Energy Savings and Cost-Effectiveness Analysis of the 2024 New York State Energy Conservation Construction Code Commercial Provisions

Final Report

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Preferred Citation

New York State Energy Research and Development Authority (NYSERDA). 2024. "Energy Savings and Cost-Effectiveness Analysis of the 2024 Energy Conservation Construction Code New York State Commercial Provisions," Prepared by NORESCO LLC. NYSERDA.NY.gov/publications.

Abstract

This report summarizes the energy savings and cost-effectiveness analysis of the commercial provisions of the 2024 Energy Conservation Construction Code compared to the commercial provisions of the 2020 Energy Conservation Construction Code of New York State. The report describes the cost-effectiveness analysis, including the life-cycle cost (LCC) methodology, and the calculation of societal effects. The LLC methodology includes the economic parameters used in the LCC, describes how costs were developed for the baseline code compared to the proposed code, and provides the results of the analysis, including incremental costs, energy consumption, energy cost, 30-year LCC. The societal effects analysis includes the monetized value of greenhouse gas savings across new construction in New York State.

Keywords

New York, commercial, construction, cost-effectiveness, energy code, NYSERDA.

Acknowledgements

The authors would like to thank the NYSERDA Codes and Standards Team, including Chris Sgroi, John Lee, Elizabeth Staubach, Tomi Vest, and Chris Corcoran for providing guidance and review throughout the project. The authors are also grateful to the contractor team, including Christina LaPerle (Karpman Consulting), Rhys Davis (Resource Refocus), Grant Sheely (NBI), and Tristan Grant (NBI) for supporting the modeling analysis, and for coordinating and reviewing the results and the report.

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Acronyms and Abbreviations

AHU	air handling unit
ASHP	air source heat pump
AWHP	air-to-water heat pump
CHW	chilled water
cfm	cubic foot per minute
CO_2e	carbon equivalent
CZ	climate zone
DOAS	dedicated outdoor air system
DOE	Department of Energy
DX	direct expansion
ECCNYC	Energy Conservation Code of New York City
EIA	Energy Information Association
ERV	energy recovery ventilator
EUL	effective useful life
FPFC	four pipe fan coil
ft	foot
GHG	greenhouse gas
HP	heat pump
HR	high-rise
HRV	heat recovery ventilator
HVAC	heating, ventilation, and air conditioning
HW	hot water
IECC	International Energy Conservation Code
kBtu	thousand British thermal unit
kW	kilowatt
kWh	kilowatt hours
LCC	life cycle cost
lf	linear foot
LPD	lighting power density
MBH	thousand Btu per hour
MF	multifamily
MMBtu	million British thermal unit
mt	metric ton
MWh	megawatt hour
NPV	net present value
NREL	National Renewable Energy Laboratory
NYC	City of New York

NYCECC	New York City Energy Conservation Code
NYS	State of New York
NYSDEC	New York State Department of Environmental Conservation
NYDOS	New York Department of State
NYS	State of New York
NYSERDA	New York State Energy Research and Development Authority
PNNL	Pacific Northwest National Laboratory
PTAC	packaged terminal air conditioner
PTHP	packaged terminal heat pump
PV	photovoltaic
RTU	rooftop unit
SHGC	Solar Heat Gain Coefficient
SHW	service hot water
sf	square foot
SZ	single zone
TRM	Technical Resource Manual
VAV	variable air velocity
W	watt
WSPH	water source heat pump

Executive Summary

This analysis was conducted at the request of the New York State Energy Research and Development Authority (NYSERDA). NYSERDA convened a public, collaborative process to develop proposals to update the Energy Conservation Construction Code of New York State (State Energy Code). This report evaluated the cost-effectiveness of the proposed commercial provisions of the 2024 State Energy Code relative to New York State's current commercial energy code provisions—the 2020 State Energy Code (NYDOS 2020)—and describes the methodology, analysis, and results. Buildings in the City of New York were modeled with the current 2020 New York City Energy Conservation Code and local laws (2020 ECCNYC) (NYC DOB 2020) (NYC 2021) as the baseline condition.

This analysis follows the approach set forth by NYSERDA's Evaluation Criteria for Determining the Cost Effectiveness of Proposed Changes to the Energy Conservation Construction Code of New York State codified at Part 510 of Title 21 of the Official Compilation of Codes, Rules and Regulations of the State of New York as published in the New York State Register in June 18, 2024 (NYSERDA 2023).

Prototype energy models were used to determine energy savings between the 2020 State Energy Code and the 2024 State Energy Code. While the 2024 State Energy Code and the 2020 State Energy Code have prescriptive and performance paths, only the mandatory and prescriptive provisions were evaluated in the cost-effectiveness analysis. Cash flows for each year, based on energy savings, incremental first costs incorporated into loan payments, and maintenance and replacement costs were used to determine the present value life cycle cost (LCC) savings. Additionally, this analysis quantified societal effects of avoided greenhouse gas (GHG) emissions by establishing net, annual emissions based on energy savings and emission factors published by NYSERDA, and calculated the annual value of those avoided emissions using New York State Department of Environmental Conservation's published guidance, *Establishing a Value of Carbon, Guidelines for Use by State Agencies*. For both LCC savings and societal effects, this analysis used a 30-year study period.

The major changes to the proposed 2024 State Energy Code relative to 2020 State Energy Code include lighting power reductions and improved controls, updated equipment efficiencies, and energy credits. The intent is to allow owners and designers to improve building performance in ways that best fit the economics, design, and operation of the building. Mixed fuel and all-electric packages with minimum efficiency equipment and systems were modeled as baselines to represent those commonly used in current construction and those that are in-scope of the All-Electric Building Act [Energy Law Section 11-104(6)(b)] ((New York State Assembly 2023).

Eight building models representing approximately 76 percent of New York's floor area were selected for the analysis: Large Office, Standalone Retail, Large Hotel, High-rise Apartment (10-story), "NYC" High-rise Apartment (20-story), Mid-rise Apartment (4-story), Secondary School, and Warehouse. Incremental costs were collected for each measure applicable to the prototypes. Costs were collected from several sources, including: RSMeans, direct distributor and manufacturer quotes, past national cost-effectiveness studies, as well as custom costs developed for this analysis. Changes to the requirements for HVAC systems, on-site generation, and lighting were the primary drivers of incremental costs. Reductions in HVAC equipment size due to downsizing from other efficiency measures were incorporated in the incremental costs.

The study assumes that Energy Law Section 11-104(6)(b), which prohibits installation of fossil fuel equipment in certain new construction, will prohibit all buildings under 7 stories and 100,000 sf buildings that fall under the 2024 Energy Code from using fossil fuels starting December 31, 2025. This means, assuming a three-year code cycle, that all 3 years of construction for the Standalone Retail, Mid-rise Apartment, and Warehouse building types will be with electric end uses, in compliance with Energy Law. New York City's Local Law 154 (NYC 2021) mandates electrification of all buildings for the final year of the 3-year code cycle modeled. This is incorporated into the study and the final weighting of results.

Table ES-1 shows the weighted results of the cost-effectiveness analysis of the proposed 2024 State Energy Code relative to the 2020 State Energy Code, and, in New York City, the 2020 NYCECC. Individual prototypes were weighted by construction floor area to develop aggregated results for all buildings in New York. The analysis showed positive savings over the 30-year period of analysis, that is, the proposed commercial provisions of the proposed 2024 State Energy Code were cost-effective compared to the baseline 2020 State Energy Code with the 2020 NYCECC in NYC. Overall, the proposed 2024 State Energy Code is expected to yield 19.5 percent site energy savings and provide a 30-year net present value savings of $10.72 per square foot compared to the current 2020 codes, across all new commercial construction in the state for this code cycle.

Table ES-1. Statewide Energy Cost Savings, Incremental Cost, and Lifecycle Cost Savings by Prototype

Building Type	First year energy cost savings ($/sf)	Incremental first cost ($/sf)*	LCC savings ($/sf)	Societal effects ($/sf)	LCC savings with societal effects ($/sf)
NYC High-rise Apartment	$0.43	($1.61)	$9.18	$0.60	$9.78
High-rise Apartment	$0.60	$0.11	$11.88	$0.84	$12.72
Mid-rise Apartment	$0.80	$1.46	$13.25	$0.69	$13.94
Large Hotel	$0.60	$3.40	$7.97	$1.25	$9.22
Standalone Retail	$1.05	$1.28	$18.23	$0.88	$19.10
Large Office	$0.45	($2.63)	$13.53	$0.29	$13.82
Secondary School	$0.22	$2.13	$2.26	$0.34	$2.60
Warehouse	$0.28	$3.14	$1.75	$0.33	$2.08
New York Statewide Weighted Average	**$0.53**	**($0.01)**	**$10.06**	**$0.66**	**$10.72**

*Negative values indicate savings, positive values indicate costs.

1 Introduction

The New York State Energy Research and Development Authority (NYSERDA) promotes energy efficiency, renewable energy, and reductions of energy-related emissions in the State of New York. The building sector is a major contributor to energy use and is responsible for almost a third of statewide emissions (EIA 2023) (New York State Climate Action Council 2022). To reduce building energy use, NYSERDA has supported the development of energy code measures, exceeding the current Energy Conservation Code of New York State and of New York City (baseline) (NYDOS 2020) (NYC DOB 2020). This analysis contributes to benchmarking statewide goals for a clean energy future (NYSERDA 2024). The following cost analysis report documents the proposed commercial provisions.

This 2024 New York State Energy Code (proposed) is an overlay to the national model energy code, the 2024 International Energy Conservation Code (2024 IECC) (ICC 2024). The 2024 IECC includes, by reference, ASHRAE Standard 90.1-2022 as a compliance pathway (ASHRAE 2023). The amended 90.1-2016 (NYDOS 2020) (NYC DOB 2020) compliance option of the current energy codes was the baseline to which the proposed code was compared.

This document describes the energy and economic effects of the commercial provisions in the proposed code. While baseline and proposed codes have prescriptive and performance paths, only the mandatory and prescriptive provisions were compared in the cost-effectiveness analysis. The energy modeling informing this analysis used EnergyPlus (DOE 2022), also used for the energy and cost determination for the national model energy codes (DOE 2022). The analysis follows the approach set forth by NYSERDA's Evaluation Criteria for Determining the Cost Effectiveness of Proposed Changes to the Energy Conservation Construction Code of New York State codified at Part 510 of Title 21 of the Official Compilation of Codes, Rules and Regulations of the State of New York as published in the New York State Register in June 18, 2024 (NYSERDA 2023). The basis of the Cost Effectiveness Rule is the private ownership methodology used for the national model code determinations (Hart and Liu 2015). The building models are based on the national prototype models (DOE 2022) used in the national analysis, modified by the Pacific Northwest National Laboratory (PNNL) and the analysis team to reflect the unique building stock of New York and the provisions in the baseline and proposed codes. For example, the New York City (NYC) High-rise Apartment is almost identical to the High-rise Apartment prototype, but with 20 stories instead of 10, and with reconfiguration of some common spaces and equipment.

Eight building models representing approximately 76 percent of New York’s floor area were selected for the analysis: Large Office, Standalone Retail, Large Hotel, High-rise Apartment (10-story), NYC High-rise Apartment (20-story), Mid-rise Apartment (4-story), Secondary School, and Warehouse. Incremental costs were collected for each measure applicable to the prototypes. Cost sources were RSMeans, direct distributor and manufacturer quotes, past national cost-effectiveness studies, as well as custom costs developed for this analysis.

The changes to the proposed code relative to the baseline code included building envelope measures, especially thermal bridging mitigation and reduced air leakage. Additional efficiency credit packages allow owners and designers to choose energy saving options that fit the design and operation of their buildings. For HVAC, improved efficiency energy credits were modeled. Reductions in HVAC equipment size due to downsizing from additional efficiency and other measures were incorporated in the incremental costs. Lighting improvements in total power and controls were included. Changes to the lighting, envelope, and HVAC systems were the primary drivers of incremental costs. Other specific measures modeled have been detailed in their respective sections in this document. This document describes the methodology used to perform the cost-effectiveness analysis (Section 2), provides details of how incremental costs were calculated (Section 3), and shows the impacts of the proposed code relative to the baseline code in terms of incremental first costs, site energy savings, energy cost and carbon equivalent savings, and life-cycle cost savings (Section 4).

2 Methodology

2.1 Overview

The cost-effectiveness methodology used in this analysis uses NYSERDA's Cost Effectiveness Rule (NYSERDA 2023) for analyzing whether the proposed energy code remains cost-effective with respect to current building construction in the State. The basis of the Cost Effectiveness Rule is the private ownership methodology used for the national model code determinations (DOE Commercial Methodology) (Hart and Liu 2015). Deviations from the DOE Commercial Methodology are noted in the relevant sections. This analysis includes the value of avoided greenhouse gas emissions as a measure of the societal effects of energy consumed. The analysis team modified national prototype models (DOE 2022) to comply with the baseline codes, 2020 State Energy Code with New York City modifications (90.1-2016 with State or NYC amendments), and proposed code, 2024 State Energy Code (90.1-2022 with NYDOS amendments). The energy modeling informing this analysis uses EnergyPlus (DOE 2022), also used for the energy and cost determination for the national model energy codes (DOE 2022).

Only those changes between the proposed and baseline that impact energy consumption and affect the systems and components of the selected prototypes were evaluated. Additionally, the impact of a code change must be capable of being captured by the energy model to be evaluated. The energy consumption results from the prototypes and incremental costs for the proposed measures were used to inform a lifecycle cost model. The cost model analyzed cash flows over the analysis period and calculated the life cycle costs for each prototype. The analysis team performed the energy modeling analysis. The energy consumption results from modeling were used by NORESCO to perform the cost-effectiveness analysis.

2.2 Prototypes and Climate Zones

Eight building prototypes were selected for the analysis and are shown in Table 1. These eight prototypes represent approximately 76 percent of the statewide floor area. New York City building stock and construction is dominated by high-rise residential buildings.

Table 1. Prototype Characteristics

Prototype	Floors	Total Floor Area (sf)
NYC High-rise Apartment	20	168,719 [a]
High-rise Apartment	10	84,359
Mid-rise Apartment	4	33,744
Large Hotel	6	122,132 [a]
Standalone Retail	1	24,695
Large Office	13	498,637 [a]

Prototype	Floors	Total Floor Area (sf)
Secondary School	2	210,907
Warehouse	1	52,050

a. Parking garage area not included (equal to two floors' area).

In addition to customizing the building models to represent unique New York City typology, the analysis team modified them to incorporate the mandatory and prescriptive provisions of both baseline and proposed codes. Other compliance options exist, and the design choices made for these models are not necessarily required for all construction, but the intent is that they are representative of typical and financially reasonable construction for New York.

Prototype model results were aggregated to the statewide level by construction weights by prototype and climate zone. Table 2 shows the construction weights by prototype and climate zone (Lei, et al. 2020) (DCN 2024).

Table 2. Construction Weights by Prototype

Zone	Prototype	Construction Weights Statewide
4A-NYC	NYC High Rise Apartment	34.7%
	High Rise Apartment	16.2%
	Large Hotel	4.8%
	Standalone Retail	3.0%
	Large Office	9.2%
	CZ4- NYC Total Weight	**67.9%**
4A-Other	NYC High Rise Apartment	3.0%
	High Rise Apartment	1.2%
	Large Hotel	0.3%
	Standalone Retail	1.3%
	Large Office	0.3%
	CZ4-Other Total Weight	**6.2%**
5A	High Rise Apartment	0.8%
	Large Hotel	1.8%
	Standalone Retail	2.1%
	Secondary School	0.9%
	Warehouse	9.8%
	Midrise Apartment	7.0%
	CZ5 Total Weight	**22.4%**
6A	Large Hotel	0.7%
	Standalone Retail	0.4%
	Secondary School	0.1%
	Warehouse	1.2%

Zone	Prototype	Construction Weights Statewide
	Midrise Apartment	1.1%
	CZ6 Total Weight	**3.5%**

2.3 Building Fuels and Carbon Accounting

The analysis assumes the proposed code will take effect in 2026. The study also assumes that Energy Law Section 11-104(6)(b) (New York State Senate 2023), which prohibits installation of fossil fuel equipment in new construction less than 7 stories or 100,000 sf, will prohibit low-rise buildings from using fossil fuels starting December 31, 2025. This means, assuming a three-year code cycle, that 3 years of construction have electric end uses for the Standalone Retail, Mid-rise Apartment, and Warehouse, in compliance with Energy Law. The decarbonized regulated loads include HVAC and non-process water heating. The second phase of Energy Law decarbonization for larger buildings occurs outside of the analysis period and was not considered in the statewide analysis, however NYC Local Law 154 (NYC 2021) requires the electrification of regulated end-uses 24 months into the analysis. For the final 12 months of the code cycle, all new buildings are all-electric.

For societal effects accounting, year one emissions were calculated using the initial mix of fuels, and emissions in subsequent years were calculated using the year one fuel usage with grid emissions corresponding to each subsequent year. The 3-year cohort of new buildings determined to be constructed during the code cycle consumes fuels through the 30-year analysis period to determine total carbon emissions. Societal effects were included in the cost-effectiveness analysis by multiplying the incremental annual building electricity and fuel consumption by the corresponding GHG emissions factors and monetized values. Sources for emissions rates (NYSERDA 2022) (NYSERDA 2022) and associated social cost of carbon (NYSDEC 2022) were New York-specific and were calculated separately for downstate (CZ4) and upstate (CZ5, CZ6).

2.4 Incremental Cost Sources

Multiple cost sources were used for this analysis. RSMeans Online (Gordian 2022) was a primary source, as well as product distributors, testimony at international consensus standards, and retail sellers. Summaries of cost sources are provided in Table 3. Measure cost development for individual measures is described in further detail in their individual sections of this report.

Table 3. Primary Incremental Cost Sources

Building Component Category	System	Source
HVAC	Central Plant (Chiller, Pumps, Cooling Tower, Fluid Cooler)	RSMeans Online, regressions of material cost with capacity, labor cost with capacity
	Gas Boiler	Material Cost - Distributor pricing; Labor Cost, misc. Components (expansion tank, air separator) – RSMeans
	Zonal Equipment (Heat Pumps)	RSMeans Online – regression with capacity
	Terminal Unit (VAV Unit, FPFC)	RSMeans Online, regressions of material cost with capacity, labor cost with capacity
	Air-to-Water Heat Pump	Material Cost – direct distributor estimates; Labor Cost – RSMeans Online
	Zonal Equipment (Heat Pumps)	Material Cost – distributor estimates; high-efficiency HP – 20% markup from distributor estimates and CEC codes evaluation; Labor-RSMeans Online
	Distribution System Cost (piping, ductwork)	Representative Costs of Internal MEP Projects
	Heat Pump Water Heater	Material-Distributor Costs; Labor-RSMeans
	Dedicated Outside Air System with Ductwork	NEEA (Red Car Analytics 2019); for High-Rise Apartment buildings, a central, multiroom ERV cost is from a distributor
Lighting	All lighting	PNNL (Tyler 2021), distributors
PV	Photovoltaic System	PV system cost benchmarking report (NREL 2023) and PV and Battery Storage Measure Proposal (CEC 2021)
Envelope	Opaque insulation, fenestration, air leakage, and thermal bridging	RSMeans, ASHRAE 90.1,[1] PNNL (Hart, Nambiar, et al. 2018)
Service Water Heating	Water heater and distribution	Distributor pricing for equipment; RSMeans Online for labor costs
Conveyance	Elevator	RSMeans Online

2.5 Regional Adjustments

Costs were collected for individual measures, and, in nearly all cases, these costs were normalized national averages. This approach allows the costs to be reused for cost-effectiveness in any location in New York by applying a regional cost adjustment to the national estimate. RSMeans provides regional adjustments for various locations and adjustment factors were averaged across representative cities in

[1] Information about ASHRAE, committees, and publications can be found at https://www.ashrae.org.

each climate zone. After all unit, fixed, and system costs are totaled, the adjustment was applied as shown in Table 4.

Table 4. Regional Cost Multipliers

Climate Zone	Multiplier
4A-NYC	1.264
4A-Other	1.175
5A	1.041
6A	1.008

2.6 Lifecycle Analysis

This analysis evaluates the net present value (NPV) of annual cash flows over 30 years to determine the lifecycle cost (LCC). NPV recognizes the time value of money and gives more value to current dollars over the same amount in the future. Costs are incurred in the form of first costs, which pay for energy saving measures, and incremental replacement and maintenance costs. Cost savings arise from the reduction in energy consumption and the associated reduction in annual energy costs. Additional savings are derived from the societal effects. Capital cost savings sometimes occur in the proposed case, for example, from equipment downsizing or fewer lighting fixtures providing the same illumination. In this analysis, energy cost savings were assumed to be reinvested and not taxed as they would be if kept as cash on hand. That is, owners were assumed to minimize tax liability where possible.

Each of these cash flows is evaluated on a yearly basis over the period of analysis to determine the NPV of all cash flows. In this analysis, all costs were inflated and discounted using a nominal rate. A positive NPV indicates that the proposed savings cashflows exceed the proposed cost cashflows and the change is considered cost-effective.

This analysis considers the cost-effectiveness of the entire 2024 State Energy Code and does not examine each measure individually. Additionally, the results are weighted by building type and climate zone to determine the weighted cost-effectiveness of all new construction in New York. To account for the social effects, the same method is employed with the addition of natural gas and grid emissions.

2.6.1 Economic Parameters

The LCC methodology used to perform this analysis generally follows the NYSERDA methodology established for analyzing the cost-effectiveness of commercial codes (NYSERDA 2023). The economic parameters listed in Table 5 and the fuel price presented in Table 6 were used to perform the analysis.

The Cost Effectiveness Rule permits more granular fuel costs, where available. Electricity costs in each New York State climate zone were averaged for residential and commercial electricity prices for the utilities serving each county in the zone. Revenue and sales data were derived from Form EIA-861M's Sales and Revenue data for 2023 (EIA 2024) and then averaged for each zone, based on the utility territory, weighted by population served in each county. Natural gas costs were determined using the 2023-2024 winter small commercial gas tariffs from each utility listed by the New York State Department of Public Service using the same weighted average methodology for the regional costs as electric utilities (National Grid NYC 2023) (ConEd 2023) (Central Hudson 2023) (National Grid Long Island 2023) (NYSEG 2023) (NYSEG 2023) (National Grid Upstate 2023) (ORU 2023) (RG&E 2023) (RG&E 2023) (National Fuel 2024).

Table 5. Economic Parameters

Parameter	Value	Source
Analysis Period	30 years	NYSERDA Methodology (NYSERDA 2023)
Loan Term	30 years	Same as Analysis Period
Depreciation Term	39 years	IRS Publication 946 (IRS 2012)
Inflation Rate	2.63%	BLS Producer Price Index, new construction (BLS 2022)
Nominal Discount Rate	6.00%	NYSERDA Methodology
Real Discount Rate	3.29%	NYSERDA Methodology
Loan Interest Rate	6.00%	Online Source (RealtyRates 2022)
Overhead and Profit	28.8%	NYSERDA Methodology
Gas Price Escalation Rate	Varies annually	Supplement to NIST 135, Table Ca-1 (Kniefel 2023)
Electricity Price Escalation Rate	Varies annually	Supplement to NIST 135, Table Ca-1
Fuel Price	Table 6	EIA and NYS utilities

Table 6. Fuel Prices

Fuel Cost	Commercial		Residential	
Region	Electricity ($/kWh)	Gas ($/therm)	Electricity ($/kWh)	Gas ($/therm)
CZ4-NYC	$0.25	$1.31	$0.30	$2.17
CZ4-Other	$0.20	$1.32	$0.23	$1.83
CZ5	$0.13	$0.81	$0.18	$1.05
CZ6	$0.13	$0.91	$0.17	$1.16

2.6.2 Replacement Costs and Residual Value

Replacement occurs in the year following the expected useful life (EUL); a 15-year expected useful life requires replacement in year 16. Where the replacement schedule or expected useful life year exceeded the analysis period, a residual value was added to the final year of the analysis period. Table 7 shows the expected useful life for major building components. The primary source used to determine the expected useful life was Appendix P of the New York Technical Resources Manual, where applicable.

Where practical, partial replacements were assumed. For example, a lighting fixture could have a driver and lamp replacement. Built-up HVAC components, specifically the variable air velocity air handling units and dedicated outdoor air systems, assume partial replacement.

Table 7. Expected Useful Life

Component or Class	EUL	Source
Opaque Envelope	30	New York Technical Resource Manual (NYTRM) (TRM Management Committee 2022)
Fenestration	20	NYTRM
Lighting	Variable	Group-R compact fluorescent bulbs 10,000 hours, Large Office linear high-efficiency LEDs 75,000 hours, all others 50,000 hours. Expected useful life is calculated as the rated hours, assuming 9 hours per day burn.
HVAC Equipment (general)	Variable	NYTRM, 2020 ASHRAE Handbook – HVAC Systems and Equipment (ASHRAE 2020)
Elevator Modernization	15	NYTRM
PV System	30	NYSERDA (NYSERDA 2021)
Service Water heating (general)	Variable	NYTRM, 2020 ASHRAE Handbook
Chillers	20	NYTRM
Boilers	35	NYTRM
Built-Up VAV Air Handling Units	25	ASHRAE Life Expectancy Chart
Packaged Single Zone Heat Pumps, Air-to-Water Heat Pumps	15	NYTRM
Water-source heat pumps	19	ASHRAE Life Expectancy Chart
Four-pipe fan coil, VAV terminal units	20	ASHRAE Life Expectancy Chart
Centrifugal base-mounted pumps	20	ASHRAE Life Expectancy Chart
HVAC Ductwork	30	ASHRAE Life Expectancy Chart
Hydronic Piping	30	ASHRAE Life Expectancy Chart

2.6.3 Societal Effects of GHG Emissions

The societal effects of avoided greenhouse gas (GHG) emissions were monetized. The Cost Effectiveness Rule specified the method for including the societal effects of GHG emissions (NYSERDA 2023) and this method was used to perform the calculations. Avoided GHG emissions were calculated by multiplying the annual building electricity and gas savings by GHG emissions factors published by NYSERDA (NYSERDA 2022). The avoided GHG emissions were then converted to annual dollars by following guidance published by the New York State Department of Environmental Conservation (DEC) (NYSDEC 2022), *Establishing a Value of Carbon, Guidelines for Use by State Agencies*. A 2 percent discount rate was used and the value of avoided GHG emissions was added to the annual cash flow.

2.6.4 Cash Flows

Over the 30-year analysis period expenses and savings were added, inflated as necessary, and discounted to net present value. Those cash flows were:

- First costs amortized over the 30-year loan term.
- Flat depreciation over the 30-year period of analysis.
- Maintenance, inflated, in years where it occurs.
- Replacements, inflated, in years where they occur.[2]
- Escalated and inflated fuel costs or savings.
- Escalated and inflated grid and fossil fuel costs associated with emissions.

[2] Any residual value at the end of the analysis period was added to the net cash flow in the final year.

3 Incremental Cost Estimates

Incremental first costs for each prototype were developed by gathering cost information for components within a system that changed between the 2020 baseline model and the 2024 proposed model. A qualitative analysis was conducted, and where 2024 proposed differed from 2020 baseline, differences were documented. Where there was no change to the code requirement and therefore no change to the prototype models in the analysis, generally, costs were not included in the estimate for those components. For example, the daylighting control requirements stayed the same, so no costs were calculated for daylighting controls for either the baseline or proposed case. Specifics are provided in each section.

Where there were changes, *i.e.*, the measures, they were costed on an incremental basis, *i.e.*, only the difference in components are costed, where practicable. For example, fenestration is costed from a double-pane clear window, with the costs of performance technologies added to reach the baseline or proposed requirements. For other components, a boiler, for example, two full pieces of equipment of different size or efficiency were costed.

Most costs were converted into a per unit cost, for example, dollars per linear foot for wire. Any fixed costs not affected by the number of units were added separately. In some cases, an entire system was used, for example, a packaged HVAC, where that provides a more accurate estimate. The overall approach was to find the lowest cost component that likely would be used to meet the code requirement. This follows a similar approach to how cost estimating is performed during bid development for construction projects and represents the market. Unless otherwise noted, costs include overhead and profit and are weighted across climate zones where prototypes are modeled. Where practical, a weighted average of climate zones is shown for pricing, else representative zones are shown.

3.1 Opaque Assemblies

Envelope performances are shown in Table 8 for U-factors (U) and R-values (R). The cost of insulation requirements for all assemblies in each prototype is provided in Table 9 and Table 10 for reference and additional thermal bridging mitigation estimates are in
Table 11.

Table 8. Opaque Assembly Performance

Assembly	CZ	Baseline and Proposed	
Steel-framed walls, Group R	4-NYC	U-0.061 Baseline U-0.064 Proposed	R-13+R-8.5c.i. R-13+R-7.5c.i.
	4-Other	U-0.064	R-13+R-7.5c.i.
	5	U-0.055	R-13+R-10c.i.
	6	U-0.049	R-13+R-12.5c.i.
Steel-framed walls [a]	5	U-0.055	R-13+R-10c.i.
	6	U0.049	R-13+R-12.5c.i.
Mass walls, Group R	4-NYC	U-0.086 Baseline	R-13.25c.i. R-11.4c.i.
	4-Other	U-0.090	R-11.4c.i.
	5	U-0.080	R-13.3c.i.
	6	U-0.071	R-15.2c.i.
Mass walls, All Other	4-NYC	U-0.099 Baseline	R-11.2c.i. R-9.5c.i.
	4-Other	U-0.104	R-9.5c.i.
	5	U-0.090	R-11.4c.i.
	6	U-0.080	R-13.3c.i.
Metal buildings walls	5,6	U-0.050	R-19c.i.
Metal buildings walls, semi-	5,6	U-0.094	R-9.8c.i.
Below grade walls, All	4,5	U-0.119	R-7.5c.i.
	6	U-0.092	R-10c.i.
Entirely above deck roof	4-NYC	U-0.030 Baseline	R-33c.i. R-30c.i.
	4-Other, 5,6	U-0.032	R-30c.i.
Metal building roofs	5	U-0.037	R-19+R-11c.i.
	6	U-0.031	R-25+R-11c.i.
Metal building roofs, semi-heated	5	U-0.082	R-19c.i.
	6	U-0.060	R-19+R-19c.i.

a. All steel-framed walls in the analysis for climate zone 4 are in Group R buildings.

Table 9. Opaque Assembly Costs: Wall

Prototype	Baseline	Proposed
NYC High-rise Apartment	$174,710	$164,328
High-rise Apartment	$87,258	$82,256
Mid-rise Apartment	$38,964	$38,964
Large Hotel	$471,602	$464,499
Standalone Retail	$176,399	$174,404
Large Office	$1,218,771	$1,190,911
Secondary School	$122,070	$122,070
Warehouse	$109,749	$109,749

Table 10: Opaque Assembly Costs: Roof

Prototype	Baseline	Proposed
NYC High-rise Apartment	$40,674	$38,667
High-rise Apartment	$40,323	$38,389
Mid-rise Apartment	$31,886	$31,886
Large Hotel	$95,613	$92,117
Standalone Retail	$106,469	$103,681
Large Office	$186,024	$176,419
Secondary School	$479,123	$479,123
Warehouse	$108,705	$108,705

Table 11. Thermal Bridging Mitigation Costs

Prototype	Baseline	Proposed
NYC High-rise Apartment	$36,700	$47,625
High-rise Apartment	$18,210	$24,500
Mid-rise Apartment	$6,907	$10,077
Large Hotel	$17,992	$24,140
Standalone Retail	$6,861	$9,113
Large Office	$47,321	$60,908
Secondary School	$21,707	$28,578
Warehouse	$13,878	$18,792

3.2 Fenestration

The fenestration performance has been improved in the proposed code. Table 12 shows the fenestration requirements for the baseline and proposed as U-factors and Solar Heat Gain Coefficients (SHGC).

Table 12: Fenestration Performance

Assembly	CZ	Baseline U-factor	Baseline SHGC	Proposed U-factor	Proposed SHGC
Vertical fenestration, fixed	4-NYC	U-0.30	0.36	U-0.36	0.36
	4-Other	U-0.38	0.36	U-0.36	0.36
	5	U-0.38	0.38	U-0.36	0.38
	6	U-0.38	0.40	U-0.34	0.38
Vertical fenestration, operable	4-NYC	U-0.40	0.36	U-0.45	0.33
	4-Other	U-0.46	0.36	U-0.45	0.33
	5	U-0.46	0.38	U-0.45	0.33
	6	U-0.45	0.40	U-0.42	0.34
Skylights	4-NYC	U-0.48	0.38	U-0.50	0.40
	4-Other	U-0.50	0.40	U-0.50	0.40
	5	U-0.50	0.40	U-0.50	0.40
	6	U-0.50	0.40	U-0.47	0.40

Due to typical cost sources, such as RSMeans, providing insufficient detail for the fenestration performances in this analysis, current fenestration cost survey data from the Façade Tectonics Institute (FTI) were used.[3] The costs for the insulated glazing unit technologies are applicable to all fenestration, though the survey was limited to metal-framed commercial applications (curtainwall, window-wall). Without multipliers to lower the frame costs to represent smaller and non-metal windows, it should be noted that fenestration incremental costs could be elevated relative to installed costs. However, that additional cost is in both baseline and proposed cases, so it cancels in the incremental analysis. As previously noted, both baseline and proposed vertical fenestration is built up from a double-pane clear reference. Performance and costs associated with necessary additional technologies are incremental, but the reference window cost cancels in the analysis. Because the changes to fenestration performance are not extreme, technology needed to meet the prescriptive minimum does not necessarily differ between cases. That is, the lowest cost window might be common to multiple minimum performances.

Table 13 describes the window-to-wall ratio and operable fenestration fraction for each building model. The weighted U-factor and SHGC resulting from the fixed and operable fractions was used to model the

[3] Component costs were analyzed using an adaptation of the National Fenestration Rating Council (NFRC 2024) Component Modeling Approach, where performance – and, here, cost – for selected technologies was built up, piecewise. See summary (Benney n.d.) for application in codes and standards. Overhead and profit was applied globally. Cost updates were from the FTI's cost data shared during the 2024 IECC development cycle.

fenestration. For costs, fixed and operable window costs were separately calculated and added to the cost model based on the total area of fenestration of each type in the prototypes.

Table 13. Vertical Fenestration by Building Model

Prototype	Window Area	Fixed	Operable
NYC High-rise Apartment	30%	75.4%	24.6%
High-rise Apartment	30%	75.4%	24.6%
Mid-rise Apartment	20%	75.4%	24.6%
Large Hotel	30%	92.0%	8.0%
Standalone Retail [a]	7.1%	97.8%	2.2%
Large Office	40%	96.9%	3.1%
Secondary School [a]	35%	89.8%	10.2%
Warehouse [a]	0.7%	97.4%	2.6%

a. Retail skylight area is 1 percent, School skylight area is 1.4%, Warehouse skylight area is 1.5 percent

For proposed vertical fenestration and skylights, the frame is assumed to be thermally broken metal. Vertical fenestration was priced with the necessary selection of technologies to achieve a given prescriptive performance: low-e coatings, improved spacers, and argon fills. Cost estimates in Table 14 are statewide weighted averages. Most cost increase was limited to improvements in climate zone 6, which has little weight in the overall analysis. The cost decreases were a result of the 2020 NYCECC requiring better fenestration than the proposed 2024 State Energy Code in NYC.

Table 14. Fenestration Costs

Prototype	Baseline	Proposed
NYC High-rise Apartment	$579,066	$449,382
High-rise Apartment	$285,861	$223,292
Mid-rise Apartment	$49,482	$50,027
Large Hotel	$283,802	$230,370
Standalone Retail	$15,131	$21,901
Large Office	$1,268,693	$936,402
Secondary School	$374,618	$377,813
Warehouse	$53,608	$53,632

3.3 Air Leakage

The baseline has air leakage control requirements based on Standard 90.1-2016 with NYS amendments, but testing is not mandatory. The total building leakage rate dropped from 0.4 cubic feet *per* minute *per* square foot at a pressure difference of 75 Pascals in the baseline to 0.35 cfm/sf in the proposed case, with leakage testing. Leakage in the baseline is assumed to use the deemed to comply materials and assemblies lists in 90.1. Primarily, the air leakage reduction is a result of attention to detail in current designs and installation of materials.

Air leakage testing generally is less expensive for a lower leakage threshold because less fan power is required to achieve the testing pressure differential, which means smaller equipment and lower costs to transport the equipment. The real-world cost of this measure depends on the testing approach and schedule. Large buildings can be tested as whole buildings or in sections. Multiple mobilizations of testing contractors are more expensive but often better align with phased completion of the rest of the build out.

Cost estimates are based on PNNL (Hart, Nambiar, et al. 2018) research, ongoing research at the ASHRAE 90.1 Envelope Subcommittee Air Leakage Working Group, and professional experience. Cost estimates for the air leakage measure are in Table 15.

Table 15. Air Leakage Reduction Costs

Prototype	Baseline	Proposed
NYC High-rise Apartment	$0	$19,465
High-rise Apartment	$0	$10,531
Mid-rise Apartment	$0	$4,365
Large Hotel	$0	$13,749
Standalone Retail	$0	$4,020
Large Office	$0	$54,292
Secondary School	$0	$19,716
Warehouse	$0	$5,955

3.4 Clean Energy

In alignment with the Climate Act of 2019 (NY State Senate 2019) “clean energy” provisions reduce carbon- and carbon-equivalent emissions. Additional detail has been provided below. Projected costs (New York State Department of Environmental Conservation 2023), grid emission factors (NYSERDA 2022), and projected natural gas emission factors (NYSERDA 2022) informed the societal effects analysis and annual carbon-equivalent (CO_2e) savings.

3.4.1 PV System

The photovoltaic (PV) system proposal requires the building to have on-site renewable energy equipment with a rated capacity of at least 0.75 W/sf multiplied by the sum of the three largest floors' gross conditioned floor area (CFA). For prototypes less than three stories, the total CFA was used to calculate the capacity. In addition, a renewable energy generation energy credit is used for compliance in most prototypes. The potential cost of increasing the electrical panel breaker space capacity is excluded, because buildings with installed PV would be sized for the proper panel capacity (NBI 2022). A baseline system is shown for climate zone 4A-NYC but is limited to New York City.

Equipment costs were estimated at $1.22/W and labor costs at $1.46/W, based on NREL national average cost (NREL 2023) as shown in Table 16, cost-adjusted and weighted by climate zone. Additionally, an annual maintenance cost of $11/kW was assumed, derived from NREL's 2020 Annual Technology Baseline (NREL 2020).

Table 16. PV System Costs

Prototype	Baseline	Proposed
NYC High-rise Apartment	$17,381	$89,085
High-rise Apartment	$16,755	$88,444
Mid-rise Apartment		$73,462
Large Hotel	$11,995	$234,592
Standalone Retail	$8,337	$80,457
Large Office	$18,299	$406,449
Secondary School		$612,571
Warehouse		$151,228

3.5 Energy Credits

Prescriptive compliance with the proposed code requires projects to achieve credits based on additional energy efficiency measures. Required energy credit totals and the number of credits earned for a specific measure vary by building occupancy to reflect the energy savings achieved for a given measure. For example, residential occupancies earn more credits than an office occupancy for efficient water heating, storage, and distribution, because they use more hot water. Table 17 shows a summary of the credits selected for this analysis to meet the requirements. Note that credit options not used are not shown.

Efficiency Credits	Energy Credits Modeled							
Applicable measures for modeled building types.	NYC High-rise Apartment	High-rise Apartment	Mid-rise Apartment	Large Hotel	Standalone Retail	Large Office	Secondary School	Warehouse
E01 Envelope performance				X				
W08 SHW distribution sizing	X	X	X					
H02 Heating efficiency	X	X	X	X	X	X	X	X
H03 Cooling efficiency	X	X	X	X	X	X	X	X
L02 Lighting dimming and tuning				X	X	X	X	
L03 Increase occupancy sensor				X	X	X	X	X
L05 Residential lighting control	X	X	X					
L06 Lighting power reduction	X	X	X	X	X	X	X	X
R01 Renewable energy	X	X	X	X	X	X	X	

It is not feasible to model every combination of credits that could be used to meet the requirements. A package of credit measures was created to achieve the points total for each prototype (based on the prototype occupancy). Credit selection was informed by the number of available credit points and the likelihood of the measure being used in an actual building of the given type. A typical and financially reasonable package of credits was chosen for each building and climate. The energy credits included in the cost analysis are in Table 17 and briefly are described below. Additional detail has been provided in subsequent sections.

Table 17. Energy Credits Modeled for Each Prototype

Efficiency Credits	Energy Credits Modeled							
Applicable measures for modeled building types.	NYC High-rise Apartment	High-rise Apartment	Mid-rise Apartment	Large Hotel	Standalone Retail	Large Office	Secondary School	Warehouse
E01 Envelope performance				X				
W08 SHW distribution sizing	X	X	X					

Efficiency Credits	Energy Credits Modeled							
Applicable measures for modeled building types.	NYC High-rise Apartment	High-rise Apartment	Mid-rise Apartment	Large Hotel	Standalone Retail	Large Office	Secondary School	Warehouse
H02 Heating efficiency	X	X	X	X	X	X	X	X
H03 Cooling efficiency	X	X	X	X	X	X	X	X
L02 Lighting dimming and tuning				X	X	X	X	
L03 Increase occupancy sensor				X	X	X	X	X
L05 Residential lighting control	X	X	X					
L06 Lighting power reduction	X	X	X	X	X	X	X	X
R01 Renewable energy	X	X	X	X	X	X	X	

- Envelope Performance – Decreases overall envelope load to be satisfied by space conditioning equipment through lower thermal transmission across a selection of assemblies.
- Efficient space heating and cooling equipment adds 10 percent efficiency improvement.
- Residential Lighting Control – In the apartment prototypes this is an additional master switch in an existing gang for each dwelling unit.
- Lighting Dimming and Tuning, and Power Reduction – This measure contributes to lower lighting energy use. Cost development discussed in a dedicated section below.

3.6 Mechanical Systems

Mechanical systems covered in the scope of this analysis include heating, cooling, and ventilation systems (HVAC), as well as other regulated loads that are not energy-neutral between the 2020 baseline case and the 2024 proposed case. For example, water heating is included because there is an efficiency measure for the 2024 code, but kitchen exhaust and data center space conditioning systems are not included in the life-cycle cost analysis, directly, because the systems are assumed to be unchanged for the 2024 case. The analysis generally assumes mixed fuel in buildings, except where mandated electrification of regulated loads occurs due to the Energy Law and NYC local laws (see Section 0 regarding fuels). Note that representative equipment is detailed below, with generally minor differences between climate zones.

3.6.2 Heating, Cooling, and Ventilation Measures

Heating and cooling efficiencies affected every prototype in the analysis. Table 18 shows the data sources used to determine system costs. Table 19 describes system modeling assumptions. Prototype energy model output was used to gather equipment capacities and flowrates. The fuel mix is shown in Table 20.

Table 18. Cost Data Sources for HVAC System Components

Product	Equipment Cost Source	Labor Cost Source
Single Zone Variable Air Velocity Heat Pump (SZVAV HP) [a]	Distributor – HVACDirect, CEC 2022 Title 24 Update	RSMeans Online (Gordian 2022)
Dedicated Outdoor Air System (DOAS) Unit Only	(Bulger 2019)	(Bulger 2019)
DOAS Ductwork w/ Energy Recovery Ventilation (ERV)	(Bulger 2019)	(Bulger 2019)
ERV DOAS	Distributor Estimate	RSMeans Online
Boiler [a]	RSMeans Online	RSMeans Online
Chiller	RSMeans Online	RSMeans Online
Packaged Terminal Air Conditioning (PTAC)	RSMeans Online	RSMeans Online
Packaged Terminal Heat Pump (PTHP)	RSMeans Online	RSMeans Online
Primary Pump	RSMeans Online	RSMeans Online
Secondary Pump	RSMeans Online	RSMeans Online
Expansion Tank	RSMeans Online	RSMeans Online
Air Separator	RSMeans Online	RSMeans Online
Fan Coil Units	RSMeans Online	RSMeans Online
Cooling Tower, axial fan	RSMeans Online	RSMeans Online
VAV Air Handling Unit (AHU)	RSMeans Online	RSMeans Online
VAV Ductwork	RSMeans Online (sizing from recent projects)	RSMeans Online
Hydronic Piping	RSMeans Online (sizing from recent projects)	RSMeans Online
Air to Water Heat Pump (AWHP)	Manufacturer and Distributor Cost Survey	RSMeans Online
Water Source Heat Pump (WSHP) [a]	Distributor Estimates	RSMeans Online

[a] Components use a linear regression of system cost with capacity (tons or cfm) from available data sources.

Table 19. HVAC System Costing Approach

Prototype	Ventilation Costing Approach	HVAC Costing Approach
Standalone Retail	Ventilation is provided by the HVAC systems (no separate cost)	Smallest equipment in nominal ton size to meet cooling cap for gas case, or smallest to meet larger of cooling and heating load in electric case

Prototype	Ventilation Costing Approach	HVAC Costing Approach
Large Hotel	A central DOAS system is included with energy recovery. Both the DOAS unit and ductwork costs are a function of the design ventilation rate (cfm).	Smallest nominal ton capacity to meet the heating and cooling load of each zone for 2024 case; chiller sized for coincident loads in 2020 case
Large Office	A central DOAS system is included with energy recovery. Both the DOAS unit and ductwork costs are a function of the design ventilation rate (cfm).	From model plant capacities for 2024; zone equipment smallest nominal size for 2020
High-rise Apartment	The proposed case has a DOAS with an ERV. The base case has exhaust only ventilation.	Coil (zone) capacities, with nominal sizes listed
NYC High-rise Apartment	Instead of a central DOAS rooftop unit, a set of distributed multiroom energy recovery ventilators provide ventilation to the apartments. Each unit provides 600 cfm of outside air. This is functionally equivalent to a central DOAS, since the system has no active cooling or heating.	Coil (zone) capacities, with nominal sizes listed.
Mid-rise Apartment	The proposed case has a DOAS with an ERV. The base case has exhaust only ventilation.	Split systems of nominal tonnage per apartment; larger units for larger common area zones
Secondary School	Both the 2024 proposed case and the base case use built-up VAV air handling units that provide ventilation.	For base case, central Air-Cooled Chiller and Boiler are sized for the building loads. For hot water coils serving terminal units, hydronic piping and ductwork are used for the distribution system. The DOAS cost is based on the required airflow (cfm).
Warehouse	Packaged space conditioning units also provide ventilation (no separate system).	The warehouse is conditioned by packaged units that are sized to the nearest nominal size in tons. A single unit heater that meets the open storage area is included.

Table 20. Fuel Mix for Prototypes

Period	Baseline		Proposed	
	Mixed Fuel	Electric	Mixed Fuel	Electric
State Energy Code (0-36 Months)	NYC High-rise Apartment High-rise Apartment Large Hotel Large Office Secondary School	Mid-rise Apartment Standalone Retail Warehouse	NYC High-rise Apartment High-rise Apartment Large Hotel Large Office Secondary School	Mid-rise Apartment Standalone Retail Warehouse
NYCECC in 4A-NYC (0-24 Months)	NYC High-rise Apartment High-rise Apartment Large Hotel Large Office Secondary School	Mid-rise Apartment Standalone Retail Warehouse	NYC High-rise Apartment High-rise Apartment Large Hotel Large Office Secondary School	Mid-rise Apartment Standalone Retail Warehouse
NYCECC in 4A-NYC (24-36 Months)	None	All Prototypes	None	All Prototypes

Representative prototypes' HVAC components are described below. Where a prototype appears in multiple climate zones, a single zone is representative. The component costs do not include regional multipliers and prevailing wage assumptions; including these regional adjustment factors increase the component costs by 58.3%.

Standalone Retail

The Standalone Retail prototype includes four single-zone variable air velocity (VAV) packaged heat pump units for space conditioning in the proposed case. The single-zone rooftop units serve large open areas and include full ventilation capability with airside economizers and heat pumps for cooling and heating. The systems for both the base case and the proposed case have efficiency ratings that minimally comply with code requirements. The capacities were sufficiently large to trigger the requirement for single zone two-speed fan control; costed units included standard practice of variable speed drives on supply fans. The 2020 base case uses a direct expansion (DX) rooftop unit with electric resistance heat, having lower first cost, but expected higher operating cost. Exhaust air energy recovery is included in one rooftop unit (RTU) for the 2024 case to conform to code requirements: air-to-air energy recovery with an enthalpy wheel. Details of incremental first costs for the electric proposed case and base case for climate zone 4 are in Table 21 and

Table 22, respectively. First costs for climate zone 5 and climate zone 6 are not shown, but they follow the same equipment schedule, with capacities sized for those climate zones.

Table 21. Standalone Retail CZ4 HVAC Cost Summary (Proposed Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
SZVAV HP	8 ton	$11,505
SZVAV HP	15 ton x 2	$43,440
SZVAV HP	20 ton	$28,530
SZVAV HP	25 ton	$35,340
RTU Heat Recovery	25 ton	$11,725

Table 22. Standalone Retail CZ4 HVAC Cost Summary (Base Electric)

Baseline Unit	Baseline Capacity	Baseline Cost
DX with Elec Resistance Heat	8 ton	$8,883
DX with Elec Resistance Heat	15 ton x 2	$30,671
DX with Elec Resistance Heat	25 ton x 2	$$47,878

Large Hotel

These larger buildings are electrified only in New York City (see Section 0 regarding fuels). The Large Hotel prototype is served by a central air-cooled chiller and a natural gas boiler in both mixed fuel base case and proposed case. Fan coil units for each of the zones provide heating and cooling from the hot water coils and chilled water coils. Ventilation to the guestrooms and other spaces is provided by a central dedicated outdoor air system (DOAS), which includes energy recovery.

A 10-hp primary pump and 15-hp secondary circulation pump were used with the distribution system. The balance of the system includes hydronic steel piping, an expansion tank and air separator, and fan coil units serving each of the zones.

To cost the individual systems, the capacity first was determined for each zone as the smallest nominal size system (tons) meeting the heating and cooling load. A set of costs was developed, spanning the range of equipment sizes, and correlations were developed for both system cost and labor cost as a function of system capacity. Costs and capacities are shown in Table 23 through Table 26 for the proposed and base cases, respectively, by fuel.

Table 23. Large Hotel CZ4 HVAC Cost Summary (Proposed Gas)

Proposed Unit	Proposed Capacity	Proposed Cost
Air-Cooled Chiller	250 ton	$165,861
Gas HW Boiler	1,400 MBH	$28,570
Hydronic Piping	2,320 lf	$131,428
CHW Pumps	10 hp	$3,005
HHW Pump	15 hp	$3,005

Expansion Tank		$1,209
Air Separator		$1,209
Four-Pipe Fan Coil	250 ton	$94,398
VAV AHU	41,440 cfm	$98,563
DOAS Ductwork	29,500 cfm	$221,250
DOAS Unit w/ ERV	29,500 cfm	$96,875

Table 24. Large Hotel CZ4 HVAC Cost Summary (Proposed Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
Air-Cooled chiller	250 ton	$165,861
Air-to-Water Heat Pump	70 ton	$98,983
Hydronic Piping	2,320 lf	$131,428
Circulation Pumps	10 hp x 3	$9,015
Expansion Tank		$1,209
Air Separator		$1,209
Four-Pipe Fan Coil	250 ton	$94,398
DOAS Ductwork + ERV	29,500 cfm	$221,250
DOAS Unit	29,500 cfm	$96,875
VAV AHU	41,440 cfm	$98,563
SZVAV	13 ton	$13,640
SZVAV	20 ton x 3	$60,910

Table 25. Large Hotel CZ4 HVAC Cost Summary (Base Gas)

Baseline Unit	Baseline Capacity	Baseline Cost
Air-Cooled Chiller	230 ton	$154,598
Gas HW Boiler	1,400 MBH	$28,570
Hydronic Piping	2,320 lf	$131,428
CHW Pumps	10 hp	$3,005
HHW Pump	15 hp	$3,005
Expansion Tank		$1,209
Air Separator		$1,209
Four-Pipe Fan Coil	230 ton	$87,091
DOAS Ductwork	20,400 cfm	$153,000
DOAS Unit	20,400 cfm	$67,300

Table 26. Large Hotel CZ4 HVAC Cost Summary (Base Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
Electric HW Boiler	420 kW	$21,993
Air-Cooler Chiller	230 ton	$154,598
Four-Pipe Fan Coil	230 ton	$87,091
Circulation Pump	5 hp x 2	6,010
Circulation Pump	2 hp	$1,447
Hydronic Piping	2,329 lf	$131,428
Expansion Tank		$1,209
Air Separator		$1,209
DOAS Ductwork + ERV	20,400 cfm	$153,000
DOAS Unit Only	20,400 cfm	$67,300
DX SZVAV	13 ton	$13,640
DX SZVAV	20 ton x 3	$69,910

Large Office

The Large Office prototype ground floor includes a small data center that is served by a dedicated HVAC system. That system was not included in the cost scope because the data center HVAC system is unchanged between the 2020 base case and the 2024 proposed case.

The HVAC system includes a water source heat pump (WSHP) that provides heating and cooling, with a cooling tower for heat rejection and a gas boiler for supplemental loop heating. Ventilation is provided by a central DOAS unit to temper the outside air. The WSHP system was reported to have the highest prevalence among HVAC systems in large office buildings, particularly in New York City, and this was the primary reason for selecting the system for the Large Office prototype in the analysis.

Because the simulation model does not fully articulate the distribution system details, pipe length estimates are determined from representative projects and engineering experience and adjusted in proportion to building area and the number of zones. Costs and capacities are in Table 27 through Table 30.

Table 27. Large Office CZ4 HVAC Cost Summary (Proposed Gas)

Proposed Unit	Proposed Capacity	Proposed Cost
Water Source Heat Pump	752 tons	$754,993
Gas HW Boiler	10,076 MBH	$173,486
DOAS Unit w/ ERV	42,375 cfm	$138,719
DOAS Ductwork	42,375cfm	$254,250
Hydronic Piping	1,280 lf	$72,512

Proposed Unit	Proposed Capacity	Proposed Cost
Circulation Pump	10 hp	$5,603
Axial Fan Cooling Tower	850 ton	$190,808

Table 28. Large Office CZ4 HVAC Cost Summary (Proposed Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
Water Source Heat Pump	752 ton	$754,993
HW Electric Boiler	2,953 kW	$99,728
DOAS Unit	42,375 cfm	$138,719
DOAS Ductwork	42,375 cfm	$254,250
Hydronic Piping	1,280 lf	$72,512
Axial Fan Cooling Tower	850 ton	$190,808
Circulation Pump	10 hp	$5,603

Table 29. Large Office CZ4 HVAC Cost Summary (Base Gas)

Baseline Unit	Baseline Capacity	Baseline Cost
Water Source Heat Pump	834 tons	$837,190
Gas HW Boiler	10,076 MBH	$173,486
DOAS Unit w/ ERV	42,375 cfm	$138,719
DOAS Ductwork	42,375 cfm	$254,250
Hydronic Piping	1,280 lf	$72,512
Circulation Pump	10 hp	$5,603
Axial Fan Cooling Tower	850 ton	$190,808

Table 30. Large Office CZ4 HVAC Cost Summary (Base Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
Gas Boiler	1600 MBH x 6	$164,370
Water Heat Pump	834 ton	$837,190
Electric HW Boiler	2,953 kW	$99,728
Axial Fan Cooling Tower	850 ton	$190,808
DOAS Ductwork	42,375 cfm	$254,250
DOAS Unit Only	42,375 cfm	$138,719
Circulation Pump	10 hp	$5,603
Hydronic Piping	1,280 lf	$72,512

High-rise Apartment

The High-rise Apartment prototype is a ten-story multifamily building. The systems include packaged terminal air conditioning units (PTACs) with a central gas boiler for gas space heating and packaged terminal heat pumps (PTHP) for electric space heating. Ventilation for the base case is exhaust-only ventilation, with dedicated exhaust fans at each unit. The proposed 2024 case uses energy recovery ventilation (ERV). The summary of HVAC first cost is shown in Table 31 through Table 34.

Table 31. High-rise Apartment CZ4 HVAC Cost Summary (Proposed Gas)

Baseline Unit	Baseline Capacity	Baseline Cost
PTAC	0.5 ton x 2	$2,306
PTAC	1 ton x 6	$8,388
PTAC	1.5 ton x 7	$13,440
PTAC	2 ton x 52	$125,216
Hydronic Piping	2,160 lf	$122,364
Apartment ERV	76 units	$120,536

Table 32. High-rise Apartment CZ4 HVAC Cost Summary (Proposed Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
PTHP	0.5 ton x 2	$2,306
PTHP	1 ton x 6	$9,168
PTHP	1.5 ton x 7	$13,720
PTHP	2 ton x 52	$150,748
Apartment ERV	76 units	$120,536

Table 33. High-rise Apartment CZ4 HVAC Cost Summary (Base Gas)

Proposed Unit	Proposed Capacity	Proposed Cost
PTAC	1 ton x 4	$5,592
PTAC	1.5 ton x 9	$17,280
PTAC	2 ton x 68	$163,744
Gas HW Boiler	2,420 MBH	$45,607
Hydronic Piping	2,880 lf	$163,152
Vent only	76 units	$38,000

Table 34. High-rise Apartment CZ4 HVAC Cost Summary (Base Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
PTHP	1 ton x 4	$6,112
PTHP	1.5 ton x 9	$17,640
PTHP	2 ton x 68	$197,132
Vent Only	76 Unit	$38,000

NYC High-rise Apartment

The twenty-story NYC High-rise Apartment prototype represents tall residential apartment buildings found in the New York City area. The gas base case includes PTACs with hot water coils served by a gas-fired hot water boiler and hydronic piping serving the zonal units. Ventilation for the base cases consists of exhaust ventilation only, with no energy recovery, which is costed as dedicated exhaust fans for each dwelling unit.

The proposed 2024 case includes zonal PTAC units for gas and PTHP units for electric. Ventilation for the 2024 case includes energy recovery ventilation for each dwelling unit providing tempered fresh air. This system could be implemented as rooftop DOAS units with ducted outside air to each of the dwelling units; however, for costing purposes, this has been specified as distributed multiroom ERV units. Some cost savings for the proposed case result from the elimination of the boiler and hydronic piping. A slight reduction in peak loads for the 2024 cases and the resulting reduction in system capacity offsets the increased costs of package terminal heat pumps. System first costs and capacities are in Table 35 through Table 38.

Table 35. NYC High-rise Apartment CZ4 HVAC Cost Summary (Proposed Gas)

Proposed Unit	Proposed Capacity	Proposed Cost
PTAC	0.5 ton	$1,153
PTAC	1.5 ton x 25	$48,000
PTAC	2 ton x 115	$276,920
Apartment ERV	145 units	$229,970

Table 36. NYC High-rise Apartment CZ4 HVAC Cost Summary (Proposed Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
PTHP	0.5 ton	$1,153
PTHP	1.5 ton x 25	$49,000
PTHP	2 ton x 115	$333,385
Apartment ERV	145 units	$229,970

Table 37. NYC High-rise Apartment CZ4 HVAC Cost Summary (Base Gas)

Baseline Unit	Baseline Capacity	Baseline Cost
PTAC	0.5 ton	$1,153
PTAC	1.5 ton x 25	$48,000
PTAC	2 ton x 125	$301,000
Hydronic Piping	2,800 lf	$163,152
Gas HW Boiler	4,900 MBH	$87,051
Vent Only	145 units	$72,500

Table 38. NYC High-rise Apartment CZ4 HVAC Cost Summary (Base Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
PTHP	0.5 ton	$1,153
PTHP	1.5 ton x 25	$49,000
PTHP	2 ton x 125	$362,375
Vent Only	145 Unit	$72,500

Midrise Apartment

The Midrise Apartment prototype is a four-story apartment with common corridor areas. The HVAC system for the base case uses split direct expansion (DX) systems, with exhaust-only ventilation for each apartment unit. The 2020 case uses electric resistance for heating each unit.

The 2024 proposed case uses split system air-source heat pumps to provide heating and cooling in each dwelling unit. For costing, nominal sizes were used for each dwelling unit and common spaces. The system for each zone uses the smallest nominal capacity that can meet the cooling load for the mixed case or can meet the larger of the cooling load and heating load for the 2024 electric case. The capacity of the 2024 electric case, which uses heat pumps, is higher than the base system capacity because the heating load drives the system capacity. For ventilation, the proposed case uses in-unit energy recovery ventilation to temper the incoming air. The costs for the Midrise Apartment systems are included in Table 39 and Table 40.

Table 39. Midrise Apartment CZ5 HVAC Cost Summary (Proposed Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
Split DX Heat Pump	1.5 ton x 6	$16,265
Split DX Heat Pump	2.0 ton x 5	$16,284
Split DX Heat Pump	2.5 ton x 5	$19,013
Split DX Heat Pump	3.5 ton x 4	$19,577
Split DX Heat Pump	4.0 ton x 2	$10,880
Split DX Heat Pump	4.5 ton x 2	$11,972

Proposed Unit	Proposed Capacity	Proposed Cost
Refrigerant Piping	1,200 lf	$16,860
Split Indoor Unit	62.5 ton	$16,521
Apartment ERV	31 units	$49,166

Table 40. Midrise Apartment CZ5 HVAC Cost Summary (Base Electric)

Baseline Unit	Baseline Capacity	Baseline Cost
Split DX Unit	1.5 ton x 6	$11,931
Split DX Unit	2 ton x 20	$43,656
Split DX Unit	2,5 ton x 5	$11,885
Split DX Unit	3.5 ton x 4	$11,062
Split DX Unit	4 ton x 2	$5,920
Split DX Unit	4.5 ton x 2	$6,308
Split Indoor Unit	55 ton	$14,466
Elec Furnace	6,342 MBH	$53,441
Refrigerant Piping	1,200 lf	$16,860
Vent Only	31 units	$15,500

Secondary School

The base cases HVAC system for the Secondary School is an air-cooled chiller and boiler, with central variable air velocity (VAV) air handling units delivering conditioned air to VAV terminal units with hot water reheat. Both the base cases and the proposed cases use an extensive amount of ductwork for air distribution.

Both the 2020 and 2024 cases use packaged rooftop DX units to serve the kitchen and cafeteria areas. The 2020 gas-fuel base case uses large, packaged rooftop DX HVAC units serving areas including the kitchen, cafeteria, and auditorium. The 2024 case uses large rooftop DX single zone heat pump units serving these spaces.

The systems are sized so that each zone can be served by unit(s) with nominal capacities between 3 tons and 25 tons of cooling. Since some of the zone sizes are large enough that they require systems in excess of the maximum commonly available heat pump size on the market (25 tons), multiple units are used for costing purposes for a single zone to reflect what is available in the market. For instance, a zone that has a modeled system capacity of 64.5 tons would be served by two 25-ton single-zone heat pumps and one 15-

ton heat pump, for costing purposes. Another zone with a modeled size of 36.9 tons would be served by two 20-ton units. See Table 41 through Table 44 for capacities and costs.

Table 41. Secondary School CZ5 HVAC Cost Summary (Proposed Gas)

Proposed Unit	Proposed Capacity	Proposed Cost
Air-Cooled Chiller	220 ton x 2	$297,934
Gas HW Boiler	3,300 MBH	$60,306
Chilled Water Pump	10 hp	$8,075
Circulation Pump	10 hp	$5,603
Circulation Pump	15 hp	$8,200
VAV AHU	100,000 cfm	$228,549
VAV Ductwork	4300 LF	$1,164,999
VAV Terminal Unit HW	200,000 cfm	$89,304
SZVAV	25 ton x 2	$49,491
SZVAV	20 ton x 6	$121,820
SZVAV	15 ton x 3	$47,583
SZVAV	5 ton	$6,976

Table 42. Secondary School CZ5 HVAC Cost Summary (Proposed Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
Air-Cooled Chiller	220 ton x2	$297,934
Gas Boiler	3,300 MBH	$60,306
Chiller Water Pump	10 hp	$8,075
Circulation Pump	10 hp	$5,603
Circulation Pump	15 hp	$8,200
VAV AHU	100,000 cfm	$228,549
VAV Ductwork	4,300 lf	$1,164,999
VAV Terminal Unit	200,000 cfm	$89,304
SZVAV HP	30 ton x 5	$184,269
SZVAV HP	25 ton	$30,044
SZVAV HP	20 ton x 4	$92,985
SZVAV HP	10 ton	$14,909

Table 43. Secondary School CZ5 HVAC Cost Summary (Base Gas)

Baseline Unit	Baseline Capacity	Baseline Cost
Air-Cooled Chiller	220 ton x 2	$297,934
Gas HW Boiler	4,400 MBH	$78,679
Chilled Water Pump	10 hp	$8,075
Circulation Pump	10 hp	$5,603
Circulation Pump	15 hp	$8200
VAV AHU	111,800 cfm	$254,741
VAV Ductwork	4300 LF	$1,164,999
VAV Terminal Unit HW	217,048 cfm	$96,774
DX with Elec Resistance Heat	25 ton x 4	$95,755
DX with Elec Resistance Heat	20 ton x 8	$157,097
DX with Elec Resistance Heat	5 ton	$6,732

Table 44. Secondary School CZ5 HVAC Cost Summary (Base Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
Air-Cooled Chiller	220 ton x 2	$297,934
Electric HW Boiler	4,400 kW	$144,136
VAV AHU	111,800 cfm	$254,741
VAV Ductwork	4,300 lf	$1,164,999
VAV Terminal Unit	217,048 cfm	$72,311
Chiller Water Pump	10 hp	$8,075
Circulation Pump	10 hp	$5,603
DX with Elec resistance Heat	10 ton x 4	$44,135
DX with Elec resistance Heat	15 ton x 4	$61,341
DX with Elec resistance Heat	20 ton	$19,637
DX with Elec resistance Heat	25 ton x 5	$119,694

Warehouse

The base case HVAC system for this prototype consists of packaged DX rooftop units, with electric resistance heating. The proposed case uses packaged heat pumps instead of the DX units. An electric resistance unit heater supplements the semi-heated bulk storage space. See Table 45 and Table 46 for capacities and costs.

Table 45. Warehouse CZ5 HVAC Cost Summary (Proposed Electric)

Proposed Unit	Proposed Capacity	Proposed Cost
Single Zone Heat Pump	5 ton	$8,099

Proposed Unit	Proposed Capacity	Proposed Cost
Single Zone Heat Pump	15 ton	$21,719
Single Zone Heat Pump	8.5 ton	$12,866
Electric Unit Heater	131 kW	$11,828

Table 46. Warehouse CZ5 HVAC Cost Summary (Base Electric)

Baseline Unit	Baseline Capacity	Baseline Cost
DX with Elec Resistance Heat	6 ton	$7,523
DX with Elec Resistance Heat	15 ton	$15,335
Electric Unit Heater	160 kW	$14,480

3.6.3 Service Water Heating Measures

The proposed High-rise Apartment and Large Hotel prototypes contain a water heating system energy credit for distribution systems that follow advanced IAPMO guidelines. For the High-rise Apartment, these savings are assumed to be achieved with low-flow fixtures, and they are not included in the cost estimate. The advanced distribution system is included for the Large Hotel hot water system, as a 20 percent incremental cost in hydronic piping. Piping costs are provided per linear foot; the piping length is estimated by assuming a main piping branch around the perimeter of each floor excluding the lobby (480ft for five floors) and by assuming an extra 5 feet of piping to each guestroom. Details are in Table 47.

Table 47. Service Water Heating Cost Summary

Prototype	Fuel	Baseline System	Cost	Proposed System	Cost
Large Office (CZ4)	Gas	Gas Boiler 300 MBH, 300 gal storage	$18,408	Gas Boiler 300 MBH, 300 gal storage	$18,408
	Elec	Elec Boiler 88 kW, 300 gal storage	$20,012	Elec Boiler 88 kW, 300 gal storage	$20,012
High-rise Apartment (CZ4)	Gas	Gas Boiler 600 MBH, 600 gal storage	$31,630	Gas Boiler 600 MBH, 600 gal storage	$31,630
	Elec	Elec Boiler 180 kW, 600 gal storage	$31,049	Elec Boiler 180 kW, 600 gal storage	$31,049
NYC High-rise Apartment (CZ4)	Gas	Gas Boiler 1200 MBH, 1200 gal storage	$58,074	Gas Boiler 1200 MBH, 1200 gal storage	$58,074

Prototype	Fuel	Baseline System	Cost	Proposed System	Cost
	Elec	Elec Boiler 360 kW, 1200 gal storage	52,995	Elec Boiler 360 kW, 1200 gal storage	52,995
Large Hotel (CZ4)	Gas	Gas Boiler 980 MBH, 600 gal storage, hydronic piping 3300 lf	$217,994	Gas Boiler 600 MBH, 600 gal storage, hydronic piping 3300 lf meeting IAPMO 2017 Apx C	$255,964
	Elec	Elec Boiler 180 kW, 600 gal storage, piping 3,300 lf	$217,994	Elec Boiler 180 kW, 600 gal storage, hydronic piping 3300 lf	255,383
Standalone Retail (CZ4)	Elec	Two Elec Storage Water Heaters (50 gal, 120 gal)	$8,269	Two Elec Storage Water Heaters (50 gal, 120 gal)	$8,269
Midrise Apartment (CZ5)	Elec	Elec Boiler 40 kW, 200 gal storage	$15,805	Elec Boiler 54 kW, 200 gal storage	$16,234
Secondary School (CZ5)	Gas	Gas Boiler 600 MBH, 600 gal storage	$31,630	Gas Boiler 600 MBH, 600 gal storage	$31,630
	Elec	Gas Boiler 600 MBH, 600 gal storage	$31,630	Elec Boiler 30 kW, Gas[a] Boiler 500 MBH, 600 gal storage	$39,984
Warehouse (CZ5)	Elec	Elec Storage Heater 50 gal	$1,222	Electric Storage Heater 50 gal	$1,222

a. Majority of service hot water supplies electrification-exempt end use; use in scope electrified.

3.7 Lighting Measures

Three lighting measures were selected in the credits package: lighting power (LPD) reduction, lighting dimming and tuning, and residential lighting control. The lighting dimming and tuning measure includes requirements for luminaire level dimming control and high-end trim. Costs for these luminaires, where applicable, were combined with the cost estimation for the LPD measures. The residential lighting control measure was applied to the three apartment prototypes. For this measure, wiring and relay costs for a manual lighting control that switches off all lights in the space was added to the proposed case. The LPD reduction measure was applied to all proposed prototypes and the cost estimation approach for the measure is described in greater detail below.

The costing approach for the LPD reduction measure used a similar approach to the one used by ASHRAE 90.1 Lighting Subcommittee (LSC) to evaluate the cost-effectiveness of changes to the lighting power allowances (LPAs) in Standard 90.1. The 90.1 LSC assigns lighting fixtures to space types. This assignment was used to develop a fixture-to-space type mapping. Each zone in the prototype models was mapped to a single space type or a combination of space types. Once the fixture type assignments were made, the LPD allowances in the baseline and proposed cases informed the energy models. The resulting modeled lighting energy end uses were used to determine the total lighting power by zone and subsequently the corresponding number of fixtures. Fixture first costs, fixture expected useful life, replacement costs, and installation and labor costs, derived from past 90.1 cost analyses and selected lighting properties, were applied to the prototype spaces to develop total lighting costs for the baseline and the proposed cases.

The baseline LPDs are low enough to require high-performance LED fixtures in most instances and, therefore, often the same fixture is assigned to both the baseline case and the proposed case. As a result, while the LPD is reduced in proposed, the total fixture costs also are reduced because fewer fixtures are needed to provide the lower LPD. This is not unexpected because LPDs of real projects are often much lower than the maximum lighting power allowed by the current code, let alone a previous code edition. LED fixtures of higher efficiency and high-performance lenses continue to drop in cost, as the technology becomes the industry standard. Beyond the first cost, the replacement of lighting components contributes significantly to the lifecycle cost. Costs for each prototype are summarized in Table 48.

Table 48. Lighting Costs

Prototype	Baseline	Proposed
NYC High-rise Apartment	$602,180	$444,294
High-rise Apartment	$184,017	$168,679
Mid-rise Apartment	$67,250	$45,300
Large Hotel	$953,958	$771,646
Standalone Retail	$244,604	$186,863
Large Office	$7,656,156	$6,146,185
Secondary School	$168,312	$121,380
Warehouse	$238,727	$208,816

3.8 Cost Summary by Building Prototype

Table 49 through Table 56 summarize the incremental cost of building components for each prototype impacted by measures in the proposed case relative to the baseline. Where there were changes, they were costed on an incremental basis, *i.e.*, only those components of a system that provided the increase in performance were costed. The difference between the sum of these component costs is the total incremental cost between baseline and proposed, weighted across climate zones where the prototypes are modeled.

Table 49. NYC High-rise Apartment Measure Costs

System	Component	Baseline	Proposed
Envelope	Opaque Assembly	$215,384	$202,995
	Fenestration	$579,066	$449,382
	Thermal Bridging Mitigation	$36,700	$47,625
	Air Leakage reduction	$0	$19,465
HVAC	Central System	$1,201,528	$1,002,305
Water Heating	Central System	$101,627	$93,399
Lighting	Interior Lighting	$602,180	$444,294
Clean Energy	PV system	$17,381	$89,085

Table 50. High-rise Apartment Measure Costs

System	Component	Baseline	Proposed
Envelope	Opaque Assembly	$127,581	$120,645
	Fenestration	$285,861	$223,292
	Thermal Bridging Mitigation	$18,210	$24,500
	Air Leakage reduction	$0	$10,531
HVAC	Central System	$762,589	$643,255
Water Heating	Central System	$54,953	$38,203
Lighting	Interior Lighting	$184,017	$168,679
Clean Energy	PV system	$16,755	$88,444

Table 51. Mid-rise Apartment Measure Costs

System	Component	Baseline	Proposed
Envelope	Opaque Assembly	$70,850	$70,850
	Fenestration	$49,482	$50,027
	Thermal Bridging Mitigation	$6,907	$10,077
	Air Leakage reduction	$0	$4,365
HVAC	Central System	$201,989	$151,860

System	Component	Baseline	Proposed
Water Heating	Central System	$20,204	$20,204
Lighting	Interior Lighting	$67,250	$45,300
Clean Energy	PV system	$0	$73,462

Table 52. Large Hotel Measure Costs

System	Component	Baseline	Proposed
Envelope	Opaque Assembly	$579,598	$568,999
	Fenestration	$283,802	$230,370
	Thermal Bridging Mitigation	$17,992	$24,140
	Air Leakage reduction	$0	$13,749
HVAC	Central System	$1,046,650	$1,385,394
Water Heating	Central System	$339,314	$395,247
Lighting	Interior Lighting	$953,958	$771,646
Clean Energy	PV system	$11,995	$234,592

Table 53. Standalone Retail Measure Costs

System	Component	Baseline	Proposed
Envelope	Opaque Assembly	$282,868	$278,085
	Fenestration	$15,131	$21,901
	Thermal Bridging Mitigation	$6,861	$9,113
	Air Leakage reduction	$0	$4,020
HVAC	Central System	$146,479	$147,023
Water Heating	Central System	$8,695	$7,290
Lighting	Interior Lighting	$244,604	$186,863
Clean Energy	PV system	$8,337	$80,457

Table 54. Large Office Measure Costs

System	Component	Baseline	Proposed
Envelope	Opaque Assembly	$1,419,246	$1,381,780
	Fenestration	$1,268,693	$936,402
	Thermal Bridging Mitigation	$47,321	$60,908
	Air Leakage reduction	$0	$54,292
HVAC	Central System	$2,782,124	$3,120,728
Water Heating	Central System	$126,524	$32,325
Lighting	Interior Lighting	$7,656,156	$6,146,185
Clean Energy	PV system	$18,299	$406,449

Table 55. Secondary School Measure Costs

System	Component	Baseline	Proposed
Envelope	Opaque Assembly	$601,194	$601,194
	Fenestration	$374,618	$377,813
	Thermal Bridging Mitigation	$21,707	$28,578
	Air Leakage reduction	$0	$19,716
HVAC	Central System	$3,159,363	$3,017,179
Water Heating	Central System	$48,648	$45,672
Lighting	Interior Lighting	$168,312	$121,380
Clean Energy	PV system	$0	$612,571

Table 56. Warehouse Measure Costs

System	Component	Baseline	Proposed
Envelope	Opaque Assembly	$218,454	$218,454
	Fenestration	$53,608	$53,632
	Thermal Bridging Mitigation	$13,878	$18,792
	Air Leakage reduction	$0	$5,955
HVAC	Central System	$54,586	$67,912

System	Component	Baseline	Proposed
Water Heating	Central System	$2,425	$2,357
Lighting	Interior Lighting	$238,727	$208,816
Clean Energy	PV system	$0	$151,228

4 Results

4.1 Incremental First Costs

Table 57 shows the weighted incremental first costs of the proposed commercial provisions of the 2024 State Energy Code relative to the current 2020 State Energy code, which include the material, labor, and equipment cost for the initial construction phase and exclude maintenance and replacement costs. The first costs can be normalized by the floor area of the prototype, providing a dollar per square foot incremental first cost, as shown in the rightmost column of Table 57.

Table 57. Weighted, Statewide Incremental Cost Change of Proposed 2024 State Energy Code*

Prototype	Incremental construction cost	
	Total $	$/sf
NYC High Rise Apartment	($271,642)	($1.61)
High Rise Apartment	$9,419	$0.11
Midrise Apartment	$49,267	$1.46
Large Hotel	$415,427	$3.40
Standalone Retail	$31,521	$1.28
Large Office	($1,311,156)	($2.63)
Secondary School	$450,260	$2.13
Warehouse	$163,234	$3.14
Statewide ($, $/sf weighted)	**($165,037)**	**($0.01)**

*Negative values indicate savings, positive values indicate costs.

4.2 Site Energy, Energy Cost, and Carbon Equivalence

Site energy includes electricity and natural gas for all end-uses. Electricity generated by proposed PV systems, presented in Table 58, was subtracted from the annual electricity consumption of the prototype prior to the calculation of annual electricity cost. Generation is weighted across climate zones. Under New York City conditions, a flat 4 kW of generation was assigned to the baseline. Electricity and natural gas were the only fuels used in the prototype models and comprise all end-uses with positive values indicating saving in energy cost. Site energy and energy cost savings from the proposed case relative to the baseline are shown in Table 59.

Table 61 shows energy savings used to calculate carbon equivalence savings, which are presented in Table 60.

Table 58. On-Site Electricity Generation

Prototype	On-Site electricity generation (kWh)
NYC High-rise Apartment	24,400
High-rise Apartment	24,380
Mid-rise Apartment	23,863
Large Hotel	67,575
Standalone Retail	23,578
Large Office	110,941
Secondary School	197,851
Warehouse	49,031

Table 59. Site Energy and Energy Cost Savings

Prototype	Total site energy savings		Energy cost savings		Total energy cost savings
	Elec (kWh)	Gas (therm)	Elec ($)	Gas ($)	First Year ($)
NYC High Rise Apartment	189,803	5,440	$60,906	$11,366	$72,272
High Rise Apartment	136,738	3,735	$43,317	$7,336	$50,653
Midrise Apartment	142,097	0	$26,968	$0	$26,968
Large Hotel	287,872	8,129	$64,185	$9,154	$73,339
Standalone Retail	130,042	0	$26,033	$0	$26,033
Large Office	861,623	68	$224,317	$90	$224,407
Secondary School	325,073	1,363	$44,969	$1,147	$46,116
Warehouse	105,533	0	$14,603	$0	$14,603
Statewide Weighted	**235,369**	**3,366**	**$63,036**	**$6,335**	**$69,371**

Table 60. First Year Emissions Savings

Prototype	CZ4-NYC[a] (lbs CO_2e/sf)	CZ4-Other[a] (lbs CO_2e/sf)	CZ5[a] (lbs CO_2e/sf)	CZ6[a] (lbs CO_2e/sf)
NYC High Rise Apartment	1.13	2.16	-	-
High Rise Apartment	1.58	2.50	2.94	-
Midrise Apartment	-	-	2.41	2.48
Large Hotel	2.37	2.66	2.72	2.78
Standalone Retail	2.70	3.30	3.45	3.59
Large Office	1.03	1.38	-	-

Prototype	CZ4-NYC[a] (lbs CO_2e/sf)	CZ4-Other[a] (lbs CO_2e/sf)	CZ5[a] (lbs CO_2e/sf)	CZ6[a] (lbs CO_2e/sf)
Secondary School	-	-	0.98	1.10
Warehouse	-	-	1.17	1.11
Weighted Average	1.38	0.22	0.64	0.11
Statewide Weighted Average Savings	**1.60**			

a. Climate zone (CZ) 4 uses downstate grid emissions; CZ5 and CZ6 use upstate grid emissions.

Table 61. Total Energy and Carbon Savings

Fuel	First Year Savings	30-Year Savings
Electricity (MWh)	50,190	4,366,528
Natural Gas (MMBTU)	63,421	5,517,597
CO_2e (mt)	18,150	382,868

4.3 Cost-Effectiveness Results

Cost-effectiveness savings includes all incremental (first) costs, replacements, maintenance, energy cost savings, and societal effects. Based on the costs and assumptions chosen, the commercial provisions of the proposed 2024 code were cost-effective compared to the statewide 2020 State Energy Code baseline with 2020 ECCNYC in NYC, as shown in Table 62. Including the societal effects of carbon, the proposed commercial provisions were cost-effective compared to the statewide 2020 State Energy Code baseline with 2020 ECCNYC in NYC, as shown in Table 63. The proposed 2024 State Energy Code is expected to yield 19.5 percent site energy savings and provide a 30-year net present value savings of $10.72 per square foot compared to the current 2020 codes, across all new commercial construction in the state for this code cycle.

Table 62. Results Summary LCC

Prototype	Construction weights by building type	First year energy cost savings ($/sf)	Incremental first cost ($/sf)*	LCC savings ($/sf)
NYC High Rise Apartment	37.7%	$0.43	($1.61)	$9.18
High Rise Apartment	18.3%	$0.60	$0.11	$11.88
Midrise Apartment	8.1%	$0.80	$1.46	$13.25
Large Hotel	7.5%	$0.60	$3.40	$7.97
Standalone Retail	6.9%	$1.05	$1.28	$18.23

Prototype	Construction weights by building type	First year energy cost savings ($/sf)	Incremental first cost ($/sf)*	LCC savings ($/sf)
Large Office	9.5%	$0.45	($2.63)	$13.53
Secondary School	1.0%	$0.22	$2.13	$2.26
Warehouse	10.9%	$0.28	$3.14	$1.75
Statewide Weighted Average Results	**100%**	**$0.53**	**($0.01)**	**$10.06**

*Negative values indicate savings, positive values indicate costs.

Table 63. Results Summary Societal Effects

Prototype	LCC savings - no societal benefits ($/sf)	First year emissions savings (lbs CO2e/sf)	Net present value of societal benefits savings ($/sf)	Cost-Effectiveness ($/sf)
NYC High Rise Apartment	$9.18	1.21	$0.60	$9.78
High Rise Apartment	$11.88	1.71	$0.84	$12.72
Midrise Apartment	$13.25	2.42	$0.69	$13.94
Large Hotel	$7.97	2.50	$1.25	$9.22
Standalone Retail	$18.23	3.10	$0.88	$19.10
Large Office	$13.53	1.04	$0.29	$13.82
Secondary School	$2.26	0.99	$0.34	$2.60
Warehouse	$1.75	1.16	$0.33	$2.08
Statewide Weighted Average Results	**$10.06**	**1.60**	**$0.66**	**$10.72**

5 References

AES Engineering. 2021. "Electric Vehicle Charging Infrastructure Costing Study." Accessed 2023. https://council.cleanairpartnership.org/wp-content/uploads/2021/10/2-21-050-GTHA-EV-Ready-Costing-Study-2021.10.14.pdf.

ASHRAE. 2020. *2020 AHSRAE Handbook - HVAC Systems and Equipment.* Atlanta, GA.

—. 2023. "Read-Only Versions of ASHRAE Standards." *ASHRAE.org.* Accessed April 03, 2024. https://ashrae.iwrapper.com/ASHRAE_PREVIEW_ONLY_STANDARDS/STD_90.1_2022_IP.

Benney, Jim. n.d. "NFRC's Component Modeling Approach: Simplifying Energy Code Compliance for Commercial." *International Code Council.* Accessed 2024. https://media.iccsafe.org/geo/docs/CommercialFenestration-NFRCs_ComponentModelingApproach.pdf.

BLS. 2022. *Producer Price Index (2009-2022).* Washington, D.C.: Bureau of Labor Statistics.

Bulger, Neil. 2019. *Economic Analysis of Heat Recovery Equipment in Commercial Dedicated Outside Air Systems.* Portland, OR: Northwest Energy Efficiency Alliance.

CALGreen. 2021. "Medium- and Heavy-Duty Electric Vehicle Charging Infrastructure Cost Analysis for California's CALGreen Building Code." https://title24stakeholders.com/wp-content/uploads/2021/09/CALGreen-2022-Medium-and-Heavy-Duty-EV-Charging-Cost-Analysis-2021-09.pdf.

CEC. 2021. "Nonresidential PV and Battery Storage Measure Proposal for California Energy Code, Title 24, Part 6." file:///C:/Users/YousefFa/Downloads/TN237776_20210511T085914_Nonresidential%20PV%20and%20Battery%20Storage%20Measure%20Proposal.pdf.

Central Hudson. 2023. "Gas Rate Structure." Accessed 2024. https://www.cenhud.com/en/account-resources/rates/gas-rate-structure/.

ConEd. 2023. "Gas Rates & Tarriff." Accessed 2023. https://lite.coned.com/_external/cerates/documents/allrates.pdf.

DCN. 2024. *Dodge Construction Network.* Accessed 2024. https://www.construction.com/.

DOE. 2022. *Determinations.* Building Energy Codes Program at the Office of Energy Efficiency and Renewable Energy, Department of Energy. Accessed 2022. https://www.energycodes.gov/determinations.

—. 2022. *EnergyPlus.* National Renewable Energy Laboratory. Accessed 2022. https://energyplus.net/.

—. 2022. *Prototype Building Models.* Department of Energy. Accessed 2022. https://www.energycodes.gov/prototype-building-models.

EIA. 2023. *Average retail electricity prices by end-use sector.* Washington, D.C.: Energy Information Administration. Accessed 2023. https://www.eia.gov/beta/states/states/ny/data/dashboard/electricity.

—. 2024. "Form EIA-861M: Sales to Ultimate Customers." Accessed 2024. https://www.eia.gov/electricity/data/eia861m/.

EIA. 2023. *Natural Gas Prices.* Washington, D.C.: Energy Information Administration. Accessed 2023. https://www.eia.gov/dnav/ng/NG_PRI_SUM_DCU_SNY_A.htm.

—. 2023. "State Energy Profile Data." *U.S. Energy Information Administration.* December. Accessed 2024. https://www.eia.gov/state/data.php?sid=NY.

Goel, Supriya, et al. 2021. *HVAC System Performance for Energy Codes.* Richland, WA: PNNL.

Gordian. 2022. *RSMeans data from Gordian version 8.7.* Accessed 2024. https://www.rsmeansonline.com.

Hart, Reid, and Bing Liu. 2015. *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes.* Richland, WA: PNNL. Accessed 2024. https://www.osti.gov/servlets/purl/1773017/.

Hart, Reid, and Bing Liu. 2015. *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes.* Richland, WA: PNNL. Accessed 2024. https://www.osti.gov/servlets/purl/1773017/.

Hart, Reid, Chitra Chandrasekharan Nambiar, Jian Zhang, and YuLong Xie. 2018. *PNNL-28367. Envelope Air Tightness for Commercial Buildings.* Richland, WA: Pacific Northwest National Laboratory. https://www.osti.gov/servlets/purl/1489004.

ICC. 2024. *2024 International Energy Conservation Code (IECC).* Country Club Hills, IL: International Code Council Inc.

IRS. 2012. *Publication 946. How to Depreciate Property.* Washington, D.C.: Internal Revenue Service.

Kniefel, J, and P Lavappa. 2023. *NISTIR 85-3273-38. Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – 2023. Annual Supplement to NIST Handbook 135.* Gaithersburg, MD: National Institute of Standards and Technology. Accessed 2024. https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=956573.

LBNL. 2021. "Grid Interactive Efficient Building Technology Cost, Performance and Lifetime Characteristics." 01. Accessed 2024. https://escholarship.org/content/qt44t4c2v6/qt44t4c2v6.pdf.

Lei, Xuechen , Joshua Butzbaugh, Yan Chen, Jian Zhang, and Michael Rosenberg. 2020. *Development of National New Construction Weighting Factors for the Commercial Building Prototype Analyses (2003-2018).* Richland, WA: PNNL. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29787.pdf.

National Fuel. 2024. "Rates Summary." January. Accessed 2024. https://www.nationalfuel.com/wp-content/uploads/documents/NY-Jan24.pdf.

National Grid Long Island. 2023. "Service Rates." Accessed 2023. https://www.nationalgridus.com/Long-Island-NY-Home/Bills-Meters-and-Rates/Service-Rates.

National Grid NYC. 2023. "Service Rates." Accessed 2023. https://www.nationalgridus.com/NY-Home/Bills-Meters-and-Rates/Service-Rates.

National Grid Upstate. 2023. "Service Rates." Accessed 2023. https://www.nationalgridus.com/media/pdfs/billing-payments/gas-rates/upstate-ny/psc_no-219_rates.pdf.

NBI. 2022. "Cost Study of the Building Decarbonization Code." *New Buildings Institute.* April 13. Accessed 2024. https://newbuildings.org/resource/cost-study-of-the-building-decarbonization-code/.

New York State Assembly. 2023. "All-Electric Building Act." 132-139. Accessed April 02, 2024. https://nyassembly.gov/leg/?default_fld=&leg_video=&bn=A03006&term=&Summary=Y&Text=Y.

New York State Climate Action Council. 2022. "New York State Climate Action Council ." http://climate.ny.gov/ScopingPlan.

New York State Department of Environmental Conservation. 2023. *Department of Environmental Conservation.* 08. Accessed 2024. https://www.dec.ny.gov/docs/administration_pdf/vocguide23final.pdf.

New York State Senate. 2023. *Energy (ENG) CHAPTER 17-A, ARTICLE 11.* May 12. Accessed May 7, 2024. https://www.nysenate.gov/legislation/laws/ENG/11-104.

NFRC. 2024. "Home." *National Fenestration Rating Council.* https://nfrccommunity.org/.

NREL. 2020. "2020 Annual Technology Baseline." https://data.nrel.gov/submissions/145 .

NREL. 2023. "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2023." https://www.nrel.gov/docs/fy23osti/87303.pdf.

NREL. 2023. "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2023"." 20. https://www.nrel.gov/docs/fy23osti/87303.pdf.

NY State Senate. 2019. "Bill S6599 of 2019 - An act to amend the environmental conservation law, the public service law,."

NYC DOB. 2020. *2020 New York City Energy Conservation Code.* New York, New York: Department of Buildings, New York City. https://www.nyc.gov/site/buildings/codes/2020-energy-conservation-code.page.

NYC DOF. 2022. *Property Tax Rates.* New York, New York: New York City Department of Finance. Accessed 2022. https://www.nyc.gov/site/finance/taxes/property-tax-rates.page.

NYC. 2021. *Local Laws of the City of New York for the Year 2021: No. 154.* Accessed 2024. https://www.nyc.gov/assets/buildings/local_laws/ll154of2021.pdf.

NYDOS. 2020. "2020 New York State Energy Conservation Construction Code." *ICC Digital Codes.* Accessed April 02, 2024. https://codes.iccsafe.org/content/NYSECC2020P1.

—. 2020. "New York Codes, Rules and Regulations." *Westlaw.* Accessed April 03, 2024. https://govt.westlaw.com/nycrr/Browse/Home/NewYork/NewYorkCodesRulesandRegulations?guid=I2faf8040ac4311dd81fce471ddb5371d&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default).

NYS Taxation. 2022. *Definitions for Article 9-A corporations.* Albany, NY: New York State Department of Taxation and Finance. Accessed 2022. https://www.tax.ny.gov/bus/ct/def_art9a.htm.

NYSDEC. 2022. *Establishing a Value of Carbon: Guidelines for Use by State Agencies.* Department of Environmental Conservation, State of New York, State of New York. Accessed 2022. https://www.dec.ny.gov/docs/administration_pdf/vocguid22.pdf.

NYSEG. 2023. "Residential Gas." Accessed 2023. https://www.nyseg.com/w/residential-gas.

—. 2023. "Small Nonesidential Gas." Accessed 2023. https://www.nyseg.com/w/small-nonresidential-gas.

NYSERDA. 2023. "Amendment to Title 21 of the Official Compilation of Codes, Rules and Regulations of the State of New York, addition of Part 510." Albany, NY: New York State Register, December 27. Accessed April 02, 2024. https://www.nyserda.ny.gov/All-Programs/Clean-Resilient-Building-Codes/Stakeholder-Feedback/Proposed-Rule.

—. 2024. "Clean & Resilient Building Energy Codes." Accessed 2024. https://www.nyserda.ny.gov/All-Programs/Clean-Resilient-Building-Codes.

NYSERDA. 2022. *Fossil and Biogenic Fuel Greenhouse Gas Emission Factors.* Report Number 22-23, Albany, NY: NYSERDA. nyserda.ny.gov/publications.

—. 2023. *FY 2024 Budget Highlights Energy Affordability, Sustainable Buildings, and Clean Energy.* May 03. Accessed April 17, 2024.

https://www.nyserda.ny.gov/About/Newsroom/2023-Announcements/2023-05-03-Governor-Hochul-Announces-FY-2024-Budget-Investments-in-Energy-Affordability.

—. 2021. "New York Solar Study." Accessed 2023. https://www.nyserda.ny.gov/About/Publications/Program-Planning-Status-Reports/Solar-Study.

NYSERDA. 2022. *Projected Emission Factors for New York State Grid Electricity.* Report Number 2-18, Albany, NY: NYSERDA. nyserda.ny.gov/publications.

ORU. 2023. "Gas Supply Charge." Accessed 2023. https://lite.oru.com/_external/orurates/tariffsandregulatorydocuments/newyork/gassupplycharge.html.

RealtyRates. 2022. *Commercial Mortgage Rates and Terms.* Accessed 2022. http://www.realtyrates.com/commercial-mortgage-rates.html.

Red Car Analytics. 2019. *Economic Analysis of Heat Recovery Equipment in Commercial Dedicated Outside Air Systems.* Northwest Energy Efficiency Alliance.

RG&E. 2023. "Residential Gas." Accessed 2023. https://www.rge.com/w/Residential-gas.

—. 2023. "Small Nonresidential Gas." Accessed 2023. https://www.rge.com/w/small-nonresidential-gas.

Sachs, H, H Misuriello, S Kwatra. 2015. *Advancing Elevator Energy Efficiency.* Washington, D.C.: American Council for an Energy-Efficient Economy.

TRM Management Committee. 2022. "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs - Residential, Multi-Family, and Commercial/Industrial (Version 10)." *New York Department of Public Service.* December 30. Accessed April 05, 2024. https://dps.ny.gov/system/files/documents/2023/12/q3-2023-record-of-revision-revisions.pdf.

Tyler, M, R Hart, et al. 2021. *PNNL-29940. National Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019.* Richland, WA: Pacific Northwest National Laboratory. Accessed 2022. https://www.energycodes.gov/sites/default/files/2021-07/90.1-2019_National_Cost-Effectiveness.pdf.

U.S. Congress. 2017. *Public Law 115-97.* Washington, D.C.: United States Congress. Accessed 2022. https://www.congress.gov/115/plaws/publ97/PLAW-115publ97.pdf.

Washington State University. 2014. *Emerging Technologies: High Performance Elevators.* Accessed 2022. http://e3tnw.org/ItemDetail.aspx?id=471.