Energy Savings and Cost-Effectiveness Analysis of the 2020 NYStretch Energy Code Residential Provisions

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Energy Savings and Cost-Effectiveness Analysis of the 2020 NYStretch Energy Code Residential Provisions

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Abstract

This report summarizes the energy savings and cost-effectiveness analysis of the residential provisions of the 2020 NYStretch Energy Code of New York State. This is compared to the residential provisions of the 2016 New York City Energy Conservation Code (NYCECC) in New York City, and the residential provisions of the 2020 ECCC NYS in the rest of the state. The report includes the methodology used in the analysis, assumptions, and results at the applicable climate design zones for New York State. An additional analysis evaluating the energy savings and cost-effectiveness of the additional energy efficiency credits path (R407) is also conducted. The results associated with the analysis are summarized in the Appendix.

Keywords

Energy code, stretch energy code, cost effectiveness, NYSERDA

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Acronyms and Abbreviations

CDZ	climate design zone
CPI	consumer price index
DHW	domestic hot water
DOE	US Department of Energy
DWHR	drain water heat recovery
ECCC NYS	2020 Energy Conservation Construction Code of New York State
EF	energy factor
EIA	Energy Information Association
ERV	energy recovery ventilator
EUL	effective useful life
EV	electric vehicle

ft	feet
HRV	heat recovery ventilator
HVAC	heating, ventilation, and air conditioning
IECC	International Energy Conservation Code
kWh	kilowatt hours
LCC	life cycle cost
lf	linear foot
lm	lumen
LPD	lighting power density
MF	multifamily
m/s	meters per second
MW	megawatts
NAHB	National Association of Home Builders
NPV	net present value
NREL	National Renewable Energy Laboratory
NREM	National Residential Efficiency Measures Database
NYC	New York City
NY	New York
NYCECC	New York City Energy Conservation Code
NYDOS	New York Department of State
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
PNNL	Pacific Northwest National Laboratory
RGGI	Regional Greenhouse Gas Initiative
SF	single family
SRE	sensible recovery efficiency
UEF	uniform energy factor
W	watts

Summary

This analysis was conducted at the request of the New York State Energy Research and Development Authority (NYSERDA) to assist with the adoption of the 2020 NYStretch Energy Code. The analysis evaluates the energy savings and cost-effectiveness potential of the residential prescriptive and mandatory provisions of the 2020 NYStretch code when compared to the residential provisions of the 2020 Energy Conservation Construction Code of New York State (ECCC NYS) and the 2016 New York City Energy Conservation Construction Code (NYCECC).

The analysis closely follows the methodology set forth by the U.S. Department of Energy (U.S. DOE) for conducting cost-effectiveness analyses of residential code changes (Taylor et al. 2015) and the procedure used for the previous energy and cost-effectiveness evaluation of the 2020 ECCC NYS (NYSERDA 19-32, 2019). The analysis also leverages the residential prototype building models developed by Resource Refocus LLC for the evaluation of the 2020 ECCC NYS, which were in turn developed from the set of DOE residential prototype building models developed by the Pacific Northwest National Laboratory (PNNL) for the 2015 IECC code development analysis. This approach maintains a consistency between the current analysis and past work conducted by NYSERDA, U.S. DOE, and PNNL for New York State (NYSERDA 2019 and Mendon et al. 2016).

The analysis included a qualitative assessment to evaluate the anticipated energy impact of code changes proposed by the 2020 NYStretch code, including a determination of which impacts could be quantified through an energy analysis. An energy analysis was then conducted by creating customized energy models tailored to the code requirements for New York State. The energy savings from the energy analysis were then combined with the incremental construction costs associated with the changes to determine the simple payback, the 10-year net present value (NPV) of energy cost savings and the 30-year Life Cycle Cost (LCC) savings.

Overall, the prescriptive and mandatory provisions of the 2020 NYStretch code are expected to yield positive energy savings and cost-effective benefits to homeowners compared to the baseline 2020 ECCC NYS and the 2016 NYCECC. Table S-1 summarizes the statewide site energy, source energy, and energy cost savings, and Table S-2 summarizes the disaggregated energy and cost savings for each

climate design zone (CDZ). Table S-3 summarizes the disaggregated incremental construction costs and simple payback by building type in each CDZ. Finally, Table S-4 summarizes the average energy cost savings, incremental construction costs and cost-effectiveness results for the prescriptive and mandatory provisions of NYStretch, weighted over the single- and multifamily building construction weights for New York State.

Table S-1. Statewide Average Annual Energy and Cost Savings

	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
Baseline*	59926.4	91545.1	1514.9
2020 NYStretch	45161.4	71769.2	1216.7
Savings	24.6%	21.6%	19.7%

* The baseline code is the 2016 NYCECC in CDZ 4A-NYC and 2020 ECCC NYS in all other CDZs

Table S-2. Average Annual Energy and Cost Savings by Climate Design Zone

Climate Design Zone	Total Regulated Site Energy Savings	Total Regulated Source Energy Savings	Total Energy Costs Savings
4A-NYC	21.1%	19.9%	19.0%
4A-balance	21.5%	19.8%	18.8%
5A	25.3%	21.9%	19.6%
6A	26.2%	23.1%	20.9%

Table S-3. Average Annual Simple Payback by Building Type and Climate Design Zone

Climate Design Zone	Single-family			Multifamily		
	Total Annual Energy Cost Savings ($/dwelling unit)	Total Incremental Costs ($/dwelling unit)	Simple Payback (Years)	Total Annual Energy Cost Savings ($/dwelling unit)	Total Incremental Costs ($/dwelling unit)	Simple Payback (Years)
4A-NYC	$301	$1,910	6.3	$176	$1,625	9.2
4A-balance	$301	$2,463	8.2	$167	$1,488	8.9
5A	$351	$2,202	6.3	$172	$1,751	10.2
6A	$372	$1,506	4.1	NA	NA	NA
NY State	$348	$2,057	5.9	$171	$1,591	9.3

Table S-4. Weighted Results

For the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code at the State Level

	New York State Average
Annual Energy Cost Savings ($/dwelling unit)	$278
Incremental Costs ($/dwelling unit)	$1,795
Simple Payback (Years)	6.4
10-Year NPV of Cost Savings Including Replacement Costs and Residual Values ($/dwelling unit)	$2,854
30-Yr LCC Savings ($/dwelling unit)	$1,741

While the present analysis focuses on the prescriptive and mandatory provisions of NYStretch, the code offers other compliance paths. The multiple compliance paths in NYStretch are expected to yield equal or higher savings. The performance paths offer flexibility to the builder in meeting the code, resulting in a wide variability in the performance of homes complying with the simulated paths or the passive house path. It should also be noted that this analysis assumes no fuel switching between the baseline and the NYStretch cases. Additionally, while NYStretch contains many elements that encourage better building design, this analysis used conservative savings and incremental cost estimates for many of the measures. In this respect, the estimated energy savings reported from the analysis are likely to be conservative compared to actual energy savings that can be achieved by the 2020 NYStretch code.

1 Introduction

The New York State Energy Research and Development Authority (NYSERDA) developed the 2020 NYStretch Energy Code with guidance from an advisory group composed of public and private stakeholders. It is a voluntary, locally adoptable stretch energy code designed as an overlay to the 2020 Energy Conservation Construction Code of New York State (ECCC NYS) and is expected to be far more efficient than the residential provisions of the 2018 International Energy Conservation Code (IECC) and the commercial provisions of ASHRAE Standard. 90.1-2016.

In order to assist communities in adopting the stretch code, NYSERDA requested an analysis of the energy savings and cost-effectiveness of the 2020 NYStretch code compared to the State baseline codes, the 2016 New York State Energy Conservation and Construction Code (NYSECC) and the 2020 ECCC NYS. This analysis was conducted in each of the three climate design zones (CDZ) in New York State: 4A, 5A, and 6A and results are provided in this technical report, along with a narrative summarizing the findings and their implications for New York State's code development process.

The analysis builds on previous analysis conducted by the team for NYSERDA, including the cost-effectiveness analysis of the 2020 ECCC NYS compared to the previous 2016 NYSECC as well as technical reports and analyses published by the U.S. Department of Energy (U.S. DOE) and the Pacific Northwest National Laboratory (PNNL). Additionally, the methodology also draws from other technical resources as needed. Relevant to the residential scope of the analysis, NYSERDA made available the proposed Draft NYStretch Energy Code, January 2019[1] and results of an energy analysis conducted by the New Buildings Institute (NBI) and Earth Advantage during the stretch code development process. The firm Earth Advantage provided a presentation describing the potential savings for the residential provisions of the 2020 NYStretch code based on their modeling results using REMRate.

2 Qualitative Assessment

This section contains qualitative comparison tables for the prescriptive and mandatory provisions of the proposed 2020 NYStretch Energy Code (NYStretch) compared to the 2020 Energy Conservation Construction Code of New York State (ECCC NYS) in climate design zones (CDZ) 4A, 5A, and 6A. Because CDZ 4A covers New York City, which follows the more stringent 2016 New York City Energy Conservation Code (NYCECC), an additional evaluation of the 2020 NYStretch compared to the 2016 NYCECC is also conducted for New York City.

The qualitative assessment includes an evaluation of the expected energy impact of each provision and whether the change will be captured through energy modeling during the quantitative analysis. The assessment is limited to prescriptive and mandatory provisions of the residential provisions of the code as they apply to new construction only. It does not include editorial, clarification, and administrative type of changes, which are not expected to have a direct impact on energy. Table 1 summarizes the changes between the baseline 2020 ECCC NYS and the proposed 2020 NYStretch code, along with the results of the qualitative assessment.

Table 1. A Preliminary Qualitative Comparison

The Differences with the Largest Energy Impact between the 2020 NYStretch Code and the 2020 ECCC NYS (Prescriptive + Mandatory Provisions)

Code Section	Component	CDZ	2020 ECCC NYS		2020 NYStretch	Energy Impact Captured through Energy Modeling (Yes/No)
R402.1	Fenestration U-factor	4A	0.32		0.27	Yes The overall impact of the changes to the prescriptive envelope are expected to yield positive energy savings across all CDZs.
		5A	0.3		0.27	
		6A	0.3 [a]	0.28 [a]	0.27	
	Fenestration SHGC	4A	0.4		0.4	
		5A	NR		NR	
		6A	NR [a]	NR [a]	NR	
	Ceiling R value	4A	49		49	
		5A	49		49	
		6A	49 [a]	60 [a]	49	
	Wood-framed R-value	4A	20 or 13+5		21 int or 20+5 or 13+10	
		5A	20 or 13+5		21 int or 20+5 or 13+10	
		6A	20+5 or 13+10 [a]	23 cavity [a]	20+5 or 13+10	

Table 1 continued

<table>
<tr><th>Code Section</th><th>Component</th><th>CDZ</th><th colspan="2">2020 ECCC NYS</th><th>2020 NYStretch</th><th>Energy Impact Captured through Energy Modeling (Yes/No)</th></tr>
<tr><td rowspan="12">R402.1</td><td rowspan="3">Floor R-value</td><td>4A</td><td colspan="2">19</td><td>30</td><td rowspan="12"></td></tr>
<tr><td>5A</td><td colspan="2">30</td><td>30</td></tr>
<tr><td>6A</td><td>30 [a]</td><td>30 [a]</td><td>30</td></tr>
<tr><td rowspan="3">Basement wall R-value</td><td>4A</td><td colspan="2">10 or 13</td><td>15 or 19</td></tr>
<tr><td>5A</td><td colspan="2">15 or 19</td><td>15 or 19</td></tr>
<tr><td>6A</td><td>15 or 19 [a]</td><td>15 or 19 [a]</td><td>15 or 19</td></tr>
<tr><td rowspan="3">Slab R-value and depth</td><td>4A</td><td colspan="2">10, 2 ft</td><td>10, 4 ft</td></tr>
<tr><td>5A</td><td colspan="2">10, 2 ft</td><td>10, 4 ft</td></tr>
<tr><td>6A</td><td>10, 4 ft [a]</td><td>10, 4 ft [a]</td><td>10, 4ft</td></tr>
<tr><td rowspan="3">Crawlspace wall R-value</td><td>4A</td><td colspan="2">15 or 19</td><td>15 or 19</td></tr>
<tr><td>5A</td><td colspan="2">15 or 19</td><td>15 or 19</td></tr>
<tr><td>6A</td><td>15 or 19*</td><td>15 or 19*</td><td>15 or 19</td></tr>
<tr><td>R402.4.1.1</td><td>Insulation Installation</td><td>all</td><td colspan="2">Grade Not Specified</td><td>No more than 2% of total insulated area shall have compressed insulation or gaps/voids (Grade I insulation required)</td><td>No

Assumptions for the baseline configuration would need significant installation quality data. In absence of such data, the impact of this change cannot be evaluated through energy modeling.

This change is expected to improve insulation installation, resulting in better U-factors for the overall assemblies. Thus, the practical impact of this change is expected to be positive energy savings.</td></tr>
<tr><td>R403.3</td><td>Duct Location</td><td>all</td><td colspan="2">Not controlled</td><td>Duct System is required to be within conditioned space.</td><td>Yes

The savings from this change will not be modeled explicitly, but will be applied to the heating, cooling and fan energy during post-processing.

This change is expected to save conduction and leakage losses from ducts and result in positive energy savings.</td></tr>
</table>

Table 1 continued

Code Section	Component	CDZ	2020 ECCC NYS	2020 NYStretch	Energy Impact Captured through Energy Modeling (Yes/No)
R403.3.8	Duct Sizing	all		Ducts are required to be sized in accordance with ACCA Manual D.	No Modeling this change would require developing a full duct network in *EnergyPlus* as well as adequate information about current trends in duct sizing in the field. Both issues would result in several configurations of the duct layout making the exercise cost prohibitive. This change is expected to save losses from incorrectly sized ducts and result in positive energy savings.
R403.5.5	Supply of heated water	all	None	The new section adds four options for increasing the efficiency of hot water supply. These include limiting the maximum allowable pipe length or volume, installing drain water heat recovery units or recirculation systems.	Yes The savings from this change will not be modeled explicitly but will be applied to the hot water energy during post-processing. This change is expected to reduce losses from domestic hot water (DHW) pipes and is expected to result in positive energy savings.
R403.6.2	Balanced and HRV/ERV systems	all	None	The new section requires an energy or heat recovery ventilator (ERV or HRV) in each dwelling unit in CDZ 5A and 6A. In CDZ 4A, it allows a balanced ventilation system to comply with the requirement.	Yes The impact from this code change will be modeled assuming an ERV/HRV system in CDZ 5A and 6A and balanced ventilation in CDZ 4A and CDZ 4A-balance. This change is expected to reduce heating energy but also comes with an increase in fan energy. The overall impact may thus be neutral.

Table 1 continued

Code Section	Component	CDZ	2020 ECCC NYS	2020 NYStretch	Energy Impact Captured through Energy Modeling (Yes/No)
R403.6.3	Verification of ventilation systems	all	None	The new section requires that the performance of ventilation systems be tested and verified by an approved agency.	No This is a verification requirement and thus cannot be modeled. This change is expected to ensure proper functioning of the ventilation system. The energy impact from this provision is expected to be neutral.
R404.1	Lighting Equipment	all	60 lm/W for lamps over 40 W; 50 lm/W for lamps between 15 W and 40 W; 40 lm/W for lamps 15 W or less.	This change increases the minimum required efficacy of lamps to be 65 lm/W and the total luminaire efficacy to be 45 lm/W.	Yes The savings from this change will be modeled by reducing the lighting power density (LPD) in the models per the revised efficacy limits. This change is expected to reduce losses from inefficient lighting and is expected to result in positive energy savings.
R404.2	Electrical power packages	all	None	This new section adds requirements for a solar ready zone and electrical vehicle (EV) service equipment	No This code change requires the buildings to be solar ready and have EV infrastructure but does not explicitly mandate any specific equipment. This change is expected to yield savings by encouraging design considerations for solar energy and EV infrastructure.

[a] The 2020 ECCC NYS includes two prescriptive envelope options for CZ 6A.

Table 2 summarizes the additional differences between the baseline 2016 NYCECC and the 2020 NYStretch code, along with the results of the qualitative assessment.

Table 2. A Preliminary Qualitative Comparison

The Additional Differences between the 2020 NYStretch Code and the 2016 NYCECC (Prescriptive + Mandatory Provisions)

Component	2016 NYCECC	2020 NYStretch	Energy Impact Captured through Energy Modeling (Yes/No)
Fenestration U-factor	0.32	0.27	Yes The impact is expected to yield positive energy savings in CDZ 4A.
Fenestration SHGC	0.4	0.4	No The exterior walls will be modeled as R-20+5 in both the baseline and the NYStretch cases. All other requirements are the same between the baseline and the 2020 NYStretch code.
Ceiling R value	49	49	
Wood-framed R-value	20+5	21 int or 20+5 or 13+10	
Floor R-value	30	30	
Basement wall R-value	15/19	15/19	
Slab R-value and depth	10,4	10, 4 ft	
Crawlspace wall R-value	15/19	15/19	
Lighting Equipment	75% of permanently installed lamps are required to be high efficacy	90% of permanently installed lamps have to be high efficacy with a minimum required efficacy of lamps to be 65 lm/W and the total luminaire efficacy to be 45 lm/W.	Yes The savings from this change will be modeled by reducing the lighting power density (LPD) in the models per the revised efficacy limits. This change is expected to reduce losses from inefficient lighting and result in positive energy savings.

In summary, the overall energy impact of the 2020 NYStretch code is expected to be positive (energy savings) over the baseline codes.

3 Quantitative Analysis

This section describes the overall quantitative analysis used to assess the stringency and cost-effectiveness of the residential provisions of the proposed 2020 NYStretch Energy Code compared to the 2016 New York City Energy Conservation Code (2016 NYCECC) in New York City and the 2020 Energy Conservation Construction Code of New York State (2020 ECCC NYS) in the rest of the State. The analysis methodology builds on US Department of Energy's (DOE) methodology for determining the cost-effectiveness of residential code changes (Taylor et al. 2015), similar work conducted by the Pacific Northwest National Laboratory (PNNL) in previous code cycles (Mendon et al. 2016) and the previous analysis of the 2020 ECCC NYS conducted by Resource Refocus LLC for NYSERDA (NYSERDA 2019). Additionally, the analysis leverages the DOE residential prototype building models developed by PNNL for the 2015 International Energy Conservation Code (IECC) code development process and modified by Resource Refocus LLC for support to the New York Department of State (DOS) for the 2020 ECCC NYS Rulemaking process (NYSERDA 2019).

3.1 Overview of the Analysis

The 2020 NYStretch is designed to overlay the 2020 ECCC NYS. Thus, the stretch code continues to offer multiple paths for compliance, including a prescriptive option, a Passive House option, and two simulated performance path alternatives. Regardless of the compliance path chosen, additional mandatory requirements need to be met. The multiple compliance paths offer flexibility to the builder in meeting the code, resulting in a wide variability in the performance of homes complying with the simulated performance paths or the passive house path. The prescriptive path on the other hand offer less variability in terms of design and is typically more widely used in residential buildings compared to performance paths. Thus, the present analysis is based on the prescriptive and mandatory provisions of the 2020 NYStretch code. An overview of the analysis along with the methodology involved in the process is described in the following sections.

3.1.1 Determining the Baseline Annual Energy Use and Energy Cost for Residential Prototypes

This task involved the following steps:

1. The energy models developed by Resource Refocus LLC for the previous 2020 ECCC NYS cost-effectiveness analysis were leveraged for this step. The models were modified to reflect the revised federal minimum efficiencies for oil and gas furnaces, heat pumps, and oil boilers.

2. The baseline models for CDZ 4A were further split into two sets: one representing the requirements of the 2016 NYCECC and the other set representing the requirements of the 2020 ECCC NYS. This was done to accurately compute the energy savings and cost-effectiveness of the 2020 NYStretch in New York City because the 2016 NYCECC has different envelope requirements compared to the 2020 ECCC NYS.
3. The two sets of models were used to simulate energy use for the baseline case for single-family and low-rise multifamily units. The set representing the requirements of the 2016 NYCECC was simulated in CDZ 4A, which was selected as the representative climate location for New York City and the other set representing the requirements of the 2020 ECCC NYS was simulated in the balance of CDZ 4A and CDZs 5A and 6A.
4. The annual energy use for the code-regulated end-uses of heating, cooling, fans, lighting, and domestic hot water (DHW) were extracted and converted to energy costs.
5. The annual energy use and energy cost were aggregated to the CDZ and State level using the weights provided by NYSERDA.

3.1.2 Determining the Annual Energy Use, Annual Energy Cost, and Incremental Construction Cost for Residential Prototypes using NYStretch

This task involved the following steps:

1. A detailed evaluation of the residential provisions of the 2020 NYStretch code was conducted as it applies to the three CDZs in the State (4A, 5A, and 6A).
2. A set of NYStretch models was developed to minimally meet the residential prescriptive and mandatory provisions of the 2020 NYStretch Code.
3. The whole building incremental construction costs were calculated for the NYStretch set compared to the respective baseline. These costs were further adjusted for location and inflation.
4. The annual energy use for the code-regulated end uses of heating, cooling, fans, lighting, and DHW was extracted and converted to annual energy costs.
5. The annual energy use and energy cost were aggregated to the CDZ and State level using the weights provided by NYSERDA.

3.1.3 Cost Effectiveness of Residential Provisions of NYStretch

This task involved the following steps:

1. The energy use estimates were used to calculate energy cost savings for each prototype.
2. The energy savings were matched with corresponding incremental construction costs for each case.
3. A simple payback, 10-year present value calculation of energy cost savings, and a 30-year life cycle cost (LCC) savings were calculated.
4. The cost-effectiveness metrics were aggregated to the CDZ and State level using the associated construction weights.

3.2 Suite of Energy Models and Aggregation Scheme

The analysis leverages the models developed by Resource Refocus during the previous 2020 ECCC NYS cost-effectiveness analysis conducted for NYSERDA (NYSERDA 2019). These models, in turn developed from a set of 32 DOE/PNNL 2015 IECC residential prototype models, represent a majority of the new residential building construction stock. The set includes a detached single-family building model (total conditioned floor area of 2,400 ft^2, two stories and 8.5’ ceilings) and a low-rise multifamily building model (a three-story apartment building with six dwelling units per floor, in rows of three separated by a central breezeway; conditioned floor area of 1,200 ft^2 per unit and 8.5’ ceilings), each configured with four common heating systems (gas-fired furnace, electric resistance furnace, heat pumps, and oil-fired furnaces) and four foundation types (slab-on-grade, heated and unheated basements, and crawlspaces) (Mendon et al. 2014 and Taylor et al. 2015).

These models are supplemented with a set of associated construction weights for the State, provided by NYSERDA and are summarized in Table 3. NYSERDA recommended a smaller subset of models to optimize the analysis effort and accuracy of results, resulting in a total representative construction weight of 93%. Thus, the weights were normalized to total 100% at the CDZ and State level during the analysis.

Table 3. Matrix of Construction Weights Used in the Analysis

	CDZ 4A		CDZ 5A		CDZ 6A		
	SF	MF	SF	MF	SF	MF	TOTALS
Slab-on-Grade, Heat Pump	0.64%	1.69%	2.01%	0.56%	0.86%	0.0%	5.76%
Slab-on-Grade, Oil Furnace	0.0%	0.0%	0.38%	0.0%	0.0%	0.0%	0.38%
Slab-on-Grade, Gas Furnace	1.80%	2.12%	5.68%	0.70%	2.44%	0.0%	12.74%
Heated Basement, Heat Pump	0.81%	2.14%	2.55%	0.71%	1.10%	0.0%	7.31%
Heated Basement, Oil Furnace	0.0%	0.33%	0.48%	0.0%	0.0%	0.0%	0.81%
Heated Basement, Gas Furnace	2.29%	2.69%	7.21%	0.89%	3.09%	0.0%	16.18%
Unheated Basement, Heat Pump	1.30%	3.45%	4.11%	1.15%	1.76%	0.0%	11.77%
Unheated Basement, Oil Furnace	0.0%	0.53%	0.77%	0.0%	0.33%	0.0%	1.64%
Unheated Basement, Gas Furnace	3.69%	4.33%	11.61%	1.44%	4.98%	0.0%	26.05%
Crawlspace, Heat Pump	0.0%	0.99%	1.18%	0.33%	0.51%	0.0%	3.01%
Crawlspace, Gas Furnace	1.06%	1.24%	3.34%	0.41%	1.43%	0.0%	7.50%
			Percentage of total NYS Construction weights				93.14%

The weights for CDZ 4A were further divided between New York City and the balance of CDZ 4A using an average of county-level housing starts from 2014 to 2018 based on data provided by NYSERDA from the Dodge Data and Analytics database. Average housing starts for the counties of Bronx, King, New York, Queens, and Richmond were grouped into "CDZ-4A-NYC" and the counties of Nassau, Suffolk, and Westchester were grouped into "CDZ 4A-balance" as summarized in Table 4.

Table 4. Split of Construction Weights between CDZ 4A-NYC and CDZ 4A-balance

Prototype	CDZ 4A-NYC	CDZ 4A-balance	Total
Single-family	19.6%	80.4%	100.0%
Multifamily	38.0%	62.0%	100.0%

3.3 Energy Analysis

3.3.1 Simulation Tool

The analysis was conducted in version 8.0 of EnergyPlus. While more recent versions of the engine are currently available, the analysis was conducted using the same version of EnergyPlus as the previous cost-effectiveness analysis conducted for the 2020 ECCC NYS to minimize the time required for model upgrades and potential troubleshooting. Additionally, version upgrades often involve changes in estimated energy use and maintaining the same version of EnergyPlus allows for a direct comparison with earlier work conducted by PNNL for New York State (Mendon et al. 2016).

3.3.2 Weather Locations

The analysis was conducted using weather data for New York City (CDZ 4A), Buffalo (CDZ 5A) and Watertown (CDZ 6A). The baseline set of models representing the 2020 ECCC NYS was simulated in all three climate design zones with the exception of a portion of CDZ 4A representing New York City, in which a baseline set representing the 2016 NYCECC was simulated. Correspondingly, the NYStretch models were simulated in all three climate design zones.

3.3.3 Site, Source, and Energy Cost Calculations

Site energy use from the annual simulation was extracted for the major code regulated end-uses, including heating, cooling, ventilation, fans, lighting, and DHW and converted to energy costs using the average fuel costs for electricity, natural gas, and fuel oil for the State, which was published by the Energy Information Association (EIA). Site energy was also converted to source energy using site-source conversion factors for electricity, natural gas, and fuel oil.

3.3.4 Baseline Models for New York State

Energy models representing the baseline 2020 ECCC NYS developed for the previous 2020 ECCNYS cost-effectiveness analysis were leveraged for this analysis. First, the models were modified to use the revised federal minimum equipment efficiencies as shown in Table 5. The baseline set for CDZ 4A was then further split into a set representing the minimum requirements of the 2016 NYCECC.

Table 5. Federal Minimum Equipment Efficiencies

Parameter	Updated Federal Minimum Efficiency2
Gas furnace	80%
Oil furnace	83%
Oil boiler	84%
Heat pump	SEER 14

3.3.4.1 Adjustment for Duct Sealing

The 2020 ECCC NYS models were developed from the 2015 IECC PNNL/DOE models provided by NYSERDA. The PNNL/DOE models do not account for losses associated with an air distribution system, and the savings associated with duct sealing provisions were added to the energy use by PNNL with an involved post-processing setup (Mendon et al. 2013). Consistent with the previous 2020 ECCC NYS cost-effectiveness analysis, this analysis used a conservative estimate of 10% heating and cooling savings across the board from duct sealing provisions for the baseline and NYStretch cases.

3.3.5 Implementation of the 2020 NYStretch Requirements

The 2020 NYStretch code requires more stringent windows, insulation, and lighting compared to the baseline codes. Additionally, it also requires several improvements to the mechanical systems, including requiring ducts to be placed within conditioned zones, efficient hot water delivery systems, and balanced ventilation systems including heat or energy recovery in the colder climate zones. Each change was qualitatively evaluated to identify the changes that would result in an energy impact and could be captured using energy modeling. This section describes the modeling methodology used for evaluating the applicable changes.

3.3.5.1 Envelope Improvements

The 2020 NYStretch code requires a lower U-factor for fenestration in all three climate design zones, improved wall insulation in CDZ 4A and 5A, improved floor insulation in CDZ 4A, improved basement wall insulation in CDZ 4A and higher depth of slab insulation in CDZ 4A and 5A. All these changes were modeled by updating the material properties for the respective assembly layers in the relevant *EnergyPlus* objects. For windows, the U-factor field in the simple glazing object was updated to use a value of 0.27. For exterior walls, basement walls, and floors, the conductivity of the consolidated insulation and framing layer was adjusted to yield the required R value.

The 2020 NYStretch code allows three options for meeting the prescriptive wall insulation requirement in CDZ 4A and 5A, including R-21 intermediate framing (walls with R-10 insulated headers), R-20+5 and R-13+10. This compares with the baseline requirement of R-20 or R-13+5 in the 2020 ECCC NYS and a requirement of R-20+5 in the 2016 NYCECC. This code provision was evaluated by assuming R-21 intermediate framing walls in CDZ 4A-balance and 5A in the NYStretch cases. In CDZ 4A-NYC, because the baseline already required R-20+5, the NYStretch cases were also modeled using the R-20+5 option.

3.3.5.2 Ducts in Conditioned Space

The PNNL/DOE models do not account for losses associated with an air distribution system and cannot be used to determine the energy savings from moving ducts into conditioned space without a major change to the models. Analogous to the treatment of duct sealing, a flat multiplier was applied to heating and cooling energy consumption to account for moving the ducts. A literature review revealed reported savings of 10–25%, but basic assumptions, including CDZ and original duct placement, were often unavailable. Therefore, a simplified modeling exercise was conducted in *BEopt* version 2.8 to evaluate savings in CDZs 4A, 5A, and 6A.

BEopt models of a 2,400 ft^2 two-story, single-family home with three foundation types—slab, unheated basement, and heated basement—were constructed to calculate the savings from moving ducts to conditioned space. All other house characteristics were maintained as the Building America defaults except the duct location.

Table 6 shows the savings from moving ducts with 15% leakage, insulated with R-8, to conditioned space. Broadly, the cooling savings were relatively consistent in all three CDZs – about 15% for the slab, 10% for the unheated basement, and 5% for the heated basement. For heating, CDZs 5A and 6A have similar savings, but the savings in CDZ 4A were about 10 percentage points higher—15% vs 25% for the slab, 10% vs 20% for the unheated basement, and 5% vs. 15% for the heated basement.

Table 6. Savings from Moving Ducts to Conditioned Space

		Duct Location	CDZ 4A	CDZ 5A	CDZ 6A
Cooling	Slab	Attic	16%	17%	16%
	Unheated basement	Basement	11%	10%	13%
	Heated basement	Basement	7%	6%	5%
Heating – electricity[a]	Slab	Attic	22%	12%	12%
	Unheated basement	Basement	19%	8%	7%
	Heated basement	Basement	16%	5%	5%
Heating - gas	Slab	Attic	26%	16%	16%
	Unheated basement	Basement	20%	9%	9%
	Heated basement	Basement	15%	5%	4%

[a] While the house has a gas furnace, there is a small amount of electricity consumption for heating, particularly fan use.

When combined with the foundation weights for CDZs 4A, 5A, and 6A, the average cooling savings were found to be between 10% and 17%, the fan energy savings between 7% and 22%, and the heating savings between 9% and 26%, depending on the CDZ. Based on these results, an average savings of 20% from the code provision were assumed in CDZ 4A-NYC and CDZ 4A-balance and 10% in CDZs 5A and 6A. These savings were applied only to prototypes with slab-on-grade, crawlspace, and unheated basements because prototypes with heated basements were conservatively assumed to have most of the ducting system located within the conditioned basement, based on Building America House Simulation Protocols (Wilson et al. 2014). For the applicable prototypes, the savings were assumed to be in addition to the 10% savings assumed from the duct sealing provisions in the baseline and implemented as a savings multiplier to the heating, cooling, and fan energy in the 2020 ECCC NYS and 2020 NYStretch cases.

3.3.5.3 Drain Water Heat Recovery

The 2020 NYStretch code includes provisions for improving the efficiency of hot water supply systems. The code offers multiple options, including a compact piping layout with limits on pipe run lengths, drain water heat recovery (DWHR), or a hot water recirculation system. While all three options are designed to cut losses in the hot water delivery systems, they are associated with different costs and challenges. For example, a compact piping layout can be efficiently implemented during the design of a house. However, a DWHR or a recirculation system might be more suitable for a broader range of house configurations. Similarly, the savings that can be harnessed from any of these options vary significantly with the configuration of the house and the hot water usage profile.

The PNNL/DOE models use a simplifying assumption of treating hot water pipes as adiabatic, meaning there is no heat transfer between them and other spaces in the building. Therefore, adding DWHR to the models or shortening pipe lengths does not account for any interactive effects with space heating and cooling. Because the interactive effects are expected to be of the second order in nature, the analysis uses a savings multiplier based on a literature review. Savings percentages ranging from 25–40% were found in the literature including an estimate of 40% from Minnesota Power,[3] an estimate of 25 to 30% from Van Decker,[4] and 25% from Manitoba Hydro.[5] This analysis uses a conservative savings estimate of 25%. These savings are implemented by applying a multiplier of 0.75 to the hot water energy consumption in the 2020 NYStretch cases.

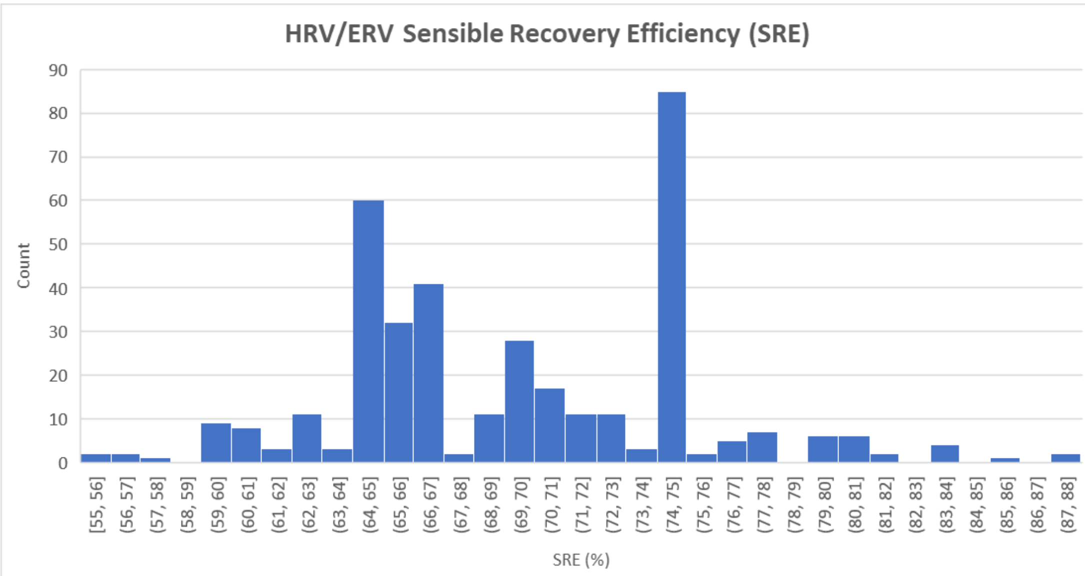
3.3.5.4 Ventilation

The 2020 NYStretch code requires energy recovery ventilation (ERV) or a heat recovery ventilation (HRV) in CDZ 5A and 6A. In CDZ 4A, a balanced ventilation system is allowed to comply. The baseline 2020 ECCC NYS or 2016 NYCECC do not require ERV/HRVs or balanced ventilation. This code provision is evaluated by assuming balanced ventilation in CDZ 4A-NYC and CDZ 4A-balance and HRVs in CDZ 5A and 6A.

Because the 2020 NYStretch code does not include a minimum efficiency requirement for HRVs, the directory of available products from the Home Ventilation Institute (HVI) was reviewed to identify a suitable assumption. Figure 1 shows the distribution of the sensible recovery efficiency (SRE) of products available in the market today. Most of the products have SRE between 64% and 75% with some exceptionally high-efficiency units with SRE greater than 85% also available. The analysis assumes HRVs with SRE of 70% in the NYStretch cases in CDZ 5A and 6A. The HRVs are modeled using the *EnergyPlus* "ZoneVentilation:EnergyRecoveryVentilator" object, by setting latent heat recovery efficiency to zero and sensible heat recovery efficiency to 0.7. In CDZ 4A-NYC and CDZ 4A-balance, the NYStretch models are configured with the "balanced" zone ventilation option in *EnergyPlus*.

Figure 1. Distribution of Sensible Recovery Efficiencies of ERVs/HRVs

See endnotes for more information[6]



3.3.5.5 High Efficacy Lighting

The 2020 NYStretch makes an incremental improvement to the minimum lighting efficacy requirement. Compared to the tiered requirements in the baseline 2020 ECCC NYS and the 75% high-efficacy lighting requirement in the 2016 NYCECC, the 2020 NYStretch code requires 90% of all permanently installed lighting to be high-efficacy with the minimum efficacy of lamps to be 65 lm/W and that of the total luminaire to be 45 lm/W. This code provision is expected to yield a reduction in the annual lighting energy use.

The lighting energy in the DOE/PNNL 2015 IECC models is calculated using the Building America Benchmark specifications (Wilson et al. 2014) and translated to the models as a lighting power density (LPD) or a peak lighting power input (Mendon et al. 2013). A similar approach was utilized in the previous 2020 ECCNYS cost-effectiveness analysis (NYSERDA 2019). The present analysis uses a modified approach based on the same principles by updating the energy ratio (ER) associated with the CFLs in the Building America equations to use 65 lm/W. All other parameters in the equations are left unchanged.

Table 7 shows the calculated lighting energy use for the baseline and 2020 NYStretch for the single-family prototype and each multifamily unit.

Table 7. Lighting Energy Use

	2020 ECCC NYS		2016 NYCECC		2020 NYStretch	
	Single-family	Multifamily	Single-family	Multifamily	Single-family	Multifamily
Interior Hard-Wired Lighting Energy (kWh/yr)	787.1	474.0	867.6	522.4	762.3	459.0
Interior Hard-Wired Lighting LPD (W/ft^2)	0.106	0.106	0.117	0.117	0.103	0.103
Exterior Lighting Energy (kWh/yr)	209.4	104.7	230.9	115.4	202.8	101.4
Exterior Lighting Peak (W)	47.63	47.63	52.50	52.50	46.13	46.13
Garage Lighting Energy (kWh/yr)	14.4	14.4	15.9	15.9	14.0	14.0
Garage Lighting Peak (W)	7.81	7.81	8.61	8.61	7.56	7.56

3.4 Incremental Cost Calculations

The incremental costs associated with the code changes captured in the energy analysis are determined using sources such as RS Means (RS Means 2019), DOE's Building Community Cost database developed by PNNL,[7] the construction cost estimation study conducted by Faithful+Gould for DOE (F+G 2012), National Renewable Energy Laboratory's (NREL) National Residential Efficiency Measures (NREM) database, and technical reports published by DOE. Where required, the costs are adjusted to current dollars using the consumer price index (CPI). Finally, the costs are adjusted using location cost multipliers to come up with representative construction cost estimates for the State.

3.4.1 Location Multipliers

Location multipliers are used to adjust national average costs to account for locational diversity in material and labor costs. This analysis uses location factors from the 2019 RS Means Residential Costs Data Book (RS Means 2019). The data for all available locations in New York State is grouped into CDZs 4A, 5A, and 6A using the 2018 IECC climate zone map (ICC 2017). CDZ 4A is further split into CDZ 4A-NYC and CDZ 4A-balance by separating the factors for New York City and surrounding areas from the remainder of CDZ 4A. The factors are then averaged to yield the overall factors used in this analysis, as summarized in Table 8.

Table 8. Location Cost Multipliers Used in the Analysis

Climate Design Zone	Average Location Factor
4A-NYC	1.374
4A-balance	1.234
5A	1.059
6A	0.998

3.4.2 Incremental Cost for Each Measure

This section describes the assumptions behind the development of incremental costs for each measure that was evaluated in the energy analysis.

3.4.2.1 Fenestration

The 2020 NYStretch requires a more stringent fenestration U-factor of 0.27 in all CDZs. This compares to a baseline requirement of U-0.32 in CDZ 4A and U-0.30 in CDZ 5A and 6A. In CDZ 6A, the 2020 ECCC NYS has an additional prescriptive path with a U-0.28.

Incremental costs associated with code fenestration requirements, especially at higher efficiencies, are often difficult to map to real fenestration products because available products have rated U-factors and SHGC for various combinations of framing and glass and lack the level of granularity used by the code. ENERGY STAR® addresses this complexity by using a regression-based approach in its Cost and Savings Estimates for homes certified under ENERGY STAR Version 3 (ENERGY STAR 2016). The regression uses data from National Residential Efficiency Measures Database (NREM) developed by the National Renewable Energy Laboratory (NREL) to develop a set of regression equations. These regression equations are used to calculate the incremental costs associated with this code provision resulting in an incremental cost of $1.04/ft^2 in CDZ 4A including CDZ 4A-balance, $0.62/ft^2 in CDZ 5A and an average of $0.33/ft^2 based on the two prescriptive baseline options in CDZ 6A. This results in an incremental cost of $391 in CDZ 4A and CDZ 4A-balance, $235 in CDZ 5A, $157 in CDZ 6A for the single-family prototype, $196 in CDZ 4A and CDZ 4A-balance, $117 in CDZ 5A, and $63 in CDZ 6A for each multifamily unit, after adjusting for inflation. These estimates are further multiplied by the location factors before use in the analysis.

3.4.2.2 Exterior Wall Insulation

There are multiple baseline and 2020 NYStretch prescriptive options for wall insulation (Tables 1 and 2). In CDZ 4A-balance and 5A, this analysis assumes R-20 in the baseline and R-21 intermediate framing (with R-10 insulated headers) in the NYStretch case. In CDZ 4A-NYC and 6A, this analysis assumed R-20+5 in both the baseline and NYStretch cases.

The additional cost associated with R-21 int compared to R-20 walls is the cost of insulating the wall headers with R-10 insulation. The analysis assumes the headers are insulated with 2" of extruded polystyrene (XPS) at R-5/inch. Table 9 shows three estimates of incremental cost.

Table 9. Incremental Cost Estimates for Exterior Wall Insulation: R-21 int vs. R-20

Source	Incremental Cost	Notes
F+G (2012)	$1.77/ft^2$	$1.62/ft^2$ in 2012 dollars, adjusted to 2019 dollars
RS Means (2019)	$1.88/ft^2$	
NREL NREM (2019)	$1.70/ft^2$	
Assumption	**$1.77/ft^2$**	

According to the dimensions of the DOE/PNNL single-family prototype building used by Faithful + Gould in their 2012 cost estimation exercise, the total length of 2x10 headers is 258 feet (F+G 2012). This results in a total incremental cost of $380 associated with this code provision for the single-family prototype. Detailed drawings of the multifamily prototype building are not available. Thus, the analysis assumes that the ratio of headers to exterior wall area is the same in the single- and multifamily prototypes, which translates to an incremental cost of $136 for each multifamily unit. These estimates are further multiplied by the location factors before use in the analysis.

3.4.2.3 Floor Insulation

The 2020 NYStretch code requires R-30 floor insulation in CDZ 4A compared to R-19 required by the 2020 ECCC NYS in CDZ 4A. The analysis assumes that fiberglass blanket insulation is installed between floor joists. Two estimates of incremental cost are shown in Table 10.

Table 10. Incremental Cost Estimates for Floor Insulation: R-30 vs. R-19

Source	Incremental Cost	Notes
F+G (2012)	$0.46/ft^2$	$0.42/ft^2$ in 2012 dollars, adjusted to 2019 dollars
RS Means (2019)	$0.40/ft^2$	
Assumption	**$0.40/ft^2$**	

Using $0.40/ft^2, the total incremental cost works out to $480 for the single-family prototype and $160 for each multifamily unit. Because the 2016 NYCECC already requires floor insulation of R-30 in the areas governed by the code (CDZ 4A-NYC in this analysis), this incremental cost is assumed to apply only to the balance of CDZ 4A (CDZ 4A-balance), after applying applicable location multipliers.

3.4.2.4 Slab Insulation

The 2020 NYStretch code requires slab insulation to be installed up to a depth of four feet compared to the two feet required by the baseline 2020 ECCC NYS in CDZ 4A and 5A. The analysis assumes slab edge insulation to be 2" thick XPS (R-10) with 60 PSI compressive strength. Table 11 shows three estimates of the incremental cost.

Table 11. Incremental Cost Estimates for Slab Insulation: 4' vs. 2' R-10 XPS

Source	Incremental Cost	Notes
F+G (2012)	$1.77/ft^2	$3.24/lf for 2' deep slab edge insulation with R-10 XPS in 2012 dollars, adjusted to 2019 dollars
RS Means (2019)	$2.42/ft^2	2" thick XPS used in foundation applications
NREL NREM (2019)	$2.00/ft^2	2" thick XPS used in foundation applications
Assumption	**$2.00/ft^2**	

Using a cost of $2.00/ft^2, the total incremental cost is $560 for the single-family prototype and $247 for each multifamily unit. Because the 2016 NYCECC already requires four feet of R-10 slab insulation in the areas governed by the code (CDZ 4A-NYC in this analysis), this incremental cost is assumed to apply only to the balance of CDZ 4A (CDZ 4A-balance) and CDZ 5A, after applying applicable location multipliers.

3.4.2.5 Basement Wall Insulation

The 2020 NYStretch code requires R-15 continuous or R-19 cavity insulation for basement walls compared to the R-10 continuous or R-13 cavity insulation required by the baseline 2020 ECCC NYS in CDZ 4A. The analysis assumes basement walls insulation to be kraft-faced fiberglass placed within the wall cavity. Table 12 shows three estimates of incremental cost including the cost of additional insulation as well as deeper framing because R-13 insulation is 3.5" thick and can be placed in a 2 x 4 cavity.

An average incremental cost of $0.8/ft^2$ results in a total incremental cost of $784 for the single-family prototype and $345 for each multifamily unit. Because the 2016 NYCECC already requires R-15/R-19 basement wall insulation in the areas governed by the code (CDZ 4A-NYC in this analysis), this incremental cost is assumed to apply only to prototypes with conditioned basements in the balance of CDZ 4A (CDZ 4A-balance), after applying applicable location multipliers.

Table 12. Incremental Cost Estimates for Basement Wall Insulation: R-19 vs. R-10 Cavity

Source	Incremental Cost	Notes
F+G (2012)	$0.84/ft^2$	$0.77/ ft^2$ in 2012 dollars, adjusted to 2019 dollars
RS Means (2019)	$0.97/ft^2$	
NREL NREM (2019)	$0.5/ft^2$	
Assumption	**$0.8/ft^2$**	

3.4.2.6 Efficient Hot Water Supply

The 2020 NYStretch code has several options for encouraging the efficient delivery of hot water, including an option for a compact piping system, a recirculation system, and a DWHR system. Like other elements of the code that are focused on good design practices, the incremental cost associated with this measure varies from case to case. For example, Klein (2012) lays out several examples for developing a compact hot water delivery system, which when implemented correctly during the early design stages of a project would most likely result in first cost savings by eliminating long pipe runs that require installation and insulation. If a compact hot water delivery system is not feasible for any reason, a DWHR system or recirculation pump in some water heater configurations can help reduce heat loss through pipes or recover a portion of the waste heat.

Similar to the range in energy savings from these systems, the incremental costs also tend to vary. The U.S. Department of Energy (DOE) reports a range of $300 to $500 for installing DWHR systems, noting that installation is likely to be less expensive in new home construction.[8] The final Codes and Standards Enhancement (CASE) report developed by the California Energy Commission on DHWR reports a total cost of $700 to $800 for a complete installation. The study further notes that the product life for DWHR is 30 to 50 years and that no maintenance is required because the equipment has no moving parts. [9] Finally, the third option, recirculating pumps, are cheaper to install depending on the water heater configuration and can be controlled using a timer or a switch. The cost of installing a recirculation pump is approximately $400.[10]

The present analysis assumes a DHWR because it is suitable for a wide range of home designs. Additionally, it is expected that some builders will use the compact piping layout option, thus achieving energy savings for negligible incremental costs. An average incremental cost of $400 is assumed for this measure for both the single-family prototype as well as each multifamily unit. The cost is further adjusted by location factors.

3.4.2.7 Ventilation

The 2020 NYStretch code requires heat recovery ventilation (HRV) or energy recovery ventilation (ERV) in CDZ 5A and 6A. In CDZ 4A, a balanced ventilation system is deemed to comply. As discussed previously in the energy analysis, this analysis assumes a balanced ventilation system in CDZ 4A and an HRV with 70% sensible recovery efficiency (SRE) in CDZ 5A and 6A.

HRVs and ERVs are becoming more popular as the recent energy codes have driven down the air leakage thresholds, thereby introducing the need for controlled mechanical ventilation systems. While point exhaust-based systems are still commonly used to meet the IECC requirement across the country, central fan-integrated supply (CFIS) systems and ERV/HRVs are beginning to be introduced because of the better ventilation effectiveness they provide.

This analysis assumes an average incremental cost of $300 for the single-family prototype and each multifamily unit for the CFIS unit that meets the requirement in CDZ 4A. For CDZs 5A and 6A, the analysis assumes an incremental cost of $1,000 for the single-family prototype and each multifamily unit. These costs are further adjusted using location factors.

Tables 13 and 14 show three estimates of total cost and incremental cost compared to local exhaust-based systems for HRV/ERVs and CFIS.

Table 13. Incremental Cost Estimates for Ventilation: HRV/ERV System vs. Exhaust Ventilation

Source	Total Cost	Incremental Cost	Notes
Moore (2018)	$1,300	$1,103	New construction HRV
Aldrich et al (2013)	$1,500	$1,100	Local ERV system
NREL NREM (2019)	$1,300	$940	HRV with 70% SRE
Assumption		**$1,000**	HRV with 70% SRE

Table 14. Incremental Cost Estimates for Ventilation: CFIS System vs. Exhaust Ventilation

Source	Total Cost	Incremental Cost
Moore (2018)	$310	$113
Aldrich et al (2013)	$650	$250
NREL NREM (2019)	$850	$490
Assumption		**$300**

3.4.2.8 Lighting

The 2020 NYStretch code raises the threshold of high-efficacy lamps to require a minimum of 65 lm/W and that of luminaires to require a minimum of 45 lm/W, while leaving the required percentage of high-efficacy hard-wired lighting unchanged at 90% as the baseline 2020 ECCC NYS. The required percentage of high-efficacy hard-wired lighting in the 2016 NYCECC, however, is 75%.[11]

The overall impact of the 2020 NYStretch code is to require the installation of CFLs at the higher end of the CFL efficacy spectrum or LEDs. Many of the CFLs designed to replace 40-60 W incandescent lamps that are currently labeled under the ENERGY STAR program have efficacies greater than 65 lm/W[12] and would, therefore, meet the NYStretch requirement. LEDs typically have higher efficacies, around 80 lm/W,[13] but this analysis is based on conservative estimates of energy savings and assumes the code provision is met with CFLs. Thus, the incremental cost associated with this change is assumed to be negligible because most CFLs available in the market today easily meet the ENERGY STAR designation for no incremental cost. For CDZ 4A-NYC, however, the baseline 2016 NYCECC requires only 75% of permanently installed lamps to be high efficacy. Thus, the incremental cost of meeting the 2020 NYStretch code provisions for those cases is based on purchasing more CFL bulbs at an incremental cost of $2.93/bulb compared to incandescent lamps. In the single-family prototype, the cost of replacing seven bulbs is assumed to be $20.51; for each multifamily unit, the cost of replacing three bulbs is assumed to be $8.79 (NYSERDA 2019).

3.4.2.9 Ducts in Conditioned Space

The 2020 NYStretch code requires that all ducts be located within conditioned space, while the baseline codes do not regulate the location of ducts. Moving ducts into conditioned zones reduces losses associated with heat transfer and is proven to be a source of significant savings especially in warmer climates.

However, the typical placement of ducts varies widely depending on the house configuration, HVAC layout and even foundation type. Homes with basements tend to have a portion or all the ducts located inside basements while homes with slab-on-grade or crawlspaces tend to have most of the ducts located in the attic space which unless it is conditioned, can result in large losses.

DOE's Building America program developed several case studies and low-cost installation methods for locating ducts within the thermal boundary of a house by implementing dropped ceilings or chases in single-story homes and installing ducts between floor in multi-story ones.[14] They also suggest sealing an attic or crawlspace and insulating them at the perimeter to create a suitable conditioned zone for placing ducts. However, the actual cost associated with this measure depends on many factors as they apply to a given house. Building America found costs ranging from as little as $0.39/ft^2 of conditioned floor area when utilizing efficient chase systems to as much as $2.50/ft^2 when using spray foam insulation (Beal et al. 2011).

In the 2018 IECC, a new code provision related to buried ducts was approved (ICC 2017). This provision, which has been carried through the 2020 ECCC NYS and the 2020 NYStretch code, allows ducts buried within attic insulation to be considered "inside conditioned space" if they meet certain criteria. The criteria includes a lower leakage rate, the air handling unit (AHU) being placed inside conditioned space, and a minimum insulation level above and below the duct surface. The approach is expected to yield good energy savings while still being a lower cost solution.

Research conducted by the National Association of Home Builders (NAHB) Home Innovation Research labs compares different strategies for meeting this code requirement along with a comparison of costs.[15] This analysis assumes that this requirement is met by implementing buried ducts within conditioned space, including building a mechanical closet to house the AHU. The cost for this method per NAHB's research is between $913 and $1,107 for a 2,428 ft^2 single-story, slab-on-grade house configuration. It is further noted that the cost for a two-story design would be proportional to the percentage of living area on the second floor. Because the single-family prototype used in this analysis has 50% of the living area on the second floor, the incremental cost associated with this measure is assumed to be $505 for the single-family prototype. The incremental cost for each multifamily unit is also accordingly assumed to be $505 because the conditioned floor area is half that of the NAHB prototype. The prototypes with conditioned basements are assumed to incur no additional costs because most of the ducts are already assumed to be placed in the conditioned basement as described in section 3.3.5.2. Therefore, the incremental costs are assumed to apply only to the prototypes with slab-on-grade, crawlspace and unconditioned basement.

3.4.2.10 Credit Associated with Down-Sizing HVAC Equipment

The collective impact of the prescriptive and mandatory requirements of the 2020 NYStretch code reduce the design heating and cooling loads of the building and result in a reduction in the size of HVAC equipment required to service the loads for the single- and multifamily dwelling units. Because the analysis employs a whole building cost approach, the impact of equipment downsizing due to improved shell efficiency is considered in the analysis. The HVAC sizing information reported by *EnergyPlus* indicates a range in equipment capacity reduction between different prototypes and CDZs and is more notable on the cooling side. It is also expected that the actual sizes installed in the field will vary based on individual design practices. Thus, the analysis conservatively assumes a 0.5-ton reduction in HVAC equipment in CDZ 4A-balance and 5A where most of the envelope improvements apply over the baseline 2020 ECCC NYS. In CDZ 4A-NYC and 6A, the downsizing in equipment is less noticeable because the envelope requirements are mostly similar between the baseline and the 2020 NYStretch code. Thus, an equipment downsizing credit of $330 was assumed in this analysis only for CDZ 4A-balance and 5A (ENERGY STAR 2016). This credit is subtracted from the total incremental cost after adjusting for inflation and location factors.

3.4.3 Total Incremental Costs by Prototype and Climate Design Zone

The total incremental costs per dwelling unit for each prototype in each climate design zone are shown in Table 15.

Table 15. Total Incremental Costs of the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code Compared to the 2016 NYCECC in CDZ 4A-NYC and 2020 ECCC NYS Elsewhere

	Single-family				Multifamily			
	Slab	Crawlspace	Heated Basement	Unheated Basement	Slab	Crawlspace	Heated Basement	Unheated Basement
4A-NYC	$2,048	$2,048	$1,528	$2,048	$1,763	$1,763	$1,243	$1,763
4A-balance	$3,278	$3,180	$3,087	$3,180	$1,917	$1,810	$1,571	$1,810
5A	$2,900	$2,307	$1,905	$2,307	$2,117	$1,856	$1,455	$1,856
6A	$1,602	$1,602	$1,224	$1,602	$1,509	$1,509	$1,131	$1,509

3.5 Cost-Effectiveness Analysis

Combined with the respective energy cost savings, the incremental construction costs were used to calculate a simple payback, present value of savings over a 10-year period, and 30-year Life-Cycle Cost (LCC) savings. While the cost-effectiveness calculations are based on the parameters and equations laid out in DOE's cost-effectiveness methodology (Taylor et al. 2015), certain economic parameters have been updated using latest New York specific data where available.

3.5.1 Fuel Prices

Energy use from the annual simulation is extracted for the major code regulated end-uses of heating, cooling, ventilation, fans, lighting, and domestic DHW and converted to energy costs using the average fuel costs for electricity, natural gas, and fuel oil for the State published by the Energy Information Association (EIA). The latest full year data published by EIA is for 2017 (EIA 2019a, 2019b, and 2019c). Additionally, NYSERDA provided electricity and natural gas prices specific to New York City, which were used only in CDZ 4A-NYC. The average fuel prices used in the analysis are described in Table 16.

Table 16. Fuel Prices

Fuel	CDZ 4A-NYC	All Other CDZs
Electricity	$ 0.200/kWh	$ 0.180/kWh
Natural gas	$ 0.900/therm	$ 1.167/therm
Fuel Oil	$ 2.774/therm	$ 2.774/therm

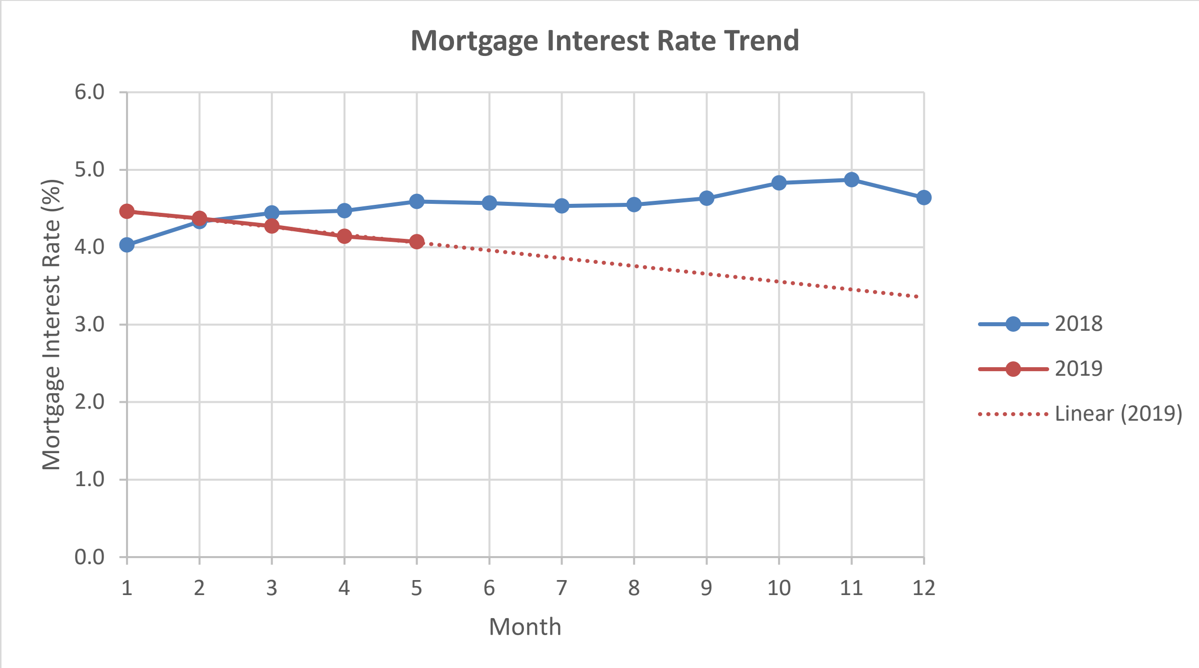
3.5.2 Economic Parameters

The protocols and economic factors used in DOE's cost-effectiveness methodology were followed to calculate the present value and LCC savings. The present value calculation of energy cost savings requested by the State was conducted using a 10-year term, and the LCC savings calculation used a 30-year term to match the typical term used by DOE in its analysis.

3.5.2.1 Mortgage Interest Rate

The mortgage interest rate has averaged around 4.5% in 2018 per latest estimates from Freddie Mac and has been trending downwards in the first half of 2019 as shown in Figure 2.[16]

Figure 2: Mortgage Interest Rate Trends for 2018 and 2019[17]



Based on the trajectory, this analysis uses an estimate of 4.0% mortgage interest rate. The discount rate is maintained the same as the mortgage interest rate per DOE's methodology.

3.5.2.2 Inflation Rate

The analysis uses the latest annualized inflation rate for December 2018 of 1.9%.[18] The home price escalation rate is maintained the same as the inflation rate per DOE's methodology.

3.5.2.3 Fuel Price Escalation Rates

The fuel price escalation rates used in the analysis are the average escalation rates for the 2018–2050 period reported by EIA in its 2019 Annual Energy Outlook for the Mid Atlantic census region.[19] The escalation rate for electricity is assumed to be 0.6%, that for natural gas is assumed to be 0.9% and that for fuel oil is assumed to be 1%.

3.5.2.4 Down Payment Rate

The analysis assumes a 20% down payment rate to be more representative of the current scenario in the State (NYSERDA 2019).

3.5.2.5 Income Tax Rate

The federal income tax rate is assumed to be 15% and the state income tax rate for the State is assumed to be 6.33% for a married filing jointly bracket of $43,000 through $161,550.[20]

3.5.2.6 Property Tax Rate

The property taxes in the State vary widely by location. This analysis uses an average property tax rate of 1.65%. The economic parameters used this analysis are summarized in Table 17.

Table 17. Summary of Economic Parameters

Parameter	Value
Mortgage Interest Rate	4%
Loan Term	30 years
Down Payment Rate	20.0%
Points and Loan Fees	0.5% (non-deductible)
Discount Rate	4% (equal to Mortgage Interest Rate)
Period of Analysis	30 years
Property Tax Rate	1.65%
Income Tax Rate	21.3%
Home Price Escalation Rate	1.9%
Inflation Rate	1.9%
Energy Escalation Rates - Electricity	0.6%
Energy Escalation Rates – Natural Gas	0.9%
Energy Escalation Rates – Fuel Oil	1.0%

3.5.2.7 Useful Measure Life, Replacements, and Residual Value

For building components that have useful lives longer than 30 years, a credit for “residual life” was applied at year 30 in the LCC calculation. For building components with a useful life less than the analysis term, the analysis assumes a like-for-like replacement consistent with the DOE methodology. Table 18 summarizes the effective useful life (EUL) of components assumed in the analysis. In order to streamline the cost-effectiveness analysis and calculations, measures with similar EULs were grouped together. For example, all measures related to opaque insulation requirements and the provision for buried ducts were grouped together into the “opaque insulation” set with an EUL of 60 years. Windows and lighting were individually evaluated with an EUL of 20 years and seven years respectively, and the provisions associated with ventilation were included in the “HVAC” set and evaluated with an EUL of 15 years.

Table 18. Effective Useful Life of Building Components

Component	EUL (Years)
Opaque Insulation	60
Windows	20
Lighting	7
HVAC	15

4 Results

This section summarizes the results of the energy and cost-effectiveness analysis of the 2020 NYStretch Energy Code compared to the 2016 New York City Energy Conservation Code (NYCECC) in CDZ 4A-NYC and 2020 Energy Conservation Construction Code of New York State (ECCC NYS) elsewhere.

4.1 Energy Savings at the Climate Design Zone and State Level

The results of the energy savings analysis of the proposed 2020 NYStretch code over the respective baseline code, by end-use at the climate design zone and State level are included. These results have been aggregated over the entire set of building types, foundation types and heating systems using the construction weights matrix.

4.1.1 Site Energy Savings

Tables 19–21 summarize the site energy savings for code regulated end-uses by CDZ and at the State level. The results for the CDZ 6A baseline have been averaged over the two alternative options and the results for multifamily buildings in CDZ 6A are not included because the associated construction weight was zero. In summary, the results show ~24.6% site energy savings at the State level.

Table 19. Regulated Site Energy Savings for the Prescriptive and Mandatory Provisions the 2020 NYStretch Code for Single-Family Buildings

Climate Zone 4A-NYC						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2016 NYCECC	25990.3	6066.3	5472.2	2937.8	16426.6	56893.3
2020 NYStretch	20244.0	4889.8	4966.9	2309.2	12318.2	44728.1
Savings (%)	22.1%	19.4%	9.2%	21.4%	25.0%	21.4%
Climate Zone 4A-balance						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCC NYS	29118.5	6083.7	5093.2	3156.3	16431.5	59883.2
2020 NYStretch	21981.5	4988.1	4966.9	2412.6	12320.5	46669.6
Savings (%)	24.5%	18.0%	2.5%	23.6%	25.0%	22.1%

Table19 continued

Climate Zone 5A						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCC NYS	43133.8	3926.1	5096.0	3232.6	18050.4	73438.9
2020 NYStretch	29343.4	3621.9	4969.6	3396.8	13527.8	54859.5
Savings (%)	32.0%	7.7%	2.5%	-5.1%	25.1%	25.3%
Climate Zone 6A						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCC NYS	44539.3	3634.2	5083.3	2887.5	19014.7	75159.1
2020 NYStretch	29811.0	3346.4	4957.2	3135.4	14251.9	55502.0
Savings (%)	33.1%	7.9%	2.5%	-8.6%	25.0%	26.2%

Table 20. Regulated Site Energy Savings for the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code for Multifamily Buildings

Climate Zone 4A-NYC						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2016 NYCECC	7896.4	3597.9	2933.5	1492.7	12053.4	27973.9
2020 NYStretch	6171.9	3058.3	2662.1	1233.4	9039.5	22165.2
Savings (%)	21.8%	15.0%	9.3%	17.4%	25.0%	20.8%
Climate Zone 4A-balance						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCC NYS	8631.2	3592.6	2730.0	1546.6	12054.4	28554.8
2020 NYStretch	6606.6	3055.2	2662.1	1268.1	9040.0	22632.0
Savings (%)	23.5%	15.0%	2.5%	18.0%	25.0%	20.7%

Table 20 continued

Climate Zone 5A						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCC NYS	12643.5	2438.2	2730.0	1610.1	13026.2	32447.9
2020 NYStretch	7078.5	2540.4	2662.1	2134.9	9763.8	24179.6
Savings (%)	44.0%	-4.2%	2.5%	-32.6%	25.0%	25.5%

Table 21. Weighted Average Regulated Site Energy Savings for the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code

Climate Zone 4A-NYC						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2016 NYCECC	14639.4	4517.8	3879.6	2031.2	13683.2	38751.2
2020 NYStretch	11416.1	3740.8	3521.0	1634.4	10261.4	30573.7
Savings (%)	22.0%	17.2%	9.2%	19.5%	25.0%	21.1%
Climate Zone 4A-balance						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCC NYS	16266.1	4521.0	3610.7	2146.5	13685.6	40229.9
2020 NYStretch	12336.3	3775.5	3521.0	1694.6	10262.6	31590.0
Savings (%)	24.2%	16.5%	2.5%	21.1%	25.0%	21.5%
Climate Zone 5A						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCC NYS	38986.7	3723.7	4774.2	3011.9	17367.0	67863.6
2020 NYStretch	26315.1	3474.8	4655.8	3225.1	13015.9	50686.6
Savings (%)	32.5%	6.7%	2.5%	-7.1%	25.1%	25.3%

Table 21 continued

Climate Zone 6A						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCC NYS	44539.3	3634.2	5083.3	2887.5	19014.7	75159.1
2020 NYStretch	29811.0	3346.4	4957.2	3135.4	14251.9	55502.0
Savings (%)	33.1%	7.9%	2.5%	-8.6%	25.0%	26.2%
New York State						
	Heating (kBtu/dwelling unit)	Cooling (kBtu/dwelling unit)	Lighting (kBtu/dwelling unit)	Fan (kBtu/dwelling unit)	DHW (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
Baseline	32381.7	3974.2	4440.3	2700.8	16429.4	59926.4
2020 NYStretch	22265.5	3552.5	4330.2	2698.0	12315.3	45161.4
Savings (%)	31.2%	10.6%	2.5%	0.1%	25.0%	24.6%

4.1.2 Source Energy Savings

The site energy savings calculated based on the results of the energy simulation exercise are converted into source energy savings using site-source conversion factors included in Table 4.2.1.2 of the 2020 NYStretch code. Factors for fuels relevant to this analysis are summarized in Table 22.

Table 22. Site to Source Energy Conversion Ratios

Energy Type	New York Ratio
Electricity (Grid Purchase)	2.55
Natural Gas	1.05
Fuel Oil	1.01

Tables 23–25 summarize the source energy savings resulting from the prescriptive and mandatory provisions of the 2020 NYStretch code compared to the respective baseline code in each CDZ.

Table 23. Source Energy Savings for the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code for Single-family Buildings

Climate Zone	Baseline Total Source Energy (kBtu/dwelling unit)	2020 NYStretch Total Source Energy (kBtu/dwelling unit)	Source Energy Savings
4A-NYC	90636.9	72065.8	20.5%
4A-balance	94033.4	74807.6	20.4%
5A	108649.2	84773.9	22.0%
6A	110706.5	85165.4	23.1%

Table 24. Source Energy Savings for the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code for Multifamily Buildings

Climate Zone	Baseline Total Source Energy (kBtu/dwelling unit)	2020 NYStretch Total Source Energy (kBtu/dwelling unit)	Source Energy Savings
4A-NYC	50053.5	40359.2	19.4%
4A-balance	50626.1	41010.5	19.0%
5A	56132.8	44709.6	20.4%

Table 25. Weighted Average Source Energy Savings for the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code

Climate Zone	Baseline Total Source Energy (kBtu/dwelling unit)	2020 NYStretch Total Source Energy (kBtu/dwelling unit)	Source Energy Savings
4A-NYC	65177.7	52175.2	19.9%
4A-balance	66802.6	53605.6	19.8%
5A	101506.3	79324.6	21.9%
6A	110706.5	85165.4	23.1%
NY State Average	91545.1	71769.2	21.6%

4.2 Energy Cost Savings at the Climate Design Zone and State Level

The energy cost savings from the NYStretch code over the 2020 Energy Conservation Construction Code of New York State by fuel type at the CDZ and State level are included in Tables 26-28. The results for the CDZ 6A baseline have been averaged over the two alternative options and the results for multifamily buildings in CDZ 6A are not included because the associated construction weight was zero. In summary, the results show ~19.7% energy cost savings at the State level. Results by building type and climate zone can be found in Appendix B.

Table 26. Annual Energy Cost Savings of the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code for Single-family Buildings

Climate Zone 4A-NYC				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2016 NYCECC	1207.5	326.6	0.0	1534.1
2020 NYStretch	980.9	251.9	0.0	1232.8
Savings (%)	18.8%	22.9%	NA	19.6%
Climate Zone 4A-balance				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2020 ECCC NYS	1097.6	456.3	0.0	1553.9
2020 NYStretch	909.1	343.8	0.0	1252.8
Savings (%)	17.2%	24.7%	NA	19.4%
Climate Zone 5A				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2020 ECCC NYS	1115.2	576.4	81.2	1772.8
2020 NYStretch	960.1	403.9	57.5	1421.5
Savings (%)	13.9%	29.9%	29.1%	19.8%
Climate Zone 6A				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2020 ECCC NYS	1122.0	612.0	40.7	1774.7
2020 NYStretch	948.7	426.3	28.0	1403.0
Savings (%)	15.4%	30.3%	31.3%	20.9%

Table 27. Annual Energy Cost Savings of the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code for Multifamily Buildings

Climate Zone 4A-NYC				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2016 NYCECC	810.0	117.1	31.9	958.9
2020 NYStretch	669.1	88.8	24.7	782.5
Savings (%)	17.4%	24.2%	22.6%	18.4%
Climate Zone 4A-balance				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2020 ECCC NYS	728.9	158.2	33.3	920.4
2020 NYStretch	608.9	118.9	25.5	753.3
Savings (%)	16.5%	24.9%	23.4%	18.2%
Climate Zone 5A				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2020 ECCC NYS	777.2	207.0	0.0	984.2
2020 NYStretch	680.7	131.8	0.0	812.5
Savings (%)	12.4%	36.3%	NA	17.4%

Table 28. Weighted Average Annual Energy Cost Savings of the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code

Climate Zone 4A-NYC				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2016 NYCECC	958.1	195.2	20.0	1173.3
2020 NYStretch	785.3	149.6	15.5	950.3
Savings (%)	18.0%	23.4%	22.6%	19.0%

Table 28 continued

Climate Zone 4A-balance				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2020 ECCC NYS	866.3	269.3	20.9	1156.5
2020 NYStretch	720.7	202.7	16.0	939.4
Savings (%)	16.8%	24.7%	23.4%	18.8%
Climate Zone 5A				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2020 ECCC NYS	1069.2	526.2	70.1	1665.5
2020 NYStretch	922.1	366.9	49.7	1338.7
Savings (%)	13.8%	30.3%	29.1%	19.6%
Climate Zone 6A				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2020 ECCC NYS	1122.0	612.0	40.7	1774.7
2020 NYStretch	948.7	426.3	28.0	1403.0
Savings (%)	15.4%	30.3%	31.3%	20.9%
New York State				
	Electricity Cost ($/dwelling unit)	**Natural Gas Cost ($/dwelling unit)**	**Fuel Oil Cost ($/dwelling unit)**	**Total Energy Cost ($/dwelling unit)**
2020 ECCC NYS	1010.8	455.6	48.5	1514.9
2020 NYStretch	859.6	322.6	34.6	1216.7
Savings (%)	15.0%	29.2%	28.6%	19.7%

4.3 Cost-Effectiveness

The results of the cost-effectiveness analysis in terms of simple payback, a 10-year net present value (NPV) of energy cost savings including replacement costs and residual value of efficiency measures, and a 30-yr Life Cycle Cost (LCC) savings are described below.

4.3.1 Simple Payback

Table 29 shows the weighted average annual energy cost savings, the associated total incremental costs, and the resulting simple payback for the 2020 NYStretch code compared to the 2016 NYCECC in CDZ 4A-NYC and 2020 ECCC NYS elsewhere, for the single- and multifamily prototypes.

Table 29. Weighted Average Simple Payback

Climate Design Zone	Single-family			Multifamily		
	Total Annual Energy Cost Savings ($/dwelling unit)	Total Incremental Costs ($/dwelling unit)	Simple Payback (Years)	Total Annual Energy Cost Savings ($/dwelling unit)	Total Incremental Costs ($/dwelling unit)	Simple Payback (Years)
4A-NYC	$301	$1,910	6.3	$176	$1,625	9.2
4A-balance	$301	$2,463	8.2	$167	$1,488	8.9
5A	$351	$2,202	6.3	$172	$1,751	10.2
6A	$372	$1,506	4.1	NA	NA	NA
NY State	$348	$2,057	5.9	$171	$1,591	9.3

4.3.2 10-Year Present Value of Energy Cost Savings

Table 30 shows the 10-year net present value of energy cost savings for the NYStretch code compared to the 2016 NYCECC in CDZ 4A-NYC and 2020 ECCC NYS elsewhere, for the single- and multifamily prototypes. The results include applicable replacement costs for measures with EULs less than the analysis term of 30 years and residual values for measures with EULs longer than the analysis term. The results have been aggregated over the entire set of building types, foundation types, and heating systems using the construction weights matrix. In all cases, the energy cost savings comfortably exceed the first-year incremental costs.

Table 30. Weighted Average Net Present Value (NPV) of Energy Cost Savings over 10 Years

	Single-family		Multifamily	
Climate Design Zone	Total First Year Incremental Costs ($/dwelling unit)	10-Year NPV of Cost Savings Including Replacement Costs and Residual Values ($/dwelling unit)	Total First Year Incremental Costs ($/dwelling unit)	10-Year NPV of Cost Savings Including Replacement Costs and Residual Values ($/dwelling unit)
4A-NYC	$1,910	$2,866	$1,625	$1,784
4A-balance	$2,463	$3,509	$1,488	$1,930
5A	$2,202	$3,590	$1,751	$1,825
6A	$1,506	$3,473	NA	NA
NY State	$2,057	$3,524	$1,591	$1,862

4.3.3 30-year Life Cycle Cost (LCC) Savings

Table 31 summarizes the LCC savings of the NYStretch code over the 2020 ECCC NYS at the CDZ and State level. The results have been aggregated over the entire set of building types, foundation types and heating systems using the construction weights matrix. The residential provisions of NYStretch code are found to be cost-effective for the homeowner and yield positive savings over the life of the home in all cases, except for multifamily buildings in CDZ 5A. However, the overall State average LCC savings are positive.

Table 31. Weighted Average 30-Year LCC Savings

Climate Design Zone	Single-family 30 Year LCC Savings ($/dwelling unit)	Multifamily 30 Year LCC Savings ($/dwelling unit)
4A-NYC	$1,804	$94
4A-balance	$1,763	$649
5A	$2,235	$(442)
6A	$2,724	NA
NY State	$2,275	$226

Table 32 summarizes the average energy cost savings, incremental construction costs, and cost-effectiveness results for the prescriptive and mandatory provisions of NYStretch, weighted over the single- and multifamily building construction weights for the State.

Table 32. Weighted Results for the Prescriptive and Mandatory Provisions of the 2020 NYStretch Code at the State Level

	New York State Average
Annual Energy Cost Savings ($/dwelling unit)	$278
Incremental Costs ($/dwelling unit)	$1,795
Simple Payback (Years)	6.4
10-Year NPV of Cost Savings Including Replacement Costs and Residual Values ($/dwelling unit)	$2,854
30-Yr LCC Savings ($/dwelling unit)	$1,741

4.3.3.1 Consideration of the Avoided Cost of Carbon Emissions

The analysis and results described thus far do not include the impact of carbon emissions in the calculations. However, as New York State moves towards aggressive carbon goals for buildings, accounting for the impact of carbon emissions of different fuels becomes imperative. To understand the magnitude of this impact, an exploratory exercise was conducted by blending in a "avoided cost of carbon emissions" in the fuel prices and recalculating the 30-year LCC savings. These factors for electricity, natural gas, and fuel oil were obtained from NYSERDA's Regional Greenhouse Gas Initiative (RGGI) analysis.

Consistent with the Benefit Cost Analysis Framework adopted by the NYS Public Service Commission, the analysis that developed the avoided cost of carbon emissions uses the U.S. Environmental Protection Agency's estimate of the social cost of carbon (SCC) at the 3% discount rate. For electricity, the net social cost of carbon emissions on a per-MWh basis ($/MWh) is net of the projected RGGI compliance costs included in the New York State Independent System Operator (NYISO) CARIS2 2018 Base Case model, and is derived using the NYS Department of Public Service (DPS) estimate of the marginal emissions factor for electricity (lb. CO2/MWh) calculated using the CARIS2 2018 Base Case model; a description of the DPS methodology is provided in Attachment B of the Order Establishing the Benefit Cost Analysis Framework (issued January 21, 2016 in NYS PSC Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision). For natural gas and oil, the social cost of carbon emissions on a per-MMBtu basis ($/MMBtu) is derived using the marginal emissions factors for buildings (lb. CO2e/MMBtu) published in the Final Performance Metrics Report of the NYS Clean Energy Advisory Council – Metrics, Tracking and Performance Assessment Working Group (filed July 19, 2017 in NYS PSC Matter 16-00561).

The fuel prices used in the analysis, before and after including the cost of carbon, are summarized in Table 33 and the revised LCC savings results are included in Table 34.

Table 33. Fuel Prices used in the Analysis, With and Without the Cost of Carbon

Climate Zone	Without the Cost of Carbon			With the Cost of Carbon		
	Electricity ($/kWh)	Natural Gas ($/therm)	Fuel Oil ($/therm)	Electricity ($/kWh)	Natural Gas ($/therm)	Fuel Oil ($/therm)
4A NYC	0.200	0.900	2.774	0.223	1.248	3.258
4A except NYC	0.180	1.167	2.774	0.203	1.515	3.258
5A	0.180	1.167	2.774	0.203	1.515	3.258
6A	0.180	1.167	2.774	0.203	1.515	3.258

Table 34. Weighted Average 30-Year LCC Savings When the Avoided Cost of Carbon is Included

Climate Design Zone	Single-family 30 Year LCC Savings ($/dwelling unit)	Multifamily 30 Year LCC Savings ($/dwelling unit)
4A-NYC	$2,804	$610
4A-balance	$2,810	$1,162
5A	$3,617	$191
6A	$5,088	NA
NY State	$3,838	$769

It is observed that the inclusion of carbon cost in the fuel price increases LCC savings across the board, including multifamily buildings in CDZ 5A. This indicates the added benefit of including such costs in cost-effectiveness analyses for buildings, especially as decarbonization goals replace energy savings goals and since the buildings are likely to exist as they are constructed for the next 70 to 100 years.

5 Discussion

The 2020 NYStretch code contains many elements that encourage better building design such as better hot water piping layouts, better duct placement etc., which can be easy to implement in new construction if planned well at the design stage. This analysis typically uses conservative savings and incremental cost estimates for many of these measures because of the range of designs and performances that can be achieved in the field. Consequently, the energy savings and cost-effectiveness results reported fall on the lower end of potential savings that can be achieved through the 2020 NYStretch code. The actual energy savings that can be achieved in the field are likely to be higher leading to better cost-effectiveness outcomes.

Additionally, this analysis assumes no fuel switching between the baseline and the 2020 NYStretch cases. The energy cost savings and correspondingly lower LCC savings for models with gas furnaces because it is an inexpensive way for water and space heating. It is plausible that newer homes, especially those built under a stretch code, would be more likely to use electric heating to leverage on-site or off-site generation resulting in better cost-effectiveness outcomes across the board. Furthermore, as demonstrated in section 4.3.3.1, when the avoided cost of carbon is included in the analysis, the LCC savings improve substantially. This effect is mainly driven by the models with gas heating. As the State works toward decarbonization goals for buildings, the consideration of carbon in conducting energy and cost-effectiveness analyses for buildings would need to be central in policy development.

6 Conclusion

The prescriptive and mandatory elements of the residential provisions of the 2020 NYStretch Energy Code are expected to yield positive energy savings over the baseline 2020 Energy Conservation Construction Code of New York State (2020 ECCC NYS) and the 2016 New York City Energy Conservation Construction Code (2016 NYCECC). The savings range from 21 to 26% at the CDZ level in terms of site energy savings and from 18 to 21% in terms of energy costs. The provisions are also found to be cost-effective when evaluated using a 10-year net present value of energy cost savings as well as a full 30-year LCC savings calculations from the perspective of the homeowner for single-family buildings and most multifamily buildings.

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Appendix A. Cost-Effectiveness Analysis of Section R407

A.1 Background

This section summarizes the results of an additional analysis of a Section R407 (Additional Energy Efficiency Credits) contained in the draft NYStretch Energy Code version dated January 2019.[21] Section R407 includes a table of additional efficiency credits for various envelope, equipment and generation options, with different points for a single-family versus multifamily dwelling unit. Table A-1 summarizes the additional efficiency credits table along with the available credits. When complying with this path, detached one- and two-family dwellings, semi-detached two-family dwellings and townhouses are required to obtain 2.0 credits from column A and all other residential buildings are required to obtain 3.0 credits from column B.

Table A-1. Summary of the Options and Credits from the R407 Additional Energy Efficiency Credits Table

Category	Option	Measure	Column A	Column B
High-efficiency Envelope Options	1.1	U ≤ 0.042 Exterior Above Grade Walls	1	0.5
	1.2	U ≤0.020 Ceilings + U≤0.25 Windows	0.5	0.5
	1.3	15% Better UA	1.5	1
	1.4	U≤ 0.24 Windows	0.5	0.5
	1.5	2 ACH50 + High-efficiency Fans	0.5	0.5
	1.6	2 ACH50 + High-efficiency Fans + Heat Recovery Ventilation (HRV)	1	1
High-efficiency Equipment and Power Generation Options	2.1	High-efficiency Furnace or Heat Pump	1.5	1
	2.2	Ducted/Ductless Minisplit Heat Pump	0.5	1
	2.3	High-efficiency Water Heater	0.5	1.5
	2.4	Higher-efficiency Water Heater	1	2
	2.5	Minimum 1 kW of photovoltaic power or wind power.	1.0/kW/housing unit (max 2 credits)	1.0/kW/housing unit (max 2 credits)
	2.6	Solar Domestic Hot Water	1.0/dwelling unit	1.0/dwelling unit

Thus, based on the main analysis methodology and building types under consideration, the single-family prototype would need to obtain 2.0 credits from column A and each multifamily unit would need to obtain 3.0 credits from column B. The additional analysis included the energy savings and cost-effectiveness evaluation of two least incremental cost package options that satisfied the requirements of the additional efficiency credits path.

Based on the results of this analysis and a concern that the section as written might face federal preemption, NYSERDA decided to remove the Additional Energy Efficiency Credits section from the final version of NYStretch. This appendix memorializes the approach, assumptions, and results of the cost effectiveness analysis.

A.2 Overview of the Analysis

The scope of the additional analysis included the evaluation of two least incremental cost options that would satisfy the credit requirements set forth in section R407. Because the additional efficiency credits associated with the same measures are different for single-family versus multifamily dwelling units, this analysis optimized the least cost packages separately for the single- and multifamily prototypes. The analysis, however, did not optimize packages at the CDZ level.[22] The packages were evaluated as whole building packages, including the prescriptive and mandatory provisions of the 2020 NYStretch code.

The costs associated with each measure from Table A-2 were calculated and mapped against the credit points offered by each to create optimal combinations to yield the required number of 2.0 credits for the single-family prototype and 3.0 credits for the multifamily prototype. Figures A-1 and A-2 show the spread of incremental costs for various measures related to the associated credits offered for the single-family and multifamily prototypes.

Figure A-1. Incremental Costs versus Additional Efficiency Credit Offered for Each Option for a Single-Family Building

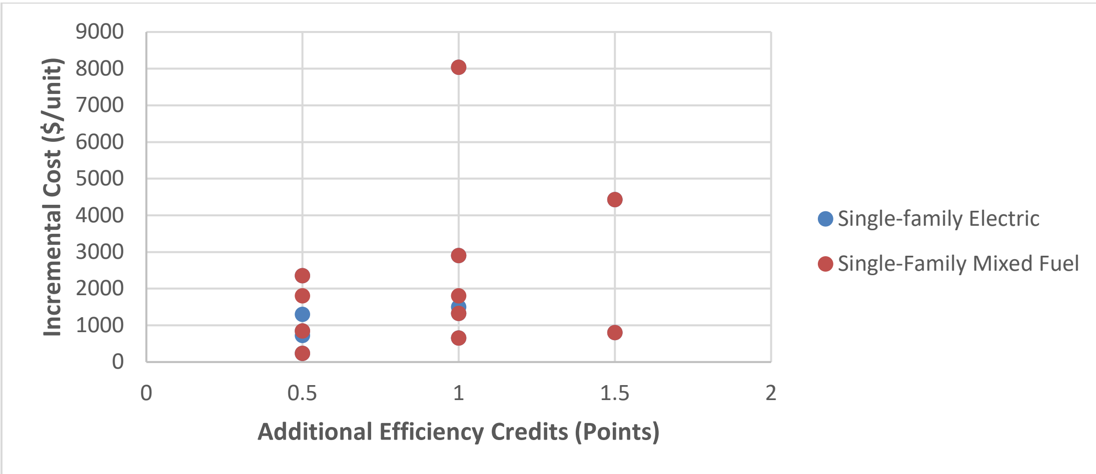
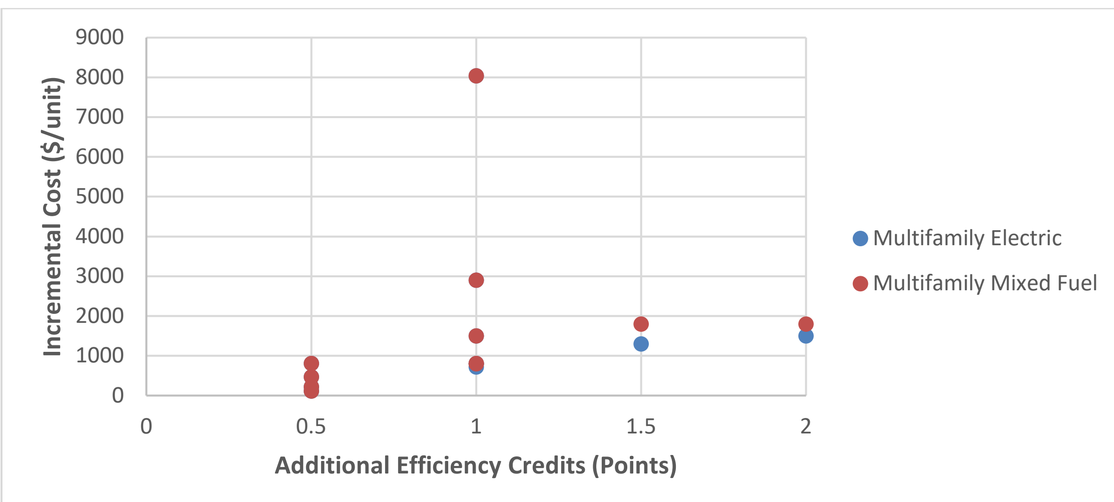


Figure A-2. Incremental Costs versus Additional Efficiency Credit Offered for Each Option for Each Multifamily Unit



For the single-family prototype, high-efficiency space conditioning equipment (option 2.1 in Table A-1) was found to be the least expensive way to obtain 1.5 points out of the required total of 2.0. On the multifamily side, higher-efficiency water heating equipment (option 2.4 in Table A-1) was found to be the least expensive way to obtain 2.0 out of the required total of 3.0 points. Thus, high-efficiency space conditioning equipment was part of both least expensive package options for single-family and higher-efficiency water heating equipment was part of both least expensive package options for multifamily.

A.3 Single-Family Prototype Packages

As described earlier, option 2.1 from Table A-1 was the least expensive way to capture 1.5 points out of the required 2.0 points for the single-family prototype. The high-efficiency space conditioning measure requires an air source heat pump with a heating seasonal performance factor (HSPF) of 9.0, gas or oil-fired furnaces or boilers with an annual fuel utilization efficiency (AFUE) of 94% or a ground-source heat pump (GSHP) with a co-efficient of performance (COP) of 3.3. Because the cost of implementing GSHPs varies widely depending on the site and the set of models used in the analysis does not include a model with a GSHP, this analysis was conducted by assuming higher-efficiency air source heat pumps in the single-family prototype models with heat pumps and higher-efficiency gas and oil-fired furnaces in the single-family prototype models with gas and oil-fired furnaces respectively for the 2020 NYStretch cases. The baseline models in each case are maintained at the standard federal minimum efficiencies specified in Table 5 in the body of this report.

Additional measures that would yield 0.5 points were then required to create the two least first-cost option packages to yield a total of 2.0 credits for the additional energy efficiency credits path. Based on an evaluation of all options available in the additional efficiency credits table, these least expensive options were determined to be option 1.4 (U-0.24 windows) and option 1.5 (tighter envelope option with high-efficiency fans). The elements of the least incremental cost packages assumed in this analysis for the single-family prototype are summarized in Table A-2.

Table A-2. Additional Efficiency Credits Packages Selected for the Single-Family Prototype

No.	Package Description	Points
1	High-eff Furnace/HP + U-0.24 Windows	2.0
2	High-eff Furnace/HP + 2 ACH50 + High-efficiency Fans	2.0

It is noted that the incremental costs associated with some of the options from the additional efficiency credits table are less in some CDZs compared to the others because the baseline code requirements vary by CDZ while the additional credit options do not. For example, the option of U-0.042 walls can be met with R-20+6 walls, which when the baseline wall configuration is R-20+5, such as in CDZ 4A-NYC or CDZ 6A, would require only an additional 0.5” of insulating sheathing. This would make this measure inexpensive for capturing 1.0 point. However, because the packages were not optimized at the CDZ level, the analysis uses the same packages in all CDZs for simplicity.

A.3.1. Energy Modeling

In order to conduct a whole building evaluation, the measures for the two least expensive packages were implemented by modifying the energy models that already include the prescriptive and mandatory provisions of the 2020 NYStretch code.

The high-efficiency gas and oil-fired furnaces were modeled by directly changing the thermal efficiency field in the *EnergyPlus* heating coil objects to 0.90. In the case of heat pumps, the required heating seasonal performance factor HSPF of 9.0 is more typically found in two-stage equipment. Additionally, while option 2.1 does not require an improved seasonal energy efficiency ratio (SEER), typical heat pumps with higher HSPFs also include better SEERs. This analysis assumes an improved SEER of 18 in addition to the HSPF of 9.0 for the high-efficiency heat pumps based on Cutler et al. (2013). The *EnergyPlus* objects associated with heat pumps require a heating and cooling coil COP. This analysis assumes COPs recommended by Cutler et al. (2013) for modeling residential heat pumps at the required SEER and HSPF levels. The efficiencies and COPs assumed in this analysis are summarized in Table A-3.

Table A-3. Heat Pump COPs Used in Analysis

	HSPF	SEER	EER	COP_cooling	COP_heating
Speed 1	9.3	18	14.5	4.25	4
Speed 2			13.3	3.90	3.5

Improved air leakage is modeled by adjusting the effective leakage area (ELA) input to the models based on the methodology for converting results of a blower door test in air changes at 50 Pa (ACH50) to ELA described in Mendon et al. (2013). Table A-4 summarizes the ELA values used in this analysis.

Table A-4. Effective Leakage Areas (ELAs) Used in Analysis for the Single-family Prototype

	ELA at 3 ACH50 (cm^2)	ELA at 2 ACH50 (cm^2)
Living_unit	360.92	240.62

A.3.2. Incremental Costs

The incremental cost associated with high-efficiency space conditioning equipment is calculated over the current federal standards for equipment efficiency as summarized in Table 5. The cost includes equipment and installation as well as additional venting costs for condensing furnaces where applicable.

The National Residential Efficiency Measures Database (NREM) developed by the National Renewable Energy Laboratory (NREL) reports an additional cost of $700 for a installing a gas furnace with an AFUE of 95% compared to a standard furnace with AFUE of 80% and an incremental cost of $800 for installing a heat pump with HSPF 9.3 compared to a standard heat pump with HSPF 7.7. Navigant (2011) reports an incremental cost of $1,438 for 94% AFUE furnaces, replaced on burnout, compared to 80% AFUE furnaces including a labor cost of $308. The installation costs for condensing furnaces are typically higher in retrofit applications due to a higher cost of venting so this cost is likely on the higher end of the spectrum. DOE (2016) reports an average incremental installed cost of $630 in 2015 dollars for an AFUE 95% furnace compared to an AFUE 80% furnace, which when adjusted for inflation works out to $680 in 2019 dollars. This analysis conservatively assumes an incremental cost of $1,000/unit associated with this measure.

The incremental cost associated with the U-0.24 windows is calculated by applying the same regression-based methodology described in section 3.4.2.1 to calculate the additional incremental cost associated with U-0.24 windows compared to the U-0.27 windows. The additional cost of U-0.24 windows over U-0.27 windows is thus assumed to be $0.62/ft^2$ (ENERGYSTAR 2016). This works out to an additional incremental cost of $235 for the single-family prototype after adjusting for inflation.

The incremental cost associated with a tighter envelope that meets the 2 ACH50 requirement compared to the 3 ACH50 required in the baseline codes is estimated at $0.31/ft^2$ of conditioned floor area by NREM. Additionally, ENERGY STAR (2016) estimates a cost of $0.11/ft^2$ for reducing infiltration from 7 ACH50 to 6 ACH50, $0.22/ft^2$ for reducing infiltration from 7 ACH50 to 5 ACH50 and $0.31/ft^2$ for reducing infiltration from 7 ACH50 to 4 ACH50. This analysis assumes an incremental cost of $0.31/ft^2$ for this measure which works out to $744 for the single-family prototype building.

The additional requirement for a high-efficiency ventilation fan can be met either with a fan with an efficiency better than 0.35 W/CFM or alternatively with furnaces with multispeed fans that are controlled to operate at the lowest speed required to provide adequate ventilation in ventilation-only mode. Thus, the incremental cost associated with this measure is assumed to be $100/unit.

These additional costs were combined with the costs associated with the prescriptive and mandatory provisions described in Chapter 3 to yield whole building costs for use in the analysis. Table A-5 summarizes the total incremental cost for each of the two additional efficiency credits packages for the single-family prototype, including the prescriptive and mandatory provisions of the 2020 NYStretch code. All costs are further adjusted for location factors as applicable.

Table A-5. Total Incremental Costs for the Single-family Prototype

CDZ	Single-family Package 1 (High-eff Furnace/HP + U-0.24 Windows)				Single-family Package 2 (High-eff Furnace/HP + 2 ACH50 + High-efficiency Fans)			
	Slab	Crawlspace	Heated Basement	Unheated Basement	Slab	Crawlspace	Heated Basement	Unheated Basement
4A-NYC	$3,745	$3,745	$3,225	$3,745	$4,582	$4,582	$4,062	$4,582
4A-balance	$4,090	$3,992	$3,899	$3,992	$4,842	$4,743	$4,651	$4,743
5A	$4,086	$3,493	$3,092	$3,493	$4,731	$4,138	$3,737	$4,138
6A	$2,835	$2,835	$2,457	$2,835	$3,442	$3,442	$3,064	$3,442

A.3.3. Effective Useful Life

This analysis assumes an effective useful life (EUL) of 20 years for the high-efficiency furnaces and heat pumps based on DOE (2016). For windows, the EUL is assumed to be 20 years, as it is in the main analysis. The EUL of improved envelope tightness is assumed to be 60 years and the EUL of high-efficiency fans is assumed to be 20 years.

A.4 Multifamily Prototype Packages

For multifamily buildings, the additional efficiency credits table includes two options, option 2.3 and option 2.4, for high-efficiency water heating equipment with varying levels of required minimum efficiencies. Option 2.4 with the higher required efficiencies of the two, natural gas or propane water heating with a minimum a uniform energy factor (UEF) of 0.97, or Heat Pump Water Heaters (HPWH) with a minimum UEF of 2.6, was found to be the least expensive method to capture 2.0 points out of the required 3.0 points. Additional measures that would yield 1.0 point were then required to create the two least first-cost option packages that would yield 3.0 credits for the additional efficiency credits path. Based on an evaluation of all options available in the additional efficiency credits table, these least expensive options were determined to be option 1.6 (tighter envelope option with heat recovery ventilation (HRV) and high-efficiency fans) and option 2.1 (high-efficiency space conditioning equipment). The elements of the least incremental cost packages assumed in this analysis for the single-family prototype are summarized in Table A-6.

The 2020 NYStretch code already requires HRVs in CDZ 5A and 6A. However, the code does not specify a required level of efficiency in the mandatory provisions. The basis for the assumption of a sensible recovery efficiency (SRE) of 0.70 used in lieu of a requirement in the prescriptive and mandatory provisions, is described in section 3.3.5.4. Thus, the additional efficiency credit associated with option 1.6 is then only the relative improvement of the SRE to 0.80 in CDZ 5A and 6A.

Table A-6 summarizes the elements of the least incremental cost packages assumed in this analysis for each multifamily unit.

Table A-6. Additional Efficiency Credits Packages Selected for the Multifamily Prototype

No.	Package Description	Points
1	High-eff Furnace/HP + Higher-eff Water Heater	3.0
2	Higher-eff Water Heater + 0.8 SRE HRVs + 2 ACH50 and High-eff Fans	3.0

A.4.1. Energy Modeling

The high-efficiency gas and oil-fired furnaces are modeled using the same procedure as that discussed for the single-family prototype. A similar procedure is used for modeling a tighter envelope for the multifamily prototype as that described for the single-family prototype above. However, for the DOE multifamily prototype used in this analysis, the ELA is proportionally distributed between the wall, ceiling, and floor areas as discussed by Mendon et al. (2013). Thus, the reduction in ELA from option 1.6 is also applied proportionally to the wall, ceiling, and floor areas as summarized in Table A-7.

Table A-7. Effective Leakage Areas (ELAs) Used in Analysis for the Multifamily Prototype

	ELA at 3 ACH50 (cm2)	ELA at 2 ACH50 (cm2)
MF_corner-units-middle-floor	47.01	31.33
MF_middle-units-middle-floor	34.19	22.79
MF_corner-units-other	107.35	71.55
MF_middle-units-other	94.53	63.00

Option 2.4 for high-efficiency water heating requires a natural gas or propane water heater with a UEF of 0.97 or a HPWH with a UEF of 2.6. Consistent with the DOE prototype model assumptions, the multifamily prototypes with natural gas or oil heating are assumed to use natural gas-fired water heaters while the models with heat pumps for space conditioning are assumed to use electric water

heaters in this analysis. In order to model the additional efficiency credit associated with this option, the gas water heaters are assumed to switch to tankless water heaters and the electric water heaters are assumed to switch to HPWHs in the 2020 NYStretch cases.

The *EnergyPlus* model for water heaters uses a burner efficiency and a shell loss factor (UA) to model the performance of the water heater (Mendon et al. 2013). Because this analysis assumes a tankless water heater to meet the UEF requirement for the gas water heater in option 2.4, the shell losses are set to zero in the 2020 NYStretch models. The HPWHs are modeled using the *EnergyPlus* WaterHeater:HeatPump model. The efficiency of HPWH varies depending on its mode of operation. For example, when the HPWH operates in a "pure" heat pump model, the efficiency is the highest compared to when it switches between the pure and "hybrid" supplemental resistance mode. As expected, the efficiency is the lowest when the HPWH operates in resistance mode only. Thus, HPWH manufacturers report UEFs for each mode separately. This analysis assumes that the HPWH operates in pure heat pump mode and the COP is assumed to be 3.1 based on analysis conducted by NRDC.[23]

A.4.2. Incremental Costs

The total incremental costs associated with high-efficiency space conditioning equipment are conservatively assumed to be the same as those described above for the single-family prototype. The cost for a tighter envelope is assumed to be $0.31/ft^2 based on the reasoning discussed for the single-family prototype and works out to $372 for each multifamily unit.

The average cost of HRVs with 0.8 SRE is difficult to pin-point because of the fewer products that exist in that range, as illustrated in Figure 1. Various sources note a cost from $850 per unit[24] to $1100-$1300 per unit.[25] This analysis assumes average equipment cost of $1,200 for an HRV with a 0.8 SRE. Assuming the labor and installation remain the same between an HRV with a 0.70 SRE, the total installed cost for this option is assumed to be $1,800.

NREM reports a range of $1,800–$3,500 for a gas tankless water heater compared to a storage type water heater. However, the cost is reported only for a retrofit application and the estimate includes cost of removing older equipment. In this case, the lower end of the range is more suitable for new construction. The 2015 California Codes and Standards Enhancement Initiative (CASE) report on the cost-effectiveness of gas instantaneous water heaters assumes an average incremental cost of $725[26] compared to a standard storage water heater. Navigant (2018) reports a total installed cost of $5,215 for a tankless water heater with a UEF of 0.83-0.96 and a total installed cost of $2,013 for a standard storage type water heater with a 40-gallon tank, resulting in an incremental cost of $3,200 associated with this option.[27] A 2018 study conducted by the Energy Information Administration (EIA) reports a total installed cost of $2,550 for a HPWH with an UEF 3.28 compared to a total installed cost of $1,100 for a standard electric resistance storage water heater leading to an incremental cost of $1450 for this measure.[28] The Northeast Energy Efficiency Partnership (NEEP) (2016) reports an incremental cost of $1,053–$1,144 for HPWH with EF_{nc} higher than or equal to 2.6, compared to a baseline storage water heater.[29] This analysis assumes an average incremental cost of $1,200 associated with this option for both tankless gas and HPWHs compared to standard gas and electric storage water heaters respectively. Each unit in the multifamily prototype building is assumed to have an individual water heater.

Additionally, the analysis accounted for all prescriptive and mandatory provisions of the 2020 NYStretch code. Table A-8 summarizes the total incremental cost for each of the two additional efficiency credits packages for each unit in the multifamily prototype. Like the main analysis, this analysis calculated whole package incremental construction costs for the packages compared to the baseline codes and the costs were further adjusted for location factors as applicable.

Table A-8. Total Incremental Costs for Each Unit in the Multifamily Prototype

CDZ	Multifamily Package 1 (Higher-eff Water Heaters +High-eff Furnace/HP)				Multifamily Package 2 (Higher-eff Water Heaters + 2 ACH50 + 0.8 SRE HRVs)			
	Slab	Crawlspace	Heated Basement	Unheated Basement	Slab	Crawlspace	Heated Basement	Unheated Basement
4A-NYC	$4,786	$4,786	$4,266	$4,786	$5,984	$5,984	$5,464	$5,984
4A-balance	$4,352	$4,245	$4,006	$4,245	$5,428	$5,321	$5,082	$5,321
5A	$4,393	$4,132	$3,731	$4,132	$4,575	$4,314	$3,913	$4,314
6A	$3,704	$3,704	$3,326	$3,704	$3,876	$3,876	$3,498	$3,876

A.4.3. Effective Useful Life

This analysis assumes an EUL of 15 years for HRVs like the main analysis. An EUL of 20 years for the high-efficiency furnaces and heat pumps is assumed based on DOE (2016), the EUL of improved envelope tightness is assumed to be 60 years based on Mendon et al. (2013) and the EUL of water heaters is assumed to be 20 years (DOE 2010).

A.5 Results

The energy savings results in terms of site and source energy savings associated with the two least expensive additional efficiency credits packages for the single-family and multifamily prototypes are summarized in Tables A-9 and A-10 respectively. The fuel prices and site-to-source conversion ratios are maintained the same as the main analysis. The additional efficiency options are observed to yield additional 10-15% savings beyond the prescriptive and mandatory provisions of the 2020 NYStretch code.

Table A-9. Site Energy, Source Energy and Energy Cost Savings for the Single-family Prototype

Climate Zone 4A-NYC			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2016 NYCECCC	56514.2	89670.4	1511.9
2020 NYStretch Package 1	39763.7	65736.1	1151.2
2020 NYStretch Package 2	39989.9	65920.8	1151.5
Savings Package 1(%)	29.6%	26.7%	23.9%
Savings Package 2(%)	29.2%	26.5%	23.8%
Climate Zone 4A-balance			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2020 ECCC NYS	59883.2	94033.4	1553.9
2020 NYStretch Package 1	41360.5	68060.0	1158.7
2020 NYStretch Package 2	38891.9	64157.7	1093.9
Savings Package 1(%)	30.9%	27.6%	25.4%
Savings Package 2(%)	35.1%	31.8%	29.6%
Climate Zone 5A			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2020 ECCC NYS	73155.7	107810.3	1755.9
2020 NYStretch Package 1	49147.6	78069.8	1331.0
2020 NYStretch Package 2	45966.6	73936.1	1269.5
Savings Package 1(%)	32.8%	27.6%	24.2%
Savings Package 2(%)	37.2%	31.4%	27.7%

Table A-9 continued

Climate Zone 6A			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2020 ECCC NYS	75198.4	110746.2	1775.8
2020 NYStretch Package 1	49690.2	78364.1	1314.2
2020 NYStretch Package 2	50090.1	78796.4	1319.4
Savings Package 1(%)	33.9%	29.2%	26.0%
Savings Package 2(%)	33.4%	28.8%	25.7%
New York State			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
Baseline	68021.3	101901.3	1663.3
2020 NYStretch Package 1	45411.7	72759.9	1238.8
2020 NYStretch Package 2	43601.5	70374.0	1203.0
Savings Package 1(%)	33.2%	28.6%	25.5%
Savings Package 2(%)	35.9%	30.9%	27.7%

Table A-10. Site Energy, Source Energy and Energy Cost Savings for the Multifamily Prototype

Climate Zone 4A-NYC			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2016 NYCECCC	27770.4	49534.6	947.0
2020 NYStretch Package 1	16834.5	31138.4	610.0
2020 NYStretch Package 2	16846.2	31080.4	607.8
Savings Package 1(%)	39.4%	37.1%	35.6%
Savings Package 2(%)	39.3%	37.3%	35.8%
Climate Zone 4A-balance			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2020 ECCC NYS	28554.6	50625.9	920.4
2020 NYStretch Package 1	17243.8	31725.9	586.8
2020 NYStretch Package 2	15460.2	30367.5	577.0
Savings Package 1(%)	39.6%	37.3%	36.2%
Savings Package 2(%)	45.9%	40.0%	37.3%

Table A-10 continued

Climate Zone 5A			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2020 ECCC NYS	32447.9	56132.8	984.2
2020 NYStretch Package 1	17994.0	32993.0	597.0
2020 NYStretch Package 2	18261.7	34423.4	631.6
Savings Package 1(%)	44.5%	41.2%	39.3%
Savings Package 2(%)	43.7%	38.7%	35.8%
New York State			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
Baseline	29266.1	51637.4	943.4
2020 NYStretch Package 1	17306.4	31861.6	596.0
2020 NYStretch Package 2	16534.8	31550.1	599.0
Savings Package 1(%)	40.9%	38.3%	36.8%
Savings Package 2(%)	43.5%	38.9%	36.5%

Tables A-11 and A-12 summarize the savings in terms of energy costs and the simple payback for the two prototypes.

Table A-11. Energy Cost Savings and Simple Payback for the Single-family Prototype

	Single-family Package 1 (High-eff Furnace/HP + U-0.24 Windows)			Single-family Package 2 (High-eff Furnace/HP + 2 ACH50 + High-efficiency Fans)		
Climate Design Zone	**Total Annual Energy Cost Savings ($/dwelling unit)**	**Total Incremental Costs ($/dwelling unit)**	**Simple Payback (Years)**	**Total Annual Energy Cost Savings ($/dwelling unit)**	**Total Incremental Costs ($/dwelling unit)**	**Simple Payback (Years)**
4A-NYC	$361	$3,607	10.0	$360	$4,444	12.3
4A-balance	$395	$3,987	10.1	$460	$4,739	10.3
5A	$425	$3,510	8.3	$486	$4,155	8.5
6A	$462	$2,739	5.9	$456	$3,346	7.3
NY State	$428	$3,389	7.9	$471	$4,047	8.6

Table A-12. Energy Cost Savings and Simple Payback for the Multifamily Prototype

Climate Design Zone	Multifamily Package 1 (Higher-eff Water Heaters +High-eff Furnace/HP)			Multifamily Package 2 (Higher-eff Water Heaters + 2 ACH50 + 0.8 SRE HRVs)		
	Total Annual Energy Cost Savings ($/dwelling unit)	Total Incremental Costs ($/dwelling unit)	Simple Payback (Years)	Total Annual Energy Cost Savings ($/dwelling unit)	Total Incremental Costs ($/dwelling unit)	Simple Payback (Years)
4A-NYC	$337	$4,648	13.8	$339	$5,846	17.2
4A-balance	$334	$4,203	12.6	$343	$5,279	15.4
5A	$387	$4,081	10.5	$353	$4,263	12.1
6A	NA	NA	NA	NA	NA	NA
NY State	$347	$4,302	12.4	$344	$5,198	15.1

Finally, Tables A-13 and A-14 summarize the 10-yr Net Present Value (NPV) of energy savings and the 30-year LCC savings for the single-family and the multifamily units respectively. All economic parameters are maintained the same as the main analysis.

Table A-13. Cost-Effectiveness Results for the Single-family Prototype

	Single-family Package 1 (High-eff Furnace/HP + U-0.24 Windows)			Single-family Package 2 (High-eff Furnace/HP + 2 ACH50 + High-efficiency Fans)		
CDZ	Total First Year Incremental Costs ($/dwelling unit)	10-Year NPV of Cost Savings ($/dwelling unit)	30 Year LCC Savings ($/dwelling unit)	Total First Year Incremental Costs ($/dwelling unit)	10-Year NPV of Cost Savings ($/dwelling unit)	30 Year LCC Savings ($/dwelling unit)
4A-NYC	$3,607	$3,112	$137	$4,444	$3,737	$(741)
4A-balance	$3,987	$3,445	$696	$4,739	$4,589	$238
5A	$3,510	$3,753	$1,825	$4,155	$4,991	$2,275
6A	$2,739	$4,071	$2,974	$3,346	$4,481	$2,246
NY State	$3,389	$3,595	$1,408	$4,047	$4,449	$1,005

Table A-14. Cost-Effectiveness Results for the Multifamily Prototype

	Multifamily Package 1 (Higher-eff Water Heaters + High-eff Furnace/HP)			Multifamily Package 2 (Higher-eff Water Heaters + 2 ACH50 + 0.8SRE HRVs)		
CDZ	**Total First Year Incremental Costs ($/dwelling unit)**	**10-Year NPV of Cost Savings ($/dwelling unit)**	**30 Year LCC Savings ($/dwelling unit)**	**Total First Year Incremental Costs ($/dwelling unit)**	**10-Year NPV of Cost Savings ($/dwelling unit)**	**30 Year LCC Savings ($/dwelling unit)**
4A-NYC	$4,648	$3,077	$(2,246)	$5,846	$3,304	$(4,085)
4A-balance	$4,203	$3,226	$(1,346)	$5,279	$3,515	$(2,836)
5A	$4,081	$3,573	$(246)	$4,263	$3,449	$(935)
6A	NA	NA	NA	NA	NA	NA
NY State	$4,302	$3,292	$(1,279)	$5,198	$3,423	$(2,618)

A.6 Conclusions

The additional efficiency credits proposed in section R407 of the draft NYStretch Energy Code version dated January 2019 yield additional positive energy savings of 10–15% over the prescriptive and mandatory provisions of the 2020 NYStretch energy code. An evaluation of two least expensive package options for single-family and multifamily buildings indicates simple paybacks ranging from 8 to 17 years. While the 30-year LCC savings are positive for most single-family buildings, they are negative for multifamily buildings in all climate design zones. It is further noted that because the package combinations are chosen based on the lowest first costs and not optimized based on a LCC perspective, it is possible that some other combinations of the proposed options might be more cost-effective in terms of LCC savings, even if they are more expensive in terms of first costs.

Appendix B. Energy Savings for All Models

This section summarizes the energy cost savings for each model from the prescriptive and mandatory provisions of the 2020 NYStretch energy code over the 2016 New York City Energy Conservation Code (NYCECC) baseline in CDZ 4A-NYC and the 2020 Energy Conservation Construction Code of New York State (ECCC NYS) baseline elsewhere, along with the associated incremental costs, 10-year net present value (NPV) of energy cost savings including replacement costs and 30-year LCC savings.

Table B-1. Energy Cost Savings, Incremental Costs and Cost-Effectiveness Results for the Prescriptive and Mandatory Provisions of the 2020 NYStretch Energy Code

ID	CDZ	Electricity Savings ($)	Natural Gas Savings ($)	Fuel Oil Savings ($)	Total Energy Savings ($)	Incremental Costs ($)	10-yr NPV Energy Cost Savings ($)	30-yr LCC Savings ($)
SF_gasfurnace_crawlspace	4A-NYC	149.1	120.0	0.0	269.0	2048.5	2634.4	1262.4
SF_gasfurnace_heatedbsmt	4A-NYC	34.8	56.3	0.0	91.1	2048.5	1092.0	-1956.6
SF_gasfurnace_slab	4A-NYC	133.8	119.4	0.0	253.2	2048.5	2501.3	979.4
SF_gasfurnace_unheatedbsmt	4A-NYC	139.8	114.7	0.0	254.5	2048.5	2508.3	999.2
SF_hp_crawlspace	4A-NYC	621.0	0.0	0.0	621.0	2048.5	5479.4	7449.2
SF_hp_heatedbsmt	4A-NYC	388.3	0.0	0.0	388.3	2048.5	3532.0	3300.5
SF_hp_slab	4A-NYC	601.7	0.0	0.0	601.7	2048.5	5317.3	7103.9
SF_hp_unheatedbsmt	4A-NYC	601.6	0.0	0.0	601.6	2048.5	5317.0	7103.3
SF_oilfurnace_crawlspace	4A-NYC	141.3	0.0	375.7	517.1	2048.5	4662.7	5966.5
SF_oilfurnace_heatedbsmt	4A-NYC	35.3	0.0	172.9	208.2	2048.5	2049.5	260.4
SF_oilfurnace_slab	4A-NYC	126.9	0.0	372.7	499.6	2048.5	4516.4	5652.5
SF_oilfurnace_unheatedbsmt	4A-NYC	131.9	0.0	360.2	492.1	2048.5	4451.6	5505.9
SF_gasfurnace_crawlspace	4A-bal	113.9	180.4	0.0	294.3	2664.5	3509.4	1693.0
SF_gasfurnace_heatedbsmt	4A-bal	-2.5	97.5	0.0	95.0	2664.5	1772.6	-1920.0

Table B-1 continued

ID	CDZ	Electricity Savings ($)	Natural Gas Savings ($)	Fuel Oil Savings ($)	Total Energy Savings ($)	Incremental Costs ($)	10-yr NPV Energy Cost Savings ($)	30-yr LCC Savings ($)
SF_gasfurnace_slab	4A-bal	109.5	169.1	0.0	278.6	2664.5	3368.4	1404.5
SF_gasfurnace_unheatedbsmt	4A-bal	104.0	170.2	0.0	274.2	2664.5	3332.1	1326.1
SF_hp_crawlspace	4A-bal	569.5	0.0	0.0	569.5	2664.5	5660.9	6465.9
SF_hp_heatedbsmt	4A-bal	345.5	0.0	0.0	345.5	2664.5	3786.3	2472.4
SF_hp_slab	4A-bal	548.5	0.0	0.0	548.5	2664.5	5485.5	6092.3
SF_hp_unheatedbsmt	4A-bal	549.1	0.0	0.0	549.1	2664.5	5490.1	6102.2
SF_oilfurnace_crawlspace	4A-bal	107.6	0.0	433.1	540.7	2664.5	5481.6	6380.3
SF_oilfurnace_heatedbsmt	4A-bal	-0.9	0.0	229.7	228.8	2664.5	2842.6	618.9
SF_oilfurnace_slab	4A-bal	103.0	0.0	411.9	514.8	2664.5	5262.0	5897.8
SF_oilfurnace_unheatedbsmt	4A-bal	97.5	0.0	409.8	507.2	2664.5	5198.2	5760.5
SF_gasfurnace_crawlspace	5A	3.0	260.4	0.0	263.3	2326.0	2924.0	708.4
SF_gasfurnace_heatedbsmt	5A	-44.6	204.6	0.0	160.0	2326.0	2013.0	-1173.7
SF_gasfurnace_slab	5A	1.1	259.2	0.0	260.3	2326.0	2898.1	654.4
SF_gasfurnace_unheatedbsmt	5A	-0.3	255.8	0.0	255.5	2326.0	2854.7	565.7
SF_hp_crawlspace	5A	683.0	0.0	0.0	683.0	2326.0	6217.3	7997.7
SF_hp_heatedbsmt	5A	544.0	0.0	0.0	544.0	2326.0	5054.2	5519.9
SF_hp_slab	5A	694.3	0.0	0.0	694.3	2326.0	6312.2	8199.9
SF_hp_unheatedbsmt	5A	689.5	0.0	0.0	689.5	2326.0	6271.9	8114.2
SF_oilfurnace_crawlspace	5A	1.9	0.0	614.8	616.7	2326.0	5750.1	7422.9
SF_oilfurnace_heatedbsmt	5A	-41.9	0.0	480.7	438.7	2326.0	4242.1	4118.6
SF_oilfurnace_slab	5A	-0.8	0.0	619.4	618.5	2326.0	5766.2	7460.5
SF_oilfurnace_unheatedbsmt	5A	-1.2	0.0	604.4	603.2	2326.0	5635.4	7171.5
SF_gasfurnace_crawlspace	6A	-3.1	273.1	0.0	270.0	1931.5	2693.1	961.8
SF_gasfurnace_heatedbsmt	6A	-46.7	216.6	0.0	169.9	1931.5	1808.6	-863.1
SF_gasfurnace_slab	6A	-4.8	272.8	0.0	268.1	1931.5	2676.8	927.3
SF_gasfurnace_unheatedbsmt	6A	-6.4	268.8	0.0	262.4	1931.5	2626.3	823.9
SF_hp_crawlspace	6A	751.7	0.0	0.0	751.7	1931.5	6495.1	9348.3
SF_hp_heatedbsmt	6A	614.9	0.0	0.0	614.9	1931.5	5350.2	6909.3
SF_hp_slab	6A	766.6	0.0	0.0	766.6	1931.5	6619.8	9614.1

Table B-1 continued

ID	CDZ	Electricity Savings ($)	Natural Gas Savings ($)	Fuel Oil Savings ($)	Total Energy Savings ($)	Incremental Costs ($)	10-yr NPV Energy Cost Savings ($)	30-yr LCC Savings ($)
MF_gasfurnace_crawlspace	4A-NYC	84.4	58.8	0.0	143.2	1763.2	1530.6	-481.9
SF_hp_unheatedbsmt	6A	759.2	0.0	0.0	759.2	1931.5	6558.1	9482.6
SF_oilfurnace_crawlspace	6A	-4.3	0.0	644.1	639.8	1931.5	5650.3	7989.0
SF_oilfurnace_heatedbsmt	6A	-44.1	0.0	508.4	464.3	1931.5	4162.8	4727.4
SF_oilfurnace_slab	6A	-5.8	0.0	642.2	636.4	1931.5	5621.4	7926.3
SF_oilfurnace_unheatedbsmt	6A	-7.6	0.0	634.4	626.8	1931.5	5540.4	7748.3
MF_gasfurnace_heatedbsmt	4A-NYC	12.6	40.0	0.0	52.6	1763.2	756.5	-2111.2
MF_gasfurnace_slab	4A-NYC	86.1	57.4	0.0	143.5	1763.2	1531.9	-477.7
MF_gasfurnace_unheatedbsmt	4A-NYC	85.3	57.7	0.0	143.0	1763.2	1527.8	-486.6
MF_hp_crawlspace	4A-NYC	275.6	0.0	0.0	275.6	1763.2	2588.6	1833.8
MF_hp_heatedbsmt	4A-NYC	153.2	0.0	0.0	153.2	1763.2	1564.5	-348.0
MF_hp_slab	4A-NYC	274.8	0.0	0.0	274.8	1763.2	2582.3	1820.4
MF_hp_unheatedbsmt	4A-NYC	274.7	0.0	0.0	274.7	1763.2	2581.5	1818.7
MF_oilfurnace_crawlspace	4A-NYC	78.4	0.0	191.6	270.0	1763.2	2568.9	1922.9
MF_oilfurnace_heatedbsmt	4A-NYC	13.7	0.0	123.7	137.4	1763.2	1450.5	-506.1
MF_oilfurnace_slab	4A-NYC	79.9	0.0	186.6	266.4	1763.2	2538.5	1854.7
MF_oilfurnace_unheatedbsmt	4A-NYC	79.1	0.0	187.6	266.7	1763.2	2541.1	1861.0
MF_gasfurnace_crawlspace	4A-bal	66.3	81.0	0.0	147.2	1689.7	1796.9	316.7
MF_gasfurnace_heatedbsmt	4A-bal	1.0	56.6	0.0	57.6	1689.7	1026.4	-1299.2
MF_gasfurnace_slab	4A-bal	67.5	79.4	0.0	146.9	1689.7	1792.6	309.2
MF_gasfurnace_unheatedbsmt	4A-bal	66.5	80.0	0.0	146.5	1689.7	1789.7	302.4
MF_hp_crawlspace	4A-bal	245.9	0.0	0.0	245.9	1689.7	2554.4	2015.6
MF_hp_heatedbsmt	4A-bal	135.4	0.0	0.0	135.4	1689.7	1629.8	45.8

Table B-1 continued

ID	CDZ	Electricity Savings ($)	Natural Gas Savings ($)	Fuel Oil Savings ($)	Total Energy Savings ($)	Incremental Costs ($)	10-yr NPV Energy Cost Savings ($)	30-yr LCC Savings ($)
MF_hp_slab	4A-bal	245.2	0.0	0.0	245.2	1689.7	2548.9	2003.8
MF_hp_unheatedbsmt	4A-bal	245.3	0.0	0.0	245.3	1689.7	2549.2	2004.4
MF_oilfurnace_crawlspace	4A-bal	61.1	0.0	204.7	265.8	1689.7	2750.1	2572.3
MF_oilfurnace_heatedbsmt	4A-bal	2.3	0.0	134.8	137.1	1689.7	1663.2	209.1
MF_oilfurnace_slab	4A-bal	62.1	0.0	201.0	263.1	1689.7	2727.2	2521.2
MF_oilfurnace_unheatedbsmt	4A-bal	61.2	0.0	201.3	262.5	1689.7	2722.2	2510.6
MF_gasfurnace_crawlspace	5A	-27.5	139.8	0.0	112.3	1875.2	1382.0	-1453.7
MF_gasfurnace_heatedbsmt	5A	-62.4	124.4	0.0	62.0	1875.2	948.0	-2362.2
MF_gasfurnace_slab	5A	-27.6	138.2	0.0	110.6	1875.2	1365.9	-1486.3
MF_gasfurnace_unheatedbsmt	5A	-27.7	138.6	0.0	110.9	1875.2	1369.1	-1480.1
MF_hp_crawlspace	5A	283.8	0.0	0.0	283.8	1875.2	2699.5	1499.8
MF_hp_heatedbsmt	5A	211.0	0.0	0.0	211.0	1875.2	2091.0	203.4
MF_hp_slab	5A	281.2	0.0	0.0	281.2	1875.2	2678.4	1454.9
MF_hp_unheatedbsmt	5A	282.5	0.0	0.0	282.5	1875.2	2688.9	1477.3
MF_oilfurnace_crawlspace	5A	-24.0	0.0	342.5	318.5	1875.2	3039.1	2457.6
MF_oilfurnace_heatedbsmt	5A	-56.6	0.0	296.9	240.3	1875.2	2378.2	1018.3
MF_oilfurnace_slab	5A	-24.7	0.0	337.6	312.9	1875.2	2991.1	2351.8
MF_oilfurnace_unheatedbsmt	5A	-24.6	0.0	339.0	314.4	1875.2	3003.8	2380.0
SF_gasfurnace_crawlspace	4A-NYC	149.1	120.0	0.0	269.0	2048.5	2634.4	1262.4
SF_gasfurnace_heatedbsmt	4A-NYC	34.8	56.3	0.0	91.1	2048.5	1092.0	-1956.6
SF_gasfurnace_slab	4A-NYC	133.8	119.4	0.0	253.2	2048.5	2501.3	979.4
SF_gasfurnace_unheatedbsmt	4A-NYC	139.8	114.7	0.0	254.5	2048.5	2508.3	999.2
SF_hp_crawlspace	4A-NYC	621.0	0.0	0.0	621.0	2048.5	5479.4	7449.2
SF_hp_heatedbsmt	4A-NYC	388.3	0.0	0.0	388.3	2048.5	3532.0	3300.5
SF_hp_slab	4A-NYC	601.7	0.0	0.0	601.7	2048.5	5317.3	7103.9
SF_hp_unheatedbsmt	4A-NYC	601.6	0.0	0.0	601.6	2048.5	5317.0	7103.3

Table B-1 continued

ID	CDZ	Electricity Savings ($)	Natural Gas Savings ($)	Fuel Oil Savings ($)	Total Energy Savings ($)	Incremental Costs ($)	10-yr NPV Energy Cost Savings ($)	30-yr LCC Savings ($)
SF_oilfurnace_crawlspace	4A-NYC	141.3	0.0	375.7	517.1	2048.5	4662.7	5966.5
SF_oilfurnace_heatedbsmt	4A-NYC	35.3	0.0	172.9	208.2	2048.5	2049.5	260.4
SF_oilfurnace_slab	4A-NYC	126.9	0.0	372.7	499.6	2048.5	4516.4	5652.5
SF_oilfurnace_unheatedbsmt	4A-NYC	131.9	0.0	360.2	492.1	2048.5	4451.6	5505.9
SF_gasfurnace_crawlspace	4A-bal	113.9	180.4	0.0	294.3	2664.5	3509.4	1693.0
SF_gasfurnace_heatedbsmt	4A-bal	-2.5	97.5	0.0	95.0	2664.5	1772.6	-1920.0
SF_gasfurnace_slab	4A-bal	109.5	169.1	0.0	278.6	2664.5	3368.4	1404.5
SF_gasfurnace_unheatedbsmt	4A-bal	104.0	170.2	0.0	274.2	2664.5	3332.1	1326.1
SF_hp_crawlspace	4A-bal	569.5	0.0	0.0	569.5	2664.5	5660.9	6465.9
SF_hp_heatedbsmt	4A-bal	345.5	0.0	0.0	345.5	2664.5	3786.3	2472.4
SF_hp_slab	4A-bal	548.5	0.0	0.0	548.5	2664.5	5485.5	6092.3
SF_hp_unheatedbsmt	4A-bal	549.1	0.0	0.0	549.1	2664.5	5490.1	6102.2
SF_oilfurnace_crawlspace	4A-bal	107.6	0.0	433.1	540.7	2664.5	5481.6	6380.3
SF_oilfurnace_heatedbsmt	4A-bal	-0.9	0.0	229.7	228.8	2664.5	2842.6	618.9
SF_oilfurnace_slab	4A-bal	103.0	0.0	411.9	514.8	2664.5	5262.0	5897.8
SF_oilfurnace_unheatedbsmt	4A-bal	97.5	0.0	409.8	507.2	2664.5	5198.2	5760.5
SF_gasfurnace_crawlspace	5A	3.0	260.4	0.0	263.3	2326.0	2924.0	708.4
SF_gasfurnace_heatedbsmt	5A	-44.6	204.6	0.0	160.0	2326.0	2013.0	-1173.7
SF_gasfurnace_slab	5A	1.1	259.2	0.0	260.3	2326.0	2898.1	654.4
SF_gasfurnace_unheatedbsmt	5A	-0.3	255.8	0.0	255.5	2326.0	2854.7	565.7

Endnotes

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