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

Prepared for:

New York State Energy Research and Development Authority

Albany, NY

Marilyn Dare
Senior Project Manager (ret.)

Christopher Sgroi
Senior Project Manager

Prepared by:

Resource Refocus LLC

Berkeley, CA

Vrushali Mendon
Director

Margaret Pigman
Technical Consultant

Dr. Carrie Brown
Director

Rhys Davis
Technical Consultant

Natalie Low
Associate Technical Consultant

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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 Energy Conservation Construction Code of New York (ECCCNYS) 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

Acknowledgments

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Table of Contents

List of Figures

List of Tables

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
ECCCNYS	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
int	intermediate framings
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
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
sq. ft.	square feet
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 (NYStretch-2020). The analysis evaluates the energy savings and cost-effectiveness potential of the residential prescriptive and mandatory provisions of NYStretch-2020 when compared to the residential provisions of the 2020 Energy Conservation Construction Code of New York State (ECCCNYS) and the 2016 New York City Energy Conservation Construction Code (NYCECC).

The analysis closely follows the methodology set forth by the United States Department of Energy (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 ECCCNYS (NYSERDA 19-32, 2019). The analysis also leverages the residential prototype building models developed by Resource Refocus LLC for the evaluation of the 2020 ECCCNYS, 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 NYStretch-2020, 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 NYStretch-2020 are expected to yield positive energy savings and cost-effective benefits to homeowners compared to the baseline 2020 ECCCNYS 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)	2022 Total Energy Costs ($/dwelling unit)
Baseline*	59511.0	87758.2	1441.5
NYStretch-2020	43885.8	67243.1	1136.9
Savings	26.3%	23.4%	21.1%

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	2022 Total Energy Costs Savings
4A-NYC	19.1%	17.9%	17.1%
4A-balance	19.4%	17.7%	16.7%
5A	27.9%	24.7%	22.8%
6A	29.1%	26.2%	24.5%

Table S-3. Average 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	$391	$2,167	5.5	$221	$1,856	8.4
4A-balance	$334	$2,988	8.9	$182	$1,778	9.8
5A	$355	$2,722	7.7	$168	$2,106	12.6
6A	$368	$2,346	6.4	$171	$2,195	12.8
NY State	$357	$2,646	7.4	$189	$1,898	10.1

Table S-4. Weighted Results for the Prescriptive and Mandatory Provisions of NYStretch-2020 at the State Level

	New York State Average
Annual Energy Cost Savings ($/dwelling unit)	$308
Incremental Costs ($/dwelling unit)	$2,431
Simple Payback (Years)	8.2
10-Year NPV of Cost Savings Including Replacement Costs and Residual Values ($/dwelling unit)	$3,809
30-Yr LCC Savings ($/dwelling unit)	$1,695

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 NYStretch-2020.

In addition to the main body of the report, a number of appendices present additional information and results from supplemental analyses conducted during the course of the study.

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 (ECCCNYS) 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 NYStretch-2020 compared to the State baseline codes, the 2016 New York City Energy Conservation Code (2016 NYCECC) and the 2020 ECCCNYS. This analysis was conducted in each of the three climate design zones (CDZ) in New York State: 4A (split into NYC and the remaining balance of 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 ECCCNYS compared to the previous 2016 ECCCNYS as well as technical reports and analyses published by the United States. Department of Energy (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,[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 NYStretch-2020 based on their modeling results using REMRate.

Chapter 2 contains a qualitative evaluation of the major differences in the provisions of the 2020 NYStretch compared to the 2020 ECCCNYS and the 2016 NYCECC. Chapter 3 presents the methodology and assumptions for the energy savings and cost-effectiveness evaluation of the main energy impacting provisions of the 2020 NYStretch identified in the qualitative analysis. Chapter 4 presents the results of the evaluation in each CDZ for the entire suite of residential single-family and low-rise multifamily prototype building models. Chapters 5 and 6 note observations and conclusions. These chapters have been updated with the most recent information available as of the 2022 update of this report.

In addition to the main body of the report, seven appendices present additional information and results from supplemental analyses conducted during the course of the study:

- Appendix A. Cost-Effectiveness Analysis of Section R407 presents the results of the energy savings and cost-effectiveness analyses of Section 407 titled Additional Energy Efficiency Credits which was part of the initial draft 2020 NYStretch Energy Code but was not included in the final version.
- Appendix B. 2022 Updates details updates that were made in 2022 in order to better reflect current costs and increase accuracy.
- Appendix C. Energy Savings for All Models presents the energy savings and cost-effectiveness results for each single-family and low-rise multifamily unit before aggregation.
- Appendix D. Construction Cost Details contains additional construction cost details.
- Appendix E. Supplemental Fuel Price Analysis presents the results of a supplemental cost-effectiveness analysis conducted with local fuel prices for CDZ 6A.
- Appendix F. Supplemental Propane Analysis presents the results of an energy and cost-effectiveness evaluation of homes with propane in CDZ 6A, including a comparison of switching from propane to electric heat pumps.
- Appendix G. Supplemental Ventilation Analysis presents supplemental analysis performed to further quantify ventilation measure cost-effectiveness.

2 Qualitative Assessment

This section contains qualitative comparison tables for the prescriptive and mandatory provisions of the proposed 2020 NYStretch Energy Code (NYStretch-2020) compared to the 2020 Energy Conservation Construction Code of New York State (ECCCNYS) 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 NYStretch-2020 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 ECCCNYS and the proposed NYStretch-2020, along with the results of the qualitative assessment.

Table 1. A Preliminary Qualitative Comparison: NYStretch-2020 versus 2020 ECCCNYS

The Differences with the Largest Energy Impact between NYStretch-2020and 2020 ECCCNYS
(Prescriptive + Mandatory Provisions)

<table>
<tr><th>Code Section</th><th>Component</th><th>CDZ</th><th colspan="2">2020 ECCCNYS</th><th>NYStretch-2020</th><th>Energy Impact Captured through Energy Modeling (Yes/No)</th></tr>
<tr><td rowspan="12">R402.1</td><td rowspan="3">Fenestration U-factor</td><td>4A</td><td colspan="2">0.32</td><td>0.27</td><td rowspan="12">Yes

The overall impact of the changes to the prescriptive envelope are expected to yield positive energy savings across all CDZs.</td></tr>
<tr><td>5A</td><td colspan="2">0.3</td><td>0.27</td></tr>
<tr><td>6A</td><td>0.3 [a]</td><td>0.28 [a]</td><td>0.27</td></tr>
<tr><td rowspan="3">Fenestration SHGC</td><td>4A</td><td colspan="2">0.4</td><td>0.4</td></tr>
<tr><td>5A</td><td colspan="2">NR</td><td>NR</td></tr>
<tr><td>6A</td><td>NR [a]</td><td>NR [a]</td><td>NR</td></tr>
<tr><td rowspan="3">Ceiling R value</td><td>4A</td><td colspan="2">49</td><td>49</td></tr>
<tr><td>5A</td><td colspan="2">49</td><td>49</td></tr>
<tr><td>6A</td><td>49 [a]</td><td>60 [a]</td><td>49</td></tr>
<tr><td rowspan="3">Wood-framed R-value</td><td>4A</td><td colspan="2">20 or 13+5</td><td>21 int or 20+5 or 13+10</td></tr>
<tr><td>5A</td><td colspan="2">20 or 13+5</td><td>21 int or 20+5 or 13+10</td></tr>
<tr><td>6A</td><td>20+5 or 13+10[a]</td><td>23 cavity [a]</td><td>20+5 or 13+10</td></tr>
</table>

Table 1 continued

<table>
<tr><th>Code Section</th><th>Component</th><th>CDZ</th><th colspan="2">2020 ECCCNYS</th><th>NYStretch-2020</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 ECCCNYS	NYStretch-2020	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 have a neutral energy impact because this requirement is mentioned in the mechanical code.
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 ECCCNYS	NYStretch-2020	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 ECCCNYS includes two prescriptive envelope options for CDZ 6A.

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

Table 2. A Preliminary Qualitative Comparison: NYStretch-2020 versus 2016 NYCECC

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

Component	2016 NYCECC	NYStretch-2020	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 NYStretch-2020.
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 NYStretch-2020 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 ECCCNYS) in the rest of the State. The analysis methodology builds on 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 ECCCNYS 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 ECCCNYS Rulemaking process (NYSERDA 2019).

3.1 Overview of the Analysis

The NYStretch-2020 is designed to overlay the 2020 ECCCNYS. 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, offers 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 NYStretch-2020. 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 ECCCNYS 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 ECCCNYS. This was done to accurately compute the energy savings and cost-effectiveness of the NYStretch-2020 in New York City because the 2016 NYCECC has different envelope requirements compared to the 2020 ECCCNYS.
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 ECCCNYS 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 NYStretch-2020 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 NYStretch-2020.
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. The simple payback, 10-year present value calculation of energy cost savings, and the 30-year life cycle cost (LCC) savings were calculated. The NPV and LCC calculations account for the impact of increased mortgage and down payment as well other homeowner cashflows as detailed in DOE’s cost-effectiveness methodology.
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 ECCCNYS cost-effectiveness analysis conducted for NYSERDA (NYSERDA 2019). These models, in turn were developed from a set of 32 DOE/PNNL 2015 IECC residential prototype models and 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 square feet (sq. ft.), 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 sq. ft. 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 94.7%. These 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%	0.15%	5.91%
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%	0.18%	12.92%
Heated Basement, Heat Pump	0.81%	2.14%	2.55%	0.71%	1.10%	0.19%	7.50%
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%	0.23%	16.40%
Unheated Basement, Heat Pump	1.30%	3.45%	4.11%	1.15%	1.76%	0.30%	12.07%
Unheated Basement, Oil Furnace	0.0%	0.53%	0.77%	0.0%	0.33%	0.0%	1.63%
Unheated Basement, Gas Furnace	3.69%	4.33%	11.61%	1.44%	4.98%	0.38%	26.43%
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%	0.11%	7.59%
			Percentage of total NYS Construction weights				94.65%

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 ECCCNYS 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 ECCCNYS 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 ECCCNYS 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 Efficiency[a]
Gas furnace	80%
Oil furnace	83%
Oil boiler	84%
Heat pump	SEER 14

[a] For source information, see Endnotes.[2]

3.3.4.1 Adjustment for Duct Sealing

The 2020 ECCCNYS 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 ECCCNYS 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

NYStretch-2020 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

NYStretch-2020 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.

NYStretch-2020 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 ECCCNYS 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 sq. ft. 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. The building envelope components were set to the efficiency levels proposed by NYStretch-2020. All other house characteristics were maintained as the Building America defaults per Building America House Simulation Protocols (Wilson et al. 2014).

Table 6 shows the savings from moving ducts with 4% leakage, insulated with R-8, to conditioned space for the slab-on-grade, heated basement, and unheated basement prototypes. These factors are applied to the NYStretch-2020 models to account for savings accrued from moving ducts to the conditioned space.

Table 6. Savings from Moving Ducts to Conditioned Space

Climate Design Zone	Foundation	Heating Savings	Cooling Savings	Fan Savings
4A	Slab/Crawlspace	15%	15%	14%
	Unheated Basement	12%	10%	11%
	Heated Basement	6%	6%	6%
5A	Slab/Crawlspace	15%	15%	12%
	Unheated Basement	14%	12%	12%
	Heated Basement	9%	8%	10%
6A	Slab/Crawlspace	16%	15%	12%
	Unheated Basement	14%	13%	12%
	Heated Basement	10%	11%	11%

3.3.5.3 Domestic Water Heating

NYStretch-2020 includes provisions for improving the efficiency of hot water supply systems. The code offers four different options, including a compact piping layout with limits on pipe run lengths or pipe volumes, drain water heat recovery (DWHR) units with a minimum efficiency of 40% if installed for equal flow or 52% if installed for unequal flow, or a recirculation system with no more than 0.5-gallon storage. While all four options are designed to cut losses in the hot water delivery systems, they are associated with different costs and challenges. In many cases, a compact piping layout can be efficiently implemented during the design of a house and can result in lower construction costs from reduced piping while still yielding hot water energy savings. Where compact piping layouts are not feasible due to the house design or application, a DWHR or a recirculation system can be introduced to yield hot water energy savings. 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. Savings percentages from DWHR 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] For compact piping systems with centrally located water heaters, savings ranging from 17–35% were found in the literature (NAHB 2002) along with thousands of dollars of initial construction cost savings (Klein 2020).

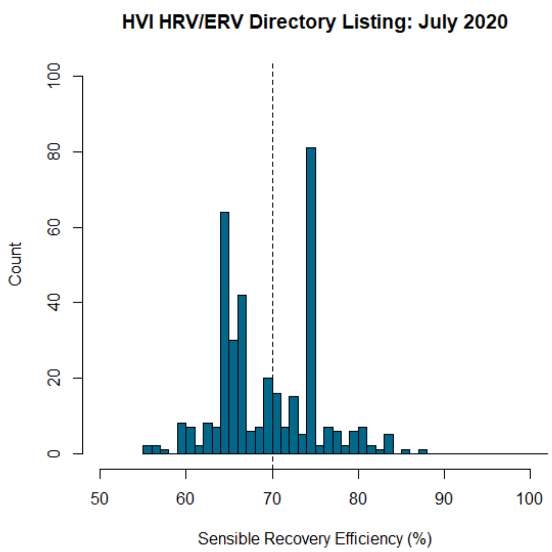
The PNNL/DOE models use a simplifying assumption of treating hot water pipes as adiabatic, meaning there is no heat transfer between them and other spaces in the building. Therefore, adding DWHR to the models or shortening pipe lengths in the model would not account for any interactive effects with space heating and cooling. These interactive effects are expected to be of the second order in nature, and the analysis uses a savings multiplier approach. This analysis conservatively assumes an average energy savings estimate of 25% based on literature review described above. These savings are implemented by applying a multiplier of 0.75 to the hot water energy consumption in the NYStretch-2020 cases.

3.3.5.4 Ventilation

NYStretch-2020 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 instead of a ERV or HRV system. The baseline 2020 ECCCNYS 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 NYStretch-2020 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 as of July 2020. 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 65% 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 65%. 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



3.3.5.5 High-Efficacy Lighting

NYStretch-2020 makes an incremental improvement to the minimum lighting efficacy requirement. Compared to the tiered requirements in the baseline 2020 ECCCNYS and the 75% high-efficacy lighting requirement in the 2016 NYCECC, NYStretch-2020 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 NYStretch-2020 for the single-family prototype and each multifamily unit.

Table 7. Lighting Energy Use

	2020 ECCCNYS		2016 NYCECC		NYStretch-2020	
	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 RSMeans (RSMeans 2019, RSMeans 2022), 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 2022 dollars using the consumer price index (CPI) or RSMeans Historical City Cost Index multipliers. Finally, the costs are adjusted using location cost multipliers to generate representative construction cost estimates for each climate zone. Appendix D. Construction Cost Details describes the costs used in 2019 and how they were changed for the 2022 update.

3.4.1 Cost Multipliers

Two sets of cost multipliers are used to adjust cost data in this analysis: location factors and historical cost index.

Location factors are used to adjust national average costs to account for locational diversity in material and labor costs (RSMeans 2022). The 2022 RSMeans location multipliers for all available locations in New York State are 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. These are then averaged to yield the overall factors used in this analysis. Table 8 shows values for 2022, which are applied uniformly across all measures to provide location-specific incremental costs.

Table 8. 2022 Location Cost Multipliers Used in the Analysis

Climate Design Zone	Average 2022 Location Factor
4A-NYC	1.429
4A-balance	1.313
5A	1.165
6A	1.130

Historical multipliers: For measures that do not have RS Means data (such as HRV), the analysis also uses the RS Means Historical City Cost Index to estimate how much the cost has changed over time (e.g. since the last referenced cost for each measure). This is akin to using the consumer price index, except that it references RSMeans data that is specific to each year in New York. For example, if a referenced cost was from 2019, the Historical Index is used to scale from 2019 to 2022 costs, then location multipliers would be applied to differentiate by climate zone.

3.4.2 Incremental Cost for Each Measure

This section describes the assumptions used to develop the incremental costs for each measure evaluated in the energy analysis.

3.4.2.1 Fenestration

NYStretch-2020 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.

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). Data from the National Residential Efficiency Measures Database (NREM) developed by the National Renewable

Energy Laboratory (NREL) is used to develop a set of regression equations. These regression equations were used to calculate the incremental costs associated with this code provision resulting in an incremental cost of $1.04/sq. ft. in CDZ 4A including CDZ 4A-balance and $0.62/sq. ft. in CDZ 5A and CDZ 6A. The analysis adjusts the original costs to 2022 dollars using the RSMeans Historical City Cost Index and location multipliers for cities in the appropriate climate zones, resulting in the incremental costs shown in Table 9.

Table 9. 2022 Fenestration Incremental Costs

Climate Design Zone	Fenestration Incremental Costs ($/unit)	
	Single-family	Multifamily
4A-NYC	$619	$310
4A-balance	$571	$286
5A	$299	$142
6A	$289	$137

3.4.2.2 Exterior Wall Insulation

There are multiple baseline and NYStretch-2020 prescriptive options for wall insulation (Table 1 and Table 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, which is $2.26/sq. ft. based on 2022 RSMeans data.

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). 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. Using the 2022 RSMeans data, this results in national average incremental costs of $486 for the single-family prototype and $174 for the multifamily unit. Applying location multipliers results in the incremental costs shown in Table 10.

Table 10. 2022 Exterior Wall Insulation Incremental Costs

Climate Design Zone	Exterior Wall Incremental Costs ($/unit)	
	Single-family	Multifamily
4A-NYC	-	-
4A-balance	$655	$234
5A	$564	$202
6A	-	-

3.4.2.3 Floor Insulation

NYStretch-2020 requires R-30 floor insulation in CDZ 4A compared to R-19 required by the 2020 ECCCNYS in CDZ 4A. The analysis assumes that fiberglass batt insulation is installed between floor joists. 2022 RSMeans data shows an incremental cost of $0.32/sq. ft. 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). The total incremental cost in CDZ 4A-balance is $517 for the single-family prototype and $172 for each multifamily unit (after applying location multipliers).

3.4.2.4 Slab Insulation

NYStretch-2020 requires slab insulation to be installed up to a depth of four feet compared to the two feet required by the baseline 2020 ECCCNYS in CDZ 4A and 5A. The analysis assumes slab edge insulation to be 2” thick XPS (R-10) with 60 PSI compressive strength, resulting in an incremental cost of $2.59/sq. ft. based on 2022 RSMeans data and a national average incremental cost of $725 for the single-family prototype and $319 for each multifamily unit. 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), so this incremental cost is assumed to apply only to CDZ 4A-balance and CDZ 5A. The total incremental costs after applying applicable location multipliers are shown in Table 11.

Table 11. 2022 Slab Insulation Incremental Costs

Climate Design Zone	Slab Insulation Incremental Costs ($/unit)	
	Single-family	Multifamily
4A-NYC	-	-
4A-balance	$977	$430
5A	$842	$371
6A	-	-

3.4.2.5 Basement Wall Insulation

NYStretch-2020 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 ECCCNYS in CDZ 4A. The analysis assumes basement walls insulation to be kraft-faced fiberglass placed within the wall cavity. The incremental cost includes 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, resulting in $1.07/sq. ft. based on 2022 RSMeans data. 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), so this incremental cost is assumed to apply only to prototypes with conditioned basements in the balance of CDZ 4A (CDZ 4A-balance). The total incremental cost in CDZ 4A-balance is $1413 for the single-family prototype and $622 for each multifamily unit (after applying location multipliers).

3.4.2.6 Efficient Hot Water Supply

NYStretch-2020 provides four options for encouraging the efficient delivery of hot water, including two options for a compact piping system, an option for a recirculation system, and one for a DWHR system. Like other elements of the code that are focused on good design practices, this measure can potentially save initial construction cost while providing energy savings. For example, Klein (2012 and 2020) lays out several examples for developing a compact hot water delivery system, which when implemented correctly during the early design stages of a project most likely result in reduced construction costs by eliminating long pipe runs that require installation and insulation. In some cases, these cost savings can be thousands of dollars in saved material and labor costs (Klein 2020). However, 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.

The DOE reports a range of $300 to $500 for costs of DWHR units, noting that installation is likely to be less expensive in new home construction.[8] The 2022 Codes and Standards Enhancement report developed by the California Energy Commission on DWHR in multifamily buildings, which was published after the last update to this report, shows a unit price of $736 plus $449 for labor resulting in a total cost of $1,185 (CASE 2020). 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] Recirculating pumps are often cheaper to install depending on the water heater configuration and can be controlled using a timer or a switch. The cost of a recirculating pump was $400 in a 2017 report.[10] To reflect 2022 costs, this was scaled using RSMeans Historical City Cost Index, resulting in a cost of $459. All new homes are required to have ground-fault circuit interrupters (GFCI) near water sources or sinks for safety considerations. Typically, the recirculation pump plugs into an available GFCI under the sink.

It is expected that the compact piping layout option would be the most economical option for new homes, thus achieving energy savings along with construction cost savings. For simplification, the analysis conservatively assumes that half of the new homes will choose the compact piping layout option with no incremental construction cost and the other half will choose either the DWHR or recirculation pump option, with the average cost of those two options used for the incremental cost. This results in an average national incremental cost of approximately $415 for this measure which is applied equally to all the single-family prototypes as well as each multifamily unit assuming individual water heaters for each unit. Table 12 shows the total incremental costs after applying location multipliers.

Table 12. 2022 Efficient Hot Water Supply Incremental Costs

Climate Design Zone	Efficient Hot Water Supply Incremental Costs ($/unit)	
	Single-family	Multifamily
4A-NYC	$606	
4A-balance	$559	
5A	$482	
6A	$466	

3.4.2.7 Ventilation

NYStretch-2020 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 65% 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.

The analysis assumes an average incremental cost of $324 for the single-family prototype and each multifamily unit for the CFIS unit that meets the requirement in CDZ 4A based on two papers and the NREM database, adjusted to 2022 dollars using the RSMeans Historical City Cost Index for cities in CDZ 4A (Moore 2018, Aldrich et al. 2013, NREL 2019).

For CDZs 5A and 6A, the analysis assumes a base incremental cost of $1,095 for the single-family prototype and each multifamily unit for an HRV based on the same resources and adjusted to 2022 dollars using the RSMeans Historical City Cost Index for cities in CDZs 5A and 6A (Moore 2018, Aldrich et al. 2013, NREL 2019).

The total incremental costs for ventilation are shown in Table 13. An analysis with more details on HRVs and ERVs that explores various HRV price points for single-family and multifamily units is included in Appendix G. Supplemental Ventilation Analysis.

Table 13. 2022 Ventilation Incremental Costs

Climate Design Zone	Ventilation Incremental Costs ($/unit)	
	Single-family	Multifamily
4A-NYC (CFIS)	$473	
4A-balance (CFIS)	$436	
5A (HRV)	$1271	
6A (HRV)	$1229	

3.4.2.8 Lighting

NYStretch-2020 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 ECCCNYS. The required percentage of high-efficacy hard-wired lighting in the 2016 NYCECC, however, is 75%.[11] The overall impact of NYStretch-2020 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] The incremental cost associated with this change is assumed to be negligible because most CFLs and LEDs available in the market today easily meet the ENERGY STAR designation with 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 NYStretch-2020 provisions for those cases is based on purchasing seven more CFL or LED bulbs instead of incandescent bulbs for the single-family prototype and three more for the multifamily prototype. For the same brand, a 60W-equivalent A19 LED bulb costs approximately $0.20 more than the analogous incandescent bulb according to a major lighting retailer. In the single-family prototype, the incremental cost of replacing seven bulbs is assumed to be $1.40; for each multifamily unit, the incremental cost of replacing three bulbs is assumed to be $0.60. With location multipliers, the total incremental costs in CDZ 4A-NYC are $2 for single-family and $0.90 for multifamily.

3.4.2.9 Ducts in Conditioned Space

NYStretch-2020 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.

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) of 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/sq. ft. of conditioned floor area when utilizing efficient chase systems to as much as $2.50/sq. ft. 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 ECCCNYS and NYStretch-2020, allows ducts buried within attic insulation to be considered "inside conditioned space" if they meet certain criteria. The criteria include 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 sq. ft. single-story, slab-on-grade house configuration. The NAHB study was published in 2017, so to adjust for 2022 costs, the average cost of the range, $1,010, was shifted using the RSMeans Historical City Cost Index, resulting in an average cost of $1,158. 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 average incremental cost associated with this measure is assumed to be $579 for the single-family prototype. The average incremental cost for each multifamily unit is also accordingly assumed to be $579 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 and adjusted using location cost multipliers.

Table 14. 2022 Ducts in Conditioned Spaces Incremental Costs

Climate Design Zone	Ducts in Conditioned Spaces Incremental Costs ($/unit)[a]	
	Single-family	Multifamily
4A-NYC	$635	
4A-balance	$585	
5A	$504	
6A	$487	

[a] Costs only apply to the prototypes with slab-on-grade, crawlspace, and unconditioned basement.

3.4.2.10 Credit Associated with Downsizing HVAC Equipment

The collective impact of the prescriptive and mandatory requirements of NYStretch-2020 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 ECCCNYS. In CDZ 4A-NYC and 6A, the downsizing in equipment is less noticeable because the envelope requirements are mostly similar between the baseline and NYStretch-2020. An equipment downsizing average credit of $379 is assumed in this analysis only for CDZ 4A-balance and 5A, which is based on Energy Star cost estimates and has been adjusted to 2022 dollars using the RSMeans Historical City Cost Index (ENERGY STAR 2016). After location multipliers, the total credit is $510 in CDZ 4A-balance and $439 in CDZ 5A.

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 NYStretch-2020 Compared to the 2016 NYCECC in CDZ 4A-NYC and 2020 ECCCNYS Elsewhere

	Single-family				Multifamily			
	Slab	Crawlspace	Heated Basement	Unheated Basement	Slab	Crawlspace	Heated Basement	Unheated Basement
4A-NYC	$2,336	$2,336	$1,701	$2,336	$2,025	$2,025	$1,390	$2,025
4A-balance	$3,273	$2,814	$3,124	$2,814	$2,020	$1,762	$1,627	$1,762
5A	$3,523	$2,681	$2,176	$2,681	$2,533	$2,162	$1,657	$2,162
6A	$2,470	$2,470	$1,983	$2,470	$2,320	$2,320	$1,833	$2,320

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 fuel costs for electricity, natural gas, and fuel oil. In the previous update, the latest full year of average fuel costs available from Energy Information Association (EIA) was for 2017 (EIA 2019a, 2019b, and 2019c). 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 2019 version of this report are described in Table 16 and the updated fuel prices in Table 17. Due to a significant difference in the fuel prices in some areas of CDZ 6A, an additional supplemental analysis was conducted for CDZ 6A and is included in Appendix E. Supplemental Fuel Price Analysis.

In an effort to update the analysis with both more recent and more granular fuel costs, the fuel costs are broken out by climate zone with a separate category for NYC and updated to 2021 values. To estimate electricity costs in each region, average residential electricity prices for each utility are pulled from Form EIA-861M's Sales and Revenue data for 2021[16] and then averaged for each region based on the utility territory weighted by population served. Natural gas costs are determined using the 2021 average bill data from each utility listed by the New York State Department of Public Service[17] using the same weighted average methodology for the regional costs as electric utilities. Fuel oil costs are determined using the average 2021-2022 heating season weekly prices by region from NYSERDA.[18]

Table 16. 2019 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	$ 1.463/therm	$ 1.463/therm

Table 17. 2022 Fuel Prices

Fuel	CDZ 4A-NYC	CDZ 4A-bal	CDZ 5A	CDZ 6A
Electricity	$ 0.266/kWh	$ 0.216/kWh	$ 0.149/kWh	$ 0.142/kWh
Natural gas	$ 1.704/therm	$ 1.605/therm	$ 1.104/therm	$ 1.115/therm
Fuel Oil	$ 2.721/therm	$ 2.717/therm	$ 2.616/therm	$ 2.526/therm

The energy models provide estimates of predicted energy use in terms of Btu or therm for heating. The price of fuel oil is thus converted from reported in $/gal to $/therm for use in the energy cost calculations assuming a heat content of 138,500 Btu/gal for fuel oil.

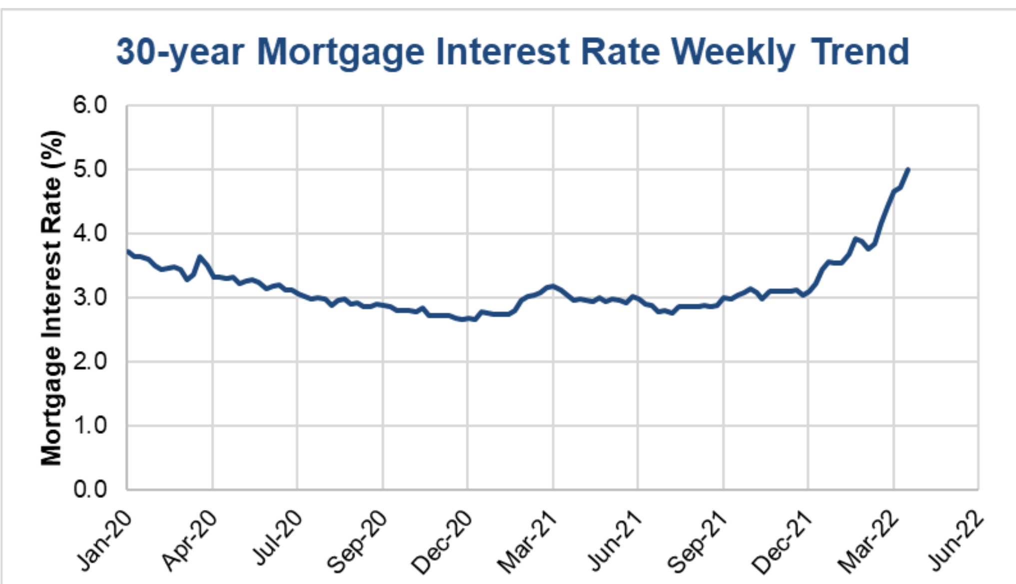
3.5.2 Economic Parameters

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 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

In the 2019 version of this report, the mortgage interest rate had been around 4.5% and trending downwards per estimates from Freddie Mac, so a value of 4.0% was used. In 2022, the rates reported by Freddie Mac have fluctuated significantly and have reached 5.0%, up from 3.0% in the last six months, as shown in Figure 2, so a rate of 5.0% is used in this update of the analysis.[19] The discount rate is maintained the same as the mortgage interest rate per DOE's methodology. The points and fees rate of 0.8% is used, determined by the same Freddie Mac data, up from 0.5% in the previous update.

Figure 2. Mortgage Interest Rate Trends for 2020 through 2022

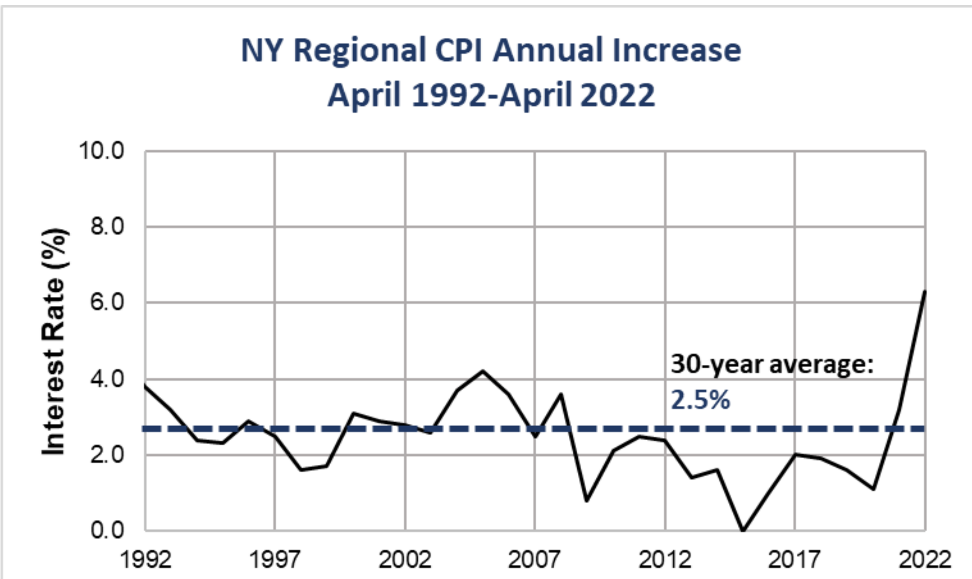


For source information, see endnotes. [20]

3.5.2.2 Inflation Rate

The 2019 version of this report used an annualized inflation rate for December 2018 of 1.9%.[21] For 2022, a value of 2.5% is used, which is equal to the average annual Consumer Price Index (CPI) increase for the New York region over the past 30 years. While inflation has risen significantly in the past year, the study assumes that the average rate for the next 30 years will be similar to the average rate for the last 30 years (as shown in Figure 3). The home price escalation rate is maintained the same as the inflation rate per DOE's methodology.

Figure 3. 30-Year CPI Change for New York Region



3.5.2.3 Down Payment Rate

The analysis assumes a 20% down payment rate to be representative of the current scenario in the State (NYSERDA 2019). In the most recent update to the American Housing Survey, the down payment rate has not changed significantly since the previous update, so the same value is used in the 2022 update to the analysis.

3.5.2.4 Income Tax Rate

The federal income tax rate is assumed to be 12% in the updated analysis, down from 15% in the 2019 version of this report, 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.[22]

3.5.2.5 *Property Tax Rate*

The property taxes in the State vary widely by location. This analysis uses an average property tax rate of 1.62%, a very slight decrease from the 2019 version of this report.

3.5.2.6 *Fuel Price Escalation Rates*

The fuel price escalation rates used in the 2019 version of this report were the average escalation rates for the 2018–2050 period reported by EIA in its 2019 Annual Energy Outlook for the Mid Atlantic census region, resulting in an escalation rate for electricity of 0.6%, 0.9% for natural gas, and 1% for fuel oil.[23] The 2022 update continues to use the 2019 EIA escalation rates due to uncertainty in fuel price forecasts at the time of this update.

The economic parameters used in this analysis are summarized in Table 18.

Table 18. Summary of Economic Parameters

Parameter	2019 Value	2022 Value
Mortgage Interest Rate	4%	5%
Loan Term	30 years	30 years
Down Payment Rate	20.0%	20.0%
Points and Loan Fees	0.5% (non-deductible)	0.8%
Discount Rate	4% (equal to Mortgage Interest Rate)	5% (equal to Mortgage Rate)
Period of Analysis	30 years	30 years
Property Tax Rate	1.65%	1.62%
Income Tax Rate	21.3%	18.3%
Home Price Escalation Rate	1.9%	2.5%
Inflation Rate	1.9%	2.5%
Energy Escalation Rates-Electricity	0.6%	0.6%
Energy Escalation Rates – Natural Gas	0.9%	0.9%
Energy Escalation Rates – Fuel Oil	1.0%	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 19 summarizes the effective useful life (EUL) of components assumed in the analysis. The analysis assumes the opaque envelope, drain water heat recovery, and the provision for buried ducts will last for the life of the home, which is assumed to be 60 years following DOE recommendations.[24]

Table 19. Effective Useful Life of Building Components

Component	EUL
Opaque Insulation	60
Drain Water Heat Recovery	60
Windows	20
Lighting	15
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 (ECCCNYS) elsewhere. All results are reported using 2022 cost assumptions.

4.1 Energy Savings at the Climate Design Zone and State Level

The results of the energy savings analysis of the proposed NYStretch-2020 code over the respective baseline code, by end-use at the climate design zone and State level are included below. 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

Table 20-Table 22 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. In summary, the results show ~26.3% site energy savings at the State level.

Table 20. Regulated Site Energy Savings for the Prescriptive and Mandatory Provisions NYStretch-2020 for Single-Family Buildings

Climate Zone 4A-NYC						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2016 NYCECC	25990.3	6066.3	5472.2	2937.8	16426.6	56893.3
NYStretch-2020	21153.5	5153.9	4966.9	2428.8	12318.2	46021.4
Savings (%)	18.6%	15.0%	9.2%	17.3%	25.0%	**19.1%**
Climate Zone 4A-balance						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2020 ECCCNYS	29118.5	6083.7	5093.2	3156.3	16431.5	59883.2
NYStretch-2020	22965.0	5258.3	4966.9	2538.0	12320.5	48048.7
Savings (%)	21.1%	13.6%	2.5%	19.6%	25.0%	**19.8%**

Table 20 continued

Climate Zone 5A						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2016 NYCECC	43133.8	3926.1	5096.0	3232.6	18050.4	73438.9
NYStretch-2020	27797.0	3397.3	4969.6	3237.1	13528.4	52929.5
Savings (%)	35.6%	13.5%	2.5%	-0.1%	25.1%	**27.9%**
Climate Zone 6A						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2020 ECCCNYS	44539.3	3634.2	5083.3	2887.5	19014.7	75159.1
NYStretch-2020	28030.8	3070.5	4957.2	2956.7	14251.9	53267.2
Savings (%)	37.1%	15.5%	2.5%	-2.4%	25.0%	**29.1%**

Table 21. Regulated Site Energy Savings for the Prescriptive and Mandatory Provisions of NYStretch-2020 for Multifamily Buildings

Climate Zone 4A-NYC						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2016 NYCECC	7896.4	3597.9	2933.5	1492.7	12053.4	27973.9
NYStretch-2020	6424.5	3232.6	2662.1	1298.2	9039.5	22657.0
Savings (%)	18.6%	10.2%	9.3%	13.0%	25.0%	**19.0%**
Climate Zone 4A-balance						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2020 ECCCNYS	8631.2	3592.6	2730.0	1546.6	12054.4	28554.8
NYStretch-2020	6877.6	3229.4	2662.1	1334.6	9040.0	23143.8
Savings (%)	20.3%	10.1%	2.5%	13.7%	25.0%	**18.9%**

Table 21 continued

Climate Zone 5A						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2016 NYCECC	12643.5	2438.2	2730.0	1610.1	13026.2	32447.9
NYStretch-2020	6903.1	2365.1	2662.1	2043.4	9764.1	23737.9
Savings (%)	45.4%	3.0%	2.5%	-26.9%	25.0%	**26.8%**
Climate Zone 6A						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2020 ECCCNYS	13861.2	2340.2	2730.0	1521.0	13944.2	34396.5
NYStretch-2020	7492.8	2242.9	2662.1	1975.2	10452.8	24825.8
Savings (%)	45.9%	4.2%	2.5%	-29.9%	25.0%	**27.8%**

Table 22. Weighted Average Regulated Site Energy Savings for the Prescriptive and Mandatory Provisions of NYStretch-2020

Climate Zone 4A-NYC						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2016 NYCECC	14639.4	4517.8	3879.6	2031.2	13683.2	38751.2
NYStretch-2020	11913.6	3948.6	3521.0	1719.5	10261.4	31364.2
Savings (%)	18.6%	12.6%	9.2%	15.3%	25.0%	**19.1%**
Climate Zone 4A-balance						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2020 ECCCNYS	16266.1	4521.0	3610.7	2146.5	13685.6	40229.9
NYStretch-2020	12872.9	3985.5	3521.0	1783.1	10262.6	32425.1
Savings (%)	20.9%	11.8%	2.5%	16.9%	25.0%	**19.4%**

Table 22 continued

Climate Zone 5A						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2016 NYCECC	38986.7	3723.7	4774.2	3011.9	17367.0	67863.6
NYStretch-2020	24955.2	3256.9	4655.8	3074.8	13016.4	48959.1
Savings (%)	36.0%	12.5%	2.5%	-2.1%	25.1%	**27.9%**
Climate Zone 6A						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
2020 ECCCNYS	41920.4	3523.7	4882.4	2770.9	18581.9	71679.4
NYStretch-2020	26277.6	2999.9	4767.1	2872.9	13927.6	50845.1
Savings (%)	37.3%	14.9%	2.4%	-3.7%	25.0%	**29.1%**
New York State						
(kBtu / dwelling unit)	Heating	Cooling	Lighting	Fan	DHW	Total Regulated Energy
Baseline	32080.3	3947.6	4412.5	2681.6	16389.0	59511.0
NYStretch-2020	21237.2	3447.3	4304.1	2611.9	12285.2	43885.8
Savings (%)	33.8%	12.7%	2.5%	2.6%	25.0%	**26.3%**

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 NYStretch-2020, as summarized in Table 23.

Table 23. Site to Source Energy Conversion Ratios

Energy Type	New York Ratio
Electricity (Grid Purchase)[a]	2.38
Natural Gas[b]	1.05
Fuel Oil[c]	1.01

[a, b, c] For source information, see endnotes.[25,26, 27]

Table 24 through Table 26 summarize the source energy savings resulting from the prescriptive and mandatory provisions of NYStretch-2020 compared to the respective baseline code in each CDZ, resulting in average State source savings of 23.4%.

Table 24. Source Energy Savings for the Prescriptive and Mandatory Provisions of NYStretch-2020 for Single-Family Buildings

Climate Zone	Baseline Total Source Energy (kBtu/dwelling unit)	NYStretch-2020 Total Source Energy (kBtu/dwelling unit)	Source Energy Savings
4A-NYC	87135.0	71225.5	18.3%
4A-balance	90502.4	74008.7	18.2%
5A	105061.6	78896.2	24.9%
6A	107097.0	78847.1	26.4%

Table 25. Source Energy Savings for the Prescriptive and Mandatory Provisions of NYStretch-2020 for Multifamily Buildings

Climate Zone	Baseline Total Source Energy (kBtu/dwelling unit)	NYStretch-2020 Total Source Energy (kBtu/dwelling unit)	Source Energy Savings
4A-NYC	47704.5	39349.0	17.5%
4A-balance	48281.0	40009.5	17.1%
5A	53632.4	41575.9	22.5%
6A	55471.8	42652.3	23.1%

Table 26. Weighted Average Source Energy Savings for the Prescriptive and Mandatory Provisions of NYStretch-2020

Climate Zone	Baseline Total Source Energy (kBtu/dwelling unit)	NYStretch-2020 Total Source Energy (kBtu/dwelling unit)	Source Energy Savings
4A-NYC	62399.0	51228.4	17.9%
4A-balance	64015.6	52680.0	17.7%
5A	98066.5	73820.1	24.7%
6A	102683.9	75757.3	26.2%
NY State Average	87758.2	67243.1	23.4%

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 Table 27 through Table 31. The results for the CDZ 6A baseline have been averaged over the two alternative options. In summary, the results show 21.1% energy cost savings at the State level. Results by building type and climate zone can be found in appendix C. Energy Savings for All Models.

Table 27. Annual Energy Cost Savings of the Prescriptive and Mandatory Provisions of NYStretch-2020 for Single-Family Buildings

($/dwelling unit)	Electricity Cost	Natural Gas Cost	Fuel Oil Cost	Total Energy Cost
Climate Zone 4A-NYC				
2016 NYCECC	1605.9	618.4	--	2224.4
NYStretch-2020	1342.5	490.8	--	1833.3
Savings (%)	16.4%	20.6%	NA	**17.6%**
Climate Zone 4A-balance				
2020 ECCCNYS	1314.9	627.8	--	1942.7
NYStretch-2020	1121.3	486.9	--	1608.2
Savings (%)	14.7%	22.4%	NA	**17.2%**
Climate Zone 5A				
2020 ECCCNYS	921.6	545.5	76.6	1543.6
NYStretch-2020	768.3	368.1	52.2	1188.6
Savings (%)	16.6%	32.5%	31.8%	**23.0%**
Climate Zone 6A				
2020 ECCCNYS	883.6	584.9	37.1	1505.6
NYStretch-2020	718.3	390.5	24.9	1133.7
Savings (%)	18.7%	33.2%	32.8%	**24.7%**

Table 28. Annual Energy Cost Savings of the Prescriptive and Mandatory Provisions of NYStretch-2020 for Multifamily Buildings

($/dwelling unit)	Electricity Cost	Natural Gas Cost	Fuel Oil Cost	Total Energy Cost
Climate Zone 4A-NYC				
2016 NYCECC	1077.2	221.6	31.3	1330.2
NYStretch-2020	914.1	170.9	24.5	1109.6
Savings (%)	15.1%	22.9%	21.5%	**16.6%**
Climate Zone 4A-balance				
2020 ECCCNYS	873.3	217.6	32.6	1123.5
NYStretch-2020	749.5	166.5	25.4	941.3
Savings (%)	14.2%	23.5%	22.2%	**16.2%**
Climate Zone 5A				
2020 ECCCNYS	642.3	195.8	--	838.1
NYStretch-2020	546.7	123.9	--	670.6
Savings (%)	14.9%	36.8%	NA	**20.0%**
Climate Zone 6A				
2020 ECCCNYS	605.7	221.3	--	826.9
NYStretch-2020	516.7	139.1	--	655.9
Savings (%)	14.7%	37.1%	NA	**20.7%**

Table 29. Weighted Average Annual Energy Cost Savings of the Prescriptive and Mandatory

($/dwelling unit)	Electricity Cost	Natural Gas Cost	Fuel Oil Cost	Total Energy Cost
Climate Zone 4A-NYC				
2016 NYCECC	1274.3	369.5	19.6	1663.4
NYStretch-2020	1073.8	290.1	15.4	1379.3
Savings (%)	15.7%	21.5%	21.5%	**17.1%**
Climate Zone 4A-balance				
2020 ECCCNYS	1037.9	370.5	20.5	1428.8
NYStretch-2020	888.0	285.9	15.9	1189.8
Savings (%)	14.4%	22.8%	22.2%	**16.7%**
Climate Zone 5A				
2020 ECCCNYS	883.6	497.9	66.2	1447.7
NYStretch-2020	738.2	334.9	45.1	1118.1
Savings (%)	16.5%	32.7%	31.8%	**22.8%**
Climate Zone 6A				
2020 ECCCNYS	859.8	553.8	33.9	1447.6
NYStretch-2020	701.1	369.0	22.8	1092.9
Savings (%)	18.5%	33.4%	32.8%	**24.5%**
New York State				
Baseline	929.8	466.7	45.0	1441.5
NYStretch-2020	780.4	325.3	31.3	1136.9
Savings (%)	16.1%	30.3%	30.5%	**21.1%**

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-year Life Cycle Cost (LCC) savings are described below.

4.3.1 Simple Payback

Table 30 shows the weighted average annual energy cost savings, the associated total incremental costs, and the resulting simple payback for NYStretch-2020 compared to the 2016 NYCECC in CDZ 4A-NYC and 2020 ECCCNYS elsewhere, for the single- and multifamily-prototypes. These are calculated using average fuel prices summarized in Table 16-19. In New York State, the weighted average for simple payback is 7.4 years for single-family and 10.1 years for multifamily.

Due to a significant difference in the fuel prices in some areas of CDZ 6A, an additional supplemental analysis was conducted for CDZ 6A and is included in Appendix E. Supplemental Fuel Price Analysis.

Table 30. 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	$391	$2,167	5.5	$221	$1,856	8.4
4A-balance	$334	$2,988	8.9	$182	$1,778	9.8
5A	$355	$2,722	7.7	$168	$2,106	12.6
6A	$368	$2,346	6.4	$171	$2,195	12.8
NY State	**$357**	**$2,646**	**7.4**	**$189**	**$1,898**	**10.1**

4.3.2 10-Year Present Value of Energy Cost Savings

Table 31 shows the 10-year net present value of energy cost savings for NYStretch-2020 compared to the 2016 NYCECC in CDZ 4A-NYC and 2020 ECCCNYS 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 31. Weighted Average Net Present Value (NPV) of Energy Cost Savings over 10 Years

Climate Design Zone	Single-family		Multifamily	
	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	$2,167	$4,200	$1,856	$2,712
4A-balance	$2,988	$4,650	$1,778	$2,710
5A	$2,722	$4,345	$2,106	$2,429
6A	$2,346	$3,965	$2,195	$2,291
NY State	**$2,646**	**$4,288**	**$1,898**	**$2,623**

4.3.3 30-Year Life Cycle Cost (LCC) Savings

Table 32 summarizes the 30-year LCC savings of the NYStretch-2020 over the 2020 ECCCNYS 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-2020 are found to be cost-effective for the homeowner and yield positive savings over the life of the home in all single-family cases. In multifamily, LCC savings are positive in 4A, but not in 5A and 6A. However, the overall State average LCC savings are positive. It should be noted that the negative 30-year LCC savings for the multifamily results were heavily affected by the gas furnace models, which tend to generate less savings. In general, the heat pump and oil furnace prototypes had better savings but represented a smaller proportion of the State. A full list of results by CDZ, foundation type, and heating type can be found in Appendix C. Energy Savings for All Models.

Table 32. 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	$3,517	$1,163
4A-balance	$1,946	$783
5A	$1,967	$(455)
6A	$2,567	$(588)
NY State	$2,167	$528

Table 33 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 33. Weighted Results for the Prescriptive and Mandatory Provisions of NYStretch-2020 at the State Level

	New York State Average
Annual Energy Cost Savings ($/dwelling unit)	$308
Incremental Costs ($/dwelling unit)	$2,431
Simple Payback (Years)	8.2
10-Year NPV of Cost Savings Including Replacement Costs and Residual Values	$3,809
30-Yr LCC Savings ($/dwelling unit)	$1,695

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 an "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. It should be noted that the factors used in this analysis pre-date New York's Climate Leadership and Community Protection Act, also known as the Climate Act. The work currently under way will inform future assumptions for analyses.

The avoided cost of carbon emissions is calculated using the NY Department of Environmental Conservation's estimate of the social cost of carbon (SCC) at the 2% discount rate.[28] For electricity, the net social cost of carbon emissions on a per-MWh basis ($/MWh) is net of the projected RGGI compliance costs included in the New York State Independent System Operator (NYISO) CARIS1 2019 Base Case model and is derived using the marginal emissions factors for buildings (lb. CO2e/MWh) published in the Final Performance Metrics Report of the NYS Clean Energy Advisory Council – Metrics, Tracking and Performance Assessment Working Group (filed July 19, 2017 in NYS PSC Matter 16-00561). A constant marginal emissions factor of 0.55 tons.CO2e/MWh is used for electricity between 2020 to 2034. Between 2035 and 2040, the marginal emissions factor is assumed to gradually step down to 0. Beyond 2040, a marginal emissions factor of 0 is used to account for New York's long-term electric grid decarbonization goals. For natural gas and oil, the social cost of carbon emissions on a per-MMBtu basis ($/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.

The fuel prices used in the analysis, before and after, including the cost of carbon, are summarized Table 34 and the revised LCC savings results are included in Table 35.

Table 34. Fuel Prices Used in the Analysis, with and without the Cost of Carbon

Climate Design 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	0.266	1.704	2.721	0.325	2.659	4.049
4A-balance	0.216	1.605	2.717	0.295	2.560	4.045
5A	0.149	1.104	2.616	0.228	2.059	3.944
6A	0.142	1.115	2.526	0.221	2.070	3.854

Table 35. 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	$5,340	$2,307
4A-balance	$5,999	$2,113
5A	$6,491	$1,449
6A	$6,268	$1,435
NY State	**$6,328**	**$1,976**

It is observed that the inclusion of carbon cost in the fuel price increases LCC savings across the board, resulting in positive LCC saving in all CDZs, including all multifamily buildings. This indicates the importance of considering such impacts in cost-effectiveness analyses for buildings, especially because buildings are likely to exist for 70-100 years.

5 Discussion

NYStretch-2020 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 NYStretch-2020. 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 NYStretch-2020 cases. The energy cost savings and correspondingly LCC savings are lower for models with gas furnaces because it is an inexpensive fuel 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 in general. Furthermore, as demonstrated in section 4.3.3.1 Consideration of the Avoided Cost of Carbon Emissions, 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 NYStretch-2020 Energy Code are expected to yield positive energy savings over the baseline 2020 Energy Conservation Construction Code of New York State (2020 ECCCNYS) and the 2016 New York City Energy Conservation Construction Code (2016 NYCECC). The savings range from 19 to 29% at the CDZ level in terms of site energy savings and from 16 to 24% 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, 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. This section was not adopted into the final code, so the results in this section all reflect 2019 cost assumptions.

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	1.0/kW/ housing unit
			(max 2 credits)	(max 2 credits)

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.[29] The packages were evaluated as whole building packages, including the prescriptive and mandatory provisions of NYStretch-2020.

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. Figure A-1 and Figure 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

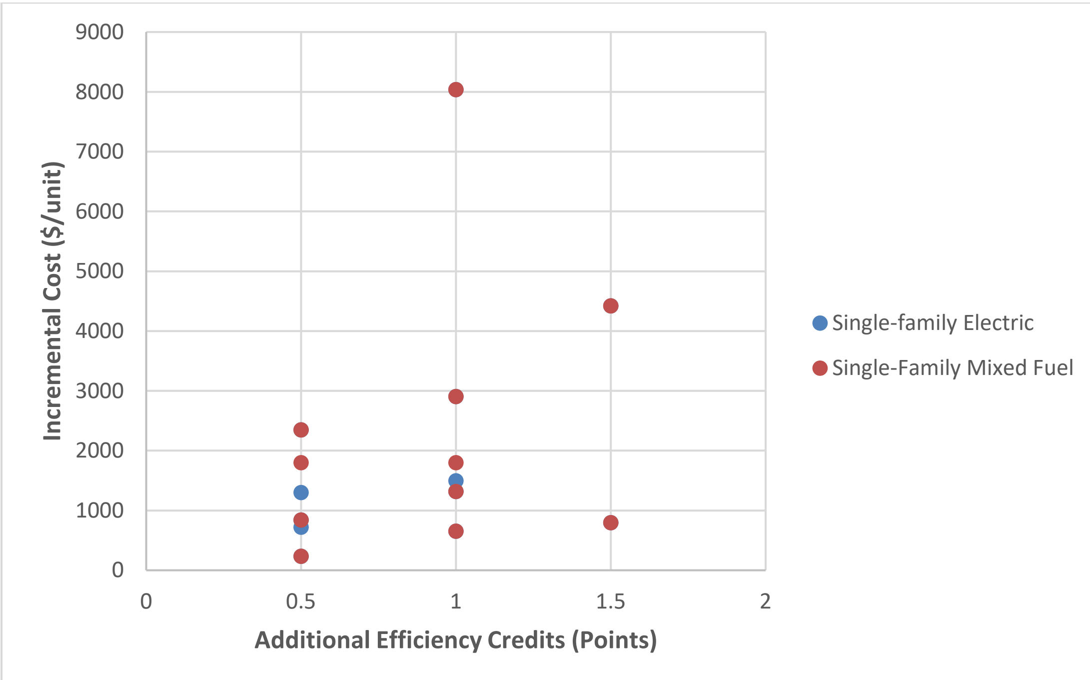
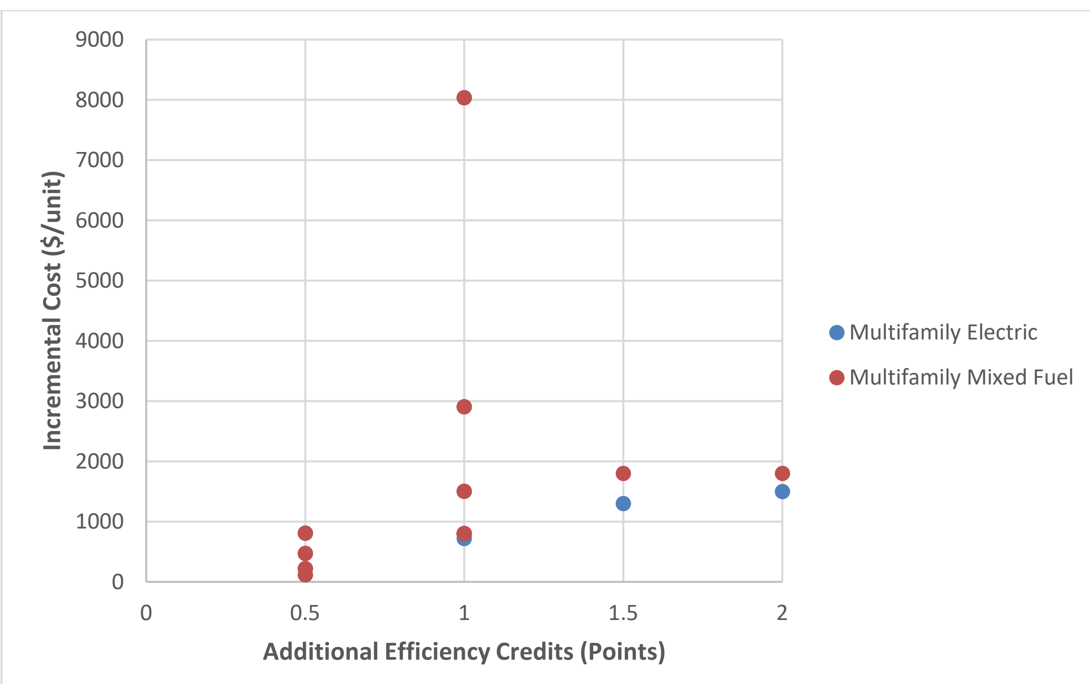


Figure A-2. Incremental Costs versus Additional Efficiency Credit Offered for Each Option for Each Multifamily Unit



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 NYStretch-2020 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 NYStretch-2020.

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 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/sq. ft. (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/sq. ft. of conditioned floor area by NREM. Additionally, ENERGY STAR (2016) estimates a cost of $0.11/sq. ft. for reducing infiltration from 7 ACH50 to 6 ACH50, $0.22/sq. ft. for reducing infiltration from 7 ACH50 to 5 ACH50 and $0.31/sq. ft. for reducing infiltration from 7 ACH50 to 4 ACH50. This analysis assumes an incremental cost of $0.31/sq. ft. 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 NYStretch-2020. 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.

NYStretch-2020 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 NYStretch-2020 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.[30]

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/sq. ft. 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[31] to $1100-$1300 per unit.[32] 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[33] 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.[34] 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.[35] The Northeast Energy Efficiency Partnership (NEEP) (2016) reports an incremental cost of $1,053–$1,144 for HPWH with EFnc higher than or equal to 2.6, compared to a baseline storage water heater.[36] 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 NYStretch-2020. 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 Table A-9 and Table 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 NYStretch-2020.

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 ($/dwelling unit)
2016 NYCECC	56514.2	89670.4	1511.9
NYStretch-2020 Package 1	39763.7	65736.1	1151.2
NYStretch-2020 Package 2	39989.9	65920.8	1151.5
Savings Package 1(%)	29.6%	26.7%	23.9%
Savings Package 2(%)	29.2%	26.5%	23.8%
Climate Zone 4A-balance			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2020 ECCCNYS	59883.2	94033.4	1553.9
NYStretch-2020 Package 1	41360.5	68060.0	1158.7
NYStretch-2020 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 ($/dwelling unit)
2020 ECCCNYS	73155.7	107810.3	1755.9
NYStretch-2020 Package 1	49147.6	78069.8	1331.0
NYStretch-2020 Package 2	45966.6	73936.1	1269.5
Savings Package 1(%)	32.8%	27.6%	24.2%
Savings Package 2(%)	37.2%	31.4%	27.7%
Climate Zone 6A			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2020 ECCCNYS	75198.4	110746.2	1775.8
NYStretch-2020 Package 1	49690.2	78364.1	1314.2
NYStretch-2020 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
NYStretch-2020 Package 1	45411.7	72759.9	1238.8
NYStretch-2020 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 ($/dwelling unit)
2016 NYCECC	27770.4	49534.6	947.0
NYStretch-2020 Package 1	16834.5	31138.4	610.0
NYStretch-2020 Package 2	16846.2	31080.4	607.8
Savings Package 1(%)	39.4%	37.1%	35.6%
Savings Package 2(%)	39.3%	37.3%	35.8%
Climate Zone 4A-balance			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2020 ECCCNYS	28554.6	50625.9	920.4
NYStretch-2020 Package 1	17243.8	31725.9	586.8
NYStretch-2020 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%
Climate Zone 5A			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
2020 ECCCNYS	32447.9	56132.8	984.2
NYStretch-2020 Package 1	17994.0	32993.0	597.0
NYStretch-2020 Package 2	18261.7	34423.4	631.6
Savings Package 1(%)	44.5%	41.2%	39.3%
Savings Package 2(%)	43.7%	38.7%	35.8%
New York State			
	Total Regulated Site Energy (kBtu/dwelling unit)	Total Regulated Source Energy (kBtu/dwelling unit)	Total Energy Costs ($/dwelling unit)
Baseline	29266.1	51637.4	943.4
NYStretch-2020 Package 1	17306.4	31861.6	596.0
NYStretch-2020 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%

Table A-11 and Table 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

Climate Design Zone	Single-family Package 1 (High-eff Furnace/HP + U-0.24 Windows)			Single-family Package 2 (High-eff Furnace/HP + 2 ACH50 + High-		
	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			Multifamily Package 2 (Higher-eff Water Heaters + 2 ACH50 +		
	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, Table A-13 and Table A-14 summarize the 10-year 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

Climate Design Zone	Single-family Package 1 (High-eff Furnace/HP + U-0.24 Windows)			Single-family Package 2 (High-eff Furnace/HP + 2 ACH50 + High-		
	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

Climate Design Zone	Multifamily Package 1 (Higher-eff Water Heaters + High-eff			Multifamily Package 2 (Higher-eff Water Heaters + 2 ACH50 +		
	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. 2022 Updates

B.1. Erratum

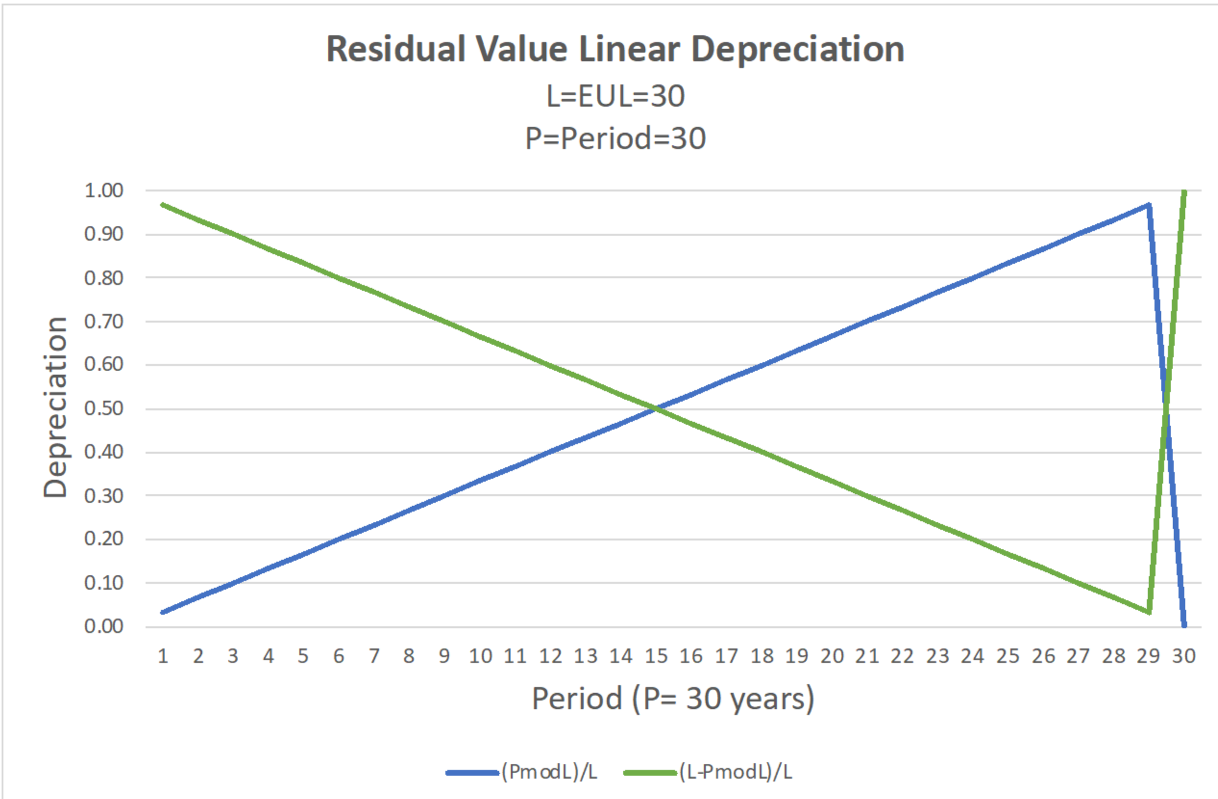
During the 2022 update to this analysis, a few errors and inconsistencies in the cost-effectiveness calculations were discovered and corrected, resulting in minor impacts on the results. The calculation of the annual mortgage payment and tax deductions had minor order-of-operation errors in their formulas, which reduced cost-effectiveness results when corrected, and the mortgage payment was erroneously not discounted in future years, which increased cost-effectiveness when corrected. When combined, these errors did not significantly change the magnitude of the results when compared to the other updates made to the analysis in the 2022 update.

As discussed above, the cost-effectiveness calculations follow the methodology specified in DOE's Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes. When performing the 2022 updates to the NYStretch analysis, an error was discovered in DOE's residual value calculation:

> Finally, there is a *residual value* for efficiency features with remaining useful life at the end of the analysis period. This is related to the replacement costs in that a feature replaced shortly before the end of the analysis period would have a higher residual value than one nearing the end of its service life. At the end of the analysis period *P*, the residual value of each efficiency measure is based on straight-line "depreciation" of its inflated first cost based on the number of years left in its useful life. That is, the residual value for measure *m* (RV_m) is a beneficial cash flow occurring at the end of year *P* and is given by:
>
> $$RV_m = (1 + E_H)^P \times FC_m \times \left(\frac{P \bmod L}{L}\right) \tag{3.17}$$

The residual value is calculated based on the incremental cost associated with the measure and should be equal to zero at the end of the measure's EUL, assuming a linear depreciation over time. As shown Figure B-1 below, DOE's residual value formula results in a linear increase in residual value over time, rather than a decrease as expected. To correct this error, the final term of the calculation should instead be [(L – PmodL)/L]. The cost-effectiveness in this analysis has been updated accordingly.

Figure B-1. Cost Effectiveness Residual Value Calculation



B.2. Cost Effectiveness

B.2.1 Fuel Prices

To address concerns that costs have changed since the report's earlier publication, updated fuel costs are included. Fuel costs previously used in cost savings and cost-effectiveness analysis are detailed in Section 3.5.1 Fuel Prices and Appendix E.1. Fuel Prices. Initially fuel costs were predominantly based on NY state averages published in 2017 from Energy Information Association (EIA). The supplemental analysis later performed to address the particularly high variability of fuel prices in CDZ 6A also included data from local utilities.

For the 2022 analysis, more region-specific data was incorporated by looking at average fuel price for each climate zone and NYC using average county fuel prices within each climate zone, weighted by county population, as compared with previous analysis that used state average and NYC fuel costs only. Different data resources were used depending on fuel type. Electricity costs are based on 2021 EIA data, gas prices are from 2021 published consumer bills, and oil and propane prices, used in Appendix F, from NYSERDA's 2021-2022 heating price database. The original fuel costs versus the 2022 updated fuel costs are summarized below in Table B-1.

Table B-1. Comparison of Initial NYStretch-2020 versus Updated NYStretch Fuel Costs Used in Cost Savings and Cost-Effectiveness Analysis.

	Region	Electricity ($/kWh)	Gas ($/therm)	Oil ($/therm)	Propane ($/therm)
Updated Fuel Costs (3/21/2022)	CDZ4-NYC	0.266	1.70	2.72	n/a
	CDZ4-bal.	0.216	1.61	2.72	4.15
	CDZ5	0.149	1.10	2.62	3.44
	CDZ6	0.142	1.11	2.53	3.52
	Statewide	0.191	1.22	2.62	3.38
2019 Fuel Costs (from 2019 version of this report)	CDZ4-NYC	0.200	0.90	1.46	3.07
	CDZ4-bal.	0.180	1.17	1.46	3.07
	CDZ5	0.180	1.17	1.46	3.07
	CDZ6 v1	0.180	1.17	1.46	3.07
	CDZ6 v2.1	0.118	1.00	2.18	3.07
	CDZ6 v2.2	0.118	1.00	1.75	3.07
	Statewide	0.180	1.17	1.46	3.07

B.2.2 Economic Parameters

To further reflect current market realities, additional updates were made to parameters that are used in cost-effectiveness analysis as discussed in Section 3.5.2 Economic Parameters.

B.2.3 Incremental Costs

From 2019 to 2022, construction costs have changed substantially. Updates to the measure incremental costs are discussed in Section 3.4.2 Incremental Cost Calculations and Appendix D. Construction Cost Details.

B.3. HRV SRE

The Sensible Recovery Efficiency (SRE) for HRVs has been amended to 65% from 70%. This change is to both better reflect the current product market inventory and to align with IECC's 2021 requirement for CDZs 7 and 8.

Appendix C. 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 (ECCCNYS) 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 C-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	152	201	0	353	2,167	3,905	2,932
SF_gasfurnace_heatedBsmt	4A-NYC	95	137	0	232	2,167	2,931	886
SF_gasfurnace_slab	4A-NYC	138	199	0	337	2,167	3,780	2,673
SF_gasfurnace_unheatedBsmt	4A-NYC	113	174	0	287	2,167	3,376	1,824
SF_hp_crawlspace	4A-NYC	745	0	0	745	2,167	7,002	9,289
SF_hp_heatedBsmt	4A-NYC	606	0	0	606	2,167	5,896	6,992
SF_hp_slab	4A-NYC	724	0	0	724	2,167	6,835	8,942
SF_hp_unheatedBsmt	4A-NYC	672	0	0	672	2,167	6,424	8,088
SF_oilfurnace_crawlspace	4A-NYC	145	0	325	470	2,167	4,863	5,010
SF_oilfurnace_heatedBsmt	4A-NYC	91	0	221	313	2,167	3,595	2,324
SF_oilfurnace_slab	4A-NYC	132	0	322	453	2,167	4,730	4,732
SF_oilfurnace_unheatedBsmt	4A-NYC	107	0	282	390	2,167	4,219	3,650
SF_gasfurnace_crawlspace	4A-bal	98	221	0	319	2,988	4,538	1,742
SF_gasfurnace_heatedBsmt	4A-bal	38	165	0	203	2,988	3,605	-216

Table C-1 continued

D	CDZ	Electricity Savings ($)	Natural Gas Savings ($)	Fuel Oil Savings ($)	Total Energy Savings ($)	Incremental Costs ($)	10yr NPV Energy Cost Savings ($)	30yr LCC Savings ($)
SF_gasfurnace_slab	4A-bal	97	206	0	303	2,988	4,407	1,466
SF_gasfurnace_unheatedBsmt	4A-bal	63	191	0	253	2,988	4,011	637
SF_hp_crawlspace	4A-bal	612	0	0	612	2,988	6,844	6,449
SF_hp_heatedBsmt	4A-bal	492	0	0	492	2,988	5,886	4,460
SF_hp_slab	4A-bal	591	0	0	591	2,988	6,678	6,105
SF_hp_unheatedBsmt	4A-bal	547	0	0	547	2,988	6,326	5,373
SF_oilfurnace_crawlspace	4A-bal	93	0	377	470	2,988	5,773	4,414
SF_oilfurnace_heatedBsmt	4A-bal	36	0	280	317	2,988	4,538	1,800
SF_oilfurnace_slab	4A-bal	92	0	356	448	2,988	5,596	4,037
SF_oilfurnace_unheatedBsmt	4A-bal	59	0	325	384	2,988	5,083	2,954
SF_gasfurnace_crawlspace	5A	18	267	0	285	2,722	3,792	838
SF_gasfurnace_heatedBsmt	5A	1	227	0	228	2,722	3,332	-131
SF_gasfurnace_slab	5A	14	266	0	279	2,722	3,750	751
SF_gasfurnace_unheatedBsmt	5A	8	253	0	261	2,722	3,604	443
SF_hp_crawlspace	5A	610	0	0	610	2,722	6,352	6,055
SF_hp_heatedBsmt	5A	540	0	0	540	2,722	5,790	4,888
SF_hp_slab	5A	616	0	0	616	2,722	6,401	6,157
SF_hp_unheatedBsmt	5A	595	0	0	595	2,722	6,227	5,795
SF_oilfurnace_crawlspace	5A	16	0	630	646	2,722	6,739	7,175
SF_oilfurnace_heatedBsmt	5A	0	0	537	537	2,722	5,854	5,290
SF_oilfurnace_slab	5A	11	0	634	645	2,722	6,732	7,162
SF_oilfurnace_unheatedBsmt	5A	6	0	598	605	2,722	6,406	6,467
SF_gasfurnace_crawlspace	6A	15	288	0	302	2,346	3,421	1,465
SF_gasfurnace_heatedBsmt	6A	4	245	0	249	2,346	2,994	564
SF_gasfurnace_slab	6A	11	287	0	298	2,346	3,390	1,400
SF_gasfurnace_unheatedBsmt	6A	5	269	0	274	2,346	3,194	987
SF_hp_crawlspace	6A	649	0	0	649	2,346	6,144	7,013
SF_hp_heatedBsmt	6A	584	0	0	584	2,346	5,627	5,940
SF_hp_slab	6A	658	0	0	658	2,346	6,214	7,159

Table C-1 continued

ID	CDZ	Electricity Savings ($)	Natural Gas Savings ($)	Fuel Oil Savings ($)	Total Energy Savings ($)	Incremental Costs ($)	10yr NPV Energy Cost Savings ($)	30yr LCC Savings ($)
SF_hp_unheatedBsmt	6A	625	0	0	625	2,346	5,955	6,621
SF_oilfurnace_crawlspace	6A	13	0	650	662	2,346	6,357	7,779
SF_oilfurnace_heatedBsmt	6A	3	0	554	557	2,346	5,507	5,967
SF_oilfurnace_slab	6A	9	0	647	656	2,346	6,311	7,683
SF_oilfurnace_unheatedBsmt	6A	4	0	606	610	2,346	5,934	6,880
MF_gasfurnace_crawlspace	4A-NYC	86	103	0	189	1,856	2,469	675
MF_gasfurnace_heatedBsmt	4A-NYC	45	86	0	131	1,856	1,999	-306
MF_gasfurnace_slab	4A-NYC	88	101	0	189	1,856	2,465	666
MF_gasfurnace_unheatedBsmt	4A-NYC	67	96	0	163	1,856	2,261	241
MF_hp_crawlspace	4A-NYC	326	0	0	326	1,856	3,542	2,864
MF_hp_heatedBsmt	4A-NYC	252	0	0	252	1,856	2,954	1,644
MF_hp_slab	4A-NYC	324	0	0	324	1,856	3,532	2,844
MF_hp_unheatedBsmt	4A-NYC	296	0	0	296	1,856	3,303	2,370
MF_oilfurnace_crawlspace	4A-NYC	81	0	173	253	1,856	2,994	1,814
MF_oilfurnace_heatedBsmt	4A-NYC	43	0	140	184	1,856	2,434	635
MF_oilfurnace_slab	4A-NYC	82	0	169	251	1,856	2,973	1,767
MF_oilfurnace_unheatedBsmt	4A-NYC	64	0	160	223	1,856	2,752	1,304
MF_gasfurnace_crawlspace	4A-bal	58	103	0	161	1,778	2,548	462
MF_gasfurnace_heatedBsmt	4A-bal	24	88	0	112	1,778	2,157	-356
MF_gasfurnace_slab	4A-bal	59	101	0	160	1,778	2,542	449
MF_gasfurnace_unheatedBsmt	4A-bal	42	97	0	139	1,778	2,368	86
MF_hp_crawlspace	4A-bal	260	0	0	260	1,778	3,326	2,039
MF_hp_heatedBsmt	4A-bal	202	0	0	202	1,778	2,864	1,079

Table C-1 continued

ID	CDZ	Electricity Savings ($)	Natural Gas Savings ($)	Fuel Oil Savings ($)	Total Energy Savings ($)	Incremental Costs ($)	10yr NPV Energy Cost Savings ($)	30yr LCC Savings ($)
MF_hp_slab	4A-bal	260	0	0	260	1,778	3,319	2,023
MF_hp_unheatedBsmt	4A-bal	236	0	0	236	1,778	3,130	1,631
MF_oilfurnace_crawlspace	4A-bal	54	0	184	238	1,778	3,177	1,822
MF_oilfurnace_heatedBsmt	4A-bal	23	0	152	176	1,778	2,676	765
MF_oilfurnace_slab	4A-bal	55	0	181	236	1,778	3,163	1,790
MF_oilfurnace_unheatedBsmt	4A-bal	39	0	171	210	1,778	2,954	1,353
MF_gasfurnace_crawlspace	5A	-12	134	0	122	2,106	2,119	-1,212
MF_gasfurnace_heatedBsmt	5A	-26	123	0	97	2,106	1,915	-1,639
MF_gasfurnace_slab	5A	-12	132	0	120	2,106	2,105	-1,240
MF_gasfurnace_unheatedBsmt	5A	-16	131	0	114	2,106	2,056	-1,343
MF_hp_crawlspace	5A	251	0	0	251	2,106	3,025	940
MF_hp_heatedBsmt	5A	215	0	0	215	2,106	2,743	324
MF_hp_slab	5A	249	0	0	249	2,106	3,010	907
MF_hp_unheatedBsmt	5A	242	0	0	242	2,106	2,958	788
MF_oilfurnace_crawlspace	5A	-10	0	329	319	2,106	3,567	2,380
MF_oilfurnace_heatedBsmt	5A	-24	0	296	272	2,106	3,205	1,566
MF_oilfurnace_slab	5A	-11	0	324	313	2,106	3,522	2,285
MF_oilfurnace_unheatedBsmt	5A	-14	0	319	305	2,106	3,460	2,140
MF_gasfurnace_crawlspace	6A	-16	145	0	129	2,195	1,967	-1,238
MF_gasfurnace_heatedBsmt	6A	-25	133	0	108	2,195	1,794	-1,601
MF_gasfurnace_slab	6A	-16	143	0	128	2,195	1,953	-1,267
MF_gasfurnace_unheatedBsmt	6A	-20	140	0	120	2,195	1,895	-1,388
MF_hp_heatedBsmt	6A	226	0	0	226	2,195	-5,521	270
MF_hp_slab	6A	259	0	0	259	2,195	2,719	817
MF_hp_unheatedBsmt	6A	249	0	0	249	2,195	2,982	642

Appendix D. Construction Cost Details

The incremental construction costs associated with the provisions of the NYStretch-2020 are summarized in Section 3.4. This appendix section provides additional details regarding the development of construction cost estimates for equipment and components that have a higher degree of variability in efficiency and costs, as well as highlighting how costs were updated for 2022.

D.1. Background

As discussed in the main body of the report, the present cost-effectiveness analysis is based on the Cost-Effectiveness Methodology developed by the DOE (Taylor et al. 2015). This methodology was first developed by DOE through a public review process in 2015 to determine the best approach for evaluating the energy savings and cost-effectiveness for individual residential code changes proposed to the International Energy Conservation Code (IECC) as well as for entire iterations of the code for DOE's codes development and adoption efforts.

The methodology defines a set of 32 detached single-family and low-rise multifamily prototype models, called the DOE/PNNL residential prototype buildings to represent most of the new residential building stock across the country. These prototype models are supplemented with construction weights developed to represent new residential building construction trends across the country. These models are used to estimate the site energy consumption for specific code requirements. The methodology also defines the economic parameters and procedures for calculating a simple payback, a 30-year Life Cycle Cost (LCC) analysis, and an annual cashflow calculation to evaluate the cost-effectiveness of measures from the perspective of a homeowner. For the cost-effectiveness metrics, the methodology uses an incremental energy savings and incremental construction cost approach in calculation. The results then show only the impact from a proposed measure or a set of proposed measures or code over a specific baseline without necessitating a detailed calculation of whole building construction costs. This approach yields the same results as if whole building construction costs were used to conduct a LCC calculation for the baseline and the proposed building type and then a difference between the two was taken to show the incremental cost-effectiveness of the proposed measures. It however simplifies the effort significantly without any loss in accuracy.

The present analysis uses a similar incremental energy savings and cost-effectiveness savings approach to compare the provisions of NYStretch-2020 and the baseline codes. Where the NYStretch code requires additional efficiency for measures present in the baseline such as insulation, only the incremental costs associated with the incremental improvement in energy efficiency are accounted for in the analysis. Where the NYStretch code requires measures absent in the baseline, the incremental cost of adding the measure to a typical new construction single-family or low-rise multifamily building is calculated using the attributes of the prototype building models used in the analysis. In some cases, where technologies used to meet the NYStretch code replace technologies used to meet the baseline code requirements, the incremental cost is calculated by subtracting the first cost of installing the baseline measure from the NYStretch measure.

In addition to the simple payback, 30-year LCC, and annual cashflows, the analysis also calculates a 10-year Net Present Value (NPV) of cashflows. The economic parameters for NPV calculation are kept the same as the other metrics. The analysis assumes that the incremental construction costs associated with the additional NYStretch code requirements would be financed through a mortgage resulting in higher annual mortgage payments and a higher down payment, both of which are included in the cashflow, NPV, and LCC calculations. These increases are offset by the reduced annual energy bills results from improved energy efficiency in the cost-effectiveness analysis. The analysis also accounts for increased property taxes and tax deductions from the incremental construction costs.

The analysis additionally accounts for replacement costs associated with the additional requirements of the NYStretch code over the period of the analysis. As discussed in the main body of the report, the period of analysis is assumed to be 30 years which corresponds with the typical mortgage terms for home buyers. Some building components such as envelope insulation have much longer useful life and likely remain unchanged for the life of the home, which can average more than 100 years in some locations. Some other components such as the HVAC systems on the other hand, have average useful lifetimes of 15-20 years. This means the equipment needs to be replaced within the 30-year analysis period. The analysis assumes a like-for-like replacement in both the baseline and the NYStretch cases, meaning the component efficiencies remain steady for each case thereby allowing a wholistic comparison between a home built to the NYStretch code compared to a home built to the baseline code. Thus, the incremental cost associated with each NYStretch measure which gets replaced during the analysis term is added as a replacement cost at the end of its useful life assuming the same incremental cost. This cost is, however, escalated to the anticipated cost in the future using the home price escalation rate. For example, if the incremental first cost associated with a measure is $100 and the useful life of the measure is 20 years, the analysis assumes an incremental cost of $100 at year 0—the year of construction—and a cost of $265 at year 20, calculated by compounding the escalation rate of 5.0% over 20 years.

Conversely, because some measures have useful lifetimes longer than the period of analysis or get replaced within the period of analysis and have some useful life remaining at year 30—the end of the analysis period, the residual value associated with each measure is adding back into the LCC calculation as residual value. The residual value is calculated based on the incremental cost associated with the measure assuming a linear depreciation in the value over the useful life of the measure and is added back at the end of the analysis.

D.2. 2022 Updates to Incremental Costs

This section describes the assumptions behind the development of incremental costs for each measure that was evaluated in the energy analysis and how they were updated for 2022.

D.2.1 Location Multipliers

This analysis originally used location factors from the 2019 RSMeans Residential Costs Data Book (RSMeans 2019) but has been updated to reflect 2022 data (RSMeans 2022). Table D-1 shows the location multipliers used in the original 2019 analysis, while Table D-2 shows updated values for 2022.

Table D-1. 2019 Location Cost Multipliers Previously Used in the Analysis

Climate Design Zone	Average 2019 Location Factor
4A-NYC	1.374
4A-balance	1.234
5A	1.059
6A	0.998

Table D-2. 2022 Location Cost Multipliers Used in the Analysis

Climate Design Zone	Average 2022 Location Factor
4A-NYC	1.429
4A-balance	1.313
5A	1.165
6A	1.130

D.2.2 Fenestration

NYStretch-2020 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 the original 2019 analysis, the Energy Star regression equations were used to calculate the incremental costs associated with this code provision resulting in an incremental cost of $1.04/sq. ft. in CDZ 4A including CDZ 4A-balance and $0.62/sq. ft. in CDZ 5A and CDZ 6A. This resulted in an incremental cost of $391 in CDZ 4A and CDZ 4A-balance and $235 in CDZ 5A and CDZ 6A for the single-family prototype, $196 in CDZ 4A and CDZ 4A-balance, $112 in CDZ 5A and CDZ 6A for each multifamily unit, after adjusting for inflation. These estimates were further multiplied by the location factors discussed above before use in the analysis.

The lack of cost data available for the level of granularity used by the code is still an issue, so to update these assumptions to reflect 2022 costs, the analysis adjusts the original costs (which were adjusted to 2019 inflation levels) using the RSMeans Historical City Cost Index for cities in the appropriate climate zones. This results in an incremental cost of $424 in CDZ4A and CDZ4A-balance and $257 in CDZ5A and CDZ6A for the single-family prototype, $212 in CDZ4A and CDZ4A-balance, $122 in CDZ5A and CDZ6A for each multifamily unit. These estimates are further multiplied by the location factors before use in the analysis.

D.2.3 Exterior Wall Insulation

There are multiple baseline and NYStretch-2020 prescriptive options for wall insulation (Table 1 and Table 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 D-3 shows three estimates of incremental cost used in the 2019 analysis. The 2022 update assumes $2.26/sq. ft. based on 2022 RSMeans data.

Table D-3. Incremental Cost Estimates for Exterior Wall Insulation: R-21 Int versus R-20

Source	Incremental	Notes	2022 Update
F+G (2012)	$1.77/ft^2$	$1.62/ft^2$ in 2012 dollars, adjusted to 2019 dollars	
RSMeans (2019)	$1.88/ft^2$		$2.26/ft^2$
NREL NREM (2019)	$1.70/ft^2$		
Assumption	**$1.77/ft^2$**		**$2.26/ft^2$**

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). 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. Updating the analysis to use the 2022 RSMeans cost of $2.26/sq. ft. results in a total incremental cost of $486 for the single-family prototype and $174 for the multifamily unit, compared with 2019 costs of $380 and $136 respectively.

D.2.4 Floor Insulation

NYStretch-2020 requires R-30 floor insulation in CDZ 4A compared to R-19 required by the 2020 ECCCNYS in CDZ 4A. The analysis assumes that fiberglass batt insulation is installed between floor joists. Two estimates of incremental cost from the original 2019 analysis are shown in Table D-4.

Table D-4. Incremental Cost Estimates for Floor Insulation: R-30 versus R-19

Source	Incremental Cost	Notes	2022 Update
F+G (2012)	$0.46/ft^2$	$0.42/ft^2$ in 2012 dollars, adjusted to 2019 dollars	
RSMeans (2019 / 2022)	$0.40/ft^2$		$0.32/ft^2$
Assumption	**$0.40/ft^2$**		**$0.32/ft^2$**

2022 RSMeans shows that while the cost of installing batt floor insulation has increased since 2019, the relative difference between installing R-30 and R-19 insulation has decreased, resulting in a 2022 incremental cost of $0.32/sq. ft. compared with the 2019 incremental cost of $0.40/sq. ft. Using $0.32/sq. ft., the total 2022 incremental cost is $384 for the single-family prototype and $128 for each multifamily unit (as compared to $480 and $160 in 2019 costs, respectively). 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.

D.2.5 Slab Insulation

NYStretch-2020 requires slab insulation to be installed up to a depth of four feet compared to the two feet required by the baseline 2020 ECCCNYS in CDZ 4A and 5A. The analysis assumes slab edge insulation to be 2” thick XPS (R-10) with 60 PSI compressive strength. Table D-5 shows three estimates of incremental cost used in the 2019 analysis. The 2022 update assumes $2.59/sq. ft. based on 2022 RSMeans data.

Table D-5. Incremental Cost Estimates for Slab Insulation: 4’ versus 2’ R-10 XPS

Source	Incremental	Notes	2022 Update
F+G (2012)	\$1.77/ft^2	\$3.24/lf for 2’ deep slab edge insulation with	
RSMeans (2019)	\$2.42/ft^2	2” thick XPS used in foundation applications	\$2.59/ft^2
NREL NREM	\$2.00/ft^2	2” thick XPS used in foundation applications	
Assumption	**\$2.00/ft^2**		**\$2.59/ft^2**

Using a cost of $2.59/sq. ft., the total 2022 incremental cost is $725 for the single-family prototype and $319 for each multifamily unit (as compared to $560 and $247 in 2019). 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.

D.2.6 Basement Wall Insulation

NYStretch-2020 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 ECCCNYS in CDZ 4A. The analysis assumes basement walls insulation to be kraft-faced fiberglass placed within the wall cavity. Table D-6 shows three estimates of incremental cost used in the 2019 analysis 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. Using 2019 values, an average incremental cost of $0.8/sq. ft. resulted in a total incremental cost of $784 for the single-family prototype and $345 for each multifamily unit. The 2022 update assumes $1.07/sq. ft. based on 2022 RSMeans data, resulting in a total incremental cost of $1049 for the single-family prototype and $462 for each multifamily unit.

Table D-6. Incremental Cost Estimates for Basement Wall Insulation: R-19 versus R-10 Cavity

Source	Incremental Cost	Notes	2022 Update
F+G (2012)	$0.84/ft^2	$0.77/ ft^2 in 2012 dollars, adjusted to 2019	
RSMeans (2019)	$0.97/ft^2		$1.07/ft^2
NREL NREM (2019)	$0.5/ft^2		
Assumption	**$0.8/ft^2**		**$1.07/ft^2**

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.

D.2.7 Efficient Hot Water Supply

NYStretch-2020 provides four options for encouraging the efficient delivery of hot water, including two options for a compact piping system, an option for a recirculation system, and one for a DWHR system.

The 2019 Codes and Standards Enhancement report developed by the California Energy Commission on DHWR reports an average DWHR unit price of $325 to $400 depending on the unit size and approximately $300 for piping, installation, and labor, resulting in a total cost of $625 to $725 (CASE 2017). The 2022 Codes and Standards Enhancement report on DWHR in multifamily buildings, which was published after the last update to this report, shows a unit price of $736 and $449 for labor resulting in a total cost of $1,185 (CASE 2020). Recirculating pumps are often cheaper to install depending on the water heater configuration and can be controlled using a timer or a switch. In the last update of the report, the cost of a recirculating pump was $400 from a 2017 source.[37] To reflect 2022 costs, this was scaled using RSMeans Historical City Cost Index, resulting in a cost of $459.

It is expected that the compact piping layout option would be the most economical option for new homes, thus achieving energy savings along with construction cost savings. For simplification, the analysis conservatively assumes that half of the new homes will choose the compact piping layout option with no incremental construction cost and the other half will choose either the DWHR or recirculation pump option, with the average cost of those two options used for the incremental cost. In 2022, this results in an average incremental cost of approximately $415 for this measure, up from $400 in the 2019 version of the report, which is applied equally to all the single-family prototypes as well as each multifamily unit assuming individual water heaters for each unit.

D.2.8 Ventilation

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. These are the main types of HRV/ERV systems used in the residential sector.

- Single-point Stand-alone HRV/ERV: A low-cost option that utilizes the exhaust airstream from a single point and provides supply to a single point and can be used in homes without a central HVAC system.
- Multi-Point Stand-alone HRV/ERV: A ducted stand-alone option that collects exhaust airstreams from multiple points and provides fresh air supply to multiple points through a dedicated duct system. These can also be installed in homes without a central HVAC system.
- HVAC Coupled Multi-Point HRV/ERV: A fully ducted option that supplies pre-heated outside air to the central HVAC system for further heating and distribution through the HVAC supply ductwork. This option requires a forced-air HVAC system for integration.

In addition to the various installation configurations, there is a wide range in the efficiencies of available products. The Home Ventilating Institute (HVI) maintains a directory of ventilation products available throughout North America along with their efficiencies. Figure 1 in the main body of the report shows a distribution of the sensible recovery efficiency (SRE) for all the products from the HVI database (HVI 2020). The SRE for available HRVs and ERVs is found to range between 60%-90% and most units are capable of supplying between 50 and 300 CFM. These compare with the required outdoor air supply rates of 60 CFM for the single-family prototype building model and 45 CFM for each multifamily unit per the requirements of the 2020 Residential Code of New York State.

NYStretch-2020 does not specify a minimum efficiency level for the HRV/ERVs but it does require them to be sized adequately. As described in Section 3.3.5, a HRV with a 65% SRE is assumed in this analysis based on the data from HVI. The analysis additionally assumes that the HRV is equipped with a separate distribution system. This configuration is expected to be more typical in new single-family construction, however, in some cases the HRV may be integrated with the central air conditioning system and use those ducts for distribution. It is further noted that smaller single-point stand-alone HRV units would potentially be adequate for multifamily units and cost significantly less than a multi-point ducted system. The additional ductwork required for a ducted HRV system depends on the house layout and the desired exhaust and supply points. In most cases, the ductwork comprises flex duct for collecting exhaust air from bathrooms and supplying fresh air to living and bedrooms.

In addition to the incremental costs and operational energy costs associated with HRVs, there may be additional maintenance costs. HRV maintenance typically includes the periodic cleaning or replacement of air filters placed on the outdoor air intake. The additional costs of replacing filters can range from $15 to $25 on annual basis. It is anticipated that the routine maintenance checks for HRVs would happen at the same time as the annual HVAC checks and not necessitate an additional visit by the HVAC contractor.

The original analysis assumed 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, which was updated to $325 in 2022 based on the RSMeans Historical City Cost Index, using cities in CDZ 4A. For CDZs 5A and 6A, the original analysis assumed an incremental cost of $1,000 for the single-family prototype and each multifamily unit for an HRV. This was updated using the RSMeans Historical City Cost Index, resulting in an incremental cost of $1,095 in 2022. An analysis exploring various HRV price points and differing prices for single-family and multifamily units is included in Appendix G. Supplemental Ventilation Analysis.

Table D-7 and Table D-8 show three estimates of total cost and incremental cost compared to local exhaust-based systems for HRV/ERVs and CFIS.

Table D-7. Incremental Cost Estimates for Ventilation: HRV/ERV System versus Exhaust Ventilation

Source	Total Cost	Incremental Cost	Notes	2022 Update
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 65% SRE**	**$1,095**

Table D-8. Incremental Cost Estimates for Ventilation: CFIS System versus Exhaust Ventilation

Source	Total Cost	Incremental Cost	2022 Update
Moore (2018)	$310	$113	
Aldrich et al (2013)	$650	$250	
NREL NREM (2019)	$850	$490	
Assumption		**$300**	**$325**

D.2.9 Lighting

There are no incremental costs for lighting in NYStretch-2020 compared to the 2020 ECCCNYS. 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 NYStretch-2020 provisions for those cases is based on purchasing seven more CFL or LED bulbs instead of incandescent bulbs for the single-family prototype and three more for the multifamily prototype. The original analysis referenced an Energy Star calculator from 2014 that showed an incremental cost of $2.93/bulb for CFL bulbs (NYSERDA 2019). LEDs were an emerging technology at that time, and they have come down in cost significantly in the last eight years. For the same brand, a 60W-equivalent A19 LED bulb costs approximately $0.20 more than the analogous incandescent bulb according to a major lighting retailer. In the single-family prototype, the incremental cost of replacing seven bulbs is assumed to be $1.40; for each multifamily unit, the incremental cost of replacing three bulbs is assumed to be $0.60.

D.2.10 Ducts in Conditioned Space

NYStretch-2020 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.

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.[38] 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 sq. ft. single-story, slab-on-grade house configuration. The NAHB study was published in 2017, so to adjust for 2022 costs, the average cost of the range, $1,010, was shifted using the RSMeans Historical City Cost Index, resulting in an average cost of $1,158. 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 $579 for the single-family prototype, up from $505 in the 2019 report. The incremental cost for each multifamily unit is also accordingly assumed to be $579 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, and adjusted using construction cost multipliers for each location.

D.2.11 Credit Associated with Downsizing HVAC Equipment

The collective impact of the prescriptive and mandatory requirements of NYStretch-2020 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. In the last update of this report, an equipment downsizing credit of $330 was assumed in this analysis only for CDZ 4A-balance and 5A (ENERGY STAR 2016). To adjust the credit to 2022 costs, the RSMeans Historical City Cost Index was used for cities in the appropriate climate zones, resulting in a credit of $379 for buildings in CDZ 4A-balances and 5A. This credit is subtracted from the total incremental cost after adjusting for inflation and location factors.

D.3. Incremental Construction Cost Summary

Section 3.4 describes the assumptions used in calculating the incremental costs associated with the provisions of NYStretch-2020 compared to the baseline code. Table D-9 summarizes the incremental costs associated with each measure of NYStretch-2020 compared to the 2016 NYC ECCC in CDZ 4A and Table D-10 summarizes the incremental costs associated with the prescriptive and mandatory provisions of NYStretch-2020 compared to the 2020 ECCCNYS in CDZ 4A, 5A and 6A. Table D-11 and Table D-12 summarize the 2022 updates to the incremental costs. The costs have been adjusted using construction cost multipliers for each CDZ identified in Table D-1 and Table D-2.

Table D-9. 2019 Incremental Costs Associated with the NYStretch-2020 Compared to the 2016 NYCECC

Prescriptive + Mandatory Provisions

Component	2016 NYCECC	NYStretch-2020	Incremental Cost		
			Unit Cost ($/sf or $/unit)	Single-family Prototype ($/unit)	Multifamily Prototype ($/unit)
Fenestration U-factor	0.32	0.27	$1.49/sf	$537.80	$268.90
Ceiling R value	49	49	$0/sf	$-	$-
Wood-framed R-value	20+5	21 int or 20+5 or 13+10	$0/sf	$-	$-
Floor R-value	30	30	$0/sf	$-	$-
Basement wall R-value	15/19	15/19	$0/sf	$-	$-
Slab R-value and depth	10, 4 ft	10, 4 ft	$0/sf	$-	$-
Crawlspace wall R-value	15/19	15/19	$0/sf	$-	$-
Ducts in Conditioned Space[a]			$0.39/sf	$520.40	$520.40
Hot Water Distribution Efficiency (Average of four options)			$549.60/unit	$549.60	$549.60
Balanced Ventilation Systems			$412.20/unit	$412.20	$412.20
High Efficacy Lighting			$2.93/bulb	$28.46	$12.08

Table D-10. 2019 Incremental Costs Associated with the NYStretch-2020 Compared to the 2020 ECCCNYS

Prescriptive + Mandatory Provisions

Component	CDZ	2020 ECCCNYS	NYStretch-2020	Incremental Cost		
				Unit Cost ($/sf or $/unit)	Single-family Prototype ($/unit)	Multifamily Prototype ($/unit)
Fenestration U-factor	4A	0.32	0.27	$1.34/sf	$482.40	$241.20
	5A	0.3	0.27	$0.69/sf	$248.40	$118.40
	6A	0.3[a]	0.27	$0.65/sf	$234.00	$111.60
Ceiling R value	4A	49	49	$0/sf	$-	$-
	5A	49	49	$0/sf	$-	$-
	6A	49[a]	49	$0/sf	$-	$-
Wood-framed R-value	4A	20 or 13+5	21 int or 20+5 or 13+10	$2.18/sf	$468.20	$167.39
	5A	20 or 13+5	21 int or 20+5 or 13+10	$1.87/sf	$402.05	$143.59

Table D-10 continued

Component	CDZ	2020 ECCCNYS	NYStretch-2020	Incremental Cost		
				Unit Cost ($/sf or $/unit)	Single-family Prototype ($/unit)	Multifamily Prototype ($/unit)
	6A	20+5 or 13+10[a]	20+5 or 13+10	$0/sf	$-	$-
Floor R-value	4A	19	30	$0.49/sf	$592.30	$197.40
	5A	30	30	$0/sf	$-	$-
	6A	30[a]	30	$0/sf	$-	$-
Basement wall R-value	4A	10 or 13	15 or 19	$0.99/sf	$967.50	$426.10
	5A	15 or 19	15 or 19	$0/sf	$-	$-
	6A	15 or 19*	15 or 19	$0/sf	$-	$-
Slab R-value and depth	4A	10, 2 ft	10, 4 ft	$2.47/sf	$691.60	$304.40
	5A	10, 2 ft	10, 4 ft	$2.12/sf	$593.60	$261.20
	6A	10, 4 ft*	10, 4ft	$0/sf	$-	$-
Crawlspace wall R-value	4A	15 or 19	15 or 19	$0/sf	$-	$-
	5A	15 or 19	15 or 19	$0/sf	$-	$-
	6A	15 or 19*	15 or 19	$0/sf	$-	$-
Ducts in Conditioned Space [b]	4A	NR	Prescriptively required	$0.26/sf	$467.40	$467.40
	5A			$0.22/sf	$401.00	$396.00
	6A			$0.21/sf	$378.00	$401.10
Hot Water Distribution Efficiency (Average of four options)	4A			$493.60/unit	$493.60	$493.60
	5A			$423.60/unit	$423.60	$423.60
	6A			$399.20/unit	$399.20	$399.20
Balanced Ventilation or HRV/ERV Systems	4A	Exhaust-based ventilation system	Balanced ventilation system	$370.20/unit	$370.20	$370.20
	5A		HRV 70% SRE	$1,059.00/unit	$1,059.00	$1,059.00
	6A		HRV 70% SRE	$998.00/unit	$998.00	$998.00
High Efficacy Lighting	4A			$0/unit	$-	$-
	5A			$0/unit	$-	$-
	6A			$0/unit	$-	$-
HVAC Downsizing Credit	4A			$(407.22)/unit	$(407.22)	$(407.22)
	5A			$(349.47)/unit	$(349.47)	$(349.47)
	6A			$0/unit	$-	$-

a The costs for CDZ 6A are based on Option 1 of the prescriptive path in the 2020 ECCCNYS. The 2020 ECCCNYS provides an additional prescriptive path for CDZ 6A.

b Prototypes with heated basements are assumed to have ducts already located within conditioned space.

Table D-11. 2022 Incremental Costs Associated with the NYStretch-2020 Compared to the 2016 NYCECC

Prescriptive + Mandatory Provisions

Component	2016 NYCECCC	NYStretch-2020	Incremental Cost		
			Unit Cost ($/sf or $/unit)	Single-family Prototype ($/unit)	Multifamily Prototype ($/unit)
Fenestration U-factor	0.32	0.27	$1.59 /sf	$619.40	$309.70
Ceiling R value	49	49	$0/sf	$-	$-
Wood-framed R-value	20+5	21 int or 20+5 or 13+10	$0/sf	$-	$-
Floor R-value	30	30	$0/sf	$-	$-
Basement wall R-value	15/19	15/19	$0/sf	$-	$-
Slab R-value and depth	10, 4 ft	10, 4 ft	$0/sf	$-	$-
Crawlspace wall R-value	15/19	15/19	$0/sf	$-	$-
Ducts in Conditioned Space[a]			$0.57/sf	$634.70	$634.70
Hot Water Distribution Efficiency (Average of four options)			$606.30/unit	$606.30	$606.30
Balanced Ventilation Systems			$473.40/unit	$473.40	$473.40
High Efficacy Lighting			$0.20/bulb	$2.00	$0.90

a Prototypes with heated basements are assumed to have ducts already located within conditioned space.

Table D-12. 2022 Incremental Costs Associated with the 2020 NYStretch Compared to the 2020 ECCCNYS

Prescriptive + Mandatory Provisions

Component	CDZ	2020 ECCCNYS	NYStretch-2020	Incremental Cost		
				Unit Cost ($/sf or $/unit)	Single-family Prototype ($/unit)	Multifamily Prototype ($/unit)
Fenestration U-factor	4A	0.32	0.27	$1.50/sf	$571.03	$285.51
	5A	0.3	0.27	$0.70/sf	$298.58	$142.18
	6A	0.3[a]	0.27	$0.70/sf	$288.55	$137.40
Ceiling R value	4A	49	49	$0/sf	$-	$-
	5A	49	49	$0/sf	$-	$-
	6A	49[a]	49	$0/sf	$-	$-
Wood-framed R-value	4A	20 or 13+5	21 int or 20+5 or 13+10	$3.00/sf	$654.51	$233.75
	5A	20 or 13+5	21 int or 20+5 or 13+10	$2.60/sf	$564.13	$201.47

Table D-12 continued

Component	CDZ	2020 ECCCNYS	NYStretch-2020	Incremental Cost Unit Cost ($/sf or $/unit)	Single-family Prototype ($/unit)	Multifamily Prototype ($/unit)
	6A	20+5 or 13+10[a]	20+5 or 13+10	$0/sf	$-	$-
Floor R-value	4A	19	30	$0.40/sf	$517.25	$172.42
	5A	30	30	$0/sf	$-	$-
	6A	30[a]	30	$0/sf	$-	$-
Basement wall R-value	4A	10 or 13	15 or 19	$1.40/sf	$1,412.46	$622.16
	5A	15 or 19	15 or 19	$0/sf	$-	$-
	6A	15 or 19*	15 or 19	$0/sf	$-	$-
Slab R-value and depth	4A	10, 2 ft	10, 4 ft	$3.50/sf	$976.84	$430.28
	5A	10, 2 ft	10, 4 ft	$3.00/sf	$841.96	$370.86
	6A	10, 4 ft*	10, 4ft	$0/sf	$-	$-
Crawlspace wall R-value	4A	15 or 19	15 or 19	$0/sf	$-	$-
	5A	15 or 19	15 or 19	$0/sf	$-	$-
	6A	15 or 19*	15 or 19	$0/sf	$-	$-
Ducts in Conditioned Space [b]	4A	NR	Prescriptively required	$0.53/sf	$585.20	$585.20
	5A			$0.45/sf	$504.40	$504.40
	6A			$0.44/sf	$487.40	$487.40
Hot Water Distribution Efficiency (Average of four options)	4A			$559.01/unit	$559.01	$559.01
	5A			$481.82/unit	$481.82	$481.82
	6A			$465.63/unit	$465.63	$465.63
Balanced Ventilation or HRV/ERV Systems	4A	Exhaust-based ventilation system	Balanced ventilation system	$436.43/unit	$436.43	$436.43
	5A		HRV 65% SRE	$1271.30/unit	$1271.30	$1271.30
	6A		HRV 65% SRE	$1228.59/unit	$1228.59	$1228.59
High Efficacy Lighting	4A			$0/unit	$-	$-
	5A			$0/unit	$-	$-
	6A			$0/unit	$-	$-
HVAC Downsizing Credit	4A			$(509.85)/unit	$(509.85)	$(509.85)
	5A			$(439.45)/unit	$(439.45)	$(439.45)
	6A			$0/unit	$-	$-

a The costs for CDZ 6A are based on Option 1 of the prescriptive path in the 2020 ECCCNYS. The 2020 ECCCNYS provides an additional prescriptive path for CDZ 6A.

b Prototypes with heated basements are assumed to have ducts already located within conditioned space.

Appendix E. Supplemental Fuel Price Analysis

Fuel prices were found to vary significantly in CDZ 6A. Thus, an additional scenario analysis was conducted to examine the cost-effectiveness of the proposed NYStretch code using fuel prices more reflective of the geographical region. This section describes the fuel price calculation and cost-effectiveness results from the additional analysis, updated with 2021-2022 costs.

E.1. Fuel Prices

In the previous update, this supplemental analysis was performed to add granularity to the cost-effectiveness study in CDZ 6A because of the region's contrast with the state overall. In the 2022 update of the report, specific fuel costs were added for all climate zones, but this supplemental analysis was kept in the report to show the difference between heating oil prices for the 2021-2022 heating season and the most recent snapshot of heating oil prices. The electricity and gas prices as well as the cost of carbon from the main body of the report for CDZ 6A remain the same for this analysis.

The price for fuel oil in CDZ 6A is estimated based on data collected by NYSERDA and reported as weekly averages for each region. The 2019 version of this report noted a seasonal shift where heating oil prices in the heating season were higher than in the cooling season. However, a closer examination of the weekly prices indicates that heating oil prices have been steadily rising in the 6 months prior to the 2022 update of this report, overshadowing any seasonal differences. Thus, two scenarios were evaluated for heating oil—one with the annual average cost for CDZ 6A region for the period of September 2021 to March 2022 and a price point based on a snapshot in time as of March 2022. An avoided cost of carbon was added to this price like discussed in Section 4.3.3.1. The energy models provide estimates of predicted energy use in terms of Btu or therm for heating. The price of fuel oil reported in $/gal is thus converted to $/therm for use in the energy cost calculations assuming a heat content of 138,000 Btu/gal for fuel oil. Table E-1 summarizes the heating oil prices used in the supplemental analyses, both including and excluding the avoided cost of carbon.

Table E-1. Fuel Prices Used in Supplemental Analysis in CDZ 6A

Fuel	Supplemental Analysis			
	Price Scenario 1 (2021-2022)		Price Scenario 2 (March 2022)	
	Costs Without Carbon	Costs With Carbon	Costs Without Carbon	Costs With Carbon
Fuel Oil ($/therm)	2.53 ($3.50/gal)	3.85	3.75 ($5.19/gal)	5.07

E.2. Cost-Effectiveness Results

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. Table E-2 shows the weighted average annual energy cost savings, the associated total incremental costs, and the resulting simple payback for NYStretch-2020 compared to the 2020 ECCCNYS in CDZ 6A, for the single- and multifamily-prototypes, averaged over all foundation and heating system types.

Table E-2. Weighted Average Simple Payback

Price Scenario 1						Price Scenario 2					
Single-family			Multifamily			Single-family			Multifamily		
Annual Energy Cost Savings ($/ dwelling unit)	Incremental Costs ($/ dwelling unit)	Simple Payback (Yrs)	Annual Energy Cost Savings ($/ dwelling unit)	Incremental Costs ($/ dwelling unit)	Simple Payback (Yrs)	Annual Energy Cost Savings ($/ dwelling unit)	Incremental Costs ($/ dwelling unit)	Simple Payback (Yrs)	Annual Energy Cost Savings ($/ dwelling unit)	Incremental Costs ($/ dwelling unit)	Simple Payback (Yrs)
$368	$2,346	6.4	$171	$2,195	12.8	$374	$2,346	6.3	$171	$2,195	12.8

Table E-3 shows the 10-year net present value of energy cost savings for the NYStretch code compared to the 2020 ECCCNYS in CDZ 6A, 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. These results have been aggregated over the entire set of building types, foundation types, and heating systems using the construction weights matrix.

Table E-3. Weighted Average Net Present Value (NPV) of Energy Cost Savings over 10 Years

Price Scenario 1		Price Scenario 2	
Single-family	**Multifamily**	**Single-family**	**Multifamily**
$3,966	$2,291	$4,013	$2,291

Table E-4 and Table E-5 summarize the LCC savings of the NYStretch code over the 2020 ECCCNYS in CDZ 6A without and with the avoided cost of carbon incorporated in the fuel prices. The residential provisions of NYStretch code are found to be cost-effective for the homeowner and yield positive savings over the life of single-family homes but not for multifamily apartments in CDZ 6A when the avoided cost of carbon is not considered. However, when those costs are accounted for, the results are found to be cost-effective for both single-family homes and multifamily apartments in CDZ 6A.

Table E-4. Weighted Average 30-Year LCC Savings without the Avoided Cost of Carbon

Price Scenario 1		Price Scenario 2	
Single-family	**Multifamily**	**Single-family**	**Multifamily**
$2,567	$(588)	$2,669	$(588)

Table E-5. Weighted Average 30-Year LCC Savings with the Avoided Cost of Carbon

Price Scenario 1		Price Scenario 2	
Single-family	**Multifamily**	**Single-family**	**Multifamily**
$7,052	$1,435	$7,154	$1,435

Appendix F. Supplemental Propane Analysis

Some residential buildings in parts of climate design zone (CDZ) 6A use propane for space and water heating. This section describes the results of an additional analysis that compares the energy savings and cost-effectiveness of baseline 2020 ECCCNYS cases with propane to NYStretch-2020 cases with propane or all-electric configurations.

The analysis is conducted using CDZ 6A models developed for the main analysis and includes single- and multifamily prototype building models for each of the four foundation types—slab-on-grade, vented crawlspace, heated basement, and unheated basement. In each case, the baseline model is configured with a split air conditioning unit with a propane-fired furnace and a propane-fired water heater. The HVAC and water heater for the propane NYStretch case are left unchanged from the baseline while the heat pump NYStretch case is configured with an electric heat pump and electric storage water heater. Because adequate data on the construction weights of propane heated buildings with different foundation types was unavailable, the results are averaged assuming equal construction weight for each foundation type.

F.1. Propane Price Calculation

In the previous update, the average price for propane was calculated by averaging the weekly prices for the Western, Central, and North Country regions for the period of September 2019-September 2020.[39] To update the analysis for 2020 costs, the same methodology was used as for heating oil using 2021-2022 heating season prices averaged by region within each climate zone. Table F-1 summarizes the annual average price of propane in each region and the overall average used in the 2019 version of this report, and Table F-2 summarizes the 2022 update.

Table F-1. Propane Prices Used in Supplemental Analysis

Region	2019-2020 Propane Prices ($/gallon)
Western	2.48
Central	2.50
North Country	3.44
Average	**2.81**

Table F-2. Updated Propane Prices Used in Supplemental Analysis

Climate Zone	2021-2022 Propane Prices ($/gallon)
CDZ4 – bal.	3.80
CDZ5	3.15
CDZ6	**3.22**

The energy models provide estimates of predicted energy use in terms of Btus or therm for heating. The price of propane reported in $/gal is thus converted to $/therm for use in the energy cost calculations. Assuming a heat content of 91,452 Btu/gal for propane, $3.22/gal results in $3.52/therm.[40]

F.2. Energy Savings and Cost-Effectiveness Results

The site energy savings and energy cost savings results for the proposed NYStretch code over the baseline 2020 ECCCNYS with propane, by end-use for CDZ 6A are included below for the single-family prototype, the multifamily apartment unit, and the weighted average across all building types.

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 also described below. These are calculated using fuel prices summarized in Table F-1 and Table F-2.

Table F-3. Site Energy Savings for NYStretch with Propane for Single-family Buildings in CDZ 6A

	Heating Energy (kBtu/dwelling unit)	Cooling Energy (kBtu/dwelling unit)	Lighting Energy (kBtu/dwelling unit)	Fan Energy (kBtu/dwelling unit)	DHW Energy (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCCNYS	51964.3	3844.6	5076.1	2429.2	20932.1	84246.4
NYStretch-2020	32795.2	3425.3	4950.2	2761.2	15687.6	59619.4
Savings (%)	36.9%	10.9%	2.5%	-13.7%	25.1%	29.2%

Table F-4. Energy Cost Savings for NYStretch with Propane for Single-family Buildings in CDZ 6A

	Electricity Cost ($/dwelling unit)	Propane Cost ($/dwelling unit)	Total Energy Cost ($/dwelling unit)
2020 ECCCNYS	472.4	2566.0	3038.3
NYStretch-2020	463.5	1706.6	2170.1
Savings (%)	1.9%	33.5%	28.6%

Table F-5. Site Energy Savings for NYStretch with Propane for Multifamily Buildings in CDZ 6A

	Heating Energy (kBtu/dwelling unit)	Cooling Energy (kBtu/dwelling unit)	Lighting Energy (kBtu/dwelling unit)	Fan Energy (kBtu/dwelling unit)	DHW Energy (kBtu/dwelling unit)	Total Regulated Energy (kBtu/dwelling unit)
2020 ECCCNYS	17192.3	2671.8	2730.0	1279.2	16604.4	40477.6
NYStretch-2020	8748.6	2536.8	2662.1	1875.6	12447.0	28270.1
Savings (%)	49.1%	5.1%	2.5%	-46.6%	25.0%	30.2%

Table F-6. Energy Cost Savings for NYStretch with Propane for Multifamily Buildings in CDZ 6A

	Electricity Cost ($/dwelling unit)	Propane Cost ($/dwelling unit)	Total Energy Cost ($/dwelling unit)
2020 ECCCNYS	278.0	1189.6	1467.7
NYStretch-2020	297.2	746.1	1043.3
Savings (%)	-6.9%	37.3%	28.9%

Table F-7. Weighted Average Site Energy Savings for NYStretch with Propane in CDZ 6A

	Heating Energy (kBtu/ dwelling unit)	Cooling Energy (kBtu/ dwelling unit)	Lighting Energy (kBtu/ dwelling unit)	Fan Energy (kBtu/ dwelling unit)	DHW Energy (kBtu/ dwelling unit)	Total Regulated Energy (kBtu/ dwelling unit)
2020 ECCCNYS	48995.9	3744.5	4875.8	2331.0	20562.7	80510.0
NYStretch-2020	30742.4	3349.4	4760.6	2685.6	15410.9	56949.1
Savings (%)	37.3%	10.6%	2.4%	-15.2%	25.1%	29.3%

Table F-8. Weighted Average Energy Cost Savings for NYStretch with Propane in CDZ 6A

	Electricity Cost ($/dwelling unit)	Propane Cost ($/dwelling unit)	Total Energy Cost ($/dwelling unit)
2020 ECCCNYS	455.7	2448.3	2904.1
NYStretch-2020	449.3	1624.6	2073.9
Savings (%)	1.4%	33.6%	28.6%

Table F-9. Cost Effectiveness of NYStretch with Propane in CDZ 6A

Single-family (Prescriptive+Mandatory Provisions)					Multifamily (Prescriptive+Mandatory Provisions)				
Annual Energy Cost Savings ($/dwelling unit)	**Incremental Cost ($/dwelling unit)**	**Simple Payback (Years)**	**10-Year NPV ($/dwelling unit)**	**30-Yr LCC Savings ($/dwelling unit)**	**Annual Energy Cost Savings ($/dwelling unit)**	**Incremental Cost ($/dwelling unit)**	**Simple Payback (Years)**	**10-Year NPV ($/dwelling unit)**	**30-Yr LCC Savings ($/dwelling unit)**
$862	$2,346	2.7	$8,289	$12,756	$424	$2,195	5.2	$4,503	$4,640

Table F-10. Site Energy Savings for NYStretch with Heat Pumps Compared to the Baseline with Propane for Single-family Buildings in CDZ 6A

	Heating Energy (kBtu/ dwelling unit)	Cooling Energy (kBtu/ dwelling unit)	Lighting Energy (kBtu/ dwelling unit)	Fan Energy (kBtu/ dwelling unit)	DHW Energy (kBtu/ dwelling unit)	Total Regulated Energy (kBtu/ dwelling unit)
2020 ECCCNYS	51964.3	3844.6	5076.1	2429.2	20932.1	84246.4
NYStretch-2020	14484.1	2075.2	4950.2	3599.9	10085.0	35194.3
Savings (%)	72.1%	46.0%	2.5%	-48.2%	51.8%	58.2%

Table F-11. Energy Cost Savings for NYStretch with Heat Pumps Compared to the Baseline with Propane for Single-family Buildings in CDZ 6A

	Electricity Cost ($/dwelling unit)	Propane Cost ($/dwelling unit)	Total Energy Cost ($/dwelling unit)
2020 ECCCNYS	472.4	2566.0	3038.3
NYStretch-2020	1464.7	0.0	1464.7
Savings (%)	-210.1%	100.0%	51.8%

Table F-12. Site Energy Savings for NYStretch with Heat Pumps Compared to the Baseline with Propane for Multifamily Buildings in CDZ 6A

	Heating Energy (kBtu/ dwelling unit)	Cooling Energy (kBtu/ dwelling unit)	Lighting Energy (kBtu/ dwelling unit)	Fan Energy (kBtu/ dwelling unit)	DHW Energy (kBtu/ dwelling unit)	Total Regulated Energy (kBtu/ dwelling unit)
2020 ECCCNYS	17192.3	2671.8	2730.0	1279.2	16604.4	40477.6
NYStretch-2020	5590.9	1768.5	2662.1	2102.9	7606.2	19730.7
Savings (%)	67.5%	33.8%	2.5%	-64.4%	54.2%	51.3%

Table F-13. Energy Cost Savings for NYStretch with Heat Pumps Compared to the Baseline with Propane for Multifamily Buildings in CDZ 6A

	Electricity Cost ($/dwelling unit)	Propane Cost ($/dwelling unit)	Total Energy Cost ($/dwelling unit)
2020 ECCCNYS	278.0	1189.6	1467.7
NYStretch-2020	824.0	0.0	824.0
Savings (%)	-196.3%	100.0%	43.9%

Table F-14. Weighted Average Site Energy Savings for NYStretch with Heat Pumps Compared to the Baseline with Propane in CDZ 6A

	Heating Energy (kBtu/ dwelling unit)	Cooling Energy (kBtu/ dwelling unit)	Lighting Energy (kBtu/ dwelling unit)	Fan Energy (kBtu/ dwelling unit)	DHW Energy (kBtu/ dwelling unit)	Total Regulated Energy (kBtu/ dwelling unit)
2020 ECCCNYS	48995.9	3744.5	4875.8	2331.0	20562.7	80510.0
NYStretch-2020	13724.9	2049.0	4760.6	3472.1	9873.4	33880.0
Savings (%)	72.0%	45.3%	2.4%	-48.9%	52.0%	57.9%

Table F-15. Weighted Average Energy Cost Savings for NYStretch with Heat Pumps Compared to the Baseline with Propane for Multifamily Buildings in CDZ 6A

	Electricity Cost ($/dwelling unit)	Propane Cost ($/dwelling unit)	Total Energy Cost ($/dwelling unit)
2020 ECCCNYS	455.7	2448.3	2904.1
NYStretch-2020	1410.0	0.0	1410.0
Savings (%)	-209.4%	100.0%	51.4%

When compared to the cost of installing a propane furnace with a split air conditioner and a propane water heater, including the cost of installing an underground propane tank or renting one from the propane supply company, the cost of installing an electric heat pump and an electric storage water heater is expected to be lower. However, the analysis conservatively assumes no incremental cost associated with these elements in this scenario.

Table F-16. Cost-Effectiveness of NYStretch with Heat Pumps Compared to the Baseline with Propane in CDZ 6A

Single-family (Prescriptive+Mandatory Provisions)					Multifamily (Prescriptive+Mandatory Provisions)				
Annual Energy Cost Savings ($/ dwelling unit)	Incremental Cost ($/ dwelling unit)	Simple Payback (Years)	10-Year NPV ($/ dwelling unit)	30-Yr LCC Savings ($/ dwelling unit)	Annual Energy Cost Savings ($/ dwelling unit)	Incremental Cost ($/ dwelling unit)	Simple Payback (Years)	10-Year NPV ($/ dwelling unit)	30-Yr LCC Savings ($/ dwelling unit)
$1,568	$2,346	1.5	$14,694	$28,618	$644	$2,195	3.4	$6,594	$10,103

F.3. Consideration of the Avoided Cost of Carbon

An additional LCC analysis was conducted after incorporating the avoided cost of carbon into the electricity and propane fuel prices. Section 4.3.3.1 in the main body of the report describes the methodology used to calculate the avoided cost of carbon for electricity. The same approach is used for calculating the avoided cost of carbon for propane. The cost of propane including the avoided cost of carbon works out to $4.182/therm. Table F-17 and Table F-18 summarize the 30-year LCC savings for single-family and multifamily buildings in CDZ 6A for the two configurations of baseline and NYStretch cases, when the avoided cost of carbon is included in the analysis.

Table F-17. Weighted Average 30-Year LCC Savings of NYStretch with Propane in CDZ 6A When the Avoided Cost of Carbon is Included

Single-family 30 Year LCC Savings ($/dwelling unit)	Multifamily 30 Year LCC Savings ($/dwelling unit)
$19,200	$7,748

Table F-18. Weighted Average 30-Year LCC Savings of NYStretch with Heat Pumps Compared to the Baseline with Propane in CDZ 6A When the Avoided Cost of Carbon is Included

Single-family 30 Year LCC Savings ($/dwelling unit)	Multifamily 30 Year LCC Savings ($/dwelling unit)
$38,522	**$13,908**

F.4. Discussion

The additional analysis shows that in all cases, the NYStretch-2020 results in cost-effective energy savings compared to the baseline cases with propane. The savings are even more significant when the avoided costs of carbon associated with propane and electricity are included in the analysis. Additionally, switching from propane to electric heat pumps also reduces the GHG emissions associated with the operation of the building.

Appendix G. Supplemental Ventilation Analysis

The cost-effectiveness analysis in the main body of the report showed that at a Statewide level, NYStretch-2020 is cost-effective. The 10-year NPV results are positive in both single- and multifamily-buildings in all CDZs. However, from a 30-year LCC perspective, the multifamily buildings in 5A and 6A had negative savings.

Compliance with NYStretch-2020 for climate zones 5A and 6A requires the use of an energy recovery ventilation system (ERV), allowing for either an ERV or a heat recovery ventilation (HRV) system, whereas climate zone 4A allows for a balanced ventilation system. In 5A and 6A, this ventilation requirement is the largest single contributor to the package incremental cost.

This appendix compares the cost-effectiveness of the NYStretch-2020 Prescriptive and Mandatory measures if an exhaust ventilation system were used in place of the code specified ventilation systems (balanced in 4A and HRV in 5A and 6A).

G.1. 30-Year LCC Results

The most important finding from this supplemental analysis is that replacing HRV with exhaust ventilation in the 5A and 6A packages results in positive 30-year LCC savings in all cases. Table G-1 summarizes the LCC savings of the NYStretch code with either an exhaust only ventilation or an HRV system over the 2020 ECCCNYS. The results have been aggregated over the entire set of building types, foundation types, and heating systems using the construction weights matrix. Of particular note, in the multifamily buildings in 5A and 6A, the 30-year LCC become positive with exhaust ventilation (as compared to the negative savings with the HRV package).

Table G-1. Weighted Average 30-Year LCC Savings of NYStretch-2020 with Ventilation

Climate Design Zone	Single-family 30 Year LCC Savings ($/dwelling unit)	Multifamily 30 Year LCC Savings ($/dwelling unit)
4A NYC -Exhaust	$4,443	$2,089
4A-balance – Exhaust	$2,799	$1,636
5A-Exhaust	$2,215	$910
6A -Exhaust	$2,572	$580
NY State -Exhaust	**$2,313**	**$904**
4A NYC -Balanced	$3,517	$1,163
4A-balance – Balanced	$1,946	$783
5A -HRV	$1,967	$(455)
6A -HRV	$2,567	$(588)
NY State -HRV	**$2,167**	**$528**

Table G-2 summarizes the average energy cost savings, incremental construction costs, and cost-effectiveness results for the prescriptive and mandatory provisions of NYStretch under the two ventilation scenarios, weighted over the single- and multifamily-building construction weights for the State. While the exhaust only scenario has lower energy savings, it also has significantly lower incremental costs, resulting in an increase of nearly $1000 for the 30-year LCC and a simple payback shortened by 2.4 years at the statewide level.

Table G-2. Weighted Results for the Prescriptive and Mandatory Provisions of NYStretch-2020 at the State Level

	New York State Average Exhaust Ventilation	New York State Average Balanced/HRV Ventilation
Annual Energy Cost Savings ($/dwelling unit)	$253	$308
Incremental Costs ($/dwelling unit)	$1,438	$2,431
Simple Payback (Years)	5.8	8.2
10-Year NPV of Cost Savings Including Replacement Costs and Residual Values ($/dwelling unit)	$3,100	$3,809
30-Yr LCC Savings ($/dwelling unit)	$2,684	$1,695

G.2. Other Energy Savings and Cost-Effectiveness Results

The previous section summarizes the high-level cost-effectiveness results for this supplemental analysis. For reference, the following section includes the detailed results of the energy and cost savings.

Table G-3 and Table G-4 summarize the regulated site energy savings in CDZs 5A and 6A for single-family and multifamily buildings, respectively. The tables exclude climate zone 4A since the change from balanced to exhaust ventilation resulted in minor differences, as compared to switching from HRV to exhaust ventilation in 5A and 6A. Energy savings data is given for both NYStretch-2020 specified HRV system and the supplemental analysis where an exhaust only ventilation system is used. Table G-5 summarizes the weighted average regulated site energy savings with an exhaust only ventilation system in CDZs 5A, 6A, and at the state level, which includes CDZ 4A.

Table G-3. Regulated Site Energy Savings of NYStretch for Single-Family Buildings

Single-family NYStretch Site Savings over 2020 ECCCNYS						
% Savings over 2020 ECCCNYS	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)
Climate Zone 5A						
HRV	35.6%	13.5%	2.5%	-0.1%	25.1%	27.9%
Exhaust	18.5%	17.3%	2.5%	20.5%	25.0%	19.0%
Climate Zone 6A						
HRV	37.1%	15.5%	2.5%	-2.4%	25.0%	29.1%
Exhaust	18.3%	13.4%	2.5%	13.9%	25.0%	19.2%

Table G-4. Regulated Site Energy Savings of NYStretch for Multifamily Buildings

Multifamily NYStretch Site Savings over 2020 ECCCNYS						
% Savings over 2020 ECCCNYS	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)
Climate Zone 5A						
HRV	45.4%	3.0%	2.5%	-26.9%	25.0%	26.8%
Exhaust	19.4%	11.8%	2.5%	14.2%	25.0%	19.4%
Climate Zone 6A						
HRV	45.9%	4.2%	2.5%	-29.9%	25.0%	27.8%
Exhaust	18.3%	13.4%	2.5%	13.9%	25.0%	**19.2%**

Table G-5. Weighted Average Regulated Site Energy Savings for NYStretch-2020

Weighted Average NYStretch Site Savings over 2020 ECCCNYS						
% Savings over 2020 ECCCNYS	**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)**
5A	18.6%	16.8%	2.5%	20.1%	25.0%	**19.1%**
6A	18.7%	19.4%	2.4%	21.0%	25.0%	**19.4%**
NY State	19.0%	15.4%	2.5%	19.4%	25.0%	**19.2%**

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 23. Table G-6 through Table G-8 show the source energy savings in the case of an exhaust only ventilation system in place of an HRV system in CDZs 5A and 6A for the 2020 Stretch.

Table G-6. Source Energy Savings for the Prescriptive and Mandatory Provisions of NYStretch-2020 with Exhaust Ventilation for Single-Family Buildings

Climate Zone	Baseline Total Source Energy (kBtu/dwelling unit)	NYStretch-2020 Total Source Energy (kBtu/dwelling unit)	Source Energy Savings
5A	105061.6	86175.9	18.0%
6A	107097.0	87169.0	18.6%

Table G-7. Source Energy Savings for the Prescriptive and Mandatory Provisions of NYStretch-2020 with Exhaust Ventilation for Multifamily Buildings

Climate Zone	Baseline Total Source Energy (kBtu/dwelling unit)	NYStretch-2020 Total Source Energy (kBtu/dwelling unit)	Source Energy Savings
5A	53632.4	43927.0	18.1%
6A	55471.8	45639.8	17.7%

Table G-8. Weighted Average Source Energy Savings for the Prescriptive and Mandatory Provisions of NYStretch-2020 with Exhaust Ventilation

Climate Zone	Baseline Total Source Energy (kBtu/dwelling unit)	NYStretch-2020 Total Source Energy (kBtu/dwelling unit)	Source Energy Savings
5A	98066.5	80429.5	18.0%
6A	102683.9	83623.9	18.6%
NY State Average	87758.2	71920.6	18.0%

The energy cost savings from the NYStretch code over the 2020 ECCCNYS by fuel type in both the case of an exhaust only and an HRV ventilation system for CDZs 5A and 6A are included in Table G-9 and Table G-10. Table G-11 summarizes the weighted average annual energy cost savings with an exhaust only ventilation system in CDZs 5A, 6A, and at the state level, which includes CDZ 4A.

Table G-9. Annual Energy Cost Savings of the Prescriptive and Mandatory Provisions of NYStretch-2020 for Single-Family Buildings

Single-family NYStretch Energy Cost Savings over 2020 ECCCNYS				
	Electricity Cost ($/dwelling unit)	Natural Gas Cost ($/dwelling unit)	Fuel Oil Cost ($/dwelling unit)	Total Energy Cost ($/dwelling unit)
Climate Zone 5A				
HRV	16.6%	32.5%	31.8%	23.0%
Exhaust	15.1%	20.6%	20.3%	17.3%
Climate Zone 6A				
HRV	18.7%	33.2%	32.8%	24.7%
Exhaust	16.4%	20.6%	20.5%	18.1%

Table G-10. Annual Energy Cost Savings of the Prescriptive and Mandatory Provisions of NYStretch-2020 for Multifamily Buildings

Multifamily NYStretch Energy Cost Savings over 2020 ECCCNYS				
	Electricity Cost ($/dwelling unit)	Natural Gas Cost ($/dwelling unit)	Fuel Oil Cost ($/dwelling unit)	Total Energy Cost ($/dwelling unit)
Climate Zone 5A				
HRV	14.9%	36.8%	NA	20.0%
Exhaust	15.8%	22.4%	NA	17.3%
Climate Zone 6A				
HRV	14.7%	37.1%	NA	20.7%
Exhaust	15.3%	21.8%	NA	17.0%

Table G-11. Weighted Average Annual Energy Cost Savings of the Prescriptive and Mandatory Provisions of NYStretch-2020 with Exhaust Ventilation

Weighted Average NYStretch Energy Cost Savings over 2020 ECCCNYS				
	Electricity Cost ($/dwelling unit)	Natural Gas Cost ($/dwelling unit)	Fuel Oil Cost ($/dwelling unit)	Total Energy Cost ($/dwelling unit)
5A	15.2%	20.7%	20.3%	**17.3%**
6A	16.3%	20.6%	20.5%	**18.1%**
NY State Average	15.1%	21.3%	20.6%	**17.3%**

The results of the cost-effectiveness analysis in terms of simple payback, a 10-year NPV, and a 30-yr LCC savings are described below. Table G-12 shows the results in CDZs 5A, 6A, and at the state level for the weighted average annual energy cost savings, the associated total incremental costs, and the resulting simple payback for NYStretch-2020 with exhaust only ventilation compared to the 2020 ECCCNYS, for the single- and multifamily-prototypes. These are calculated using average fuel prices summarized in Tables 16-19.

Table G-12. Weighted Average Simple Payback of NYStretch-2020 with Exhaust Ventilation

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)
5A	$267	$1,451	5.4	$145	$835	5.7
6A	$269	$1,118	4.2	$141	$967	6.9
NY State	$281	$1,527	5.4	$182	$1,217	6.7

Table G-13 shows the 10-NPV of energy cost savings for the NYStretch code in exhaust only ventilation and HRV systems compared to 2020 ECCCNYS, 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. As compared to the exhaust version, NYStretch has a higher 10-year NPV with HRV in both the single- and multifamily-prototypes in both CDZ 5A and 6A.

Table G-13. Weighted Average Net Present Value (NPV) of Energy Cost Savings over 10 Years of NYStretch-2020

Climate Design Zone	Single-family		Multifamily	
	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)
HRV				
4A NYC -Balanced	$2,167	$4,200	$1,856	$2,712
4A-balance – Balanced	$2,988	$4,650	$1,778	$2,710
5A -HRV	$2,722	$4,345	$2,106	$2,429
6A -HRV	$2,346	$3,965	$2,195	$2,291
NY State -HRV	**$2,646**	**$4,288**	**$1,898**	**$2,623**
Exhaust				
4A NYC -Exhaust	$1,694	$4,076	$1,383	$2,588
4A-balance – Exhaust	$2,552	$4,536	$1,342	$2,596
5A -Exhaust	$1,451	$3,303	$835	$1,916
6A -Exhaust	$1,118	$2,846	$967	$1,723
NY State -Exhaust	**$1,527**	**$3,386**	**$1,217**	**$2,390**

G.3. Consideration of the Avoided Cost of Carbon

An additional LCC analysis was conducted after incorporating the avoided cost of carbon into the electricity and fuel prices. Section 4.3.3.1 Consideration of the Avoided Cost of Carbon Emissions in the main body of the report describes the methodology used to calculate the avoided cost of carbon for electricity. The same approach is used for calculating the avoided cost of carbon in the supplemental analysis of an exhaust only ventilation system in place of an HRV system in NYStretch-2020. The revised LCC savings are included in Table G-14.

Table G-14. Weighted Average 30-Year LCC Savings of NYStretch-2020 with Exhaust Ventilation 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	$6,637	$3,232
4A-balance	$5,404	$2,966
5A	$5,973	$3,183
6A	$6,450	$2,848
NY State	$6,037	$3,081

G.4. Additional HRV Incremental Analysis

G.4.1 Incremental Cost Ranges for HRV Systems

As discussed in D.2. 2022 Updates to Incremental Costs, in the Ventilation section, HRV system costs can vary widely. This section considers the cost-effectiveness of a range of HRV system incremental costs.

As detailed in Section 3.4.2.7 Ventilation, an average incremental cost of $325 was used for the both the single-family prototype and each multifamily unit in CDZ 4A, as the addition of a CFIS combined with the code compliant exhaust system meets the NYStretch requirement for a balanced system. For CDZs 5A and 6A, the original analysis assumed an incremental cost of $1,095 for the single-family prototype and each multifamily unit for an HRV before adjusting with location factors.

Construction material and labor costs have increased since this report was last updated, but there is a lack of data on current HRV and ERV costs. RSMeans only has ERV costs for commercial systems that are larger than those used in single-family and low-rise multifamily homes. NREL's National Residential Efficiency Measures (NREM) database was last updated in 2018 with 2010 costs. As an alternative to RSMeans, some contractors use the Craftsman estimator tool. Craftsman's 2022 National Plumbing and HVAC Estimator[41] shows the cost of a conventional HRV with 65-150 CFM to be $1188 including labor and materials and a compact HRV with 65-127 CFM to be $1258. A PNNL study[42] used the home remodeling website Fixr (2021)[43] as a reference point for current costs. Fixr gives the range of $1300-$2400 for an HRV including labor.

Not all residential dwelling units need the same size of HRV or ERV system, so the costs will vary by home size and type. According to the 2020 Mechanical Code of NYS, dwelling units should receive 0.35 air changes per hour, which means an HRV or ERV system can be sized as small as 40 CFM in a small, one-bedroom multifamily unit or closer to 250 CFM in a very large single-family home.[44]

Assuming similar labor and additional installation costs to those indicated by the Craftsman National Plumbing and HVAC Estimator, costs from SupplyHouse.com for ERVs show that the smallest ERV available, a 40 CFM model appropriate for a small one-bedroom apartment, costs $450 for a unit plus $955 for labor and additional installation costs resulting in a total of $1,405, which is an appropriate minimum cost for a multifamily dwelling.[45] A 70 CFM model appropriate for up to 1,200 sq. ft. according to the manufacturer, costs $545 for a unit plus $955 for labor and additional installation costs resulting in a total of $1,500, which is an appropriate maximum cost for a multifamily dwelling.[46]

A 145 CFM model appropriate for up to 3,200 sq. ft. costs $893 for a unit plus $1,027 for labor and additional installation costs resulting in a total of $1,920, which is an appropriate minimum cost for a single-family dwelling.[47] A 240 CFM model appropriate for up to 6,000 sq. ft. costs $1,830 for a unit plus $1,130 for labor and additional installation costs resulting in a total of $2,960, which is an appropriate maximum cost for a single-family dwelling.[48]

The Craftsman Estimator shows that a 106 CFM bathroom fan costs $243 for a unit plus $152 for labor and additional installation costs resulting in a total of $395, which can be used as the baseline cost. RSMeans location multipliers are applied by climate zone, resulting in Table G-15 below showing the range of potential HRV/ERV incremental costs by climate zone.

Table G-15. HRV/ERV Incremental Cost Ranges

	Single-family Incremental Cost		**Multifamily Incremental Cost**	
Climate Zone	Minimum	Maximum	Minimum	Maximum
CDZ 5	$1,777	$2,988	$1,177	$1,287
CDZ 6	$1,723	$2,898	$1,141	$1,249

G.4.2 Justified First Costs

The justified first cost is defined as the maximum ‘first cost’ that will still result in positive cost savings overall. Following DOE’s study “Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes,” this is calculated by looking at the point at which the first cost combined with mortgage payment and property taxes is balanced out by the fuel cost savings along with any tax deductions over the measure’s effective useful life (which is 15 years in the case of the HRV system).

Table G-16 shows the energy savings of an HRV system over an exhaust-only system for single- and multifamily-buildings in CDZ 5A and 6A. A negative number indicates that the HRV system used more energy than the exhaust system (e.g. increased fan energy). Of note, this analysis does show an increase in cooling energy for the HRV system, which was also documented in Energy Use Consequences of Ventilating a Net-Zero Energy House.[49]

Over the course of a year, continuous operation of the HRV at the NZERTF resulted in an annual savings of 7% in heat pump energy use compared with the hypothetical case of ventilating without heat recovery. The heat pump electrical use varied from an increase of 5% in the cooling months to 36% savings in the heating months compared with ventilation without heat recovery. The increase in the cooling months occurred when the outdoor temperature was lower than the indoor temperature, during which the availability of an economizer mode would have been beneficial. Nevertheless, the fan energy required to operate the selected HRV at the NZERTF paid for itself in the heat pump energy saved compared with ventilation without heat recovery.

However, overall, the HRV packages had higher energy savings than the exhaust only packages.

Table G-16. Fuel per Dwelling Unit for HRV versus Exhaust Ventilation

NYStretch 2020 P+M HRV versus Exhaust Ventilation	Fuel per Dwelling Unit											
	SF-5A			SF-6A-average			MF-5A			MF-6A-average		
	kWh	Gas Therm	Oil Therm	kWh	Gas Therm	Oil Therm	kWh	Gas Therm	Oil Therm	kWh	Gas Therm	Oil Therm
gasfurnace_crawlspace	(323)	108	0	(335)	121	0	(364)	61	0	(372)	69	0
gasfurnace_heatedbsmt	(329)	106	0	(343)	118	0	(384)	57	0	(393)	65	0
gasfurnace_slab	(302)	109	0	(313)	122	0	(368)	60	0	(376)	68	0
gasfurnace_unheatedbsmt	(322)	108	0	(336)	121	0	(367)	60	0	(376)	68	0
hp_crawlspace	1,500	0	0	1,755	0	0	392	0	0	506	0	0
hp_heatedbsmt	1,451	0	0	1,685	0	0	312	0	0	420	0	0
hp_slab	1,506	0	0	1,766	0	0	366	0	0	496	0	0
hp_unheatedbsmt	1,471	0	0	1,703	0	0	385	0	0	501	0	0
oilfurnace_crawlspace	(312)	0	106	(325)	0	118	(268)	0	63	-	-	-
oilfurnace_heatedbsmt	(316)	0	104	(330)	0	116	(299)	0	58	-	-	-
oilfurnace_slab	(294)	0	107	(304)	0	119	(276)	0	62	-	-	-
oilfurnace_unheatedbsmt	(311)	0	106	(327)	0	118	(274)	0	63	-	-	-

A negative fuel number indicates that the HRV system used more energy than the exhaust system (e.g. increased fan energy).

Table G-17 summarize the justified first cost for an HRV system with an EUL of 15 when using 2022 fuel prices both with and without the avoided cost of carbon included, across various foundation and heating/cooling source types. The colors indicate whether the HRV incremental costs are justified as compared to the minimum and maximum incremental costs defined in Table G-15. Red (-) indicates the justified first cost is lower than the minimum HRV incremental costs, and thus is generally not a cost-effective measure when considered by itself. Yellow (~) indicates that the justified first cost is between the minimum and maximum incremental HRV costs. Green (+) indicates that the fuel savings are sufficient to justify even the maximum incremental costs.

Table G-17. Justified First Cost Per Dwelling Unit for HRV versus Exhaust Ventilation

NYStretch-2020 P+M HRV versus Exhaust Ventilation	Justified First Cost per Dwelling Unit ($)							
	SF-5A		SF-6A-average		MF-5A		MF-6A-average	
	w/ 2022 fuel prices	w/ ACC	w/ 2022 fuel prices	w/ ACC	w/ 2022 fuel prices	w/ ACC	w/ 2022 fuel prices	w/ ACC
gasfurnace_crawlspace	$754(-)	$1,573(-)	$920(-)	$1,855(~)	$146(-)	$460(-)	$261(-)	$649(-)
gasfurnace_heatedbsmt	$720(-)	$1,512(-)	$880(-)	$1,784(~)	$76(-)	$339(-)	$189(-)	$524(-)
gasfurnace_slab	$802(-)	$1,651(-)	$972(-)	$1,942(~)	$132(-)	$435(-)	$248(-)	$626(-)
gasfurnace_unheatedbsmt	$760(-)	$1,583(-)	$921(-)	$1,856(~)	$136(-)	$442(-)	$251(-)	$632(-)
hp_crawlspace	$2,298(~)	$3,517(+)	$2,561(~)	$3,987(+)	$600(-)	$918(-)	$739(-)	$1,150(~)
hp_heatedbsmt	$2,222(~)	$3,400(+)	$2,460(~)	$3,829(+)	$477(-)	$730(-)	$613(-)	$954(-)
hp_slab	$2,306(~)	$3,529(+)	$2,577(~)	$4,012(+)	$560(-)	$856(-)	$724(-)	$1,127(-)
hp_unheatedbsmt	$2,253(~)	$3,447(+)	$2,486(~)	$3,870(+)	$590(-)	$903(-)	$730(-)	$1,137(-)
oilfurnace_crawlspace	$2,441(~)	$3,670(+)	$2,666(~)	$4,053(+)	$1,332(+)	$2,000(+)		
oilfurnace_heatedbsmt	$2,390(~)	$3,592(+)	$2,614(~)	$3,974(+)	$1,151(-)	$1,726(+)		
oilfurnace_slab	$2,500(~)	$3,760(+)	$2,733(~)	$4,157(+)	$1,302(+)	$1,954(+)		
oilfurnace_unheatedbsmt	$2,454(~)	$3,690(+)	$2,669(~)	$4,059(+)	$1,312(+)	$1,969(+)		

ACC = Avoided Cost of Carbon

Below minimum cost (-)

Between min and max cost (~)

Above max cost (+)

G.5. Discussion

As noted in section G.4., the most important finding from this supplemental analysis is that replacing HRV with exhaust ventilation in the 5A and 6A packages results in positive 30-year LCC savings in all cases. This is particularly important in the multifamily buildings in 5A and 6A because the 30-year LCC savings are negative with the HRV package.

In general, the savings were lowest in the gas furnace prototypes, and significantly higher in the heat pump and oil furnace cases. The 10-year NPV with HRV is higher than with exhaust ventilation in both single- and multifamily-prototypes in both CDZ 5A and 6A. Furthermore, while the exhaust-only scenario has lower energy savings, it also has significantly lower incremental costs, resulting in a Statewide average increase of nearly $1000 for the 30-year LCC and a simple payback shortened from 8.2 to 5.8 years.

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New York State
Energy Research and
Development Authority

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov

State of New York
Kathy Hochul, Governor

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