

Cost & Savings Estimates

ENERGY STAR
Multifamily New
Construction,
Version 1.1

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ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Contents

Section 1: Executive Summary.....	3
Section 2: Detailed Incremental Cost Estimates	6
Section 3: Incremental Cost & Savings of the National Rater Field Checklist: Thermal Enclosure System.....	20
Section 4: Incremental Cost & Savings of the National Rater Field Checklist: HVAC System	22
Section 5: Incremental Cost & Savings of the National HVAC Design Report	24
Section 6: Incremental Cost & Savings of the National Rater Design Review Checklist	26
Section 7: Incremental Cost & Savings of the National HVAC Functional Testing Checklist	27
Section 8: Incremental Cost & Savings of the National Water Management System Req.'s	29
Section 9: Incremental Cost of Modeling ERI Certification Path	30
Section 10: Cost References.....	31
A. Thermal Enclosure System	31
B. Space Conditioning Equipment & Filter	33
C. Ventilation Equipment	34
D. Ductwork	35
E. Domestic Hot Water Equipment.....	36
F. Appliances & Lighting.....	36
G. Labor	37
Appendix A: Complete Savings Results for All Modeled Building Units	38



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 1: Executive Summary

Overview

This document is intended to provide partners, utility sponsors, and program designers with an estimate of the incremental costs to build, and associated savings from, a low-rise ENERGY STAR Multifamily New Construction building under Version 1.1 of the program in regions that have adopted the 2012 ICC codes (e.g., 2012 IECC, 2012 IRC), or an equivalent code. There are a variety of multifamily buildings eligible to participate in the ENERGY STAR Multifamily New Construction program (e.g., low-, mid-, and high-rise buildings). This document only estimates the costs and savings of a typical low-rise multifamily building, which is a common building type participating in the program. For this type of building, the residential portions of the ICC codes would be applicable, while the commercial sections of the ICC codes, or other codes and standards (e.g., ASHRAE 90.1), may be applicable to other buildings eligible to participate in the ENERGY STAR Multifamily New Construction program.

Methodology

To complete this analysis, EPA evaluated thirteen typical buildings across hot, mixed, and cold climates.

The architectural characteristics for each building were determined using the U.S. Department of Energy's Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes. Exhibit 1 shows the building and unit parameters that were modeled consistently across all Climate Zones.

The analysis was performed using a three-story low-rise multifamily building with six dwelling units per floor, arranged in two rows with an open breezeway in between. Each dwelling unit is modeled to have its own separate heating and cooling equipment. The building was considered to have no common spaces, central systems, or hydronic equipment, so program requirements for these spaces and systems were not evaluated as part of this analysis.

Exhibit 1: Building and Unit Parameters Consistent Across Climate Zones

Parameter	Value
Number of Stories in Unit	One
Conditioned Floor Area per Unit (ft ²)	1,200
Number of Stories in Building	Three
Number of Units in Building	18
Unit Perimeter (ft)	30 x 40
Ceiling Height (ft)	8.5
Bedrooms	2
Window Area & Distribution	23% of exterior wall (not including breezeway)
Exterior Door Quantity & Total Area (ft ²)	1 Doors, 21 ft ²
Framing	Wood
Foundation Type	Slab

Exhibit 2 shows parameters that were modeled with variations across Climate Zones. In Climate Zones 1 through 6, one building in each zone was configured with an electric heat pump and electric water heater, named Configuration A. A second building was configured with a gas furnace, electric air conditioner, and gas water heater, named Configuration B. In Climate Zone 7, only one building was modeled using Configuration B, based on EPA's observation that few electrically-heated buildings participate in the program from this region.

Exhibit 2: Building Parameters Varied Across Climate Zones

Parameter	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7
Location	Miami, FL	Tampa, FL	Fort Worth, TX	St. Louis, MO	Indianapolis, IN	Burlington, VT	Duluth, MN
Foundation Type	Slab						
Space Heating, Config. A	Electric Air-Source Heat Pump & Electric DHW						n/a
Cooling, & DHW Config. B	Gas Furnace, Electric AC, & Gas DHW						

The energy efficiency features of the baseline units were aligned with the 2012 IECC prescriptive path, except for the window and door performance in Climate Zone 1. In this location, the 2012 IECC defines a SHGC of 0.25 but no U-factor requirement. Given the relatively stringent SHGC, a corresponding U-factor of 0.50 was assumed. In addition, because no



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

insulation installation grade is defined or required by code, all zones were modeled with Grade III insulation installation in walls and Grade II insulation installation in ceilings and floors, which reflects EPA's experience with typical low-rise buildings built to code.

The energy efficiency features of the ENERGY STAR Multifamily New Construction buildings were aligned with the features of the Version 1.1 ENERGY STAR Multifamily Reference Design.

These energy efficiency features of the baseline buildings and ENERGY STAR Multifamily New Construction buildings are summarized in Exhibits 4 through 16.

To estimate energy savings, first, the baseline and ENERGY STAR Multifamily New Construction units were modeled in REM/Rate v15.7. Energy consumption was determined from the resulting Fuel Summary report.

Next, two factors were applied to account for ENERGY STAR program requirements not fully credited in ANSI / RESNET / ICC Standard 301 and which help ensure that the thermal enclosure system and HVAC system in ENERGY STAR units perform as designed. Because these program requirements are not required by the 2012 IECC, the factors were applied to the baseline units, thereby increasing their consumption.

The first factor reflects increased convective losses, because the baseline units are not required to achieve Grade I insulation installation nor, in Climate Zones 4 through 8, alignment of the wall insulation with the interior air barrier. This was estimated to increase heating and cooling consumption in the baseline units by 5%.

The second factor reflects less efficient operation of the air conditioner and heat pump because the baseline units are not required to be tested, per the National HVAC Functional Testing Checklist. This is estimated to increase the heating consumption for units with electric heat pumps and the cooling consumption for units with air conditioners or heat pumps by 6.9%.

These two factors were applied multiplicatively to the heating and cooling consumption reported by REM/Rate for the baseline units. The resulting energy consumption for the baseline units and ENERGY STAR units were then converted to purchased energy costs using a national average rate of \$0.121 / kWh and \$1.116 / therm, as referenced from the Energy Information Administration's 2014 Annual Energy Outlook. Finally, the purchased energy costs for the ENERGY STAR units were subtracted from those of the baseline units to determine savings.

For a multifamily building, energy costs and savings for individual units will vary based on the location of the unit (e.g., top floor, middle floor, ground floor, corner unit, interior unit) primarily due to the amount of wall / ceiling / floor area that is exposed to unconditioned space rather than another conditioned unit. To limit the amount of modeling required to estimate program savings, EPA modeled just four of six unit types in REM/Rate: ground corner, middle interior, top corner, and top interior. Ground interior units were assumed to have the same savings as a middle interior unit, and middle corner units were assumed to have the same savings as a ground corner unit. Using the modeled results for the four unit types and the assumed savings for the two remaining unit types, EPA was able to assign savings for all 18 units within the building. Finally, the weighted average unit savings across all 18 units was calculated for each climate zone. Complete savings results for each of the units modeled is presented in Appendix A.

The incremental costs of the energy efficiency features for each ENERGY STAR Multifamily New Construction building were estimated next. This included both the mandatory measures required by the ENERGY STAR inspection checklists, along with the measures that were not required by the checklists but were used to meet the ENERGY STAR Energy Rating Index (ERI) Target required by the program. Measures applicable to common spaces were not considered in this analysis, as the low-rise building considered does not have any common space. Costs were estimated for the entire building and are summarized in Exhibits 4 through 16.

Results & Discussion

Exhibit 3 summarizes the multifamily unit-weighted average annual purchased energy savings for each ENERGY STAR Multifamily New Construction building. In addition, it summarizes the unit-weighted average total upgrade cost, which is the total building costs in Exhibits 4 through 16 divided by the 18 units in the building. Finally, Exhibit 3 shows the resulting monthly purchased energy savings, monthly mortgage upgrade cost, and net cash flow per unit. The monthly mortgage upgrade cost was calculated assuming a 30-year fixed mortgage with a 5.0% interest rate. Although the majority of multifamily units are rental units, this analysis evaluates the upgrade cost as if it were included into the mortgage of a single unit, as if an individual purchased the unit. This was done to align with the approach outlined in the U.S. Department of Energy's Methodology for Evaluating Cost-Effectiveness of Residential Energy Code Changes.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Exhibit 3: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC, Illustrative Cost & Savings Summary

			ENERGY STAR MFNC Version 1.1					
CZ	Location	HVAC Equipment Type	Weighted Average Annual Purchased Energy Savings		Weighted Average Total Upgrade Cost	Monthly Purchased Energy Savings	Monthly Mortgage Upgrade Cost	Net Cash Flow
1	Miami, FL	Elec. Air-Source HP	\$155	17%	\$1,687	\$13	\$9	\$4
1	Miami, FL	Gas Furnace / Elec. AC	\$172	19%	\$1,910	\$14	\$10	\$4
2	Tampa, FL	Elec. Air-Source HP	\$156	17%	\$1,371	\$13	\$7	\$6
2	Tampa, FL	Gas Furnace / Elec. AC	\$168	19%	\$1,594	\$14	\$9	\$5
3	Fort Worth, TX	Elec. Air-Source HP	\$162	16%	\$814	\$13	\$4	\$9
3	Fort Worth, TX	Gas Furnace / Elec. AC	\$162	17%	\$1,037	\$14	\$6	\$8
4	St. Louis, MO	Elec. Air-Source HP	\$182	16%	\$884	\$15	\$5	\$10
4	St. Louis, MO	Gas Furnace / Elec. AC	\$178	18%	\$1,065	\$15	\$6	\$9
5	Indianapolis, IN	Elec. Air-Source HP	\$202	17%	\$1,114	\$17	\$6	\$11
5	Indianapolis, IN	Gas Furnace / Elec. AC	\$186	19%	\$1,079	\$15	\$6	\$10
6	Burlington, VT	Elec. Air-Source HP	\$217	17%	\$1,159	\$18	\$6	\$12
6	Burlington, VT	Gas Furnace / Elec. AC	\$187	19%	\$1,047	\$16	\$6	\$10
7	Duluth, MN	Gas Furnace / Elec. AC	\$214	20%	\$1,047	\$18	\$6	\$12

Section 2 contains Exhibits 4 through 16, which contain a more detailed breakout of the incremental upgrade costs presented in Exhibit 3. While this analysis provides illustrative incremental costs and savings, these values will vary for any specific building, dependent on variables such as baseline construction practices, geographic location, building and unit design, and vendor relationships. For example, builders or developers are likely to experience lower incremental costs than stated in this document if they are able to procure equipment or materials below retail rates or if they already build above code-minimum requirements. In addition, many partners achieve decreasing costs over time as they gain experience and develop more cost-effective strategies to meet the program requirements. Therefore, these estimates are only illustrative and are likely to represent the higher end of the cost spectrum.

Sections 3 through 9 provide a more detailed discussion of the incremental costs and savings associated with each of the checklists required by the program. With this analysis, the requirements of the checklists were compared to the requirements of the 2012 IECC and 2012 IRC codes, and only requirements above code were accounted for.

For example, code requires that HVAC systems be designed in accordance with Manual J, D, and S, or equivalent methodologies, so no costs or savings were assumed for meeting these design requirements. In contrast, residential code does not require functional testing of HVAC systems, so both incremental costs and savings were estimated for these requirements.

In addition, where the ENERGY STAR Multifamily New Construction program requires a Rater to verify a code requirement, the cost for such verification was included in the incremental costs for the program, because this third-party verification is above and beyond the oversight required by code.

This approach was pursued for two reasons. The first reason is that code is a well-defined baseline from which costs and savings can be consistently evaluated. In contrast, standard practice often varies from code-minimum requirements (both below-code and above-code) and is therefore difficult to consistently benchmark against. The second reason for this approach is that most utility-sponsored programs are not able to claim savings for improvements from below-code to code-minimum practices. Therefore, estimating the incremental costs and savings only for the above-code measures of the ENERGY STAR program requirements makes the analysis more relevant to utility sponsors and partners that wish to improve practices above code.

Despite the fact that many of the items in the ENERGY STAR Checklists are required by code, EPA believes that their inclusion provides significant benefits: code often allows these items to be traded-off for other improvements, while the Checklists help ensure that these details are included in every unit to consistently deliver a complete thermal enclosure system, complete HVAC system, and complete water management system; the ENERGY STAR Checklists consolidate critical code-required details in a relatively concise format that improves compliance; the ENERGY STAR Checklists provide a consistent set of building-science details from which to educate and train partners; and many of the items on the ENERGY STAR Checklists are required to be third-party verified by a Rater, whereas most jurisdictions do not require such oversight.

Finally, Section 10 provides additional references to support the assumptions used in the analysis.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 2: Detailed Incremental Cost Estimates

Exhibits 4 through 16 contain a more detailed explanation of the incremental upgrade costs presented for each building in Exhibit 3. For each building, the costs are divided into eight sections.

The first section in each exhibit contains the energy efficiency measures that are not required by the ENERGY STAR Inspection Checklists and were used solely to meet the ENERGY STAR ERI target.

The next six sections contain the costs required to comply with, respectively, the Thermal Enclosure System section of the National Rater Field Checklist (Rater-F), the HVAC System section of Rater-F, the National Rater Design Review Checklist (Rater-D), the National HVAC Design Report (HVAC-D), the National HVAC Functional Testing Checklist (HVAC-FT), and the National Water Management System Requirements (WMS), relative to the 2012 ICC codes. The measures included in these sections represent both requirements that improve the ERI of the unit and those that do not. For example, Grade I insulation installation is mandatory in the Rater-F, unless rigid insulation is used, so that cost is grouped with the Rater-F even though a builder not participating in the ENERGY STAR program might also select that measure to achieve a better ERI. In contrast, the Rater-F requires verification that HVAC equipment model numbers match the design, which is a mandatory requirement of this checklist, but does not impact the ERI of the unit.

For each measure, the exhibit lists the 2012 IECC baseline code requirement, the Version 1.1 ENERGY STAR Multifamily New Construction requirement, the incremental unit cost, the quantity of units per building, the cost units (e.g., tons, square feet of window area, square feet of conditioned floor area), and the total incremental measure cost.

Measures applicable to common spaces were not considered in this analysis, as the low-rise building considered does not have any common space.



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 4: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 1 - Config. A - Electric

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	5 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	14 SEER / 8.2 HSPF	15 SEER / 8.2 HSPF	\$48.00	27	Tons	\$1,296
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	-	-	-	-
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$9,354
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-30	R-38	\$0.70	7,200	Ins. Surface Area (ft ²)	\$5,040
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-13	R-13 + 3.8	\$0.71	15,300	Ins. Surface Area (ft ²)	\$10,814
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	15,300	Ins. Surface Area (ft ²)	\$1,511
Foundation Insulation	None	None	-	-	-	-
Windows	U-Value: 0.5 / SHGC: 0.25	U-Value: 0.4 / SHGC: 0.25	\$0.18	2,111	Window Area (ft ²)	\$380
Doors	R-2	R-5.9	\$48.53	18	Door	\$874
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$19,580
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						\$1,100
Sub-Total of HVAC System Checklist						-\$2,183
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	Supply Vent. System with Exhaust Backup	Supply Vent. System with Exhaust Backup	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$30,366



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 5: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 1 - Config. B - Gas

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	5 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	14 SEER Central AC	15 SEER Central AC	\$84.00	27	Tons	\$2,268
Heating Equipment	80 AFUE Gas Furnace	80 AFUE Gas Furnace	-	-	-	-
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.67 EF Gas DHW, 40 Gal. (Power Vent)	\$169.25	18	Unit	\$3,047
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$13,373
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-30	R-38	\$0.70	7,200	Ins. Surface Area (ft ²)	\$5,040
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-13	R-13 + 3.8	\$0.71	15,300	Ins. Surface Area (ft ²)	\$10,814
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	15,300	Ins. Surface Area (ft ²)	\$1,511
Foundation Insulation	None	None	-	-	-	-
Windows	U-Value: 0.5 / SHGC: 0.25	U-Value: 0.4 / SHGC: 0.25	\$0.18	2,111	Window Area (ft ²)	\$380
Doors	R-2	R-5.9	\$48.53	18	Door	\$874
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$19,580
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						\$1,100
Sub-Total of HVAC System Checklist						-\$2,183
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	Supply Vent. System with Exhaust Backup	Supply Vent. System with Exhaust Backup	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$34,385



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 6: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 2 - Config. A - Electric

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	5 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	14 SEER / 8.2 HSPF	15 SEER / 8.2 HSPF	\$48.00	27	Tons	\$1,296
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	-	-	-	-
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$9,354
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-38	R-38	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-13	R-13 + 3.8	\$0.71	15,300	Ins. Surface Area (ft ²)	\$10,814
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	15,300	Ins. Surface Area (ft ²)	\$1,511
Foundation Insulation	None	None	-	-	-	-
Windows	U-Value: 0.4 / SHGC: 0.25	U-Value: 0.4 / SHGC: 0.25	-	-	-	-
Doors	R-2.5	R-5.9	\$33.82	18	Door	\$609
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$13,895
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						\$1,100
Sub-Total of HVAC System Checklist						-\$2,183
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	Supply Vent. System with Exhaust Backup	Supply Vent. System with Exhaust Backup	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$24,681



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 7: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 2 - Config. B - Gas

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	5 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	14 SEER Central AC	15 SEER Central AC	\$84.00	27	Tons	\$2,268
Heating Equipment	80 AFUE Gas Furnace	80 AFUE Gas Furnace	-	-	-	-
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.67 EF Gas DHW, 40 Gal. (Power Vent)	\$169.25	18	Unit	\$3,047
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$13,373
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-38	R-38	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-13	R-13 + 3.8	\$0.71	15,300	Ins. Surface Area (ft ²)	\$10,814
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	15,300	Ins. Surface Area (ft ²)	\$1,511
Foundation Insulation	None	None	-	-	-	-
Windows	U-Value: 0.4 / SHGC: 0.25	U-Value: 0.4 / SHGC: 0.25	-	-	-	-
Doors	R-2.5	R-5.9	\$33.82	18	Door	\$609
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$13,895
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						\$1,100
Sub-Total of HVAC System Checklist						-\$2,183
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	Supply Vent. System with Exhaust Backup	Supply Vent. System with Exhaust Backup	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$28,700



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 8: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 3 - Config. A - Electric

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	5 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	14 SEER / 8.2 HSPF	15 SEER / 8.2 HSPF	\$48.00	27	Tons	\$1,296
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	-	-	-	-
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$9,354
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-38	R-38	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	15,300	Ins. Surface Area (ft ²)	\$691
Foundation Insulation	None	None	-	-	-	-
Windows	U-Value: 0.35 / SHGC: 0.25	U-Value: 0.3 / SHGC: 0.25	\$0.64	2,111	Window Area (ft ²)	\$1,351
Doors	R-2.9	R-5.9	\$47.65	18	Door	\$858
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$3,860
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						\$1,100
Sub-Total of HVAC System Checklist						-\$2,183
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	Supply Vent. System with Exhaust Backup	Supply Vent. System with Exhaust Backup	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$14,646



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 9: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 3 - Config. B - Gas

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	5 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	14 SEER Central AC	15 SEER Central AC	\$84.00	27	Tons	\$2,268
Heating Equipment	80 AFUE Gas Furnace	80 AFUE Gas Furnace	-	-	-	-
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.67 EF Gas DHW, 40 Gal. (Power Vent)	\$169.25	18	Unit	\$3,047
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$13,373
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-38	R-38	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	15,300	Ins. Surface Area (ft ²)	\$691
Foundation Insulation	None	None	-	-	-	-
Windows	U-Value: 0.35 / SHGC: 0.25	U-Value: 0.3 / SHGC: 0.25	\$0.64	2,111	Window Area (ft ²)	\$1,351
Doors	R-2.9	R-5.9	\$47.65	18	Door	\$858
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$3,860
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						\$1,100
Sub-Total of HVAC System Checklist						-\$2,183
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	Supply Vent. System with Exhaust Backup	Supply Vent. System with Exhaust Backup	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$18,665



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 10: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 4 - Config. A - Electric

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	3 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	14 SEER / 8.2 HSPF	15 SEER / 8.5 HSPF	\$96.00	27	Tons	\$2,592
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	-	-	-	-
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$10,650
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation*	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	15,300	Ins. Surface Area (ft ²)	\$691
Foundation Insulation	R-10, 2 ft	R-10, 2 ft	-	-	-	-
Windows	U-Value: 0.35 / SHGC: 0.4	U-Value: 0.3 / SHGC: 0.4	\$0.66	2,111	Window Area (ft ²)	\$1,394
Doors	R-2.9	R-5.9	\$47.65	18	Door	\$858
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$3,903
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						\$1,025
Sub-Total of HVAC System Checklist						-\$2,258
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	Supply Vent. System with Exhaust Backup	Supply Vent. System with Exhaust Backup	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$15,910

*The IECC value for this measure was used for modeling the ENERGY STAR units because the IECC was more stringent than the ENERGY STAR Reference Design.



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 11: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 4 - Config. B - Gas

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	3 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	13 SEER Central AC	13 SEER Central AC	-	-	-	-
Heating Equipment	80 AFUE Gas Furnace	95 AFUE Gas Furnace	\$7.85	576	kBtu/h	\$4,522
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.67 EF Gas DHW, 40 Gal. (Power Vent)	\$169.25	18	Unit	\$3,047
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$15,626
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation*	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	15,300	Ins. Surface Area (ft ²)	\$691
Foundation Insulation	R-10, 2 ft	R-10, 2 ft	-	-	-	-
Windows	U-Value: 0.35 / SHGC: 0.4	U-Value: 0.3 / SHGC: 0.4	\$0.66	2,111	Window Area (ft ²)	\$1,394
Doors	R-2.9	R-5.9	\$47.65	18	Door	\$858
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$3,903
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						-\$700
Sub-Total of HVAC System Checklist						-\$3,983
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	Supply Vent. System with Exhaust Backup	Supply Vent. System with Exhaust Backup	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$19,161

*The IECC value for this measure was used for modeling the ENERGY STAR units because the IECC was more stringent than the ENERGY STAR Reference Design.



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 12: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 5 - Config. A - Electric

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	3 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	14 SEER / 8.2 HSPF	15 SEER / 9.25 HSPF	\$237.00	27	Tons	\$6,399
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	-	-	-	-
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$14,457
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	15,300	Ins. Surface Area (ft ²)	\$691
Foundation Insulation	R-10, 2 ft	R-10, 2 ft	-	-	-	-
Windows	U-Value: 0.32 / SHGC: 0.4	U-Value: 0.27 / SHGC: 0.4	\$1.04	2,111	Window Area (ft ²)	\$2,191
Doors	R-3.1	R-5.9	\$22.06	18	Door	\$397
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$4,241
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						\$1,025
Sub-Total of HVAC System Checklist						-\$2,258
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	ENERGY STAR Exhaust Fan with Controller	ENERGY STAR Exhaust Fan with Controller	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$20,055



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 13: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 5 - Config. B - Gas

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	3 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	13 SEER Central AC	13 SEER Central AC	-	-	-	-
Heating Equipment	80 AFUE Gas Furnace	95 AFUE Gas Furnace	\$7.85	576	kBtu/h	\$4,522
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.67 EF Gas DHW, 40 Gal. (Power Vent)	\$169.25	18	Unit	\$3,047
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$15,626
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	15,300	Ins. Surface Area (ft ²)	\$691
Foundation Insulation	R-10, 2 ft	R-10, 2 ft	-	-	-	-
Windows	U-Value: 0.32 / SHGC: 0.4	U-Value: 0.27 / SHGC: 0.4	\$1.04	2,111	Window Area (ft ²)	\$2,191
Doors	R-3.1	R-5.9	\$22.06	18	Door	\$397
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$4,241
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						-\$775
Sub-Total of HVAC System Checklist						-\$4,058
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	ENERGY STAR Exhaust Fan with Controller	ENERGY STAR Exhaust Fan with Controller	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$19,424



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 14: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 6 - Config. A - Electric

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	3 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	14 SEER / 8.2 HSPF	15 SEER / 9.5 HSPF	\$288.00	27	Tons	\$7,776
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	-	-	-	-
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$15,834
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation*	R-20 + 5	R-20 + 5	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	15,300	Ins. Surface Area (ft ²)	\$691
Foundation Insulation	R-10, 4ft	R-15, 2 ft	-\$1.60	360	Slab Perimeter (ft)	-\$576
Windows	U-Value: 0.32 / SHGC: 0.4	U-Value: 0.27 / SHGC: 0.4	\$1.04	2,111	Window Area (ft ²)	\$2,191
Doors	R-3.1	R-5.9	\$22.06	18	Door	\$397
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$3,665
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						\$1,025
Sub-Total of HVAC System Checklist						-\$2,258
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	ENERGY STAR Exhaust Fan with Controller	ENERGY STAR Exhaust Fan with Controller	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$20,856

*The IECC value for this measure was used for modeling the ENERGY STAR units because the IECC was more stringent than the ENERGY STAR Reference Design.



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 15: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 6 - Config. B - Gas

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	3 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	13 SEER Central AC	13 SEER Central AC	-	-	-	-
Heating Equipment	80 AFUE Gas Furnace	95 AFUE Gas Furnace	\$7.85	576	kBtu/h	\$4,522
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.67 EF Gas DHW, 40 Gal. (Power Vent)	\$169.25	18	Unit	\$3,047
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$15,626
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation*	R-20 + 5	R-20 + 5	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	15,300	Ins. Surface Area (ft ²)	\$691
Foundation Insulation	R-10, 4ft	R-15, 2 ft	-\$1.60	360	Slab Perimeter (ft)	-\$576
Windows	U-Value: 0.32 / SHGC: 0.4	U-Value: 0.27 / SHGC: 0.4	\$1.04	2,111	Window Area (ft ²)	\$2,191
Doors	R-3.1	R-5.9	\$22.06	18	Door	\$397
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$3,665
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						-\$775
Sub-Total of HVAC System Checklist						-\$4,058
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	ENERGY STAR Exhaust Fan with Controller	ENERGY STAR Exhaust Fan with Controller	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$18,848

*The IECC value for this measure was used for modeling the ENERGY STAR units because the IECC was more stringent than the ENERGY STAR Reference Design.



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Exhibit 16: ENERGY STAR Multifamily New Construction v1.1 vs 2012 IECC Building - CZ 7 - Config. B - Gas

Measure	2012 IECC Baseline	ENERGY STAR v1.1	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						
Infiltration	3 ACH50	0.30 CFM50 / SF Shell	-	-	-	-
Cooling Equipment	13 SEER Central AC	13 SEER Central AC	-	-	-	-
Heating Equipment	80 AFUE Gas Furnace	95 AFUE Gas Furnace	\$7.85	576	kBtu/h	\$4,522
Duct Location (Top Units)	Unconditioned Space	Ductwork Located in Conditioned Space	\$0.39	7200	Cond. Floor Area (ft ²)	\$2,808
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.67 EF Gas DHW, 40 Gal. (Power Vent)	\$169.25	18	Unit	\$3,047
Lighting	75% Fluorescent Lighting	90% ENERGY STAR CFLs	\$2.80	72	Lamps	\$202
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	18	Dishwasher	\$180
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	18	Refrigerator	\$90
Clothes Washer	Standard Efficiency Clothes Washer	ENERGY STAR Clothes Washer	\$163.48	18	Clothes Washer	\$2,943
Clothes Dryer	Standard Efficiency Clothes Dryer	ENERGY STAR Clothes Dryer	\$85.44	18	Clothes Dryer	\$1,538
Water Fixtures	Standard Water Fixtures	Low-Flow WaterSense Fixtures	\$16.56	18	Unit	\$298
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR ERI Target						\$15,626
Rater Field Checklist: Thermal Enclosure System						
Ceiling Insulation	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	7,200	Ins. Surface Area (ft ²)	\$536
Above-Grade Wall Insulation*	R-20 + 5	R-20 + 5	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	15,300	Ins. Surface Area (ft ²)	\$691
Foundation Insulation	R-10, 4ft	R-15, 2 ft	-\$1.60	360	Slab Perimeter (ft)	-\$576
Windows	U-Value: 0.32 / SHGC: 0.4	U-Value: 0.27 / SHGC: 0.4	\$1.04	2,111	Window Area (ft ²)	\$2,191
Doors	R-3.1	R-5.9	\$22.06	18	Door	\$397
Additional Checklist Measures: Rater Verification						\$425
Sub-Total of Thermal Enclosure System Checklist						\$3,665
Rater Field Checklist: HVAC System						
Duct Sealing - Total Leakage	4 CFM per 100 ft ² of CFA @ Rough-In	4 CFM per 100 ft ² of CFA @ Rough-In	-	-	-	-
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	No Ins.; Ducts in Conditioned Space	-\$1.43	2,304	Duct Surface Area (ft ²)	-\$3,283
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Total Duct Leakage Tests, Etc.						-\$775
Sub-Total of HVAC System Checklist						-\$4,058
Rater Design Review Checklist						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						\$175
HVAC Design Report						
Ventilation	ENERGY STAR Exhaust Fan with Controller	ENERGY STAR Exhaust Fan with Controller	-	-	-	-
Additional Checklist Measures: Checklist Completion by Designer						\$165
Sub-Total of HVAC Design Report						\$165
HVAC Functional Testing Checklist						
Sub-Total of HVAC Functional Testing Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						\$1,625
Water Management System Requirements						
Sub-Total of Water Management System Requirements: Foreman's Completion of Checklist						\$0
Energy Modeling						
Sub-Total of Cost of Energy Modeling Performed by Rater						\$1,650
Total Incremental Cost for the Building						\$18,848

*The IECC value for this measure was used for modeling the ENERGY STAR units because the IECC was more stringent than the ENERGY STAR Reference Design.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 3: Incremental Cost & Savings of the National Rater Field Checklist: Thermal Enclosure System

Average Estimated Incremental Cost

The requirements of the Thermal Enclosure System sections of the National Rater Field Checklist (Rater-F TES) were grouped into two categories – those that impact the ERI and those that do not. This is an important distinction because partners have expressed an interest in knowing what the cost of the checklist is, yet many of the requirements are efficiency measures that might also be included as part of a standard ERI rating.

As can be seen in Exhibits 4 through 16, the net cost for complying with the Rater-F TES was estimated to be between \$3,665 and \$19,580 per building, depending on Climate Zone, and encompasses both requirements that improve the ERI and those that do not.

Excluding the requirements that only improve the ERI, the remaining checklist requirements address Rater verification of the Rater-F TES and result in a net cost of \$425 in all Climate Zones.

The Rationale section, below, discusses the costs for all measures in more detail.

Average Estimated Incremental Savings

The savings for any requirement of the Rater-F TES that impacts the ERI was captured within REM/Rate. The only impact that was estimated outside of REM/Rate was to increase the heating and cooling consumption for each baseline unit by 5% to account for the increased convective losses because these baseline units are not required to achieve the Grade I insulation installation or fully-aligned air barriers that are required by the Rater-F TES. By minimizing gaps, voids, and compressions in the ENERGY STAR units, fewer air spaces will be created within the wall cavity, thereby reducing the potential for convective loops.

The Rationale section, below, discusses the approach to estimating savings for all measures in more detail.

Rationale

Section 1 of the Rater-F TES requires high-performance fenestration. The incremental cost for improving fenestration from the requirements of the 2012 IECC to ENERGY STAR certified windows was captured in Exhibits 4 through 16. The energy savings from this measure were captured within REM/Rate.

Section 1 also requires quality-installed insulation that meets the ENERGY STAR Multifamily Reference Design levels and achieves Grade I insulation installation (or Grade II for surfaces that contain a layer of continuous, air impermeable insulation that meets a minimum specified insulation level). However, for this analysis it was assumed that all assemblies in ENERGY STAR Multifamily New Construction buildings achieved Grade I insulation.

The ENERGY STAR Multifamily Reference Design insulation levels were either 1) more stringent than the 2012 IECC requirement, 2) equally stringent, or 3) less stringent. When more stringent, there was an incremental cost and savings associated with more insulation. When equally stringent, no incremental cost or energy savings were estimated. When the ENERGY STAR Multifamily Reference Design insulation levels were less stringent than the 2012 IECC requirement, the ENERGY STAR assemblies were modeled with the same insulation as the 2012 IECC requirement assuming this would be required for code compliance and therefore no incremental cost or energy savings were estimated.

In contrast, an incremental cost was estimated for achieving Grade I insulation installation. This incremental cost was estimated for each unit configuration and each relevant assembly (i.e., ceiling, wall) as shown in Exhibits 4 through 16. The conductive savings from Grade I insulation installation were estimated within REM/Rate. In addition, achieving Grade I insulation installation will minimize gaps, voids, and compressions, resulting in fewer air spaces within assemblies and reduced convective losses. As noted above, the heating and cooling consumption for each baseline unit was increased by 5% to account for the increased convective losses because these baseline units are not required to meet these requirements.

Section 2 requires fully-aligned air barriers in walls, floors, and ceilings. These details are generally implicitly or explicitly required by the 2012 IECC. For example, code requires that the exterior thermal envelope insulation for framed walls be installed in substantial contact and continuous alignment with the building envelope air barrier, that insulation be installed to maintain permanent contact with the underside of subfloor decking, that a minimum of a 1-inch space be provided between insulation and the roof sheathing to not block the free flow of air at the location of the vent, and that air barriers in any dropped ceiling or soffit be substantially aligned with insulation. Because these requirements are required by code, no incremental cost or energy savings were estimated. The one detail not required by code that is required by this Section of



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

the Rater-F TES is that, in Climate Zones 4 through 8, an air barrier must be included on the interior surface of wall insulation. This is anticipated to be accomplished by achieving Grade I insulation installation, per Section 1, which will minimize gaps, voids, and compressions that would prevent alignment with drywall. Therefore, no additional incremental cost or energy savings were estimated for this Section.

Section 3 requires the use of details that reduce thermal bridging. Several of these details are required by the 2012 IECC, such as extending full height uncompressed insulation over the wall top plate at the eaves and requiring that access be provided to all equipment in attics that prevents damaging or compressing the insulation beneath. Section 3 also requires that a strategy be selected to reduce thermal bridging in above-grade walls, which is not required by code. For this analysis, it was assumed that the 'advanced framing' strategy would be used which allows for exceptions for structural framing members. It was assumed that these additional structural framing members would result in a framing fraction similar to a code-built building, and a default value of 23% for 16 inch on-center Standard walls in ANSI / RESNET / ICC 301-2014, January 2016. Therefore, no additional incremental cost or energy savings were estimated for this Section.

Section 4 requires air sealing of penetrations, cracks, and other openings in the unit's thermal enclosure system. These details largely overlap with the 2012 IECC, which requires that all joints, seams, and penetrations; other sources of infiltration; and utility penetrations be caulked, gasketed, weather-stripped or otherwise sealed with an air barrier material, suitable film or solid material. Code specifically requires that the junction of the foundation and sill plate be sealed (but does not require a gasket); that the space between window/door jambs and framing be sealed; and that duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space be sealed. For recessed luminaires, code requires that they be IC-rated and labeled as meeting ASTM E283 and be sealed with a gasket or with caulk between the housing and the interior wall or ceiling covering. Finally, code requires that access doors from conditioned spaces to unconditioned spaces be weather-stripped and insulated to a level equivalent to the insulation on the surrounding surfaces.

As a result of these code requirements, no incremental costs were estimated for the air sealing measures in Section 4, and it was assumed that these requirements will largely be met to achieve the code-required infiltration limit of 3 or 5 ACH50. Also note that no incremental cost was estimated for the blower door test, as it was assumed that a blower door test will be used to demonstrate compliance with the code-required infiltration limits. No incremental cost was estimated in Exhibits 4 through 16 to account for meeting the infiltration rate included in the ENERGY STAR Multifamily Reference Design for Version 1.1, as it is expected that the code limits of 3 or 5 ACH50 are more stringent than the ENERGY STAR limit of 0.30 CFM50 / ft² of enclosure. The energy impact of a 2012 IECC infiltration rate that was more stringent than the ENERGY STAR level was captured within REM/Rate.

Finally, despite the fact that many of the requirements in the Rater-F TES are also required by code, the 2012 IECC does not require third-party verification of these details by a Home Energy Rater. It is estimated that this will require two inspections plus transportation time. Combined, this was estimated to take an average of 8 hours per building. At a labor rate of approximately \$55 per hour for a Home Energy Rater, this was estimated to cost \$437.

In summary, the costs for the measures that impact the ERI are itemized in Exhibits 4 through 16. The additional cost for Rater verification of the Rater-F TES sum to \$437 for all Climate Zones, and was rounded to the nearest \$25, for a final estimated cost of \$425.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 4: Incremental Cost & Savings of the National Rater Field Checklist: HVAC System

Average Estimated Incremental Cost

The requirements of the HVAC System sections of the National Rater Field Checklist (Rater-F HVAC) were grouped into two categories – those that impact the ERI and those that do not. This is an important distinction because partners have expressed an interest in knowing what the cost of the checklist is, yet several of the requirements are efficiency measures that might also be included as part of a standard ERI rating.

As can be seen in Exhibits 4 through 16, the net cost for complying with the Rater-F HVAC was estimated to be between cost savings of -\$2,183 and a cost savings of -\$4,058, depending on Climate Zone, and encompasses both requirements that improve the ERI and those that do not.

Excluding the requirements that impact the ERI, the remaining checklist requirements address Rater verification and other requirements, which are estimated to cost \$1,025 for gas and electric buildings in Climate Zones 1-3, a savings of \$775 for gas buildings in Climate Zone 4, a savings of \$850 in gas buildings in Climate Zones 4-7, and \$950 in electric building in Climate Zones 4-7.

The Rationale section, below, discusses the costs for all measures in more detail.

Average Estimated Incremental Savings

Because the requirements of the HVAC System section of the Rater-F simply help ensure that the heating, cooling, ventilation, and duct system requirements contained in the National HVAC Design Report have been met, no additional energy savings were associated with HVAC System section of the Rater-F.

Rationale

Section 5 of the Rater-F requires Raters to check the manufacturer and model number of installed equipment against the HVAC Design Report. It was estimated that the review will take 7 minutes per unit and will be performed on 9 units in the building with sampling. At a labor rate of \$55 per hour for a Home Energy Rater, this was estimated to cost \$57. Raters are also required to duplicate the static pressure test conducted by the contractor. It is estimated that the Rater can conduct this test while on-site for their final inspection and can complete the test in approximately 10 minutes per unit and performed on 9 units in the building with sampling. Therefore, this was estimated to cost \$82 at a labor rate of \$55 per hour.

Section 5 of the Rater-F also requires the National HVAC Functional Testing Checklist(s) be collected. However, this is not required where credentialed HVAC contractors complete the National HVAC Functional Testing Checklist. It was assumed that a credentialed HVAC contractor would complete this checklist so no incremental cost was estimated for the Rater to collect the documentation. The estimated time required to verify that the HVAC contractor is credentialed is 5 minutes. At a labor rate of \$55 per hour for a Home Energy Rater, this was estimated to cost \$5.

Section 5 also contains requirements for stairwell motorized dampers, freeze protection systems, snow- and ice-melting systems, and hydronic distribution. On average, it is not expected that buildings considered in the analysis will have these systems, and therefore no incremental cost was assumed for compliance.

Section 5 and Section 6 also requires that a Rater verify thermostatic controls, duct insulation levels be visually verified, and ductwork be inspected for kinks, sharp bends, compressions. It is expected that this visual inspection will take 5 minutes per unit and will be performed on 9 units with sampling. At a labor rate of \$55 per hour for a Home Energy Rater, this was estimated to cost \$41.

Next, Section 6 requires that the bedrooms in the unit be pressure-balanced for rooms with a design supply airflow ≥ 150 CFM. It was assumed that none of the bedrooms would have a design airflow greater than 150 CFM, and, therefore, no incremental cost was estimated for this task.

Section 6 requires that ducts be tested and verified to meet air leakage limits. The ENERGY STAR Multifamily Reference Design for Version 1.1 is based upon all ducts being located within conditioned space. Since the 2012 IECC exempts units from this test for ducts that are within conditioned space, there are incremental costs for units on all floors. It was estimated that the test will take 30 minutes per unit and will be performed on 9 units in the building with sampling. At a labor rate of \$55 per hour for a Home Energy Rater, this was estimated to cost \$246. Additionally, the duct leakage limits in the 2012 IECC are equally stringent to those in the Rater-F for testing at rough-in with one or two ducted returns. Therefore, there was no incremental cost for meeting the duct leakage limits in the Rater-F included in Exhibits 4 through 16.



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Section 6 also requires inspection of common space supply, return, and exhaust ductwork; and duct leakage testing of central exhaust systems. It was assumed that for the low-rise multifamily building considered in this analysis there was no incremental cost for meeting the requirements in these sections.

Section 7 requires the dwelling unit mechanical ventilation rate to be measured. Verifying that the Rater-measured ventilation rate is within ± 15 CFM or $\pm 15\%$ of the design value on the National HVAC Design Report was estimated to take between 5 and 20 minutes. At a labor rate of \$55 per hour, the test will cost between \$5 and \$18 per unit. By averaging the two values, a cost of \$11 was estimated per unit. When performed on 9 units in the building with sampling, the total cost was estimated at \$103. Note that the incremental cost of the mechanical ventilation system itself is accounted for with the National HVAC Design Report.

Section 7 also defines dwelling unit mechanical ventilation control, fan efficiency, inlet location, and sound requirements, which are not addressed in the 2012 IRC. The requirements were assumed to only apply to units with supply ventilation in Climate Zones 1-4. These quick visual inspections were estimated to take 10 minutes per unit and be performed on 9 units in the building with sampling. At a labor rate of \$55 per hour, the cost for verification was \$82.

Section 8 primarily defines airflow requirements for kitchen and bath exhaust fans. While the 2012 IRC requires bath and kitchen exhaust fan airflow rates that are consistent with the requirements of the Rater-F, it does not require a third-party to verify the airflow rates. Because airflow must be verified by the Rater, an incremental cost was estimated to purchase a bath fan with 70 CFM of rated airflow rather than 50 CFM, to help ensure compliance. This incremental cost was estimated to be \$11 per fan for each of the 18 units. It was estimated that it takes 10 minutes to measure the bath fan and kitchen fan exhaust requirements, and that this measurement would be performed on 9 units in the building with sampling. At a labor rate of \$55 per hour, this equates to \$82. It was assumed that verification of sound level requirements for continuously running bath fans used for mechanical ventilation occurs during the airflow test, and the sound level requirement is achieved with the bath fan upgrade so no incremental cost was assumed to achieve these limits.

Section 9 defines filtration requirements. The 2012 IRC does not explicitly require the installation of a filter, that all return air and mechanically supplied outdoor air pass through filter prior to conditioning, or that the filter access panel include a gasket or comparable sealing mechanism and fit snugly against the exposed edge of the filter when closed to prevent bypass. However, a filter is routinely included with new equipment and can be installed to meet these requirements with little to no added effort or cost. Therefore, only an incremental cost of \$5 was estimated to upgrade the filter from MERV 2 to MERV 6 for all 18 units. In addition, visual verification of these requirements by the Rater was estimated to take 5 minutes and be performed on 9 units in the building with sampling. At a labor rate of \$55 per hour, this equates to \$41.

Section 10 defines combustion safety requirements. Unlike the Rater-F, the 2012 IRC does not explicitly require power-vented or direct-vented combustion appliances, nor does it explicitly require combustion safety testing. However, for buildings in Climate Zones 1 through 3, it was assumed that the most common compliance path would be to move the combustion appliances outside the pressure boundary, such as an unconditioned mechanical room on a balcony, or to use electric space and water heating equipment. In Climate Zones 4 through 8, the most common compliance path would be to use power-vented or direct-vented combustion appliances or electric space and water heating equipment. The cost associated with upgrading to a direct-vented furnace and power-vented water heater was accounted for in Exhibits 11 through 16 for the gas fueled buildings in Climate Zones 4 through 7. For these building configurations, it was assumed that a "B-vent" metal combustion vent was replaced with a PVC side-wall combustion inlet and vent system, resulting in savings of \$100 per unit, or \$1,800 for all 18 units in the building. The remainder of Section 10 defines requirements for combustion appliances, other than cooking ranges or ovens. On average, it is not expected that units will have combustion appliances of these types and, therefore, no incremental cost was assumed for compliance.

Section 11 defines domestic hot water system requirements. It is assumed that verification of these items will take 5 minutes to verify the AHRI certificate for the model used in all the units, and 10 minutes per the 9 sampled units for the pipe insulation inspection and water delivery temperature measurements. At a labor rate of \$55 per hour, this equates to \$87, or when rounded to the nearest \$25, a final cost of \$75.

Sections 12, 13, and 14 define requirements for lighting, appliances, and a whole building energy consumption data acquisition strategy respectively. It was assumed that for the low-rise multifamily building considered in this analysis there was no incremental cost for meeting the requirements in these sections.

In summary, the costs for the measures that impact the ERI are itemized in Exhibits 4 through 16. The remaining checklist requirements address Rater verification of and other requirements and sum to \$1,026 for gas and electric buildings in Climate Zones 1-3, a savings of \$774 for gas buildings in Climate Zone 4, a savings of \$856 in gas buildings in Climate Zones 4-7, and \$944 in electric building in Climate Zones 4-7. These were rounded to the nearest \$25, for a final estimated cost of \$1,025, -\$775, -\$850, and \$950, respectively.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 5: Incremental Cost & Savings of the National HVAC Design Report

Average Estimated Incremental Cost

The requirements of the National HVAC Design Report (HVAC-D) were grouped into two categories – those that impact the ERI and those that do not. This is an important distinction because partners have expressed an interest in knowing what the cost of the checklist is, yet several of the requirements are efficiency measures that might also be included as part of a standard ERI rating.

As can be seen in Exhibits 4 through 16, the net cost for complying with the HVAC-D was estimated to be \$165.

Filling out one report manually is estimated to take 30 minutes for each unique unit, plus 30 minutes for the whole building. Assuming that for the 18 unit building, with no common systems to document, there are 4 separate load calculations, the time to complete for the entire building is 2.5 hours. At a labor rate of \$66 per hour, the total labor cost equates to \$166, which was rounded to the nearest \$5, for a final estimated cost of \$165.

The Rationale section, below, discusses the costs for all measures in more detail.

Average Estimated Incremental Savings

Because code requires that heating and cooling design loads be properly calculated, that equipment capacity be properly selected, and that ducts be properly designed, no energy savings were associated with these requirements.

In addition, no energy impacts were associated with meeting the filter requirements of ASHRAE 62.2-2010. However, energy use required to meet the ventilation requirements of ASHRAE 62.2-2010 was captured within REM/Rate.

The Rationale section, below, discusses all measures in more detail.

Rationale

Some Sections and Items within the HVAC-D are intended to ensure that the HVAC Designer accounts for certain program requirements of the HVAC system (e.g., mechanical ventilation, controls, duct quality installation, filtration, and bedroom pressure differential). The costs and savings associated with these features are accounted for in other checklists, so are not included in this section.

Section 1 of the HVAC-D requires the designer to provide a basic overview of their design. While not explicitly required by the 2012 IECC, providing this information does not add any incremental cost other than the time required to complete the paperwork.

Section 2 of the HVAC-D requires that a dwelling unit mechanical ventilation system be designed and installed, which is also required by the 2012 IRC.

In Climate Zones 1 through 4, all units contained a ventilation system comprising a ventilation controller for 62.2 compliance, a 6" round motorized fresh air damper to provide ventilation air to the return-side of the HVAC system, a switch that allows the bathroom fan to ventilate when the HVAC fan is not in heating or cooling mode, and an ENERGY STAR certified bathroom exhaust fan. Units with this system use the supply ventilation system when the HVAC air handler is running in heating or cooling mode, and the bathroom exhaust fan system when the HVAC air handler is not running. The run time of both the HVAC fan and the bathroom exhaust fan is managed by the 62.2 controller, which communicates with the bath fan using the switch.

For Climate Zones 5 through 7, all units contained a ventilation system comprising an ENERGY STAR certified bathroom exhaust fan and bath fan controller. Units with this system use the bathroom exhaust fan to provide all required ventilation.

There were no incremental costs for either of these ventilation systems included in Exhibits 4 through 16, due to the similar requirements in the 2012 IECC. The energy impact from the ventilation load and the fan power were captured within REM/Rate for both 2012 IECC and ENERGY STAR units.

Sections 3 through 5 of the HVAC-D require that designers properly calculate heating and cooling design loads (generally per ACCA Manual J), select right-sized equipment capacities (generally per ACCA Manual S), and design the duct system (generally per ACCA Manual D). No incremental costs or savings were estimated specifically for these tasks, as they are required by the 2012 IRC. The baseline units and the ENERGY STAR units were assumed to be right-sized per code requirements, however the cooling equipment capacity of the ENERGY STAR units were assumed to be the same capacity as the baseline units and still meet sizing limits.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

The low-rise building in this analysis was considered to have no common spaces, central systems, or hydronic equipment, so no incremental cost or savings were associated with Items in the HVAC-D for these spaces and systems.

In summary, the costs for the measures that impact the ERI are itemized in Exhibits 4 through 16. The additional cost for the completion of the HVAC-D by the designer is estimated to be \$165. EPA is working to automate this task, such that it will require negligible time or money to complete. In the interim, however, many designers will complete this task manually. Filling out one report manually is estimated to take 30 minutes for each unique unit, plus 30 minutes for the whole building. Assuming that for the 18 unit building with no common systems to document, there are 4 separate load calculations, the time to complete for the entire building is 2.5 hours. At a labor rate of \$66 per hour for a mechanical engineer, the total labor cost equates to \$166, which was rounded to the nearest \$5, for a final estimated cost of \$165.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 6: Incremental Cost & Savings of the National Rater Design Review Checklist

Average Estimated Incremental Cost

The requirements of the National Rater Design Review Checklist (Rater-D) do not directly affect the ERI. As can be seen in Exhibits 4 through 16, the net cost for complying with the Rater-D was estimated to be \$175.

The Rationale section, below, discusses the costs for all measures in more detail.

Average Estimated Incremental Savings

While the tasks required on the Rater-D add value, there are no estimated savings directly associated with them.

Rationale

The Rater-D requires the Rater to verify that the builder or developer is an ENERGY STAR partner, to verify that the fenestration and insulation specified in the energy rating file complies with the program's requirements, to collect the HVAC Design Report, and to review the report to ensure that the documented HVAC design falls within the tolerances of the program.

Therefore, the incremental costs of this checklist are all related to the labor of the Rater. The estimated time required to verify that the builder or developer is an ENERGY STAR partner is 1 minute. Verification that the fenestration and insulation meets program requirements is estimated to take 8 minutes for the entire building. It is assumed to take one hour on average to collect the HVAC Design Report. Lastly, it is assumed that there are 4 unique load calculations for the building and that 30 minutes are required to review each. The estimated time to review is therefore 2 hours for the entire building. Finally, Section 5 of the Rater-D contains recommended, but not required verification tasks. Therefore, no additional incremental costs were estimated for Section-5 of the Rater-D.

In summary, the tasks on the Rater-D require 3 hours and 9 minutes per building. At a labor rate of \$56 per hour, the total labor cost equates to \$172. This was rounded to the nearest \$25, for a final estimated cost of \$175.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 7: Incremental Cost & Savings of the National HVAC Functional Testing Checklist

Average Estimated Incremental Cost

The requirements of the National HVAC Functional Testing Checklist (HVAC-FT) do not affect the ERI. In total, the average incremental cost of the HVAC-FT was estimated to be \$1,625.

The Rationale section, below, discusses the costs for all measures in more detail.

Average Estimated Incremental Savings

The only energy savings of the HVAC-FT were estimated outside of REM/Rate and account for complying with the functional testing requirements for heating and cooling systems (i.e., refrigerant charge test and air handler airflow test). These savings were estimated to be 6.9% of heating consumption for air-source heat pumps and 6.9% of cooling consumption for heat pumps and air conditioners.

The Rationale section, below, discusses the approach to estimating savings for all measures in more detail.

Rationale

There are several entities that may complete the HVAC-FT, one of which is a contractor credentialed, prior to installation of HVAC systems, by an HVAC Quality Installation Oversight Organization (HQUITO). For the purposes of this analysis, it was assumed this is who would complete the checklist because prior to the development of this program, 3-story buildings were eligible for the ENERGY STAR Certified Homes program, where a credentialed HVAC contractor was required to complete this work. Therefore, it is likely that a credentialed HVAC contractor would continue to work on these types of buildings under this program. Two HQUITO's are available, each with its own fee structure and an overall cost per home or unit that is dependent on the annual number of homes and units that the contractor installs systems in. Costs per home or unit can range from less than \$10 to greater than \$100. For a contractor installing systems in 25 homes or units per year, the costs per home or unit after the first year is approximately \$24, assuming no significant quality assurance issues. For the entire 18 unit building, the total cost would be \$432.

Section 1 of the HVAC-FT requires the contractor to provide a basic overview of the system they're performing functional testing on. While not explicitly required by the 2012 IECC, providing this information does not add any incremental cost other than the time required to complete the paperwork.

The HVAC-FT requires several HVAC functional tests to be completed, which are not explicitly required by the 2012 IRC. In Section 2, the contractor is required to verify the refrigerant charge. Using a digital manifold, this is estimated to take 20 minutes for each of the 18 units. In Section 3, the contractor is required to assess the air handler airflow using the measured static pressure and fan-speed setting. This was estimated to take 15 minutes for each of the 18 units. Section 4 recommends, but does not require, that the contractor measure and balance the register airflow. Because this is only a recommendation, no incremental cost was assumed. It is estimated to take 10 minutes per unit to complete the functional testing of the indoor / terminal units in Section 5, and that this would be performed on 9 units in the building with sampling. Lastly, it was estimated to take 5 minutes to fill out the checklist with the information gathered in the field for each of the 18 units. The total time for functional testing (i.e., measuring refrigerant charge, using static pressure and the fan-speed setting to approximate air handler airflow, other functional testing steps, and completing the checklist) was estimated to take 13 hours and 30 minutes for the entire 18 unit building. At a labor rate of \$88 per hour for an HVAC Contractor, this translates to \$1,189. With the addition of the \$24 per unit credential fee, this sums to a total cost of \$1,621. This was rounded to the nearest \$25, which is \$1,625.

Sections 6, 7, 8, and 9 contain requirements for VRF outdoor units, central boilers, cooling towers, and chillers. The low-rise multifamily building considered in this analysis does not contain any equipment applicable to these sections, therefore there was no incremental cost for meeting the requirements in these sections.

Energy savings from the HVAC functional testing tasks in Sections 2 and 3 were based upon the following paper: Pigg, S. (2008). Central Air Conditioning in Wisconsin: A Compilation of Recent Field Research (Report Number 241-1). Energy Center of Wisconsin.

Specifically, a savings factor of 4.0% was estimated for the testing of the refrigerant charge. This was derived from the average savings cited on page 34, which states: "If one combines this charge error distribution with the performance curves in Figure 32—together with an assumption that the majority of new units are TXV systems—aggregate savings from tuning refrigerant charge appears to be on the order of 3 to 5 percent."



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

In addition, a savings factor of 2.9% was estimated for the testing of system airflow. This was derived in part from the average savings cited on page 37, which states: “The average EER improvement from these airflow adjustments was +5.6 percent.” Because this savings amount represents only the subset of systems for which airflow had to be adjusted, and not the overall population of systems, it was reduced to account for this subset. Table 9 of the paper indicates that 52% of the new systems required airflow adjustments, as summarized below:

Description	All Homes	% With Improper Airflow
New, SEER 10-13	10	20%
New, SEER 14+	30	63%
Total	40	52%

Therefore, the savings factor of 2.9% was derived by multiplying 5.6% savings by 52% of systems requiring airflow adjustment.

Combined, this results in a savings factor of $4.0\% + 2.9\% = 6.9\%$. This factor was applied to both the heating consumption of air-source heat pumps and the cooling consumption of both air-source heat pumps and air conditioners.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 8: Incremental Cost & Savings of the National Water Management System Req.'s

Average Estimated Incremental Cost

The requirements of the National Water Management System Requirements (WMS) do not impact the ERI. Furthermore, because they are also required by the 2012 IECC, there is estimated to be no net cost for meeting these requirements.

The Rationale section, below, discusses the measures in more detail.

Average Estimated Incremental Savings

Energy savings were not anticipated as a result of implementing the WMS, as the measures implemented are focused on water management details.

Rationale

Section 1 defines water management details applicable to the site and to the building's foundation, Section 2 defines details applicable to the wall assembly, Section 3 defines details applicable to the roof assembly, and Section 4 defines requirements that help manage water in building materials. These requirements are aligned with the requirements of the 2012 IRC. Therefore, no incremental cost was estimated for meeting these code-required checklist items. Furthermore, since the WMS is simply a list of requirements and not a formal checklist that must be completed, there is no cost associated with documenting compliance with the requirements.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 9: Incremental Cost of Modeling ERI Certification Path

Average Estimated Incremental Cost

There are three paths available in the certification process to meet performance requirements. These are the Prescriptive Path, ERI Path, and ASHRAE Path. It was assumed that the ERI Path would most likely be used for a low-rise multifamily building considered in this analysis. For this path, projects must use a software rating tool approved by an EPA-Approved Verification Oversight Organization (VOO) to determine the ENERGY STAR ERI Target, which is the highest ERI value that each rated unit may achieve to earn the ENERGY STAR. It was assumed that this would be done by creating 6 base units that would be copied and edited in the software for all 18 units in the building. These base units would take no more than 2 hours each to create. It would then take an additional 45 minutes to create software files for each of the other 12 units. Finally, there would be another 30 minutes for each of the 18 units to finalize inputs after the final field inspection and testing. This results in a total of 30 hours to determine and evaluate the ERI Target for all 18 units. At a labor rate of \$55 per hour for a Home Energy Rater, this was estimated to cost \$1,640. This was rounded to the nearest \$25, for a final estimated cost of \$1,650.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Section 10: Cost References

A. Thermal Enclosure System

Air Sealing

Reference	NREL National Residential Energy Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction.

Doors

Reference	NREL National Residential Energy Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction. Costs linearly interpolated by U-factor using the following entries: <ul style="list-style-type: none"> Swinging Entry, Opaque, Steel Frame, U-Value: 0.55 Swinging Entry, Opaque, Fiberglass Frame, U-Value: 0.21

Framing

Reference	RS Means Construction Cost Data 2010
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Framing costs based upon RS Means Line Number 06 11 10.40 6145, representing 2x4 8.5 ft. high studs where applicable, and RS Means Line Number 06 11 10.40 6165, representing 2x6 8.5 ft. high studs where applicable. All costs prorated by 12.9% to adjust for inflation between 2010 and 2016 using RS Means 2016 Cost Construction Index.

Insulation Installation

Source	RS Means Construction Cost Data 2010
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Incremental cost for going from Grade III to Grade I wall insulation: <ul style="list-style-type: none"> In 2x4 wall assemblies: Assumed to cost 35% more than labor rate for RS Means Line Number 07 21 16.20 0080, representing batt insulation. In 2x6 wall assemblies: Assumed to cost 25% more than labor rate for RS Means Line Number 07 21 26.10 0020, representing blown insulation. Incremental cost for going from Grade II to Grade I ceiling insulation assumed to cost 10% more than labor rate for RS Means Line Number 07 21 16.10 2210, representing blown insulation. Incremental cost for going from Grade II to Grade I floor insulation assumed to cost 25% more than labor rate for RS Means Line Number 07 21 16.10 2215, representing blown insulation. All labor rates prorated by 12.9% to adjust for inflation between 2010 and 2016 using RS Means 2016 Cost Construction Index.

Radiant Barrier

Source	7/16 in. x 4 ft. x 8 ft. OSB Sheathing http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # 386081
	7/16 in. x 4 ft. x 8 ft. OSB TechShield Radiant Barrier



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

	http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # 22493
Accessed	September 2016
Notes	<ul style="list-style-type: none"> N/A.

Windows

Reference	NREL National Residential Energy Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/ Market data from ENERGY STAR Program Requirements for Residential Windows, Doors, and Skylights
Accessed	June 2016
Notes	<ul style="list-style-type: none"> A two-step process was used to estimate the incremental costs for windows, reflecting a dearth of data for this measure. In the first step, data from the NREL National Residential Energy Efficiency Measures Database was used to create two multivariate regression equations. Because the database represents retrofit costs, the low-end of the cost range was used as inputs into the regression. Each equation represented the cost per square foot of window, using the U-factor and SHGC as inputs. The first equation was created using the NREL data for insulated frames, representing windows with a U-factor ≤ 0.32, and is as follows: $y = [\text{SHGC}] \times (-0.688) + [\text{U-value}] \times (-96.33) + 54.5$. The second equation was created using the NREL data for non-metal frames, representing windows with a U-factor > 0.32, and is as follows: $y = [\text{SHGC}] \times (-1.32) + [\text{U-value}] \times (-8.36) + 25.8$. Even using the low-end of the retrofit cost data from the NREL database, the resulting regression equations over-predicted the cost of windows relative to incremental cost data collected during the development of Version 5 of the ENERGY STAR Program Requirements for Residential Windows, Doors, & Skylights. The incremental cost data reported for upgrading from the 2009 IECC window requirements to Version 5 of the ENERGY STAR Program Requirements for Residential Windows, Doors, & Skylights ranged from zero to \$0.66 per square foot. In contrast, the highest incremental cost predicted by the unmodified regression equations was \$3.06 per square foot in Climate Zones 5 through 7. Therefore, the second step discounted the costs predicted by the unmodified regression equations by applying a factor to align with the reported costs. That is to say that the \$3.06 per square foot predicted cost was reduced to \$0.66 per square foot by applying a factor of 21.5%. This factor was then applied to both regression equations. Using these modified regression equations, the cost of each baseline and ENERGY STAR window was calculated using the U-factor and SHGC, with the difference between the two representing the incremental cost.

Slab Insulation above Code Levels

Source	NREL National Residential Energy Efficiency Measures Database v3.1.0 http://www.nrel.gov/ap/retrofits/
Accessed	September 2018
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction. Costs were determined by rigid insulation R-value and depth specified.

Ceiling Insulation above Code Levels

Source	NREL National Residential Energy Efficiency Measures Database v3.1.0 http://www.nrel.gov/ap/retrofits/
Accessed	September 2018
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Wall Sheathing Insulation above Code Levels

Source	NREL National Residential Energy Efficiency Measures Database v3.1.0 http://www.nrel.gov/ap/retrofits/
Accessed	September 2018
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction.

Wall Cavity Insulation above Code Levels

Source	Ultra Touch R-19 Denim Insulation Batts 23 in. x 93 in http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # 10003-01923
	Ultra Touch R-21 Denim Insulation Batts 23 in. x 93 in. http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # 10003-02123
	Knauf Insulation R-19 Kraft Faced Fiberglass Insulation Batt 15 in. W x 94 in. L http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # 5001500
	Knauf Insulation R-21 Kraft Faced Fiberglass Insulation Batt 15 in. W x 93 in. L http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # 5001671
	Owens Corning R-19 EcoTouch PINK Kraft Faced Fiberglass Insulation Batt 15 in. x 93 in. http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # BF40
Owens Corning R-21 EcoTouch PINK Kraft Faced Fiberglass Insulation Batt 15 in. x 93 in. http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # BF60	
Accessed	September 2018
Notes	<ul style="list-style-type: none"> Average incremental cost from a R-19 batt to a R-20 batt from 3 insulation manufacturers.

B. Space Conditioning Equipment & Filter

Air-source Heat Pump

Reference	NREL National Residential Energy Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction. Costs were linearly interpolated by SEER and HSPF.

Central Air Conditioner

Reference	NREL National Residential Energy Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction. Costs were linearly interpolated by SEER.

Filter

Reference	True Blue 12 in. x 24 in. x 1 in. Fiberglass FPR 1 Air Filter (MERV 2) http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # 112241
	Honeywell 12 in. X 24 in. X 1 in. Allergen Plus Pleated FPR 7 Air Filter (~MERV 6) http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # 205164337



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Accessed	September 2016
Notes	<ul style="list-style-type: none"> N/A.

Gas Furnace

Reference	NREL National Residential Energy Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction. Costs were linearly interpolated by AFUE.

C. Ventilation Equipment

Exhaust Ventilation System

Reference	<p>SmartExhaust Toggle Controller http://www.aircyclor.com/products/smartexhaust</p> <p>Air King 50 CFM Bath Exhaust Fan Without Light http://www.Homedepot.com, Gulfgate Mall Store #6509 (Houston), Model # AS54</p> <p>Air King 50 CFM Bath Exhaust Fan With Light http://www.Homedepot.com, Gulfgate Mall Store #6509 (Houston), Model # ASLC50</p> <p>Air King 80 CFM ENERGY STAR Certified Bath Exhaust Fan Without Light http://www.Homedepot.com, Gulfgate Mall Store #6509 (Houston), Model # AK80</p> <p>Air King 100 CFM ENERGY STAR Certified Bath Exhaust Fan Without Light http://www.Homedepot.com, Gulfgate Mall Store #6509 (Houston), Model # AK100L</p>
Accessed	September 2016
Notes	<ul style="list-style-type: none"> Included in buildings in Climate Zones 5-7. The average incremental cost between the two non-ENERGY STAR certified and two ENERGY STAR certified bath exhaust fans was first calculated. Next, the cost of the SmartExhaust Toggle Controller was added to this incremental cost.

Supply Ventilation System

Reference	<p>AirCycler g2 http://www.aircyclor.com/products/aircyclor-g2</p> <p>Honeywell EARD6TZ 6" Round Motorized Fresh Air Damper http://www.supplyhouse.com/Honeywell-EARD6TZ-6-Round-TrueZONE-Motorized-Fresh-Air-Damper</p> <p>AirCycler FanConnect http://www.aircyclor.com/products/fanconnect</p> <p>Air King 50 CFM Bath Exhaust Fan Without Light http://www.Homedepot.com, Gulfgate Mall Store #6509 (Houston), Model # AS54</p> <p>Air King 50 CFM Bath Exhaust Fan With Light http://www.Homedepot.com, Gulfgate Mall Store #6509 (Houston), Model # ASLC50</p> <p>Air King 80 CFM ENERGY STAR Certified Bath Exhaust Fan Without Light http://www.Homedepot.com, Gulfgate Mall Store #6509 (Houston), Model # AK80</p>
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ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

	Air King 100 CFM ENERGY STAR Certified Bath Exhaust Fan Without Light http://www.Homedepot.com , Gulfgate Mall Store #6509 (Houston), Model # AK100L
Accessed	September 2016
Notes	<ul style="list-style-type: none"> • Included in buildings in Climate Zones 1-4. • The ventilation system costs are comprised of an AirCycler g2 controller for 62.2 compliance, a 6" round motorized fresh air damper to provide ventilation air to the return-side of the HVAC system, a FanConnect switch that allows the bathroom fan to ventilate when the HVAC fan is not in heating or cooling mode, and the incremental cost between a non-ENERGY STAR certified and ENERGY STAR certified bath exhaust fan.

D. Ductwork

Duct sealing

Reference	NREL National Residential Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/
Accessed	June 2016
Notes	<ul style="list-style-type: none"> • Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction. • Full costs from database were first normalized to the cost per 1% reduction in leakage relative to fan airflow. Then, because the requirements in code and the ENERGY STAR program are defined as a leakage limit per 100 sq. ft. of conditioned floor area, rather than as a % of fan airflow, the units were converted using the average cooling equipment capacity (1.5 tons), and average fan airflow (375 CFM per ton in CZ 1-4 and 400 CFM per ton in CZ 5-7). Finally, the normalized cost was multiplied by the change in leakage to arrive at the incremental cost. • A duct surface area of 384 ft² was assumed using the default area reported in REM/Rate v15.7 for a 1,200 sq. ft. 1-story unit with one return register.

Transfer Grille

Reference	Tamarack Return Air Pathway 12x6" New Construction http://www.tamtech.com/home-featured-1/tamarack-perfect-balance-interior-door-air-transfer-grille-with-sound-and-light-mitigation Model # TTi-RAP-Di
Accessed	June 2016
Notes	<ul style="list-style-type: none"> • Contents include 2-white interior grilles, 1-galvanized frame, and 1-interior baffle.

Duct Location

Reference	"Low Cost Interior Duct System for High Performance Homes in Hot Climates." FSEC, 2010. https://aceee.org/files/proceedings/2010/data/papers/1938.pdf
Accessed	June 2016
Notes	<ul style="list-style-type: none"> • Cost of \$0.39 / ft² of conditioned floor area used from conclusion of report.

Duct Insulation

Reference	NREL National Residential Energy Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/
Accessed	June 2016
Notes	<ul style="list-style-type: none"> • Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

E. Domestic Hot Water Equipment

Electric Water Heater

Reference	NREL National Residential Energy Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction. Costs linearly interpolated by Energy Factor (EF).

Gas Water Heater

Reference	NREL National Residential Energy Efficiency Measures Database v3.0.0 http://www.nrel.gov/ap/retrofits/
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction. Costs were linearly interpolated by Energy Factor (EF). Additional incremental cost for power venting capability in CZ 4-8 was estimated to be \$150.

F. Appliances & Lighting

Dishwasher

Reference	Savings Calculator for ENERGY STAR Qualified Appliances https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Incremental cost between standard-sized average new non-qualified and ENERGY STAR qualified dishwasher.

Lighting

Reference	Savings Calculator for ENERGY STAR Qualified Light Bulbs http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/light_bulb_calculator.xlsx
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Incremental cost between 40, 60, 75, 100, and 150 watt average new incandescent bulbs and corresponding 11, 13, 15, 23, and 40watt ENERGY STAR qualified compact fluorescent bulbs.

Refrigerator

Reference	Savings Calculator for ENERGY STAR Qualified Appliances https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
Accessed	June 2016
Notes	<ul style="list-style-type: none"> Incremental cost between 22.7 cubic ft. side-by-side average new non-qualified and ENERGY STAR qualified refrigerator, with automatic defrost.



ENERGY STAR Multifamily New Construction, Version 1.1 Cost & Savings Estimates

Clothes Washer

Reference	NREL National Residential Energy Efficiency Measures Database v3.1.0 http://www.nrel.gov/ap/retrofits/
Accessed	September 2018
Notes	<ul style="list-style-type: none"> • Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction. • Costs linearly interpolated by MEF using the following entries: <ul style="list-style-type: none"> ○ Top-Load, MEF=1.8, WF=7 ○ Top-Load, MEF=2.26, WF=4.48 ○ Top-Load, MEF=2.4, WF=3.8 ○ Top-Load, MEF=2.52, WF=3.6

Clothes Dryer

Reference	Department of Energy, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment. Residential Clothes Dryers and Room Air Conditioners. Chapter 8, Table 8.2.9 https://www.regulations.gov/document?D=EERE-2007-BT-STD-0010-0053
Accessed	September 2018
Notes	<ul style="list-style-type: none"> • Costs linearly interpolated by CEF using the following entries: <ul style="list-style-type: none"> ○ DOE Level 3, 3.73 CEF ○ DOE Level 4, 3.81 CEF ○ DOE Level 5, 4.08 CEF

Low-Flow Bathroom Faucets and Showerheads

Reference	CPUC DEER 2016 Database
Accessed	September 2018
Notes	<ul style="list-style-type: none"> • Measures used for costs were: "DHW-ShowerHd-Std", "DHW-ShowerHead-lowFlow", "DHW-FaucetAerator-Std", and "DHW-FaucetAerLowFlow-Res."

G. Labor

Source	RS Means Construction Cost Data 2010 Bureau of Labor Statistics, National Occupational Employment and Wage Estimates																			
Accessed	June 2016 (RS Means) September 2018 (BLS)																			
Notes	<ul style="list-style-type: none"> • Hourly rate listed by position: <table border="1"> <thead> <tr> <th>Cost & Savings Role</th> <th>RS Means Trade</th> <th>Hourly Rate with Overhead and Profit</th> </tr> </thead> <tbody> <tr> <td>Home Energy Rater</td> <td>'Helpers' Average</td> <td>\$55</td> </tr> <tr> <td>HVAC Assistant</td> <td>'Helpers' Average</td> <td>\$55</td> </tr> <tr> <td>HVAC Contractor</td> <td>Plumber</td> <td>\$88</td> </tr> <tr> <td>Foreman</td> <td>Foreman Average, Outside</td> <td>\$77</td> </tr> <tr> <td>HVAC Designer</td> <td>n/a</td> <td>\$66</td> </tr> </tbody> </table> <ul style="list-style-type: none"> • All labor rates prorated by 12.9% to adjust for inflation between 2010 and 2016 using RS Means 2016 Cost Construction Index. • For the role of an HVAC Designer, Bureau of Labor Statistics data was used for the mean hourly wage of a mechanical engineer in May 2016. Factors used for overhead and profit were applied using values for Foreman from RS Means. 		Cost & Savings Role	RS Means Trade	Hourly Rate with Overhead and Profit	Home Energy Rater	'Helpers' Average	\$55	HVAC Assistant	'Helpers' Average	\$55	HVAC Contractor	Plumber	\$88	Foreman	Foreman Average, Outside	\$77	HVAC Designer	n/a	\$66
Cost & Savings Role	RS Means Trade	Hourly Rate with Overhead and Profit																		
Home Energy Rater	'Helpers' Average	\$55																		
HVAC Assistant	'Helpers' Average	\$55																		
HVAC Contractor	Plumber	\$88																		
Foreman	Foreman Average, Outside	\$77																		
HVAC Designer	n/a	\$66																		



ENERGY STAR Multifamily New Construction, Version 1.1

Cost & Savings Estimates

Appendix A: Complete Savings Results for All Modeled Building Units

#	CZ	Location	Unit Type	HVAC Equipment Type	2012 IECC	ENERGY STAR MFNC Version 1.1	
					Annual Purchased Energy Costs	Annual Purchased Energy Costs	Annual Purchased Energy Savings
1	1	Miami, FL	Ground Corner	Elec. Air-Source HP	\$900	\$767	\$133 15%
2	1	Miami, FL	Middle Interior	Elec. Air-Source HP	\$849	\$726	\$124 15%
3	1	Miami, FL	Top Corner	Elec. Air-Source HP	\$981	\$772	\$209 21%
4	1	Miami, FL	Top Interior	Elec. Air-Source HP	\$932	\$738	\$194 21%
5	1	Miami, FL	Ground Corner	Gas Furnace / Elec. AC	\$878	\$729	\$149 17%
6	1	Miami, FL	Middle Interior	Gas Furnace / Elec. AC	\$827	\$688	\$139 17%
7	1	Miami, FL	Top Corner	Gas Furnace / Elec. AC	\$963	\$734	\$229 24%
8	1	Miami, FL	Top Interior	Gas Furnace / Elec. AC	\$914	\$699	\$215 23%
9	2	Tampa, FL	Ground Corner	Elec. Air-Source HP	\$935	\$798	\$137 15%
10	2	Tampa, FL	Middle Interior	Elec. Air-Source HP	\$868	\$745	\$123 14%
11	2	Tampa, FL	Top Corner	Elec. Air-Source HP	\$1,005	\$796	\$209 21%
12	2	Tampa, FL	Top Interior	Elec. Air-Source HP	\$949	\$757	\$192 20%
13	2	Tampa, FL	Ground Corner	Gas Furnace / Elec. AC	\$888	\$743	\$145 16%
14	2	Tampa, FL	Middle Interior	Gas Furnace / Elec. AC	\$831	\$696	\$135 16%
15	2	Tampa, FL	Top Corner	Gas Furnace / Elec. AC	\$962	\$737	\$225 23%
16	2	Tampa, FL	Top Interior	Gas Furnace / Elec. AC	\$915	\$707	\$209 23%
17	3	Fort Worth, TX	Ground Corner	Elec. Air-Source HP	\$1,037	\$894	\$143 14%
18	3	Fort Worth, TX	Middle Interior	Elec. Air-Source HP	\$906	\$782	\$124 14%
19	3	Fort Worth, TX	Top Corner	Elec. Air-Source HP	\$1,072	\$854	\$218 20%
20	3	Fort Worth, TX	Top Interior	Elec. Air-Source HP	\$1,012	\$815	\$198 20%
21	3	Fort Worth, TX	Ground Corner	Gas Furnace / Elec. AC	\$951	\$812	\$138 15%
22	3	Fort Worth, TX	Middle Interior	Gas Furnace / Elec. AC	\$816	\$690	\$126 15%
23	3	Fort Worth, TX	Top Corner	Gas Furnace / Elec. AC	\$992	\$767	\$225 23%
24	3	Fort Worth, TX	Top Interior	Gas Furnace / Elec. AC	\$932	\$725	\$207 22%
25	4	St. Louis, MO	Ground Corner	Elec. Air-Source HP	\$1,137	\$976	\$161 14%
26	4	St. Louis, MO	Middle Interior	Elec. Air-Source HP	\$974	\$841	\$133 14%
27	4	St. Louis, MO	Top Corner	Elec. Air-Source HP	\$1,207	\$954	\$253 21%
28	4	St. Louis, MO	Top Interior	Elec. Air-Source HP	\$1,110	\$892	\$218 20%
29	4	St. Louis, MO	Ground Corner	Gas Furnace / Elec. AC	\$970	\$810	\$160 17%
30	4	St. Louis, MO	Middle Interior	Gas Furnace / Elec. AC	\$829	\$703	\$127 15%
31	4	St. Louis, MO	Top Corner	Gas Furnace / Elec. AC	\$1,044	\$796	\$247 24%
32	4	St. Louis, MO	Top Interior	Gas Furnace / Elec. AC	\$956	\$741	\$215 23%
33	5	Indianapolis, IN	Ground Corner	Elec. Air-Source HP	\$1,216	\$1,038	\$178 15%
34	5	Indianapolis, IN	Middle Interior	Elec. Air-Source HP	\$1,026	\$879	\$147 14%
35	5	Indianapolis, IN	Top Corner	Elec. Air-Source HP	\$1,296	\$1,011	\$285 22%
36	5	Indianapolis, IN	Top Interior	Elec. Air-Source HP	\$1,189	\$946	\$243 20%
37	5	Indianapolis, IN	Ground Corner	Gas Furnace / Elec. AC	\$1,006	\$842	\$164 16%
38	5	Indianapolis, IN	Middle Interior	Gas Furnace / Elec. AC	\$852	\$718	\$134 16%
39	5	Indianapolis, IN	Top Corner	Gas Furnace / Elec. AC	\$1,085	\$825	\$260 24%
40	5	Indianapolis, IN	Top Interior	Gas Furnace / Elec. AC	\$995	\$769	\$226 23%
41	6	Burlington, VT	Ground Corner	Elec. Air-Source HP	\$1,294	\$1,106	\$189 15%
42	6	Burlington, VT	Middle Interior	Elec. Air-Source HP	\$1,059	\$905	\$153 15%
43	6	Burlington, VT	Top Corner	Elec. Air-Source HP	\$1,382	\$1,069	\$313 23%
44	6	Burlington, VT	Top Interior	Elec. Air-Source HP	\$1,260	\$997	\$263 21%
45	6	Burlington, VT	Ground Corner	Gas Furnace / Elec. AC	\$997	\$831	\$166 17%
46	6	Burlington, VT	Middle Interior	Gas Furnace / Elec. AC	\$835	\$700	\$135 16%
47	6	Burlington, VT	Top Corner	Gas Furnace / Elec. AC	\$1,075	\$813	\$262 24%
48	6	Burlington, VT	Top Interior	Gas Furnace / Elec. AC	\$989	\$759	\$230 23%
49	7	Duluth, MN	Ground Corner	Gas Furnace / Elec. AC	\$1,099	\$911	\$188 17%
50	7	Duluth, MN	Middle Interior	Gas Furnace / Elec. AC	\$888	\$738	\$150 17%
51	7	Duluth, MN	Top Corner	Gas Furnace / Elec. AC	\$1,185	\$881	\$304 26%
52	7	Duluth, MN	Top Interior	Gas Furnace / Elec. AC	\$1,085	\$819	\$265 24%