RetrofitNY Cost-Compression Study Phase Two:

Mid-Rise Opportunities for Cost-Effective Improvements in Net Zero-Level Performance Multifamily Residences

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RetrofitNY
Cost-Compression Study Phase Two:

Mid-Rise Opportunities for Cost-Effective Improvements in Net Zero-Level Performance Multifamily Residences

Addendum to Report 20-16

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Notice

Abstract

New York State Energy Research and Development Authority's (NYSERDA) Request for Proposal (RFP) 3750 RetrofitNY High-Performance Retrofit Solutions Design aimed to spark the creation of standardized, scalable solutions and processes to improve the performance of multifamily residential buildings in New York State. The phase two report includes functional specifications to achieve a net zero or near-net zero level of performance in the one- to three-story, low-rise typology for multifamily residential housing in New York State. This addendum focuses on the corresponding specifications to achieve a near-net zero level of performance in the four- to seven-story, mid-rise typology for multifamily residential housing in New York State.

Detailed information is presented on the window, wall, roof, foundation, air tightness, heating, cooling, dehumidification, domestic hot water, and ventilation system efficiencies and loads that correspond to the target performance levels. These figures are provided for use in sizing and designing solutions that will be aligned with the target market's needs. Target price points for comprehensive solutions are also provided.

Keywords

Net zero, construction cost, incremental cost, retrofit cost, RetrofitNY, PON 3750, electrification, air source heat pumps, energy-recovery ventilation, envelope improvement, cost compression, specification, EUI, energy use intensity, mid-rise, multifamily

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Executive Summary

This report is an addendum to the RetrofitNY Cost-Compression Study Phase Two: Opportunities for Cost-Effective Improvements in Net Zero-Level Performance Multifamily Residences, prepared by Steven Winter Associates for New York State Energy Research and Development Authority (NYSERDA) and dated May 10, 2020. The phase two report includes functional specifications to achieve a net zero or near-net zero level of performance in the one- to three-story, low-rise typology for multifamily residential housing in New York State. This addendum includes corresponding specifications for four- to seven-story midrise multifamily residential housing in New York State based on the modeling and analysis of a typical six-story site.

For the four- to seven-story mid-rise buildings, a site Energy Use Intensity (EUI) of no more than about 10–15 kilo-British thermal units per square foot (kBtu/SF) would be needed to achieve a net zero solution using roof mounted solar photovoltaic (PV) panels, as a result of the greater occupied square footage per usable roof area. This low-energy usage needed to achieve net zero energy (NZE) performance via roof-mounted solar PV is next to impossible to achieve in the studied climate. As a result, this addendum presents functional specifications for high performance, short of NZE.

The following functional specifications are presented for achieving high performance for the studied typology. The EUI target assumes a heat pump water heater is used for domestic water heating.

Table ES-1. EUI and Performance Targets for Four- through Seven-Story Multifamily Buildings

Metric	Performance Target
Heating/cooling demand (i.e., energy delivered to the space regardless of equipment efficiency)	12 kBtu/ft^2/yr
Dehumidification	0.012 lbs/lb
Energy recovery ventilations rates	20 CFM/bath and 25 CFM/kitchen exhaust with corresponding supply (min 15 CFM/person)
Domestic hot water supply	Load modeled per EERE DHW Event Generator
Overall building EUI (four- to seven-story)	25 kBtu/ft^2/yr (CZ 4&5), 26 kBtu/ft^2/yr (CZ 6)

In addition to the requirements listed above, the following criteria are also recommended:

- It is recommended that the combined space heating and cooling site EUI not exceed 6 kBtu/ft^2·year. (NOTE: EUI includes efficiency of equipment whereas heating/cooling demand does not. This EUI includes energy usage of vent fans and auxiliary power draws.)
- Minimum heating season space temperature: 68°F (daytime: 6 a.m.–1:00 p.m.), 62°F (nighttime: 10 p.m.–6 a.m.) which aligns with New York City code requirements.
- Maximum cooling season space temperature: 78°F as encouraged by NYC for low-intensity cooling to prevent adverse health effects.
- Apartment ventilation will be continuous and comply with the following:
  - The average daily air change due to ventilation should be between 0.3 and 0.5 air changes per hour (ACH) when possible to ensure adequate ventilation while preventing overly dry air.
  - Exhaust and supply streams should be balanced within 10% of each other as measured at the ventilation unit.
- Lighting and plug load EUI assumptions should be no less than 12 kBtu/ft^2 per year.
- It is recommended that the domestic hot water site EUI not exceed 8 kBtu/ft^2 per year. The calculation must include plant, distribution losses and pumping energy. (NOTE: EUI includes efficiency of equipment).

Additional detailed information is presented on the window, wall, roof, foundation, air tightness, heating, cooling, dehumidification, domestic hot water, and ventilation system efficiencies and loads that correspond to the target EUIs presented above. These figures are provided for use in sizing and designing solutions that will be aligned with the target market's needs.

Target price points for envelope and mechanical solutions are also provided. These price points are calculated based on a payback on avoided utility cost from a high-performance solution plus the base cost of business as usual replacement strategies.

A comprehensive summary of all recommended efficiencies and performance targets for buildings that are one to seven stories in height is shown in Table 2.

Table ES-2. Summary of Performance Targets and Component Efficiency Levels for Buildings with One to Seven Stories by Climate zone

	New York State Multifamily Building RetrofitNY Performance Specifications								
Building Height	1-2 Stories			3 Stories			4-7 Stories		
ASHRAE Climate Zone	4	5	6	4	5	6	4	5	6
Heating/Cooling Demand EUI Target [kBtu/ft2·yr]	12	12	12	12	12	12	12	12	12
Heating/Cooling EUI Target [kBtu/ft2·yr]	6	6	6	6	6	6	6	6	6
Dehumidification Maximum	0.012 lbs/lb								
Dehumidifcation % annual operating hours	90% with active cooling / 80% without active cooling								
Energy Recovery Ventilation Rates (continuous)	20 cfm bath / 25 cfm kitchen (min. 15 cfm per person)								
Domestic Hot Water Supply (as per EERE link)	EERE DHW Event Generator								
Overall Building Site EUI Target [kBtu/ft2·yr]	27	27	27	21	21	21	25	25	26
Opaque Vertical Walls	R-30	R-35	R-45	R-30	R-35	R-45	R-20	R-25	R-30
Windows	U-0.16								
Doors	R-2.5								
Roof	R-50	R-60	R-75	R-50	R-60	R-75	R-40	R-50	R-60
Heating Degree Days [65°F]	5200	5400< HDD 65F ≤ 7200	7200< HDD 65F ≤ 9000	5200	5400< HDD 65F ≤ 7200	7200< HDD 65F ≤ 9000	5200	5400< HDD 65F ≤ 7200	7200< HDD 65F ≤ 9000
Occupants	Number of beds +1								
Solar Heat Gain Coefficient	0.4						0.3		
Ventilation	84% effective								
Air Infiltration	1.5 ACH@50						1.0 ACH@50		
Domestic Hot Water (gal/person/day)	15 (electric resistance)			15 (heat pump water heater)					
Heating season minimum space temperature	68°F (6am-10pm) / 62°F (10pm-6am)								
Cooling season maximum space temperature	78°F								
Exhaust/supply stream balancing at ventilation unit	10%								
Lighting & Plugload EUI (assumed) [kBtu/ft2·yr]	≥12								
DHW Site EUI (incl. plant, distribution losses, pumping energy and efficiency of equipment) [kBtu/ft2·yr]	n/a						≤8		
Fixed Wall Air Infiltration per sf of wall area at 6.24 psf	0.06 CFM								
Window & Door Air Infiltration per sf of crack at 6.24 psf	0.10 CFM								
Water infiltration (under differential static pressure of 12 lb/sf after 15 minutes of exposure)	0								
Peak Cooling Load needed delivered to space at 5200 HDD per 1000 sf: Btu/hr (ton)	2470 (0.2)	n/a	n/a	2470 (0.2)	n/a	n/a	3110 (0.3)	n/a	n/a
Peak Cooling Load needed delivered to space at 5400 HDD per 1000 sf: Btu/hr (ton)	2250 (0.2)	2190 (0.2)	n/a	2250 (0.2)	2190 (0.2)	n/a	3420 (0.3)	2900 (0.2)	n/a
Peak Cooling Load needed delivered to space at 7200 HDD per 1000 sf: Btu/hr (ton)	n/a	2190 (0.2)	1820 (0.2)	n/a	2190 (0.2)	1820 (0.2)	n/a	2900 (0.2)	2770 (0.2)
Peak Cooling Load needed delivered to space at 9000 HDD per 1000 sf: Btu/hr (ton)	n/a	n/a	690 (0.1)	n/a	n/a	690 (0.1)	n/a	n/a	1700 (0.1)
Peak Heating Load needed delivered to space at 5200 HDD per 1000 sf: Btu/hr (ton)	5930 (0.5)	n/a	n/a	5930 (0.5)	n/a	n/a			
Peak Heating Load needed delivered to space at 5400 HDD per 1000 sf: Btu/hr (ton)	5640 (0.5)	6800 (0.6)	n/a	5640 (0.5)	6800 (0.6)	n/a	5160 (0.4)	5220 (0.4)	n/a
Peak Heating Load needed delivered to space at 7200 HDD per 1000 sf: Btu/hr (ton)	n/a	6800 (0.6)	5980 (0.5)	n/a	6800 (0.6)	5980 (0.5)	n/a	5220 (0.4)	5250 (0.4)
Peak Heating Load needed delivered to space at 9000 HDD per 1000 sf: Btu/hr (ton)	n/a	n/a	6780 (0.6)	n/a	n/a	6780 (0.6)	n/a	n/a	6000 (0.5)
Average Daily Water Draw in gal/day									
1-bedroom	46 total (30 hot / 16 cold)								
2-bedroom	58 total (37 hot / 21 cold)								
3-bedroom	70 total (45 hot / 25 cold)								
4-bedroom	81 total (52 hot / 29 cold)								
5-bedroom	93 total (60 hot / 33 cold)								
ERV fan power input per cfm at continuous flow	≤0.76/Watts per CFM								
ERV sound levels	25 dBA bedroom / 30 dBA extract room (bathroom/kitchen)								
Appliances									
Clothes Dryer	condensing or heat pump								
Stove/Oven	electric induction								
DHW min. temperature (instant delivery/storage)	120°F/140°F						124°F/140°F		
Cumulative total noise limit for heating/cooling system at resident open window	45 dBA								

1 Recommended Site Energy Use Intensity Target for Low- and Mid-Rise Typology

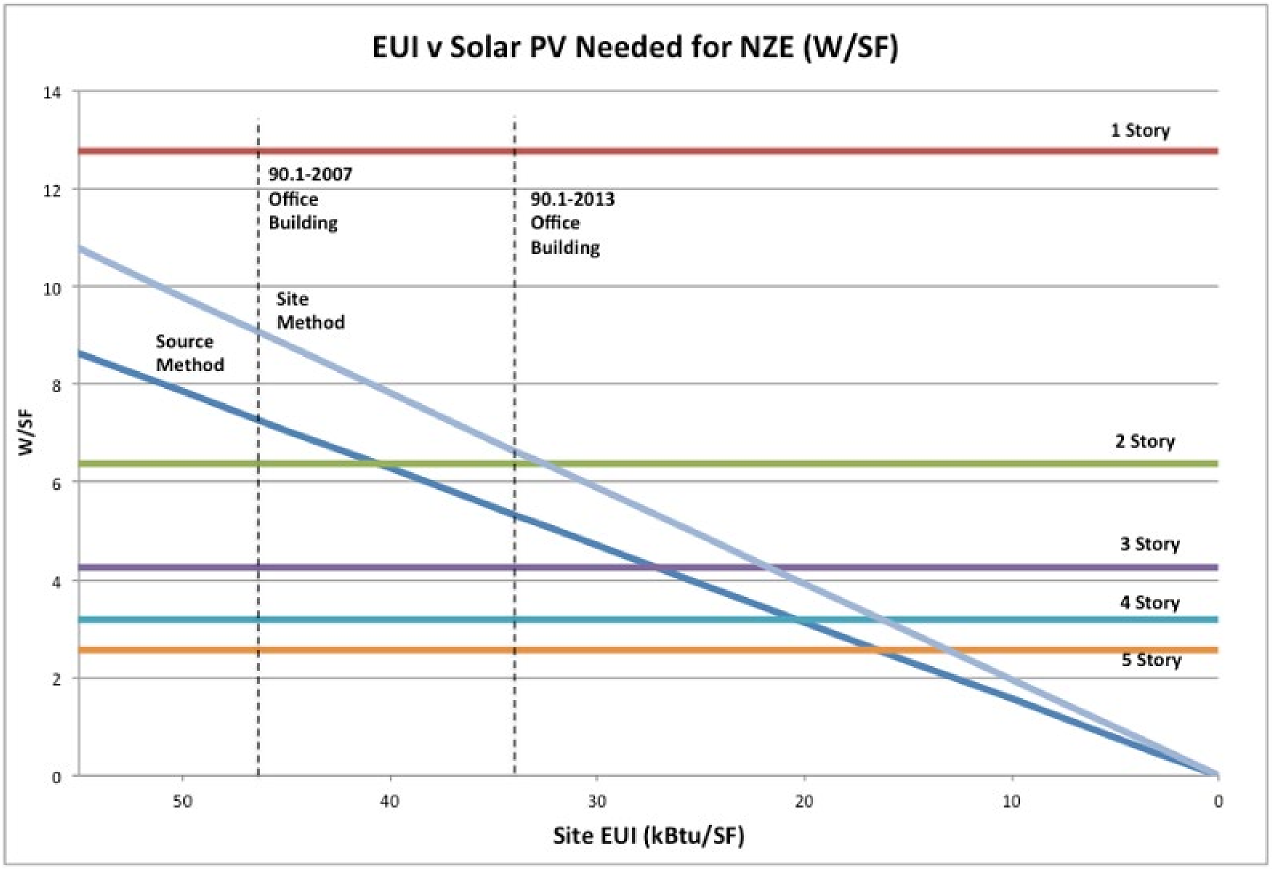
Steven Winter Associates' (SWA) recommended energy use intensity (EUI) target for the mid-rise typology is higher than the analyzed target for the three-story case studied in the previous report. The project team assessed EUI targets from two directions: the EUI target needed for net zero energy (NZE) performance was determined and modeling was conducted to verify which measures were needed to achieve that target EUI. A suite of measures applied to the models of low-rise buildings allowed for development of functional specifications that reduced the modeled performance to the NZE EUI target. The NZE EUI target and the modeled measure savings did not converge for the mid-rise buildings in the same way.

Modeling of a representative six-story building resulted in a higher site EUI than for the three-story, low-rise building case. No package of reasonable high-performance measures was able to reduce the site EUI in the six-story model down to a level that would be needed for NZE. Because the NZE target and the achieved modeled EUI did not converge, this report addendum outlines the functional specifications modeled and the site EUI that was achieved. The shortfall between achieved EUI and NZE target EUI results in the projected post-retrofit remaining site energy usage.

As can be seen in Figure 1, the taller the building, the lower the EUI must be to achieve net zero performance using roof installed PV only. The EUIs shown for buildings four stories and taller are next to impossible to achieve, making net zero energy performance for taller buildings with roof-mounted PV problematic.

Figure 1. Energy Use Intensities versus Solar PV needed for Net Zero Energy Performance (New Buildings Institute)

Source: Joshua Radoff)



There are several reasons NZE performance is not possible for these typologies. First, as multifamily buildings get taller, their common area energy end uses often get larger. Some of the factors driving up the EUIs of these taller buildings (which decreases NZE threshold) include the following:

- Domestic hot water (DHW) recirculation in buildings with central systems increases DHW and cooling loads.
- Consistent common area lighting that runs twenty-four hours a day is common in larger buildings, which have interior corridors and egress pathways.
- Taller buildings tend to have smaller apartments than their low-rise counterparts. This increases the number of appliances and people per square foot of space.
- Elevators become required in taller buildings, adding loads.
- Booster pumps are needed in some mid-rise locations and were assumed to be needed in this analysis.

Due to code, safety, and health concerns, there are limited opportunities to reduce these loads. Additionally, the equipment needed for the central systems is generally installed on the roof of taller buildings further reducing the amount of roof mounted PV that can be installed. Building integrated PV can be considered to help offset the EUI but its effectiveness/applicability may be drastically affected by shading from nearby buildings, orientation, and its slope. Where possible, ground mounted PV or installation on a neighboring building could be considered as well, but the site-specificity of that resource makes it impossible to generalize here.

2 Functional Specification for Mid-Rise Typologies

The following functional specifications for achieving high performance for the mid-rise typology are based on SWA's modeling of retrofitting a typical six-story site along with prior work performed for NYSERDA in this area. The values in Table 1 summarize the corresponding performance targets.

Table 1. Recommended Performance Targets

Metric	Performance Target
Heating/cooling demand (i.e., energy delivered to the space regardless of equipment efficiency)	12 $kBtu/ft^2$ per yr
Dehumidification	0.012 lbs/lb
Energy recovery ventilation rates	20 CFM/bath and 25 CFM/kitchen exhaust with corresponding supply (min 15 CFM/person)
Domestic hot water supply	Per EERE DHW Event Generator[a]
Overall building EUI	25 $kBtu/ft^2$ per yr (CZ 4&5), 26 $kBtu/ft^2$ per yr (CZ 6)

[a] See: https://www.energy.gov/eere/buildings/downloads/dhw-event-schedule-generator for further detail.

In addition to the requirements listed in Table 1, the following criteria are also recommended:

- It is recommended that the combined space heating and cooling site EUI not exceed 6 $kBtu/ft^2$ per year. (NOTE: EUI includes efficiency of equipment whereas heating/cooling demand does not. This EUI includes energy usage of vent fans and auxiliary power draws.)
- Minimum heating season space temperature: 68°F (daytime: 6 a.m.–10 p.m.), 62°F (nighttime: 10 p.m.–6 a.m.) which aligns with New York City code requirements.
- Maximum cooling season space temperature: 78°F as encouraged by NYC for low-intensity cooling to prevent adverse health effects.
- Apartment ventilation will be continuous and comply with the following:
  - The greater of 20 cubic feet per minute (CFM) per bathroom + 25 CFM per kitchen exhaust or 15 CFM per person based on number of bedrooms +1.
  - The average daily air change due to ventilation should be between 0.3 and 0.5 air changes per hour (ACH) when possible to ensure adequate ventilation while preventing overly dry air.
  - Exhaust and supply streams should be balanced within 10% of each other as measured at the ventilation unit.
- Lighting and plug load EUI assumptions should be no less than 12 $kBtu/ft^2$ per year.
- Mid-rise typologies are modeled to include heat pump water heaters. It is recommended that the domestic hot water site EUI not exceed 8 $kBtu/ft^2$ per year. The calculation must include plant, distribution losses and pumping energy. (NOTE: EUI includes efficiency of equipment).

2.1 Panelized Envelope Solutions for Mid-Rise Buildings

2.1.1 Recommended Building Envelope Efficiencies

Table 2 summarizes the recommended package of efficiencies for the envelope components for each of the three climate zones in New York State. These values correspond with the values derived in the RetrofitNY study and were confirmed through some simple Passive House Planning Package (PHPP) modeling for the studied typical six-story, mid-rise multifamily building in each of the three climate zones. Table 3 shows the results of the modeling and the range of values associated with the range of heating degree days for each climate zone. Assuming the recommended assumptions and criteria listed above, the mid-rise site EUI thresholds of 25 kBtu/ft^2 per year for climate zones 4 and 5 and 26 kBtu/ft^2 per year for climate zone 6 along with a combined heating/cooling energy demand of 12 kBtu/ft^2 per year can be met with these efficiency values for most locations in the State.

Table 2. Proposed Façade Efficiencies by Climate Zone

	Zone 4	Zone 5	Zone 6
Panelized envelope R value	R-20	R-25	R-30
Fenestration U values	U-0.16	U-0.16	U-0.16
Roof system R value	R-40	R-50	R-60

Table 3. Modeled Energy Use Intensities and Heating/Cooling Demand Results by Climate Zone

	Zone 4	Zone 5	Zone 6
Heating Degree Days [65°F]	5200	5400< HDD 65F ≤ 7200	7200< HDD 65F ≤ 9000
Heating + Cooling Demand [kBtu/ft^2 per yr] (i.e., energy delivered to the space regardless of equipment efficiency)	12	11	10-13
Heating + Cooling EUI [kBtu/ft^2 per yr]	6	6	6-8
Site EUI [kBtu/ft^2 per yr]	25	25	26-28

2.1.1.1 Modeling Assumptions

Proposed façade efficiencies were varied by climate zone per Table 2. The following assumptions were held constant across all climate zones:

- Occupants: number of beds +1
- Solar Heat Gain Coefficient: 0.3
- Doors: R-2.5
- Ventilation: 84% effective
- Infiltration: 1.0 ACH@50
- Domestic Hot Water: 15 gallons/person/day, central heat pump water heater for four-story buildings and higher

2.1.2 Infiltration Rates

The air leakage rate of the building following completion of the envelope improvements should be no higher than 1.0 air changes per hour at 50 pascals of pressure. Controlling infiltration rates through the envelope is paramount to ensuring performance and durability of the structure. Heating and cooling load calculations rely heavily on the assumptions made for this characteristic. Therefore, a detailed plan for implementing air tightness of the panelized approach is required along with a strategy for field testing the performance of the panelized walls, windows, and roof during and after construction. Details showing the air barrier strategy must be created for all connections, penetrations, and openings in the façade. Specific materials should be called out and compatibility between the sealants and building materials confirmed. All sealants should be in serviceable locations, long lasting, and easy to apply.

Factory testing of a mock-up must be conducted on each unique proposed panel solution and should include the following:

- Air infiltration: Fixed Wall: 0.06 CFM/ft^2 of wall area at 6.24 pounds per square foot (psf) per ASTM E283/Operable vents and doors: 0.10 CFM/ft^2 of crack at 6.24 psf per ASTM E283/ Continuous air and vapor control layers will be provided.
- Water Infiltration: No water infiltration will occur under a differential static pressure of 12 lb/ft^2 after 15 minutes of exposure in accordance with ASTM E331.

2.1.3 Overall Façade U-values

Recommendations for façade efficiencies are given in Table 2. These are guidelines and can be altered as long as the overall U-value for the building envelope including the windows does not exceed what it would otherwise have been if those recommended values are used. Calculations proving similar overall U-values are required. The items in the following sections must be included in the overall U-value calculations.

2.1.3.1 Panel Connections to Structures

Panel connections back to the structure can drastically reduce the overall performance of the façade if techniques for reducing thermal breaks are not incorporated. Thermally broken ties, clips, and rails should be used to make these connections. Three-dimensional thermal modeling should be utilized when determining the overall R-value of the panelized solutions.

2.1.3.2 Panel-to-Panel Joints

Panel connections traditionally prove to be large thermal bridges. These connections will be modeled using two- or three-dimensional thermal modeling to assess the magnitude of heat loss at these joints and to ensure condensation control has been maintained.

2.1.3.3 Window and Door Installation

Punched openings in the façade can represent a significant source of heat loss if not detailed properly. Window and door installation will be evaluated on a per linear foot basis using two-dimensional thermal modeling. Temperatures along the entire install must prove to be above the dewpoint at the winter design temperature for the location where the solution is to be installed. Interior conditions of 68°F and 50% relative humidity will be used to determine the dewpoint.

2.1.4 Bulk Water Management

A clearly delineated water management layer must be provided for the panelized system. Details showing the bulk water management strategy must be created for all connections, penetrations, and openings in the façade. Specific materials should be called out and compatibility between the sealants and building materials confirmed. All serviceable sealants will be in accessible locations, long lasting, and easy to apply.

2.1.5 Moisture Vapor Control

Moisture vapor will be controlled through a combination of proper levels of ventilation and the incorporation of a vapor control strategy within the panelized solution. A moisture analysis for each panelized system will be conducted according to ASHRAE Standard 160 Criteria for Moisture-Control Design Analysis in Buildings and must show that there is no potential for mold or decay on the interior surfaces of the building or within the panels.

A dewpoint analysis must also be conducted using two-dimensional thermal modeling to verify where the dewpoint falls within the wall assembly and that there is no potential for damage at that location.

2.1.6 Windows and Doors

The efficiency targets for the windows are listed in Table 2. Again, these are recommendations and can be altered if the overall U-value of the façade solution can be maintained. The target R-value for the doors in buildings with common exits is 2.5°F·ft^2·hr/Btu. For single-family homes, duplexes, and row houses where each dwelling unit has its own exit, the target value for doors should be R-7. The most efficient opaque doors, where fire rated assemblies are not required, are typically foam filled, fiberglass doors, which are readily available in cost-effective solutions. Storm doors are recommended to increase the efficiency of these components.

2.2 Mechanical Solution

Integrated product specifications for the mechanical solution should include design and performance considerations for consolidated HVAC solutions to deliver heating, cooling, ventilation, dehumidification, and domestic hot water for four- to seven-story, mid-rise multifamily residential housing in New York City.

Considerations for integrated HVAC solutions will include spatial constraints (including limited exterior space at the ground level), performance impacts, and installation considerations. All solutions will include open-source controls capable of connection to non-proprietary, cloud-based monitoring platforms. Controls interfaces for residents will be located in the occupied space.

2.2.1 RetrofitNY Results Summary

The RetrofitNY modeling summary results did not provide the peak heating or cooling loads (outputs the mechanical solution must meet) for either the interim or final designs. Therefore, SWA calculated both heating and cooling loads using the PHPP software for a six-story building with the same envelope and mechanical efficiencies recommended per climate zone in this functional specification. The model is described in greater detail in section 2.1. The results are displayed in Table 6.

Table 4. Peak Heating and Cooling Loads by Climate Zone

Loads		Cooling		Heating	
Zone	HDD	Btu/hr per 1000 ft^2	tons/1000 ft^2	Btu/hr per 1000 ft^2	tons/1000 ft^2
4	5200	3110	0.26	4400	0.37
5	5400	3420	0.29	5160	0.43
	7200	2900	0.24	5220	0.44
6	7200	2770	0.23	5250	0.44
	9000	1700	0.14	6000	0.50

2.2.1.1 Supplemental Domestic Hot Water Load Data

DHW loads are highly variable based on occupant density and resident schedule. The URLs in the notes below Table 7 are linked to tools provided by the United States Department of Energy and the National Renewable Energy Lab, and can be used to generate typical residential load profiles for residential units of varying size. Certain aspects of DHW use can be reduced by the installation of low-flow fixtures, but other end uses, such as filling pots and bathtubs, require a set volume of water regardless of in-unit intervention, which creates a minimum for the DHW water needed. DHW solutions will be able to meet typical usage profiles.

Table 5. Typical Domestic Hot Water Usage Profiles

Apartment Size	Avg Daily Draw (Hot + Cold) (gal per day)	Avg Daily Draw (Hot Only) (gal per day)	Avg Daily Draw (Cold Only) (gal per day)
One Bedroom	46	30	16
Two Bedroom	58	37	21
Three Bedroom	70	45	25
Four Bedroom	81	52	29
Five Bedroom	93	60	33

[a] https://www.energy.gov/eere/buildings/downloads/dhw-event-schedule-generator

[b] https://www.nrel.gov/docs/fy10osti/47685.pdf

2.2.1.2 Recommended Mechanical System Efficiencies

The proposed system must be able to meet the peak loads with some safety factor and do so efficiently enough to meet or improve upon the heating, cooling, and domestic hot water EUI targets provided. Tradeoffs on efficiency can be made between heating, cooling, and DHW efficiencies individually, but the solution must be efficient enough to stay under the sum of the EUI targets shown above.

2.3 System Interactions/Considerations

2.3.1 Dehumidification

The proposed solution will address dehumidification by providing (1) properly sized cooling units, (2) a dehumidification system in or additional to the ventilation system, or (3) a combination of both. Climate data, including cooling wet bulb and dry bulb design conditions, will be used to determine dehumidification load. The indoor humidity will remain under 0.012 lbs/lb for at least (1) 90% of annual operating hours if active cooling is provided or (2) 80% of annual operating hours without active cooling.

2.3.2 Ventilation

Minimum mechanical ventilation rates required by local building codes will be required for all systems (see IMC Section 403.3.1 for rates for R-2 occupancies above three stories in height).[1]

Figure 2. IMC Table 403.3.1.1: Minimum Ventilation Rates

TABLE 403.3.1.1
MINIMUM VENTILATION RATES

OCCUPANCY CLASSIFICATION	OCCUPANT DENSITY #/1000 FT^{2} [a]	PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE, R_p CFM/PERSON	AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE, R_a CFM/FT^{2} [a]	EXHAUST AIRFLOW RATE CFM/FT^{2} [a]
Private dwellings, single and multiple				
Garages, common for multiple units[b]	—	—	—	0.75
Kitchens[b]	—	—	—	25/100[f]
Living areas[c]	Based on number of bedrooms. First bedroom, 2; each additional bedroom, 1	0.35 ACH but not less than 15 cfm/person	—	—
Toilet rooms and bathrooms[g]	—	—	—	20/50[f]

1 https://codes.iccsafe.org/content/NYSMC2020P1/chapter-4-ventilation#NYSMC2020P1_Ch04_Sec403.3.1.1

Natural ventilation will not be relied on for meeting ventilation rates in occupied units or common areas.

All exhaust air will be routed through an energy or heat recovery ventilation unit (ERV/HRV) unless prohibited by code or when located a great distance from the nearest supply air intake to make it ineffective. Ventilation strategies should include methods for preventing freezing in the cores while providing the minimum required ventilation rates. Supply temperatures to the space will be no colder than 62°F in the heating season. Energy recovery ventilator (ERV) fan power input should be no higher than 0.76 Watts per CFM at continuous flow. Exhaust and supply flow rates will be balanced to within 10% of each other to ensure maximum recovery efficiency. Sound levels should be no higher than 25 decibels (dBA) in bedrooms and 30 dBa in extract rooms such as kitchens and baths. Note that sound levels in occupied spaces are driven largely by the grille and ductwork serving the space. Manufacturers can recommend maximum termination noise limits and/or suggested grille models for their systems.

Gas and electric dryers require make-up air if they exhaust over 200 CFM to the exterior. To reduce thermal bridging and air leakage around penetrations and remove the need for make-up air, it is recommended that exhaust dryers be eliminated and replaced with condensing or heat pump units.

2.3.3 Domestic Hot Water

The proposed domestic water heating solution will be capable of producing high-temperature hot water for instantaneous delivery of at least 124°F and/or storage of at least 140°F. These temperatures are seasonal minimums that may be exceeded but not reduced.

2.3.4 Heating and Cooling

Any proposed solution must maintain low enough noise output to comply with local noise ordinances. New York State towns and cities have individual official rules, but typically, noise from HVAC equipment must result in less than 45 dBa of noise at a resident's open window. This is a cumulative noise limit—with noise from individual products low enough so that an array of units deployed in a given building will not surpass the total noise limit.

Any product specification should utilize inverter-driven compressors and electronically commutated motors (ECM) wherever applicable. The target market of retrofit buildings will have exceptionally low-space conditioning loads, which will require solutions that can modulate down to very low outputs.

2.4 Further Considerations

Manufacturers can propose new solutions to meet the typical loads of a high-performance building based on a series of typical loads and considerations provided above. The manufacturers may choose to meet those loads in a variety of ways. The end-use energy budget (above) is so low that SWA believes no efficiency requirements need to be given. This will allow manufacturers to make tradeoffs between heating, cooling, ventilation, and water heating as required.

Solutions may tend towards terminal-unit-driven (such as split heat pumps where the terminal unit output is constrained within a range). They may also tend towards system-driven (such as a unitized hydronic solution where the single outdoor size governs, and the terminal units are simple and flexible via flow balancing). SWA recommends providing per-square foot targets and goals and allowing the manufacturers to roll those up to room level or apartment level as is rational for the type of system they are proposing. The totalized EUI targets from this report will be used as budgets for total heating, cooling, DHW, and ventilation system solutions.

3 Task 5: Identify Target Price Points

A competitive target price point will encourage building owners to pursue a high-performance solution as part of their business model. The solution will gain increasing market share once the payback falls within the typical investment period, that is, with owners beyond the innovators and early adopters choosing to invest their capital. This section of the report presents the price points that comprehensive high-performance retrofits should achieve for investment decisions to be driven by returns.

3.1 Payback Strategies

The following tables outline calculation steps for identifying target price points.

Table 6 and Table 7 show a typical distribution of building loads that approximate the high-performance building EUI target. These loads have been translated into estimated operating costs based on typical utility rates, with upstate electricity costs significantly lower than those for New York City.

Table 6 compares these cost breakdowns for a high-performance retrofit mid-rise building against those for a typical new construction gas-heated building. The breakdown illuminates the difference in operating costs an owner could expect if converting from a typical gas-heated, mid-rise building to the RetrofitNY solution, with and without solar PV to offset the electrical load. The operating cost is shown for both New York City and upstate utility costs.

SWA modeling and analysis indicates that rooftop solar PV would offset approximately 45–55% of the total site EUI of the modeled for the high-performance retrofit case.

An allowed payback window of 20 years is assumed. This window is multiplied by the operating cost savings to calculate the incremental solution cost allowable in each scenario. The solution cost is estimated assuming a 1,000 ft^2 apartment size.

Table 6. Estimated Operating Costs for High-Performance Solutions in Upstate and New York City Markets against a Typical Moderately-Well Performing Gas-Heavy Building

					No On-Site PV Used		With On-Site PV Used	
	Typical Newer Existing Building on Gas kBtu/SF Site	Typ NYC Building Example Op Cost $/SF-year	Typ Upstate Building Example Op Cost $/SF-year	Adjusted Loads: Retrofit Building kBtu/SF Site	Retrofit Example Op Cost NYC $/SF-year	Retrofit Example Op Cost Upstate NY $/SF-year	Retrofit Example Op Cost NYC $/SF-year	Retrofit Example Op Cost Upstate NY $/SF-year
Heat Load	36	$0.28	$0.28	6	$0.34	$0.25	$0.17	$0.13
Cooling Load	15	$0.82	$0.60					
DHW Load	20	$0.16	$0.16	8	$0.45	$0.33	$0.23	$0.17
Misc. House Loads	5	$0.29	$0.21	6	$0.32	$0.24	$0.16	$0.12
Plug Loads	7	$0.38	$0.28	6	$0.34	$0.25	$0.18	$0.13
Total	83	$1.92	$1.53	26	$1.45	$1.07	$0.74	$0.55
Allowed payback window (years)	20							
Equivalent Incremental Install Cost $/dwelling unit—Gas Baseline					$9,411	$9,233	$23,504	$19,618

The same information is shown again in Table 7, but this time against a starting condition of a building served by VRF instead of gas as the pre-retrofit condition. The higher operation cost for the VRF pre-retrofit building compared to the gas pre-retrofit condition results in greater supportable installation costs for the solution in this scenario.

Table 7. Estimated Operating Costs for High-Performance Solutions in Upstate and New York City Markets against a Typical Moderately Well Performing VRF Building

	Same Building on Central Heat Pump (VRF) & Central HP DHW Displacement of Gas	Typ NYC Building Example Op Cost $/SF-year	Typ Upstate Building Example Op Cost $/SF-year	Adjusted Loads: Retrofit Building kBtu/SF Site	No On-Site PV Used		With On-Site PV Used	
					Retrofit Example Op Cost NYC $/SF-year	Retrofit Example Op Cost Upstate NY $/SF-year	Retrofit Example Op Cost NYC $/SF-year	Retrofit Example Op Cost Upstate NY $/SF-year
Heat Load	9	$0.50	$0.37	6	$0.34	$0.25	$0.17	$0.13
Cooling Load	12	$0.68	$0.50					
DHW Load	15	$0.23	$0.20	8	$0.45	$0.33	$0.23	$0.17
Misc. House Loads	13	$0.71	$0.53	6	$0.32	$0.24	$0.16	$0.12
Plug Loads	7	$0.38	$0.28	6	$0.34	$0.25	$0.18	$0.13
Total	56	$2.50	$1.87	26	$1.45	$1.07	$0.74	$0.55
Allowed payback window (years)	20							
Equivalent Incremental Install Cost $/dwelling unit—VRF Baseline					$21,131	$16,096	$35,224	$26,481

The solution costs presented above do not include business as usual costs. These are purely incremental. A true total cost of solution should be calculated as follows:

$$\boldsymbol{BAU + incremental = total\ supportable\ cost}$$

Where:

$$\boldsymbol{incremental = annual\ savings \times payback}$$

A typical business-as-usual retrofit cost seen in the Phase 1 analysis is about $60,000 per unit. Therefore, the supportable cost of the mid-rise, high-performance solution would be approximately $75,000–$90,000 per unit installed.

3.2 Cost-Compression Pathways for Mid-Rise Solutions

The total supportable cost of a solution will change with changing utility rates and with changing standards of conducting business as usual. If legislation such as New York City's Climate Mobilization Act assigns a real dollar value to carbon emissions, avoided emissions would then drive up the avoided operating costs, which in turn increases the supportable incremental installation cost of the proposed net zero solution.

Table 8 summarizes the cost estimates from the RetrofitNY project teams against the supportable high-performance project costs calculated above. These projects do not all fit within the mid-rise scope covered by this report addendum, but there is comprehensive costing data available for them.

The King + King team is closest to the target while all other teams have significant overages. It is worth noting that the King + King project does not include substantial exterior wall improvements due to high level of insulation applied during prior renovation, so it does not reflect a comprehensive scope per the program's goals. Comprehensive scopes all require significant cost compression to approach becoming attractive investments.

Table 8. Summary of Cost-Compression Needs Relative to RetrofitNY Project Estimates

Project Team	Site Location	BAU + Incremental Cost $/Unit	Calculated Target Cost $/Unit	Cost Overage %
BRIGHT POWER	NYC	$148,852	$84,649	76%
CBRA	NYC	$205,063	$84,649	142%
LEVY	NYC	$114,718	$84,649	36%
KING + KING	Upstate	$88,085	$80,763	9%
SWBR	Upstate	$138,151	$80,763	71%

See the Phase 1 report for detailed manufacturer responses regarding the impact of scaling on price points. Many manufacturers had differing responses to the impact of scale on price, so there is no single one-size-fits-all pathway for compression. Some manufacturers would expect cost decreases of significant magnitude with increased market share. Others would not. The authors also cannot speak to the savings in labor expected from an integrated solution or the increase in cost from one manufacturer aggregating specialty products into an integrated solution. Table 8 does show the approximate scale of cost compression that needs to be achieved through those various balancing tradeoffs.

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