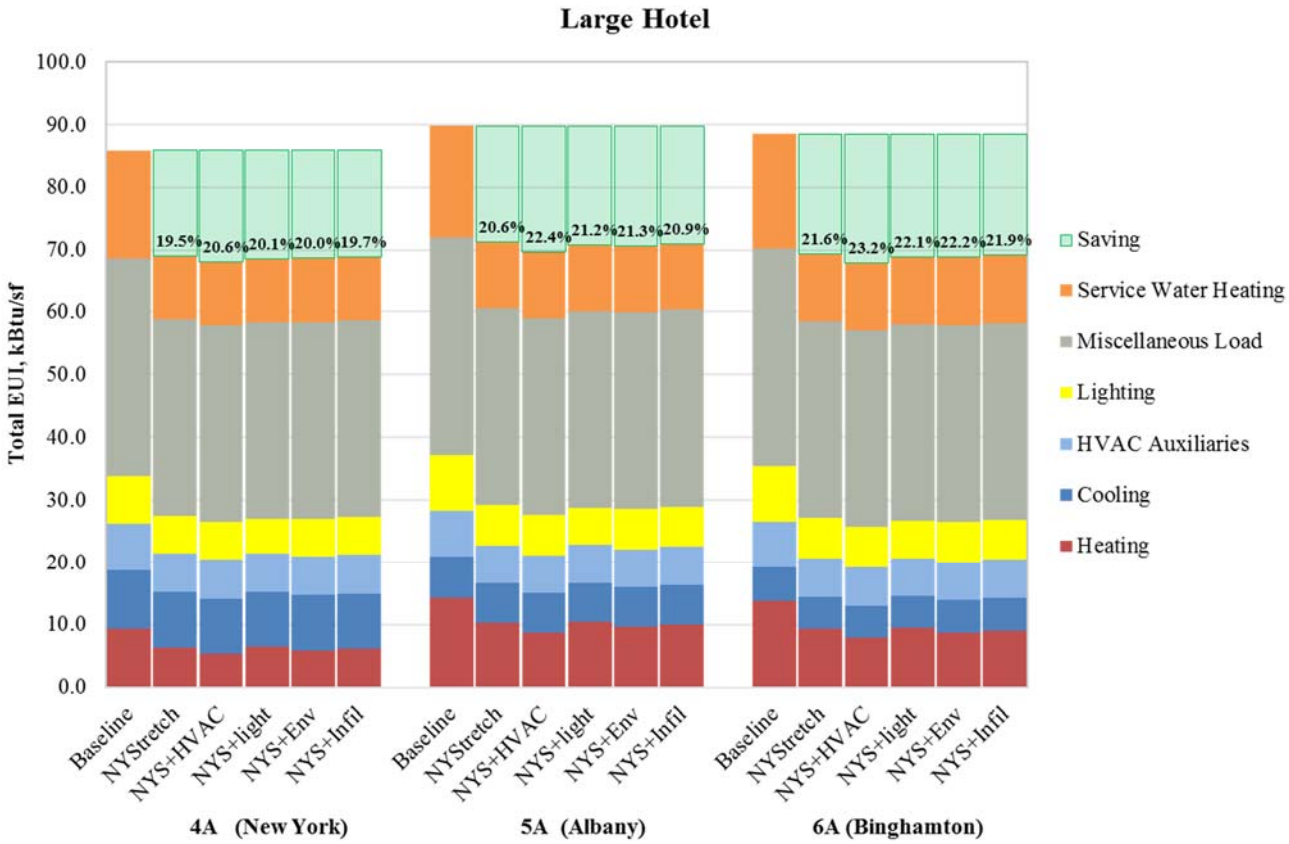

Figure 6. End-use comparison for large hotel

4.4 Summary

The goal of this study was to deliver a bundle of EEMs that could achieve at least 20% energy savings relative to ASHRAE Standard 90.1-2013 across typical building types found in the state of New York. As shown in Table 20, the bundled site energy savings exceed the 20% reduction target for most building types in most climate zones. The savings for the Large Office building are smaller because of the substantial data center and office plug and process load.

5.0 References

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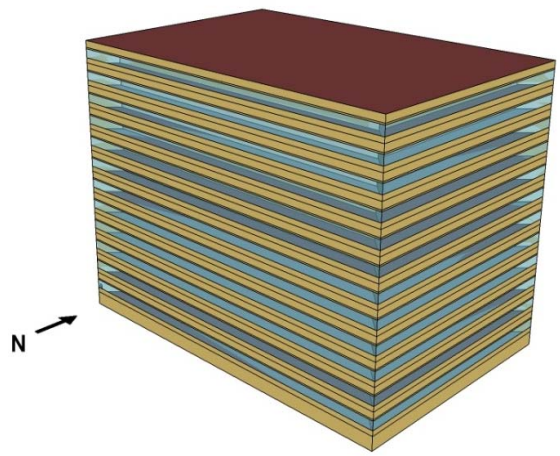
Appendix A

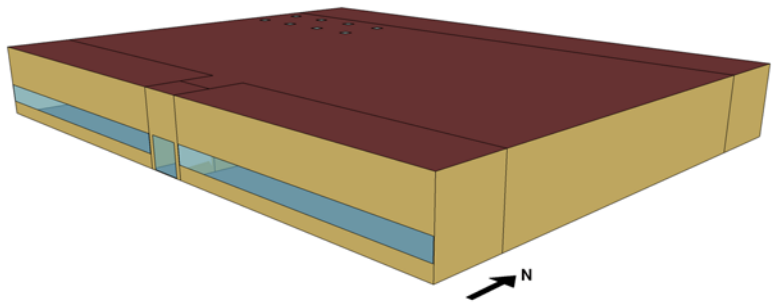
Description of the Selected Six Prototype Buildings

A.1 Large Office

Specifications	Description
Total Floor Area (sq feet)	498,600 (240 ft x 160 ft)
Building shape	
Aspect Ratio	1.5
Number of Floors	12 (plus basement)
Window Fraction (Window-to-Wall Ratio)	40% of above-grade gross walls 37.5% of gross walls (including the below-grade walls)
Floor to floor height (feet)	13
Floor to ceiling height (feet)	9
Glazing sill height (feet)	3 ft
Exterior walls construction	Mass (pre-cast concrete panel): 8 in. Heavy-Weight Concrete + Wall Insulation + 0.5 in. gypsum board
HVAC configurations	
Heating type	Gas boiler
Cooling type	Water-source DX cooling coil with fluid cooler for datacenter and IT closets and Two water-cooled centrifugal chillers for the rest of the building
Distribution and terminal units	VAV terminal box with damper and hot-water reheating coil except non-datacenter portion of the basement and IT closets that are served by CAV units. Zone control type: minimum damper positions are determined using the multizone calculation method.

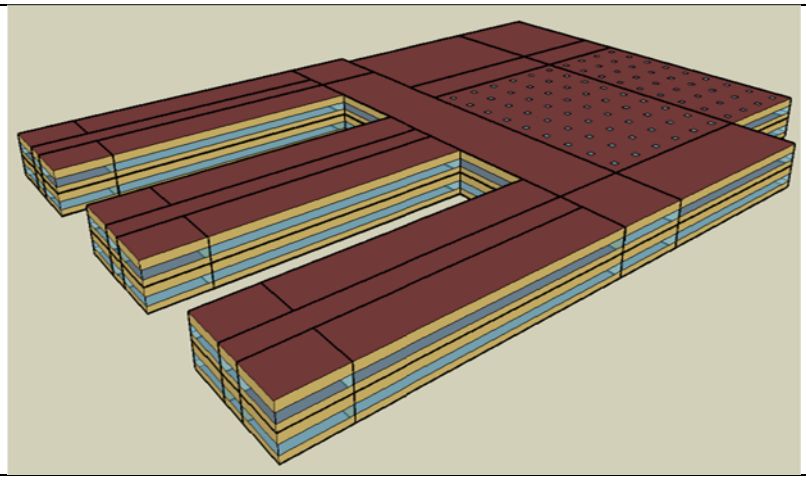
For more details about the Large Office prototype, please refer to https://www.energycodes.gov/sites/default/files/documents/PNNL_Scorecard_90_1Prototypes_Office_Large.xls

A.2 Standalone Retail

Specifications	Description
Total Floor Area (sq feet)	24,695 (178 ft x 139 ft)
Building shape	
Aspect Ratio	1.28
Number of Floors	1
Window Fraction (Window-to-Wall Ratio)	7.1% (Window Dimensions: 82.136 ft x 5 ft, 9.843 ft x 8.563 ft and 82.136 ft x 5 on the street facing facade)
Floor to floor height (feet)	N/A
Floor to ceiling height (feet)	20
Glazing sill height (feet)	5 ft (top of the window is 8.73 ft high with 3.74 ft high glass)
Exterior walls construction	Concrete Block Wall: 8 in. CMU+Wall Insulation+0.5 in. gypsum board
HVAC configurations	
Heating type	Gas furnace inside the packaged air conditioning unit for back_space, core_retail, point_of_sale, and front_retail. Standalone gas furnace for front_entry.
Cooling type	Packaged air conditioning unit for back_space, core_retail, point_of_sale, and front_retail; No cooling for front_entry.
Distribution and terminal units	Constant air volume air distribution 4 single-zone roof top units serving four thermal zones (back_space, core_retail, point_of_sale, and front_retail)

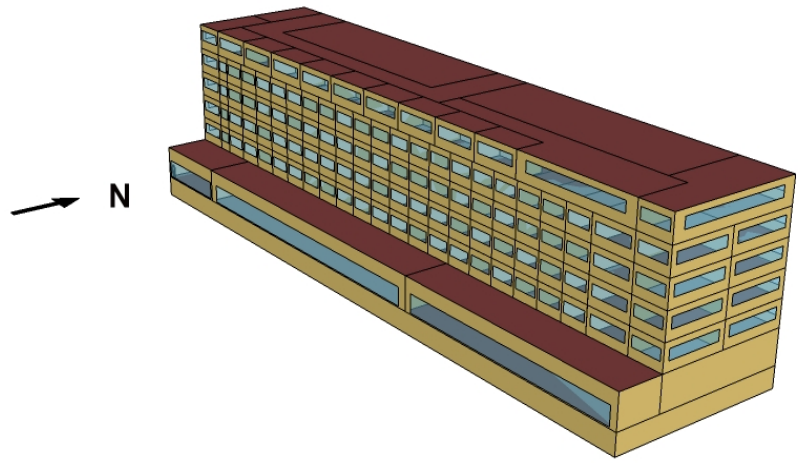
For more details about the Standalone Retail prototype, please refer to https://www.energycodes.gov/sites/default/files/documents/PNNL_Scorecard_90_1Prototypes_Retail_Standalone.xls

A.3 Secondary School

Specifications	Description
Total Floor Area (sq feet)	210,900 (340 ft x 460 ft)
Building shape	
Aspect Ratio	1.4
Number of Floors	2
Window Fraction (Window-to-Wall Ratio)	33% Ribbon window across all facades on both floors
Floor to floor height (feet)	13
Floor to ceiling height (feet)	13
Glazing sill height (feet)	3.6 (top of the window is 8.1 ft high with 4.5 ft high glass)
Exterior walls construction	Steel-Framed Walls (2X4 16IN OC) 0.4 in. Stucco+5/8 in. gypsum board + wall Insulation+5/8 in
HVAC configurations	
Heating type	1. Gas furnaces inside packaged air conditioning units 2. Gas-fired boiler
Cooling type	1. Packaged air conditioner 2. Air-cooled Chiller
Distribution and terminal units	1. CAV system: direct air from the packaged unit 2. VAV System: VAV terminal box with damper and hot water reheating coil Zone Control Type: minimum supply air at 30% of the zone design peak supply air

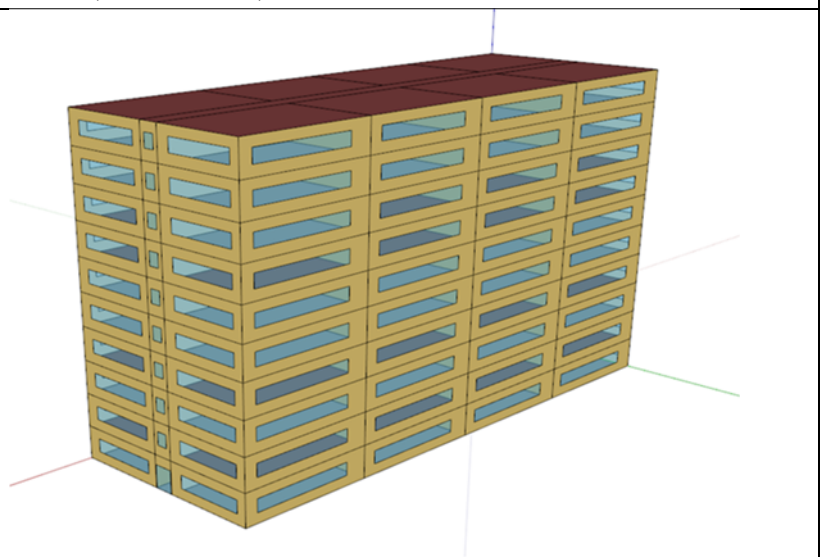
For more details about the Secondary School prototype, please refer to https://www.energycodes.gov/sites/default/files/documents/PNNL_Scorecard_90_1Prototypes_School_Secondary.xls

A.4 Large Hotel

Specifications	Description
Total Floor Area (sq feet)	122,132
Building shape	
Aspect Ratio	Ground floor: 3.79 (284 ft x 75 ft) All other floors: 5.07 (284 ft x 56 ft)
Number of Floors	6 above-ground floors plus one basement (284 ft x 75 ft)
Window Fraction (Window-to-Wall Ratio)	South: 36.7%, East: 24.5%, North: 26.0%, West: 24.5% Total: 30.2%
Floor to floor height (feet)	Basement: 8 ft Ground floor: 13 ft 2nd - 6th floors: 10 ft
Floor to ceiling height (feet)	same as above
Glazing sill height (feet)	6 in. in ground floor, 3.6 ft. in upper floors
Exterior walls construction	Mass Wall: 8 in. CMU, wall insulation and 0.5 in. gypsum board
HVAC configurations	
Heating type	One gas-fired boiler
Cooling type	One air-cooled chiller
Distribution and terminal units	Public spaces on ground floor and top floor: VAV with hot water reheating coils; Guest Rooms: dedicated outside air system + four-pipe fan-coil units.

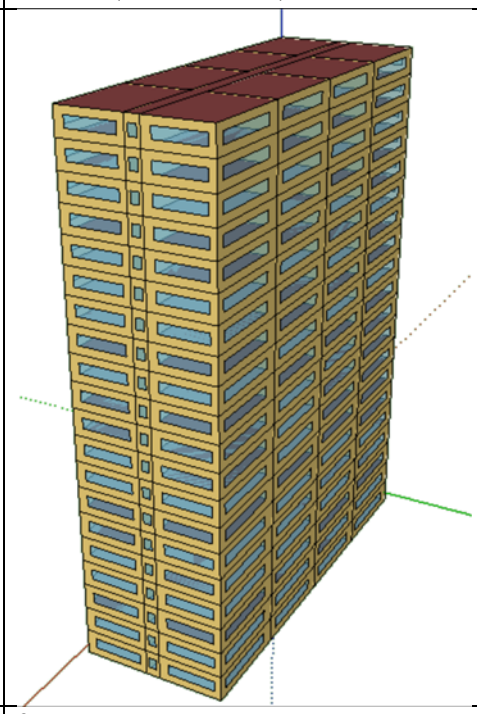
For more details about the Large Hotel prototype, please refer to https://www.energycodes.gov/sites/default/files/documents/PNNL_Scorecard_90_1Prototypes_Hotel_Large.xls

A.5 10-Story High-Rise Apartment

Specifications	Description
Total Floor Area (sq feet)	84,360 (152 ft x 55.5 ft)
Building shape	
Aspect Ratio	2.75
Number of Floors	10 (ground floor has 4 apartment units, one mechanical room, one lobby/office and two stairwells. Each of upper floors has 8 apartment units)
Window Fraction (Window-to-Wall Ratio)	South: 30%, East: 30%, North: 30%, West: 30% Average Total: 30%
Floor to floor height (feet)	10
Floor to ceiling height (feet)	10 (No drop-in ceiling plenum is modeled)
Glazing sill height (feet)	3 ft (14 ft wide x 4 ft high)
Exterior walls construction	Steel-Frame Walls (2X4 16IN OC) 0.4 in. Stucco+5/8 in. gypsum board + wall Insulation+5/8 in. gypsum board
HVAC configurations	
Heating type	Packaged terminal air conditioner (PTAC) with boiler. Makeup unit for outdoor air (rooftop DX unit with gas furnace)
Cooling type	Packaged terminal air conditioner (PTAC) Makeup unit for outdoor air (rooftop DX unit with gas furnace)
Distribution and terminal units	Constant volume

For more details about the High-Rise Apartment prototype, please refer to scorecard spreadsheet.

A.6 20-Story High-Rise Apartment

Specifications	Description
Total Floor Area (sq feet)	168,720 (152 ft x 55.5 ft)
Building shape	
Aspect Ratio	2.75
Number of Floors	20 (ground floor is retail spaces and upper floors are apartment units)
Window Fraction (Window-to-Wall Ratio)	South: 45%, East: 45%, North: 45%, West: 45% Average Total: 45%
Floor to floor height (feet)	10
Floor to ceiling height (feet)	10 (No drop-in ceiling plenum is modeled)
Glazing sill height (feet)	2 ft (14 ft wide x 7 ft high)
Exterior walls construction	Steel-Frame Walls (2X4 16IN OC) 0.4 in. Stucco+5/8 in. gypsum board + wall Insulation+5/8 in. gypsum board
HVAC configurations	
Heating type	Water Source Heat Pumps Makeup unit for outdoor air (rooftop DX unit with gas furnace)
Cooling type	Water Source Heat Pumps Makeup unit for outdoor air (rooftop DX unit with gas furnace)
Distribution and terminal units	Constant volume

For more details about the High-Rise Apartment prototype, please refer to scorecard spreadsheet.

Appendix B
Energy End-Use Breakdown Results

Table 23 Annual Energy Usage for Buildings in New York in Climate Zone 4A

CZ 4A	10-Story Apartment		20-Story Apartment		Large Hotel		Large Office		Secondary School		Stand-alone Retail	
	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2
ASHRAE 90.1-2013												
Heating	0.000	0.118	0.372	0.105	0.000	0.085	0.002	0.074	0.000	0.035	0.000	0.038
Cooling	0.907	0.000	1.224	0.000	2.778	0.000	2.061	0.000	1.617	0.000	1.387	0.000
HVAC Auxiliaries	0.565	0.565	0.783	0.783	2.168	2.168	1.714	1.714	1.455	1.455	2.304	2.304
Lighting	1.205	0.000	1.401	0.000	2.271	0.000	1.967	0.000	2.445	0.000	5.776	0.000
Miscellaneous Load	3.655	0.000	3.589	0.000	6.251	0.000	9.266	0.000	3.384	0.000	2.186	0.000
Service Water Heating	0.000	0.154	0.000	0.151	0.206	0.151	0.000	0.010	0.203	0.021	0.000	0.033
Total	**6.333**	**0.838**	**7.369**	**1.039**	**13.674**	**2.404**	**15.011**	**1.798**	**9.105**	**1.511**	**11.652**	**2.375**
NY Stretch Code												
Heating	0.000	0.049	0.194	0.042	0.000	0.059	0.003	0.068	0.000	0.030	0.000	0.042
Cooling	0.838	0.000	1.106	0.000	2.569	0.000	1.998	0.000	1.466	0.000	1.241	0.000
HVAC Auxiliaries	0.631	0.631	0.824	0.824	1.833	1.833	1.577	1.577	1.256	1.256	2.005	2.005
Lighting	0.740	0.000	0.882	0.000	1.771	0.000	1.488	0.000	1.182	0.000	4.041	0.000
Miscellaneous Load	3.629	0.000	3.563	0.000	5.858	0.000	9.118	0.000	3.255	0.000	2.186	0.000
Service Water Heating	0.000	0.090	0.000	0.088	0.124	0.091	0.000	0.010	0.203	0.021	0.000	0.033
Total	**5.838**	**0.770**	**6.569**	**0.954**	**12.154**	**1.983**	**14.184**	**1.655**	**7.363**	**1.307**	**9.473**	**2.080**
Percentage of Saving	**7.82%**	**8.17%**	**10.86%**	**8.21%**	**11.11%**	**17.52%**	**5.51%**	**7.97%**	**19.13%**	**13.50%**	**18.70%**	**12.41%**

Table 24 Annual Energy Usage for Buildings in New York in Climate Zone 5A

CZ 5A	10-Story Apartment		20-Story Apartment		Large Hotel		Large Office		Secondary School		Stand-alone Retail	
	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2
ASHRAE 90.1-2013												
Heating	0.000	0.166	0.530	0.151	0.000	0.130	0.002	0.109	0.000	0.053	0.000	0.062
Cooling	0.606	0.000	0.853	0.000	1.973	0.000	1.841	0.000	1.228	0.000	1.010	0.000
HVAC Auxiliaries	0.566	0.566	0.738	0.738	2.143	2.143	1.620	1.620	1.462	1.462	2.195	2.195
Lighting	1.205	0.000	1.401	0.000	2.634	0.000	2.281	0.000	2.522	0.000	6.171	0.000
Miscellaneous Load	3.655	0.000	3.589	0.000	6.250	0.000	9.266	0.000	3.384	0.000	2.186	0.000
Service Water Heating	0.000	0.162	0.000	0.159	0.206	0.157	0.000	0.011	0.203	0.022	0.000	0.034
Total	6.032	0.895	7.112	1.049	13.206	2.430	15.011	1.741	8.799	1.536	11.562	2.291
NY Stretch Code												
Heating	0.000	0.079	0.328	0.071	0.000	0.094	0.004	0.101	0.000	0.045	0.000	0.067
Cooling	0.578	0.000	0.788	0.000	1.853	0.000	1.789	0.000	1.133	0.000	0.923	0.000
HVAC Auxiliaries	0.641	0.641	0.783	0.783	1.798	1.798	1.464	1.464	1.260	1.260	1.908	1.908
Lighting	0.740	0.000	0.882	0.000	1.895	0.000	1.567	0.000	1.211	0.000	4.209	0.000
Miscellaneous Load	3.629	0.000	3.563	0.000	5.857	0.000	9.118	0.000	3.255	0.000	2.186	0.000
Service Water Heating	0.000	0.095	0.000	0.093	0.124	0.094	0.000	0.010	0.203	0.022	0.000	0.034
Total	5.588	0.814	6.344	0.947	11.527	1.987	13.942	1.576	7.063	1.327	9.226	2.010
Percentage of Saving	**7.37%**	**9.00%**	**10.80%**	**9.69%**	**12.71%**	**18.22%**	**7.12%**	**9.47%**	**19.73%**	**13.60%**	**20.20%**	**12.27%**

Table 25 Annual Energy Usage for Buildings in New York in Climate Zone 6A

CZ 6A	10-Story Apartment		20-Story Apartment		Large Hotel		Large Office		Secondary School		Stand-alone Retail	
	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2	Electric kWh /ft^2	Gas therms/ft^2
ASHRAE 90.1-2013												
Heating	0.000	0.165	0.549	0.152	0.000	0.126	0.002	0.106	0.000	0.049	0.000	0.060
Cooling	0.460	0.000	0.661	0.000	1.586	0.000	1.747	0.000	0.959	0.000	0.844	0.000
HVAC Auxiliaries	0.568	0.568	0.709	0.709	2.156	2.156	1.616	1.616	1.481	1.481	2.275	2.275
Lighting	1.205	0.000	1.401	0.000	2.635	0.000	2.280	0.000	2.527	0.000	6.505	0.000
Miscellaneous Load	3.655	0.000	3.589	0.000	6.250	0.000	9.266	0.000	3.384	0.000	2.186	0.000
Service Water Heating	0.000	0.170	0.000	0.166	0.206	0.161	0.000	0.011	0.203	0.023	0.000	0.035
Total	**5.888**	**0.903**	**6.909**	**1.027**	**12.833**	**2.443**	**14.910**	**1.733**	**8.554**	**1.553**	**11.810**	**2.369**
NY Stretch Code												
Heating	0.000	0.072	0.298	0.067	0.000	0.086	0.002	0.097	0.000	0.042	0.000	0.064
Cooling	0.478	0.000	0.662	0.000	1.508	0.000	1.710	0.000	0.883	0.000	0.735	0.000
HVAC Auxiliaries	0.625	0.625	0.758	0.758	1.796	1.796	1.468	1.468	1.290	1.290	1.955	1.955
Lighting	0.740	0.000	0.882	0.000	1.895	0.000	1.566	0.000	1.209	0.000	4.454	0.000
Miscellaneous Load	3.629	0.000	3.563	0.000	5.858	0.000	9.118	0.000	3.255	0.000	2.186	0.000
Service Water Heating	0.000	0.099	0.000	0.097	0.124	0.097	0.000	0.011	0.203	0.023	0.000	0.035
Total	**5.471**	**0.796**	**6.163**	**0.921**	**11.181**	**1.978**	**13.865**	**1.576**	**6.840**	**1.354**	**9.329**	**2.053**
Percentage of Saving	**7.08%**	**11.84%**	**10.79%**	**10.26%**	**12.87%**	**19.03%**	**7.01%**	**9.08%**	**20.04%**	**12.78%**	**21.01%**	**13.35%**

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