Residential Stretch Energy Code Analysis

Task 1: Develop Model Scenarios

Prepared by Performance Systems Development

For Massachusetts Department of Energy Resources

ENE-2020-016

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Background

The main goal of this task was to define the characteristics of six building and unit types that represent a spectrum of typical residential building types in Massachusetts. This set of characteristics includes basic design features and geometries that are representative of typical home or building designs. These characteristics, such as presence of a basement, will be held constant during a sensitivity analysis for which we will vary a variety of energy efficiency features to determine the most likely and cost-effective upgrades for hitting a series of target energy efficiency levels.

Methods

The Massachusetts DOER proposed six building types for the analysis, which PSD modified slightly following an analysis of HERS Rating energy model data to improve the representativeness of the prototype buildings or units. To determine the prototype building characteristics for five of the six building types, PSD used detailed HERS Rating data taken from the RESNET HERS Registry for ratings performed under PSD's HERS QA Provider services. (The sixth building is a 10-story tower, which we based on the *DOE Commercial Building Prototype Models*[1] and constructed using the corresponding OpenStudio measure[2].) While DOER supplied PSD with statewide RESNET Registry data on a basic set of data (HERS Index, conditioned floor area, building type), the statewide data set did not contain sufficient detail on building geometry and features to inform building prototype development.

To assess if the PSD Provider data was representative of Massachusetts as a whole, we compared the detailed Provider data with the statewide high-level data supplied by DOER. PSD Provider data range from January 1, 2017 through July 27, 2020 and statewide data range from January 1, 2017 through June 30, 2019. Our analysis showed that the Provider data is very representative of statewide home construction. As shown in Table 1, the average HERS Index is within 0.5 HERS points for single-family ratings and within two points for low-rise multifamily ratings. The average floor areas are close as well.

Table 1 Comparison of average HERS Index and conditioned floor area

	PSD Provider	Statewide
Single-family		
Count	4,058	10,387
Avg. HERS	53.31	53.78
Avg. CFA	3,159	3,103
Low-rise multifamily		
Count	1,262	6,434
Avg. HERS	54.44	56.19
Avg. CFA	1,314	1,174

[1] https://www.energycodes.gov/development/commercial/prototype_models
[2] https://bcl.nrel.gov/node/83661

The distributions of HERS Index scores for single-family homes (Figure 1) are nearly identical in the PSD Provider and statewide datasets with a large grouping at or just under HERS 55. The distributions appear to be close to normal with a slight skew toward the lower end of the range. For multifamily homes, the datasets were also similar in that they both had the greatest number of homes in the HERS 50-52 bin, although overall the PSD Provider data skewed slightly lower. With no glaring differences between PSD Provider data and statewide data, PSD believes the PSD Provider data is representative of homes statewide and is the best available source of detailed building characteristics data for rated homes in Massachusetts.

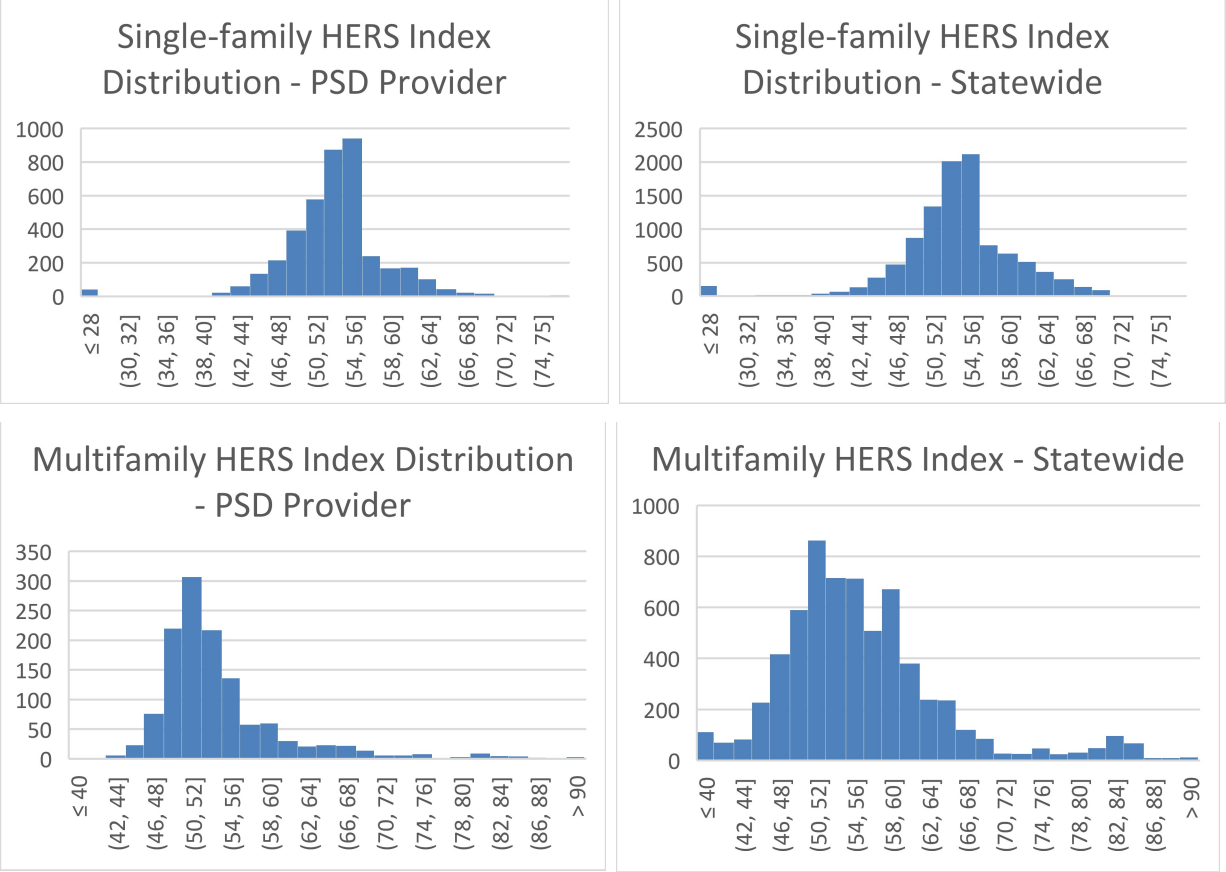


Figure 1. Distribution of single-family and multifamily HERS Index scores in the PSD Provider and statewide datasets

For the single-family detached home scenarios, PSD used Provider data to determine the typical foundation type and number of floors above grade. Using a subset of homes with those characteristics, we further narrowed the pool of homes having a certain number of bedrooms and presence or absence floors over garages. From this subset of sample homes, PSD determined the average conditioned floor area and then further narrowed the subset to a range of homes plus-or-minus 100-200 square feet of the average. From here, PSD analyzed a variety

of characteristics to determine the typical assembly areas or lengths by assembly location (e.g. between conditioned space and ambient).[3]

PSD also used the NMR 2015-2016[4] and 2019 Residential New Construction Baseline Studies[5] for additional justification of base home characteristics.

Because the RESNET data did not distinguish between townhouses and single-family detached homes, the process for determining townhouse characteristics was more granular. PSD identified 588 townhouses in our own Provider database to determine average conditioned floor area and typical number of floors above grade. From there, we reviewed multiple building files to assess common traits.

For the multifamily scenarios, PSD was able to identify several multifamily buildings of various sizes to assess how unit sizes and number of bedrooms might differ across a range of building sizes. We narrowed this analysis to Ekotrope data because it captures the number of units in a building when the user is modeling a single unit (as one does for a HERS Rating). We also used Census data for multifamily units in the Northeast to support unit floor area assumptions.

Prototype building model specifications

Single-family homes with three bedrooms in the PSD data had a significantly smaller average floor area than the initial DOER scenario of (see Table 2). For five-bedroom homes, the average floor area was almost the same as the initial DOER scenario around 4,000 square feet and the average townhouse area was significantly larger than the DOER scenario. Interestingly, the average townhouse is slightly larger than the average three-bedroom single-family detached home.

DOER did not specify unit sizes or number of bedrooms for the multifamily scenarios, so PSD relied on Provider data. Among single-floor apartment units (no stairs in the unit) the most common number of bedrooms was two and average floor area of those was 1,128, which closely matches the Census average for the Northeast of 1,153.

The location for all scenarios will be Worcester, Massachusetts, chosen for its representative weather conditions and geographic location.

Table 2. Comparison of DOER's initial scenario concepts with suggested floor areas and number of bedrooms.

Building Type	Unit Description per RFR-ENE0202-016		Unit Description per PSD HERS Rating Data Analysis	
	Floor area (sqft)	No. bedrooms	Floor area (sqft)	No. bedrooms
	2,500	3	2,100	3

[3]For fields other than basic fields like HERS Index and conditioned floor area, PSD excluded homes modeled in Ekotrope, as the RESNET data set did not provide consistent detailed characteristics from that rating tool. For the multifamily analysis, PSD was able to access valuable information from Ekotrope records within our provider database, rather than the RESNET export.

[4] http://ma-eeac.org/wordpress/wp-content/uploads/Single-Family-Code-Compliance-Baseline-Study-Volume-1.pdf

[5] http://ma-eeac.org/wordpress/wp-content/uploads/MA19X02-B-RNCBL_ResBaselineOverallReport_Final_2020.04.01_v2.pdf

Single-family detached home	4,000	5	4,050	5
Townhouse	1,600	3	2,100	3
Unit in small 6-unit building	Not specified	Not specified	1,400	3
Unit in large 4-story (wood-frame) over podium	Not specified	Not specified	1,150	2
Unit in 10-story tower (steel-frame) over podium	Not specified	Not specified	950	2
10-story tower (steel-frame) over podium, **whole building**	Not specified	Not specified	84,350	79 units, 1 office

Single-family homes – general (three- and five-bedroom, townhouse)

Prototype model inputs for the base single-family buildings are shown in Table 3.

Foundation type and conditioning status. PSD recommends that the base home for both single-family scenarios includes a basement because 86 percent of all single-family homes in the PSD data had basements. Further, PSD recommends the basement is unconditioned as 66 percent of homes with basements had floors over unconditioned basement. This closely matched the data from the NMR *2019 Residential New Construction Baseline/Compliance Study*, which showed 69 out of 100 sample homes had floors over unconditioned basements and 40 out of 100 had conditioned basements.[6] A random selection of building files from PSD data also anecdotally supports the selection of an unconditioned basement.

Floors above grade. In the PSD data, 72 percent of single-family homes had two floors above grade, so PSD recommends the prototype homes have two stories.

Attached garage. In the NMR *2015-2016 Massachusetts Single-Family Code Compliance/Baseline Study*, 85 percent of all sample homes (N=146) and 85 percent of the stretch code subset, N=46) had walls between conditioned space and a garage. In PSD's sample, 75% of all single-family homes had walls between conditioned space and a garage, indicating the presence of an attached garage. A random selection of building files from PSD data and input from a Massachusetts-based team member also anecdotally supports the selection of an attached garage.

Framing. PSD recommends all wood framing with 2x6 above-grade walls at 16" on-center, 2x10, 16" on-center roof rafters, ceiling joists, and floor joists. Per 2015-2016 NMR data, 95 percent of homes had 2x6 walls, 16" on-center. Forty-six percent of flat ceilings had 2x10 joists with a roughly equal number of homes having 2x8 and 2x20 ceiling joists. Vaulted ceilings were similar, but with an even higher proportion of 2x10s at 62 percent. Therefore, we recommend that flat and vaulted ceilings should be 2x10 at 16" on-center. These characteristics may be varied in the sensitivity analysis, especially for the Passive House target.

[6] PSD assumes that 9 homes had both conditioned and unconditioned basement areas.

Heating and cooling system type. In the 2019 NMR data, 75 percent had furnaces for the primary heating type and another 6 percent had air-source heat pumps (other than mini-splits or ground-source heat pumps). This indicates that over 80 percent of homes had forced-air systems. PSD recommends the base home have a force-air heating and cooling system.

Heating and cooling system location. NMR data show 50% of heating systems and 43% of cooling systems in unconditioned basements/enclosed crawl spaces, 31/33% in conditioned area, and 19/24% in attics. The PSD Provider data export from RESNET did not have this information, but we suggest the equipment is placed in an unconditioned basement.

Duct locations. PSD used average duct location percentages from provider data. On average, the highest proportion of ducts are in unconditioned basements, followed by conditioned space, and then vented attics.

Whole-house ventilation system. NMR appears to have analyzed exhaust fans without respect to their intent in terms of whole house versus local ventilation. We made this assumption because their count of bath fans was 322 for a sample of 100 homes. Thus, their data are not useful here. In the PSD Provider data, 84 percent of all homes, including single-family and low-rise multifamily, had exhaust-only mechanical ventilation. PSD suggests using exhaust-only ventilation for the base model with an airflow rate determined by the equation in section 403.6 of the Massachusetts energy code without taking the infiltration credit ($Q = .03 \times CFA + 7.5 \times (N_{br} + 1)$).

Water heater type and location. PSD data showed that roughly two-thirds of single-family homes had instantaneous water heaters. In the NMR data, they were less dominant at 43 percent, but still the most popular type of system. Sixty-five percent of these were in unconditioned basements/enclosed crawl spaces and 32 percent were in conditioned areas. PSD recommends the base home have an instantaneous water heater located in an unconditioned basement.

Appliances. PSD recommends the base homes have one of each of the following appliances: refrigerator, dishwasher, oven/range, clothes washer, clothes dryer. The presence of one of these appliances per home in the NMR data comprised an overwhelming majority of homes. Not all of these items are universally provided by the builder, but depending on the results of the sensitivity analysis, including appliances could help a builder achieve the stretch code target.

Single-family detached home with three bedrooms

Conditioned floor area. Out of all single-family homes in the sample, homes with three bedrooms make up the largest proportion at 46 percent. (The next most popular number of bedrooms is four, at 41 percent of the single-family sample.) The average conditioned floor area for single-family homes with three bedrooms is 2,077 sqft.

No room over garage. Roughly half of three-bedroom homes in this size category had floors over garages, but PSD decided to differentiate the three-bedroom home from the five-bedroom case by not including a room over the garage.

Assembly geometries. When determining the component areas (lengths for foundation walls), PSD analyzed a subset of three-bedroom homes that had conditioned floor areas ranging from 2,000 to 2,200 square feet.

Whole-house ventilation system. Exhaust-only, 92 cfm

$$Q = .03 \times CFA + 7.5 \times (N_{br} + 1)$$

$$Q = 0.03 \times 2{,}077 + 7.5 \times (3 + 1) = \mathbf{92\ cfm}$$

Single-family detached home with five bedrooms

Conditioned floor area. Five-bedroom homes were relatively rare in the sample at 4 percent of single-family homes but including a home of this size shows a broad range of home sizes overall. The average conditioned floor area for single-family homes with five bedrooms is 4,030 sqft.

Room over garage. Fifty-eight percent of homes in the NMR data had floors between conditioned space and a garage. PSD Provider data showed that 59 percent of homes in this size category with floors over garages.

Assembly geometries. When determining the component areas (lengths for foundation walls), PSD analyzed a subset of five-bedroom homes that had conditioned floor areas ranging from 3,800 to 4,000 square feet.

Whole-house ventilation system. Exhaust-only, 166 cfm

$$Q = .03 \times CFA + 7.5 \times (N_{br} + 1)$$

$$Q = 0.03 \times 4{,}030 + 7.5 \times (5 + 1) = \mathbf{166\ cfm}$$

Townhouse with three bedrooms

Conditioned floor area. The average conditioned floor area in the PSD's Provider data for townhouses was 2,087 square feet.

Unit location. PSD recommends selecting an end unit. If we assume that most townhouse buildings have three or four units, the most common unit type would be an end unit.

Garage. Yes

Room over garage. PSD decided not to include a room over the garage for this scenario, based on typical building practice.

Assembly geometries. When determining the component areas (lengths for foundation walls), PSD analyzed a subset of three-bedroom townhouses that had conditioned floor areas ranging from 2,000-2,200 square feet.

Whole-house ventilation system. Exhaust-only, 93 cfm

$$Q = .03 \times CFA + 7.5 \times (N_{br} + 1)$$

$$Q = 0.03 \times 2{,}087 + 7.5 \times (3 + 1) = \mathbf{93\ cfm}$$

Table 3. Prototype single-family home base building modeling inputs.

	SFD Small	SFD Large	Townhouse
Count	58	22	315
Number of bedrooms	3	5	3
Total conditioned floor area of homes used in analysis (sqft)	2,000-2,200	3,800-4,200	2,000-2,200
Floors above grade	2	2	2
Aspect ratio[7]			
Length (ft)	38	48	36

[7] Does not include footprint of room over garage.

Width (ft)	32	38	29
	Average Values		
Infiltration volume (cuft)	18,633	39,011	18,729
Floor areas (sqft)			
Cond/Uncond bsmt	1,204	1,844	1,044
Cond/Garage	NA	587	NA
Cond/Ambient	NA	25	NA
Ceiling areas (sqft)			
Cond/vented attic	1,011	1,448	1,044
Vaulted - Cond/Ambient	242	1,188	NA
Above-grade wall areas (sqft)			
Cond/Ambient	2,067	3,287	1,240
Cond/Attic	55	169	NA
Cond/Uncond bsmt	120	3,937	120
Cond/Garage	149	3,937	264
Adiabatic	NA	NA	576
Foundation wall areas (ft)			
Uncond bsmt/Ambient	136	174	72
Uncond bsmt common wall			36
Uncond bsmt/Garage	8	34	22
Height	8	8	8
Height above grade	1.5	1.5	1.5
Depth below grade	6.5	6.5	6.5
Window areas (sqft)			
Front	151	218	124
Left	29	71	0
Back	103	165	62
Right	23	75	0
Doors			
To exterior	48	48	48
To uncond bsmt	24	24	24
Ducts			
Return area	294	350	294
Supply area	370	458	370
Unconditioned basement (%)	59.7%	53.7%	59.7%
Conditioned space (%)	4.5%	21.6%	4.5%
Unconditioned attic exposed (%)	27.9%	18.2%	27.9%
Under attic insulation (%)	2.7%	6.5%	2.7%
Mechanical systems			
Air handler location	Uncond bsmt	Uncond bsmt	Uncond bsmt
Type	Gas furnace w/CAC	Gas furnace w/CAC	Gas furnace w/CAC
Water heater			
Instantaneous	Yes	Yes	Yes

Location	Uncond bsmt	Uncond bsmt	Uncond bsmt
Whole-house ventilation			
Exhaust-only ventilation	Yes	Yes	Yes
Ventilation rate (cfm/sqft)	92	166	93

Multifamily Scenarios – General

Prototype model inputs for the base multifamily buildings are shown in Table 4.

General characteristics like framing and heating and cooling system types will match those used in single-family homes. Exceptions included foundation type, duct and equipment location.

Equipment location. We plan to locate all equipment in conditioned space.

Duct location. Ducts in apartments are most commonly found in conditioned space, even when a unit is on the top floor.

Apartment in Small Six-unit Building

Conditioned floor area. The average floor area in the PSD data for units in multifamily buildings with a six units was 1,407.

Number of bedrooms. For 1,400-1500 sqft units, 53 percent had three bedrooms in the PSD data.

Unit location. PSD chose the building design to have three side-by-side units on the ground floor with three identical units located on a second floor above. For the energy modeling, PSD plans to use a top floor end unit.

Apartment in Large, Four-story Building, Wood Frame over Podium

Conditioned floor area. The average unit size for apartments built 2017-2019 in the Census data for the Northeast is 1,153 sqft and 70 percent of all apartments are below 1,200 sqft.

Number of bedrooms. For 1,000-1,100 square foot apartments, 88 percent had two bedrooms in the PSD data.

Unit location. PSD plans to model a middle unit in terms of vertical and horizontal location (i.e. other units or a hallway on 5 of 6 sides.

Apartment in 10-story tower, steel framing over podium

Conditioned floor area. The PNNL multifamily high-rise prototype has 79 units and one office, each having 950 square feet.

Number of bedrooms. The units in the PNNL multifamily high-rise prototype have two bedrooms.

Unit location. Ducts in apartments are most commonly found in conditioned space, even when located on the top floor.

Table 4. Prototype multifamily unit modeling specifications.

	Unit in small, 6-unit building	Unit in large 4-story building	Unit in 10-story tower
Count	23	Census	NA
Unit location	Top	Middle/middle	Middle/middle
Number of residential stories	2	4	10
Number of bedrooms	3	2	2
Number of units in building	6	48	79
Total conditioned floor area of units used in analysis (sqft)	1,400-1,500	1,100-1,200	950
Infiltration volume	12,672	10,395	8,550
Length	44	35	38
Width	32	33	25
	Average Values		
Floors (sqft)			
Cond/Ambient	NA	NA	
Adiabatic	1,408	1,155	950
Ceilings (sqft)			
Cond/vented attic	1,408	NA	
Adiabatic	NA	1,155	950
Above-grade walls (sqft)			
Cond/Ambient	864	264	212
Adiabatic	352	968	704
Windows (sqft)			
Front	58	132	100
Left	58	NA	NA
Back	58	NA	NA
Right	NA	NA	NA
Ducts			
Return area	392	310	257
Supply area	145	115	95
Conditioned space (%)	100	100	100
Water heater			
Instantaneous	Yes	Yes	Yes
Whole-house ventilation			
Exhaust-only ventilation	Yes	Yes	Yes
Ventilation rate (cfm/sqft)	72	57	50

Whole-building 10-story tower, steel framing over podium

The whole-building model for the 10-story tower with steel framing over a podium is taken from the PNNL prototype for a multifamily high-rise building. PSD modified the prototype to include a podium over a parking garage. A full description of the building specifications may be found in Appendix A.

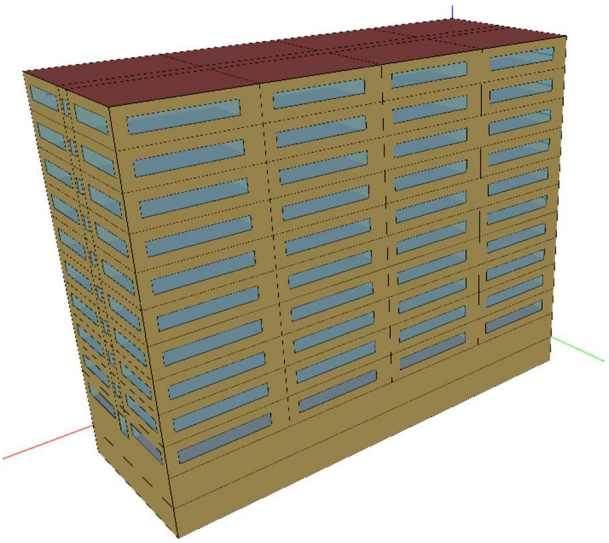


Figure 2. Building shape for the 10-story tower modeling scenario.

Baseline descriptions

Residential Baseline 1: 2020 MA Stretch Code (HERS 55)

PSD's proposed values for measures impacting energy efficiency are found in the right-hand column of Table 5 below. These values are primarily based on PSD Provider data for homes achieving a HERS 55, but in some cases data from the 2019 NMR baseline study was used.

Table 5. Prototype energy measure specifications for Baseline 1: 2020 MA Stretch (HERS 55).

	NMR Stretch Mean	PSD Rater HERS 55 Mean	Proposed Value
Envelope assembly R-values			
Floor over uncond bsmt	29.2	27	30
Rim/band joist			21
Above-grade wall	19.7	21	21
Flat ceiling	45.2	U-0.024	49
Vaulted	43.7		30
Infiltration			
ACH50		2.6	3
Windows			

U-factor	0.28	0.28	0.28
SHGC		0.29	0.29
Mechanicals			
Furnace AFUE	94	94.8	95
CAC SEER	14.2	13.4	14
Inst. Water heater EF	0.94		0.94
Pipe insulation R			3
Ducts			
Duct leakage to outside - small SFD and townhouse (cfm)		51	51
Duct leakage to outside - large SFD (cfm)		109	109
Ducts in attic R-value		8	8
Ducts in uncond bsmt R-value		6	6
Flow rates (gpm)			
Bathroom sink	1.4		Low flow unchecked
Showerhead	2.3		
Kitchen sink	1.7		
Appliances			
Dryer EF/MEF		2.7	2.7
Washer LER		244	244
Refrigerator (kWh/yr)		633	633
Dishwasher (kWh/yr)		254	254
Lighting			
% LED		75	75

Residential Baseline 2: 2021 IECC (HERS 55 + prescriptive changes)

Under 2021 IECC R407.2, the ERI must be 5% less than the otherwise required value (55 x 0.95 = 52.3). Model specifications are to be determined in the Task 2 BEopt analysis.

PSD would like to discuss with DOER if there are any other prescriptive/mandatory items that we should be considering.

10-story tower baseline 2: MA 2020 ASHRAE 90.1 Stretch Code

The energy use indices for the ASHRAE 90.1 Stretch Code Baseline for an electrically heated and gas heated prototype building were determined below. The first step was to take the 90.1-2013 baseline building and add what we believe to be the two most popular Efficiency Package Options; this sets the baseline above which a 10 percent EUI reduction must be achieved to meet the stretch code. The 10 percent lower EUI shown below sets the baseline EUI for comparison against target scenarios in the Task 2 analysis.

Table 6. Site EUI in kBtu/sqft for the electrically heated and gas-heated prototype buildings

Model	90.1-2013 Baseline Building			90.1-2013 Baseline Building (including C406.1 HVAC and Lighting Options) PTAC: 88% Eff Boiler +10% Increased EER + 10% LPD PTHP: 10% Increased COP / EER + 10% LPD			Site EUI Reduction of 10%	MA DOER "Stretch" Baseline - Site EUI (kBtu/ft²)
HVAC	**Fuel**	**Usage**	**Site EUI (kBtu/ft²)**	**Fuel**	**Usage**	**Site EUI (kBtu/ft²)**	**Site EUI (kBtu/ft²)**	**Site EUI (kBtu/ft²)**
PTAC	Electricity (kWh)	976,575	77.12	Electricity (kWh)	840,089	76.29	7.63	**68.66**
	Natural Gas (Therms)	3,173		Natural Gas (Therms)	3,568			
PTHP	Electricity (kWh)	912,736	53.25	Electricity (kWh)	888,236	52.26	5.23	**47.03**
	Natural Gas (Therms)	1,377		Natural Gas (Therms)	1,377			

Preliminary measures to achieve the 10 percent better than ASHRAE 90.1-2013 (including Efficiency Package Options) include:

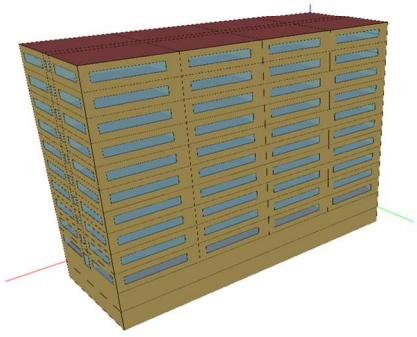
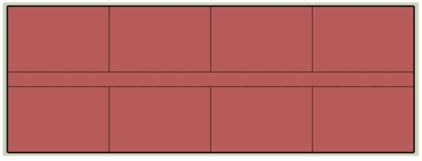
Improvement Number	OpenStudio Measure Name	Improvement Description
1	ZeroEnergyMultifamily	Add MF AEDG Net Zero HVAC System Type to apartments 1) Minisplit Heat Pumps with DX DOAS 2) Minisplit Heat Pumps with ERVs 3) Four-pipe Fan Coils with central air-source heat pump with DX DOAS 4) Four-pipe Fan Coils with central air-source heat pump with ERVs
2	AdvancedLightingControls	Reduced Base Building Corridor / Apartment LPD by defined amounts
3	Create Parametric Schedules	Reduced Base Building Apartment Hard Wired Lighting schedules by defined amount to represent occupant lighting controls

4	AddRooftopPV	Add Rooftop PV to building using different percentages of roof area
5	Modified version of MultifamilyCentralWaste-WaterHeatPump	Evaluate a Central Heat Pump Water Heater with Outdoor condenser to server DHW
6	Zero Energy Multifamily	Model improved fenestration performance for window surfaces using AEDG MF Net Zero Envelope Guidelines
7	Zero Energy Multifamily	Add additional exterior insulation to Evaluate High Performance Exterior Wall and Roof surfaces using AEDG MF Net Zero Envelope "Package" Guidelines
8	Modified version of Zero Energy Multifamily measure	Model reduced Infiltration rates specified in ASHRAE AEDG MF Net Zero Guide

Appendix A: 10 Story MF Tower Baseline Building Modeling Specifications

DOER 10 Story MF Tower Baseline Building Modeling Specifications

Pacific Northwest National Laboratory, updated on October 18, 2018

	Item	Descriptions
Program		
	Vintage	**ASHRAE 90.1-2013, including HVAC and Lighting options from C406.1**
	Location (Representing 8 Climate Zones)	Weather File: Worcestor, MA TMY3 (Hourly Weather and Design Day)
	Available fuel types	Model 1: Gas, Electricity Model 2: Electricity Only
	Building Type (Principal Building Function)	**Multifamily**
	Building Prototype	**High-Rise Apartment**
Form		
	Total Conditioned Floor Area (ft2)	84,351 (152 ft x 55.5 ft)
	Building shape	
	Aspect Ratio	2.75
	Number of Floors	Conditioned: 10 Floors Unconditiond: 2 Floors
	Window Fraction (Window-to-Wall Ratio)	South: 25%, east: 25%, north: 25%, west: 25% average total: 25%
	Window Locations	See image
	Shading Geometry	None
	Azimuth	Long axis of the building faces (North - South)
	Thermal Zoning	Each floor has 8 apartments except ground floor (7 apartments and 1 office with equivalent apartment area) Total 8 apartments per floor with corridor in center. Zone depth is 25 ft for each apartment from side walls and each apt is 25' x 38' (950 ft²). 2 Stories (one above grade one below grade) representing an unconditioned parking garage. 
	Floor to floor height (ft)	10
	Floor to ceiling height (ft)	10 (No drop-in ceiling plenum is modeled)
	Glazing sill height (ft)	3 ft (4 ft high windows)

Architecture	
Exterior walls	
Construction	Steel-frame walls (2X4 16 in o.c.)
R-value (h * ft^2 * °F / Btu)	Overall Wall Assemby R-18.18 Wall Insulation Layer R-17.33
Dimensions	Based on floor area and aspect ratio
Tilts and orientations	Vertical
Roof	
Construction	Built-up roof:
R-value (h * ft^2 * °F / Btu)	IEAD Roof R-31.25 Residential; roofs, insulation entirely above deck
Dimensions	Based on floor area and aspect ratio
Tilts and orientations	Horizontal
Window	
Dimensions	Based on window fraction, location, glazing sill height, floor area and aspect ratio
Glass-Type and frame	Hypothetical window with a weighted U-factor and SHGC
U-factor (Btu / h * ft^2 * °F)	Dbl Ref-D Clr 6mm/13mm U: 0.48 SHGC: 0.40
SHGC (all)	
Visible transmittance	Same as above requirements
Operable area	100%
Skylight	
Dimensions	Not Modeled
Glass-Type and frame	NA
U-factor (Btu / h * ft^2 * °F)	
SHGC (all)	
Visible transmittance	
Foundation	
Foundation Type	Slab-on-grade floors (unheated)
Construction	8" concrete slab poured directly on to the earth
Slab on grade floor insulation Level	Typical Insulated Carpeted 8in Slab Floor
Dimensions	Based on floor area and aspect ratio
Interior Partitions	
Construction	2 x 4 uninsulated stud wall
Dimensions	Based on floor plan and floor-to-floor height
Internal Mass	8 lbs/ft^2 of floor area
Air Barrier System	
Infiltration	Peak infiltration: 0.112 cfm/sf of above grade exterior wall surface area, adjusted by wind

HVAC	
System Type	
Heating type	PTHP
Cooling type	
Distribution and terminal units	Constant volume
HVAC Sizing	
Air Conditioning	Autosized to design day
Heating	Autosized to design day
HVAC Efficiency	
Air Conditioning	90.1-2013 Baseline: Cooling EER 10.8 - (0.213 x Capacity / 1000) Heating COP 3.7 - (0.052 x Capacity / 1000)
Heating	**MA DOER Stretch Code: EER = 10% better then 90.1-2013, COP = 10% better then 90.1-2013**
HVAC Control	
Thermostat Setpoint	75°F Cooling/70°F Heating
Thermostat Setback	No setback for apartments
Supply air temperature	
Economizers	None
Ventilation	Apartments 0.058 cfm / ft2
Demand Control Ventilation	None
Energy Recovery	None
Supply Fan	
Fan schedules	See under **Schedules**
Supply Fan Total Efficiency (%)	90.1-2013 Baseline Fan Efficiency: 38% **Mass DOER Stretch Fan Efficiency: 50%**
Supply Fan Pressure Drop	90.1-2013 Baseline Pressure Drop: ~ 0.99 Inches of water (Depending on the fan supply air cfm) **MASS DOER Stretch Code Pressure Drop: 0.25 Inches of water**

Service Water Heating	
SWH type	Central water heater with storage tank
Fuel type	Natural gas
Thermal efficiency (%)	Requirements in codes or standards
Tank Volume (gal)	600 (central)
Water temperature setpoint	140 F
Water consumption	See under **Schedules**

Internal Loads & Schedules

Lighting	
Average power density (W/ft^2)	90.1-2013 Baseline Apt / Corridor / Office / Parking Garage LPD: 1.07 / 0.792 / 1.11 / 0.19 **MASS DOER Stretch Code Apt / Corridor / Office / Parking Garage LPD: 0.963 / 0.712 / 1.00 / 0.171**
Schedule	See under **Schedules**
Daylighting Controls	In office space only
Occupancy Sensors	For parking garage lighting
Plug load	
Average power density (W/ft^2)	In Apartments, Non Hard Wired Lights modeled as 0.27 WSF. 0.62 W/ft² daily peak per apartment, including all the home appliances See under **Plug Load** for the detailed calculations
Schedule	See under **Schedules**
Occupancy	
Average people	In Apartments, 384 sqft per prson
Schedule	See under **Schedules**

Misc.

Elevator	
Quantity	1
Motor type	Traction
Peak Motor Power (watts/elevator)	20,370
Heat Gain to Building	Interior
Peak Fan/lights Power (watts/elevator)	161.9
Motor and fan/lights Schedules	See under **Schedules**
Exterior Lighting	
Peak Power (W)	10720 Watts of Exterior Lighting Peak Power
Schedule	Astronomical Clock used to control exterior lighting