

# Cost & Savings Estimates

ENERGY STAR  
Certified Homes,  
Version 3 (Rev. 09)

December 20, 2018

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# ENERGY STAR Certified Homes, Version 3 (Rev. 09) 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 .....	24
Section 5: Incremental Cost & Savings of the National HVAC Design Report .....	26
Section 6: Incremental Cost & Savings of the National Rater Design Review Checklist.....	28
Section 7: Incremental Cost & Savings of the National HVAC Commissioning Checklist .....	29
Section 8: Incremental Cost & Savings of the National Water Management System Bldr. Req.'s .....	31
Section 9: Cost References.....	32
A. Thermal Enclosure System .....	32
B. Space Conditioning Equipment & Filter .....	33
C. Ventilation Equipment .....	34
D. Ductwork .....	35
E. Domestic Hot Water Equipment.....	35
F. Appliances & Lighting.....	36
G. Labor .....	36



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) 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, an ENERGY STAR certified home under Version 3 (Rev. 09) of the program in regions that have adopted the 2009 ICC codes (e.g., 2009 IECC, 2009 IRC).

### Methodology

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

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

**Exhibit 1: House Parameters Consistent Across Climate Zones**

Parameter	Value
Number of Stories	Two
Conditioned Floor Area per Floor (ft <sup>2</sup> )	1,200
Total Conditioned Floor Area (ft <sup>2</sup> )	2,400
Perimeter (ft)	30 x 40
Ceiling Height (ft)	8.5
Bedrooms	3
Window Area (% of Floor Area) & Distribution	15%, Even
Exterior Door Quantity & Total Area	2 Doors, 42 ft <sup>2</sup>

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

**Exhibit 2: House 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			Unconditioned Basement			
Space Heating, Cooling, & DHW	Config. A	Electric Air-Source Heat Pump & Electric DHW					n/a
	Config. B	Gas Furnace, Electric AC, & Gas DHW					

The energy efficiency features of the baseline homes were aligned with the 2009 IECC prescriptive path, except for the window and door performance in Climate Zone 1. In this location, the 2009 IECC requires a window U-factor of 1.2 and door R-value of 0.8. This level of performance is worse than what is likely to be available in the marketplace, so the improved window and door requirements of Climate Zone 2 were modeled instead. In addition, because no 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 homes built to code.

The energy efficiency features of the ENERGY STAR certified homes were aligned with the features of the Version 3 (Rev. 09) ENERGY STAR Reference Design.

These energy efficiency features of the baseline homes and ENERGY STAR certified homes are summarized in Exhibits 4 through 16.

To estimate energy savings, first, the baseline and ENERGY STAR home configurations 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 301-2014, January 2016, and which help ensure that the thermal enclosure system and HVAC system in certified homes perform as designed. Because these program requirements are not required by the 2009 IECC, the



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

factors were applied to the baseline homes, thereby increasing their consumption.

The first factor reflects increased convective losses because the baseline homes are not required to achieve Grade I insulation installation nor, in Climate Zones 4 through 7, alignment of the wall insulation with the interior air barrier. This was estimated to increase heating and cooling consumption in the baseline homes by 5%.

The second factor reflects less efficient operation of the air conditioner and heat pump because the baseline homes are not required to be commissioned, per the National HVAC Commissioning Checklist. This is estimated to increase the heating consumption for homes with electric heat pumps and the cooling consumption for homes 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 homes. The resulting energy consumption for the baseline homes and ENERGY STAR certified homes 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 certified homes were subtracted from those of the baseline homes to determine savings.

The incremental costs of the energy efficiency features for each ENERGY STAR certified home 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 used to meet the ENERGY STAR HERS Index target required by the program.

## Results & Discussion

Exhibit 3 summarizes the annual purchased energy costs for each baseline and ENERGY STAR certified home. In addition, it summarizes the annual purchased energy savings and the total upgrade cost for each ENERGY STAR certified home, and the resulting monthly purchased energy savings, monthly mortgage upgrade cost, and net cash flow. The monthly mortgage upgrade cost was calculated assuming a 30-year fixed mortgage with a 5.0% interest rate.

**Exhibit 3: ENERGY STAR v3 Certified Home vs 2009 IECC Home, Illustrative Cost & Savings Summary**

#	CZ	Location	Found.	HVAC Equipment Type	ENERGY STAR Version 3							
					2009 IECC Annual Purchased Energy Costs	Annual Purchased Energy Costs	Annual Purchased Energy Savings	Total Upgrade Cost	Monthly Purchased Energy Savings	Monthly Mortgage Upgrade Cost	Net Cash Flow	
1	1	Miami, FL	Slab	Elec. Air-Source HP	\$1,735	\$1,430	\$305	18%	\$1,413	\$25	\$8	\$18
2	1	Miami, FL	Slab	Gas Furnance / Elec. AC	\$1,644	\$1,344	\$301	18%	\$1,467	\$25	\$8	\$17
3	2	Tampa, FL	Slab	Elec. Air-Source HP	\$1,784	\$1,498	\$286	16%	\$1,413	\$24	\$8	\$16
4	2	Tampa, FL	Slab	Gas Furnance / Elec. AC	\$1,687	\$1,405	\$282	17%	\$1,467	\$24	\$8	\$16
5	3	Fort Worth, TX	Slab	Elec. Air-Source HP	\$2,210	\$1,763	\$447	20%	\$1,646	\$37	\$9	\$28
6	3	Fort Worth, TX	Slab	Gas Furnance / Elec. AC	\$2,043	\$1,639	\$403	20%	\$1,700	\$34	\$9	\$24
7	4	St. Louis, MO	Bsmt.	Elec. Air-Source HP	\$2,712	\$2,214	\$498	18%	\$1,828	\$42	\$10	\$32
8	4	St. Louis, MO	Bsmt.	Gas Furnance / Elec. AC	\$2,252	\$1,799	\$453	20%	\$2,154	\$38	\$12	\$26
9	5	Indianapolis, IN	Bsmt.	Elec. Air-Source HP	\$2,991	\$2,219	\$772	26%	\$2,009	\$64	\$11	\$54
10	5	Indianapolis, IN	Bsmt.	Gas Furnance / Elec. AC	\$2,332	\$1,787	\$545	23%	\$2,067	\$45	\$11	\$34
11	6	Burlington, VT	Bsmt.	Elec. Air-Source HP	\$3,703	\$2,600	\$1,103	30%	\$2,105	\$92	\$11	\$81
12	6	Burlington, VT	Bsmt.	Gas Furnance / Elec. AC	\$2,526	\$1,883	\$643	25%	\$2,067	\$54	\$11	\$42
13	7	Duluth, MN	Bsmt.	Gas Furnance / Elec. AC	\$2,957	\$2,129	\$829	28%	\$2,067	\$69	\$11	\$58

Section 2 contains Exhibits 4 through 16, which contain a more detailed breakout of the incremental upgrade costs presented for each home in Exhibit 3. While this analysis provides illustrative incremental costs and savings, these values will vary for any specific certified home, dependent on variables such as baseline construction practices, geographic location, house design, and vendor relationships. For example, builders 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 8 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 2009 IECC and 2009 IRC codes, and only requirements above code were accounted for.



## ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

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, code does not require commissioning of HVAC systems, so both incremental costs and savings were estimated for these requirements.

In addition, where the ENERGY STAR Certified Homes program requires a Home Energy 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 v3 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 home 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 Home Energy Rater, whereas most jurisdictions do not require such oversight.

Finally, Section 9 provides additional references to support the assumptions used in the analysis.



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) 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 home in Exhibit 3. For each home, the costs are divided into seven 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 HERS Index 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 the Rater-F, the National Rater Design Review Checklist (Rater-D), the National HVAC Design Report (HVAC-D), the National HVAC Commissioning Checklist (HVAC-C), and the National Water Management System Builder Requirements (Builder-W), relative to the 2009 ICC codes. The measures included in these sections represent both requirements that improve the HERS Index of the home 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 HERS Index. In contrast, the Rater-F requires bedroom pressure balancing, which is a mandatory requirement of this checklist, but does not impact the HERS Index of the home.

For each measure, the exhibit lists the 2009 IECC baseline code requirement, the ENERGY STAR Version 3 (Rev. 09) requirement, the incremental unit cost, the quantity of units per home, the cost units (e.g., tons, square feet of window area, square feet of conditioned floor area), and the total incremental measure cost.



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 4: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 1 - Config. A - Electric

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	Radiant Barrier	\$6.56	13	Rad. Barrier (100 ft <sup>2</sup> )	\$83
Infiltration	7.0 ACH50	6.0 ACH50	\$0.13	2,400	CFA (ft <sup>2</sup> )	\$312
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	8.2 HSPF / 14 SEER	8.2 HSPF / 14.5 SEER	\$24.00	3	Tons	\$72
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	\$0.00	1	Water Heater	\$0
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$522</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-30	R-30	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-13	R-13	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$209
Foundation Insulation	No Slab Insulation	No Slab Insulation	-	-	-	-
Foundation Insulation Installation	Grade I Installation	Grade I Installation	-	-	-	-
Windows	U-value: 0.65 / SHGC: 0.30	U-value: 0.60 / SHGC: 0.27	\$0.10	360	Window Area (ft <sup>2</sup> )	\$35
Doors	R-1.5	R-4.8	\$64.71	2	Door	\$129
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						<b>-\$50</b>
Sub-Total of Thermal Enclosure System Checklist						<b>\$413</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.17	576	Duct Surface Area (ft <sup>2</sup> )	\$98
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						<b>\$200</b>
Sub-Total of HVAC System Checklist						<b>\$298</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	Supply Vent. System with Exhaust Backup	\$410.52	1	-	\$411
HVAC Equipment Right-Sizing	3.5 Tons	3.0 Tons	-\$672.00	0.5	Tons	-\$336
Additional Checklist Measures: Checklist Completion by Designer						<b>\$5</b>
Sub-Total of HVAC Design Report						<b>\$80</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$1,413</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 5: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 1 - Config. B - Gas

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit		Cost Unit	Inc. Cost
			Cost	Cost Qty		
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	Radiant Barrier	\$6.56	13	Rad. Barrier (100 ft <sup>2</sup> )	\$83
Infiltration	7.0 ACH50	6.0 ACH50	\$0.13	2,400	CFA (ft <sup>2</sup> )	\$312
Cooling Equipment	14 SEER Central AC	14.5 SEER Central AC	\$36.00	3	Tons	\$108
Heating Equipment	80 AFUE Gas Furnace	80 AFUE Gas Furnace	-	-	-	-
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	\$0.00	1	Water Heater	\$0
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$558</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-30	R-30	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-13	R-13	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$209
Foundation Insulation	No Slab Insulation	No Slab Insulation	-	-	-	-
Foundation Insulation Installation	Grade I Installation	Grade I Installation	-	-	-	-
Windows	U-value: 0.65 / SHGC: 0.30	U-value: 0.60 / SHGC: 0.27	\$0.10	360	Window Area (ft <sup>2</sup> )	\$35
Doors	R-1.5	R-4.8	\$64.71	2	Door	\$129
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						<b>-\$50</b>
Sub-Total of Thermal Enclosure System Checklist						<b>\$413</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.17	576	Duct Surface Area (ft <sup>2</sup> )	\$98
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						<b>\$200</b>
Sub-Total of HVAC System Checklist						<b>\$298</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	Supply Vent. System with Exhaust Backup	\$410.52	1	-	\$411
HVAC Equipment Right-Sizing	3.5 Tons	3.0 Tons	-\$636.00	0.5	Tons	-\$318
Additional Checklist Measures: Checklist Completion by Designer						<b>\$5</b>
Sub-Total of HVAC Design Report						<b>\$98</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$1,467</b>





# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 6: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 2 - Config. A - Electric

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit		Cost Unit	Inc. Cost
			Cost	Cost Qty		
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	Radiant Barrier	\$6.56	13	Rad. Barrier (100 ft <sup>2</sup> )	\$83
Infiltration	7.0 ACH50	6.0 ACH50	\$0.13	2,400	CFA (ft <sup>2</sup> )	\$312
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	8.2 HSPF / 14 SEER	8.2 HSPF / 14.5 SEER	\$24.00	3	Tons	\$72
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	\$0.00	1	Water Heater	\$0
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$522</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-30	R-30	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-13	R-13	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$209
Foundation Insulation	No Slab Insulation	No Slab Insulation	-	-	-	-
Foundation Insulation Installation	Grade I Installation	Grade I Installation	-	-	-	-
Windows	U-value: 0.65 / SHGC: 0.30	U-value: 0.60 / SHGC: 0.27	\$0.10	360	Window Area (ft <sup>2</sup> )	\$35
Doors	R-1.5	R-4.8	\$64.71	2	Door	\$129
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						-\$50
Sub-Total of Thermal Enclosure System Checklist						<b>\$413</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.17	576	Duct Surface Area (ft <sup>2</sup> )	\$98
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						\$200
Sub-Total of HVAC System Checklist						<b>\$298</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	Supply Vent. System with Exhaust Backup	\$410.52	1	-	\$411
HVAC Equipment Right-Sizing	3.5 Tons	3.0 Tons	-\$672.00	0.5	Tons	-\$336
Additional Checklist Measures: Checklist Completion by Designer						\$5
Sub-Total of HVAC Design Report						<b>\$80</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$1,413</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 7: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 2 - Config. B - Gas

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit		Cost Unit	Inc. Cost
			Cost	Cost Qty		
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	Radiant Barrier	\$6.56	13	Rad. Barrier (100 ft <sup>2</sup> )	\$83
Infiltration	7.0 ACH50	6.0 ACH50	\$0.13	2,400	CFA (ft <sup>2</sup> )	\$312
Cooling Equipment	14 SEER Central AC	14.5 SEER Central AC	\$36.00	3	Tons	\$108
Heating Equipment	80 AFUE Gas Furnace	80 AFUE Gas Furnace	-	-	-	-
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	\$0.00	1	Water Heater	\$0
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$558</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-30	R-30	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-13	R-13	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$209
Foundation Insulation	No Slab Insulation	No Slab Insulation	-	-	-	-
Foundation Insulation Installation	Grade I Installation	Grade I Installation	-	-	-	-
Windows	U-value: 0.65 / SHGC: 0.30	U-value: 0.60 / SHGC: 0.27	\$0.10	360	Window Area (ft <sup>2</sup> )	\$35
Doors	R-1.5	R-4.8	\$64.71	2	Door	\$129
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						<b>-\$50</b>
Sub-Total of Thermal Enclosure System Checklist						<b>\$413</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.17	576	Duct Surface Area (ft <sup>2</sup> )	\$98
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						<b>\$200</b>
Sub-Total of HVAC System Checklist						<b>\$298</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	Supply Vent. System with Exhaust Backup	\$410.52	1	-	\$411
HVAC Equipment Right-Sizing	3.5 Tons	3.0 Tons	-\$636.00	0.5	Tons	-\$318
Additional Checklist Measures: Checklist Completion by Designer						<b>\$5</b>
Sub-Total of HVAC Design Report						<b>\$98</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$1,467</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 8: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 3 - Config. A - Electric

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit		Cost Unit	Inc. Cost
			Cost	Cost Qty		
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	Radiant Barrier	\$6.56	13	Rad. Barrier (100 ft <sup>2</sup> )	\$83
Infiltration	7.0 ACH50	5.0 ACH50	\$0.22	2,400	CFA (ft <sup>2</sup> )	\$528
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	8.2 HSPF / 14 SEER	8.2 HSPF / 14.5 SEER	\$24.00	3	Tons	\$72
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	\$0.00	1	Water Heater	\$0
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$738</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-30	R-30	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-13	R-13	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$209
Foundation Insulation	No Slab Insulation	No Slab Insulation	-	-	-	-
Foundation Insulation Installation	Grade I Installation	Grade I Installation	-	-	-	-
Windows	U-value: 0.50 / SHGC: 0.30	U-value: 0.35 / SHGC: 0.30	\$0.27	360	Window Area (ft <sup>2</sup> )	\$97
Doors	R-2.0	R-4.8	\$42.65	2	Door	\$85
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						<b>-\$50</b>
Sub-Total of Thermal Enclosure System Checklist						<b>\$431</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.17	576	Duct Surface Area (ft <sup>2</sup> )	\$98
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						<b>\$200</b>
Sub-Total of HVAC System Checklist						<b>\$298</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	Supply Vent. System with Exhaust Backup	\$410.52	1	Tons	\$411
HVAC Equipment Right-Sizing	3.5 Tons	3.0 Tons	-\$672.00	0.5	Tons	-\$336
Additional Checklist Measures: Checklist Completion by Designer						<b>\$5</b>
Sub-Total of HVAC Design Report						<b>\$80</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$1,646</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 9: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 3 - Config. B - Gas

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	Radiant Barrier	\$6.56	13	Rad. Barrier (100 ft <sup>2</sup> )	\$83
Infiltration	7.0 ACH50	5.0 ACH50	\$0.22	2,400	CFA (ft <sup>2</sup> )	\$528
Cooling Equipment	14 SEER Central AC	14.5 SEER Central AC	\$36.00	3	Tons	\$108
Heating Equipment	80 AFUE Gas Furnace	80 AFUE Gas Furnace	-	-	-	-
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	\$0.00	1	Water Heater	\$0
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$774</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-30	R-30	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-13	R-13	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$209
Foundation Insulation	No Slab Insulation	No Slab Insulation	-	-	-	-
Foundation Insulation Installation	Grade I Installation	Grade I Installation	-	-	-	-
Windows	U-value: 0.50 / SHGC: 0.30	U-value: 0.35 / SHGC: 0.30	\$0.27	360	Window Area (ft <sup>2</sup> )	\$97
Doors	R-2.0	R-4.8	\$42.65	2	Door	\$85
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						<b>-\$50</b>
Sub-Total of Thermal Enclosure System Checklist						<b>\$431</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.17	576	Duct Surface Area (ft <sup>2</sup> )	\$98
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						<b>\$200</b>
Sub-Total of HVAC System Checklist						<b>\$298</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	Supply Vent. System with Exhaust Backup	\$410.52	1		\$411
HVAC Equipment Right-Sizing	3.5 Tons	3.0 Tons	-\$636.00	0.5	Tons	-\$318
Additional Checklist Measures: Checklist Completion by Designer						<b>\$5</b>
Sub-Total of HVAC Design Report						<b>\$98</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$1,700</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 10: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 4 - Config. A - Electric

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	No Radiant Barrier	-	-	-	-
Infiltration	7.0 ACH50	5.0 ACH50	\$0.22	2,400	CFA (ft <sup>2</sup> )	\$528
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	8.2 HSPF / 14 SEER	8.5 HSPF / 14.5 SEER	\$72.00	3	Tons	\$216
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	\$0.00	1	Water Heater	\$0
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$799</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-38	R-38	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-13	R-13	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$209
Foundation Insulation	R-19 Floor Insulation	R-19 Floor Insulation	-	-	-	-
Foundation Insulation Installation	Grade II Installation	Grade I Installation	\$0.16	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$186
Windows	U-value: 0.35 / SHGC: 0.40	U-value: 0.32 / SHGC: 0.40	\$0.24	360	Window Area (ft <sup>2</sup> )	\$88
Doors	R-2.9	R-4.8	\$20.59	2	Door	\$41
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						<b>-\$50</b>
Sub-Total of Thermal Enclosure System Checklist						<b>\$564</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.19	576	Duct Surface Area (ft <sup>2</sup> )	\$109
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						<b>\$200</b>
Sub-Total of HVAC System Checklist						<b>\$309</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	Supply Vent. System with Exhaust Backup	\$410.52	1		\$411
HVAC Equipment Right-Sizing	3.5 Tons	3.0 Tons	-\$720.00	0.5	Tons	-\$360
Additional Checklist Measures: Checklist Completion by Designer						<b>\$5</b>
Sub-Total of HVAC Design Report						<b>\$56</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$1,828</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09)

## Cost & Savings Estimates

Exhibit 11: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 4 - Config. B - Gas

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit		Cost Unit	Inc. Cost
			Cost	Cost Qty		
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	No Radiant Barrier	-	-	-	-
Infiltration	7.0 ACH50	5.0 ACH50	\$0.22	2,400	CFA (ft <sup>2</sup> )	\$528
Cooling Equipment	13 SEER Central AC	13 SEER Central AC	-	-	-	-
Heating Equipment	80 AFUE Gas Furnace	90 AFUE Gas Furnace	\$6.60	60	kBtu/h	\$396
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.62 EF Gas DHW, 40 Gal. (Power Vent)	\$150.00	1	Water Heater	\$150
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$1,129</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-38	R-38	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-13	R-13	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.10	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$209
Foundation Insulation	R-19 Floor Insulation	R-19 Floor Insulation	-	-	-	-
Foundation Insulation Installation	Grade II Installation	Grade I Installation	\$0.16	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$186
Windows	U-value: 0.35 / SHGC: 0.40	U-value: 0.32 / SHGC: 0.40	\$0.24	360	Window Area (ft <sup>2</sup> )	\$88
Doors	R-2.9	R-4.8	\$20.59	2	Door	\$41
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						<b>-\$50</b>
Sub-Total of Thermal Enclosure System Checklist						<b>\$564</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.19	576	Duct Surface Area (ft <sup>2</sup> )	\$109
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						<b>\$100</b>
Sub-Total of HVAC System Checklist						<b>\$209</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	Supply Vent. System with Exhaust Backup	\$410.52	1		\$411
HVAC Equipment Right-Sizing	3.5 Tons	3.0 Tons	-\$528.00	0.5	Tons	-\$264
Additional Checklist Measures: Checklist Completion by Designer						<b>\$5</b>
Sub-Total of HVAC Design Report						<b>\$152</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$2,154</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 12: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 5 - Config. A - Electric

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	No Radiant Barrier	-	-	-	-
Infiltration	7.0 ACH50	4.0 ACH50	\$0.31	2,400	CFA (ft <sup>2</sup> )	\$744
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	8.2 HSPF / 14 SEER	9.25 HSPF / 14.5 SEER	\$223.88	2.5	Tons	\$560
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	\$0.00	1	Water Heater	\$0
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$1,359</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-38	R-38	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$96
Foundation Insulation	R-30 Floor Insulation	R-30 Floor Insulation	-	-	-	-
Foundation Insulation Installation	Grade II Installation	Grade I Installation	\$0.16	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$186
Windows	U-value: 0.35 / SHGC: 0.40	U-value: 0.30 / SHGC: 0.40	\$0.66	360	Window Area (ft <sup>2</sup> )	\$238
Doors	R-2.9	R-4.8	\$20.59	2	Door	\$41
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						-\$100
Sub-Total of Thermal Enclosure System Checklist						<b>\$550</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.19	576	Duct Surface Area (ft <sup>2</sup> )	\$109
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						\$200
Sub-Total of HVAC System Checklist						<b>\$309</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	ENERGY STAR Exhaust Fan with Controller	\$121.59	1		\$122
HVAC Equipment Right-Sizing	3.0 Tons	2.5 Tons	-\$871.88	0.5	Tons	-\$436
Additional Checklist Measures: Checklist Completion by Designer						\$5
Sub-Total of HVAC Design Report						<b>-\$309</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$2,009</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 13: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 5 - Config. B - Gas

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	No Radiant Barrier	-	-	-	-
Infiltration	7.0 ACH50	4.0 ACH50	\$0.31	2,400	CFA (ft <sup>2</sup> )	\$744
Cooling Equipment	13 SEER Central AC	13 SEER Central AC	-	-	-	-
Heating Equipment	80 AFUE Gas Furnace	90 AFUE Gas Furnace	\$6.60	60	kBtu/h	\$396
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.62 EF Gas DHW, 40 Gal. (Power Vent)	\$150.00	1	Water Heater	\$150
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$1,345</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-38	R-38	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$96
Foundation Insulation	R-30 Floor Insulation	R-30 Floor Insulation	-	-	-	-
Foundation Insulation Installation	Grade II Installation	Grade I Installation	\$0.16	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$186
Windows	U-value: 0.35 / SHGC: 0.40	U-value: 0.30 / SHGC: 0.40	\$0.66	360	Window Area (ft <sup>2</sup> )	\$238
Doors	R-2.9	R-4.8	\$20.59	2	Door	\$41
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						-\$100
Sub-Total of Thermal Enclosure System Checklist						<b>\$550</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.19	576	Duct Surface Area (ft <sup>2</sup> )	\$109
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						\$100
Sub-Total of HVAC System Checklist						<b>\$209</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	ENERGY STAR Exhaust Fan with Controller	\$121.59	1		\$122
HVAC Equipment Right-Sizing	3.0 Tons	2.5 Tons	-\$528.00	0.5	Tons	-\$264
Additional Checklist Measures: Checklist Completion by Designer						\$5
Sub-Total of HVAC Design Report						<b>-\$137</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$2,067</b>





# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 14: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 6 - Config. A - Electric

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	No Radiant Barrier	-	-	-	-
Infiltration	7.0 ACH50	4.0 ACH50	\$0.31	2,400	CFA (ft <sup>2</sup> )	\$744
Cooling Equipment	(See Heating Equipment)	(See Heating Equipment)	-	-	-	-
Heating Equipment	8.2 HSPF / 14 SEER	9.50 HSPF / 14.5 SEER	\$272.00	2.5	Tons	\$680
Water Heater	0.95 EF Electric DHW, 40 Gallons	0.95 EF Electric DHW, 40 Gallons	\$0.00	1	Water Heater	\$0
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$1,479</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$96
Foundation Insulation	R-30 Floor Insulation	R-30 Floor Insulation	-	-	-	-
Foundation Insulation Installation	Grade II Installation	Grade I Installation	\$0.16	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$186
Windows	U-value: 0.35 / SHGC: 0.40	U-value: 0.30 / SHGC: 0.40	\$0.66	360	Window Area (ft <sup>2</sup> )	\$238
Doors	R-2.9	R-4.8	\$20.59	2	Door	\$41
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						-\$100
Sub-Total of Thermal Enclosure System Checklist						<b>\$550</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.19	576	Duct Surface Area (ft <sup>2</sup> )	\$109
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						\$200
Sub-Total of HVAC System Checklist						<b>\$309</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	ENERGY STAR Exhaust Fan with Controller	\$121.59	1		\$122
HVAC Equipment Right-Sizing	3.0 Tons	2.5 Tons	-\$920.00	0.5	Tons	-\$460
Additional Checklist Measures: Checklist Completion by Designer						\$5
Sub-Total of HVAC Design Report						<b>-\$333</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$2,105</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 15: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 6 - Config. B - Gas

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit Cost	Cost Qty	Cost Unit	Inc. Cost
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	No Radiant Barrier	-	-	-	-
Infiltration	7.0 ACH50	4.0 ACH50	\$0.31	2,400	CFA (ft <sup>2</sup> )	\$744
Cooling Equipment	13 SEER Central AC	13 SEER Central AC	-	-	-	-
Heating Equipment	80 AFUE Gas Furnace	90 AFUE Gas Furnace	\$6.60	60	kBtu/h	\$396
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.62 EF Gas DHW, 40 Gal. (Power Vent)	\$150.00	1	Water Heater	\$150
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$1,345</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-20	R-20	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$96
Foundation Insulation	R-30 Floor Insulation	R-30 Floor Insulation	-	-	-	-
Foundation Insulation Installation	Grade II Installation	Grade I Installation	\$0.16	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$186
Windows	U-value: 0.35 / SHGC: 0.40	U-value: 0.30 / SHGC: 0.40	\$0.66	360	Window Area (ft <sup>2</sup> )	\$238
Doors	R-2.9	R-4.8	\$20.59	2	Door	\$41
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						-\$100
Sub-Total of Thermal Enclosure System Checklist						<b>\$550</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.19	576	Duct Surface Area (ft <sup>2</sup> )	\$109
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						\$100
Sub-Total of HVAC System Checklist						<b>\$209</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	ENERGY STAR Exhaust Fan with Controller	\$121.59	1		\$122
HVAC Equipment Right-Sizing	2.5 Tons	2.0 Tons	-\$528.00	0.5	Tons	-\$264
Additional Checklist Measures: Checklist Completion by Designer						\$5
Sub-Total of HVAC Design Report						<b>-\$137</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$2,067</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Exhibit 16: ENERGY STAR v3 Certified Home vs 2009 IECC Home - CZ 7 - Config. B - Gas

Measure	2009 IECC Baseline	ENERGY STAR v3	Inc. Unit		Cost Unit	Inc. Cost
			Cost	Cost Qty		
<b>Measures Not Required by Checklists &amp; Used to Meet ENERGY STAR HERS Index Target</b>						
Radiant Barrier	No Radiant Barrier	No Radiant Barrier	-	-	-	-
Infiltration	7.0 ACH50	4.0 ACH50	\$0.31	2,400	CFA (ft <sup>2</sup> )	\$744
Cooling Equipment	13 SEER Central AC	13 SEER Central AC	-	-	-	-
Heating Equipment	80 AFUE Gas Furnace	90 AFUE Gas Furnace	\$6.60	60	kBtu/h	\$396
Water Heater	0.62 EF Gas DHW, 40 Gal. (Atmo. Vent)	0.62 EF Gas DHW, 40 Gal. (Power Vent)	\$150.00	1	Water Heater	\$150
Lighting	50% Fluorescent Lighting	80% ENERGY STAR CFLs	\$2.80	14	Lamps	\$40
Thermostat	Programmable Thermostat	Programmable Thermostat	-	-	-	-
Dishwasher	Standard Efficiency Dishwasher	ENERGY STAR Dishwasher	\$10.00	1	Dishwasher	\$10
Refrigerator	Standard Efficiency Refrigerator	ENERGY STAR Refrigerator	\$5.00	1	Refrigerator	\$5
Sub-Total of Measures Not Required by Checklists & Used to Meet ENERGY STAR HERS Index Target						<b>\$1,345</b>
<b>Rater Field Checklist: Thermal Enclosure System</b>						
Ceiling Insulation	R-49	R-49	-	-	-	-
Ceiling Insulation Installation	Grade II Installation	Grade I Installation	\$0.07	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$89
Above-Grade Wall Insulation	R-21	R-21	-	-	-	-
A-G Wall Insulation Installation	Grade III Installation	Grade I Installation	\$0.05	2,118	Ins. Surface Area (ft <sup>2</sup> )	\$96
Foundation Insulation	R-38 Floor Insulation	R-38 Floor Insulation	-	-	-	-
Foundation Insulation Installation	Grade II Installation	Grade I Installation	\$0.16	1,200	Ins. Surface Area (ft <sup>2</sup> )	\$186
Windows	U-value: 0.35 / SHGC: 0.40	U-value: 0.30 / SHGC: 0.40	\$0.66	360	Window Area (ft <sup>2</sup> )	\$238
Doors	R-2.9	R-4.8	\$20.59	2	Door	\$41
Additional Checklist Measures: Reduced Lumber from Advanced Framing, Rater Verification						<b>-\$100</b>
Sub-Total of Thermal Enclosure System Checklist						<b>\$550</b>
<b>Rater Field Checklist: HVAC System</b>						
Duct Sealing - Total Leakage	12 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	8 CFM per 100 ft <sup>2</sup> of CFA Total Leakage	\$0.19	576	Duct Surface Area (ft <sup>2</sup> )	\$109
Duct Insulation	R-8 Attic, R-6 Other Uncond. Spaces	R-8 Attic, R-6 Other Uncond. Spaces	-	-	-	-
Additional Checklist Measures: Rater Verification of Equipment Model Numbers, Static Pressure, Bedroom Pressure Balancing, Ventilation System, and Filter						<b>\$100</b>
Sub-Total of HVAC System Checklist						<b>\$209</b>
<b>Rater Design Review Checklist</b>						
Sub-Total of Rater Design Review Checklist: Rater Collection of HVAC Design Report, Rater Review of Design, Partnership, & Credential						<b>\$25</b>
<b>HVAC Design Report</b>						
Ventilation	None	ENERGY STAR Exhaust Fan with Controller	\$121.59	1		\$122
HVAC Equipment Right-Sizing	2.5 Tons	2.0 Tons	-\$528.00	0.5	Tons	-\$264
Additional Checklist Measures: Checklist Completion by Designer						<b>\$5</b>
Sub-Total of HVAC Design Report						<b>-\$137</b>
<b>HVAC Commissioning Checklist</b>						
Sub-Total of HVAC Commissioning Checklist: Credential Cost, Refrigerant Charge Check, Air Handler Airflow Check, Completion of Checklist						<b>\$75</b>
<b>Water Management System Builder Requirements</b>						
Sub-Total of Water Management System Builder Requirements: Relative to Code, No Incremental Tasks are Required						<b>\$0</b>
<b>Total Incremental Cost for the Home</b>						<b>\$2,067</b>



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) 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 HERS Index 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 HERS 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 \$413 and \$564, depending on Climate Zone and house configuration, and encompasses both requirements that improve the HERS Index and those that do not.

Excluding the requirements that only improve the HERS Index, the remaining checklist requirements address reduced thermal bridging requirements and Rater verification of the Rater-F TES and actually result in a net savings of \$50 in Climate Zone 1 through 4 and net savings of \$100 in Climate Zones 5 through 7. Net savings occur due to reduced lumber costs as a result of the reduced thermal bridging requirements.

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 HERS Index 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 home by 5% to account for the increased convective losses because these baseline homes 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 certified homes, 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 2009 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 2009 IECC 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).

The insulation levels were modeled to be consistent with the 2009 IECC requirements 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 home configuration and each relevant assembly (i.e., ceiling, wall, floor) 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 home was increased by 5% to account for the increased convective losses because these baseline homes 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 2009 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 the Rater-F TES is that, in Climate Zones 4 through 7, 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.



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

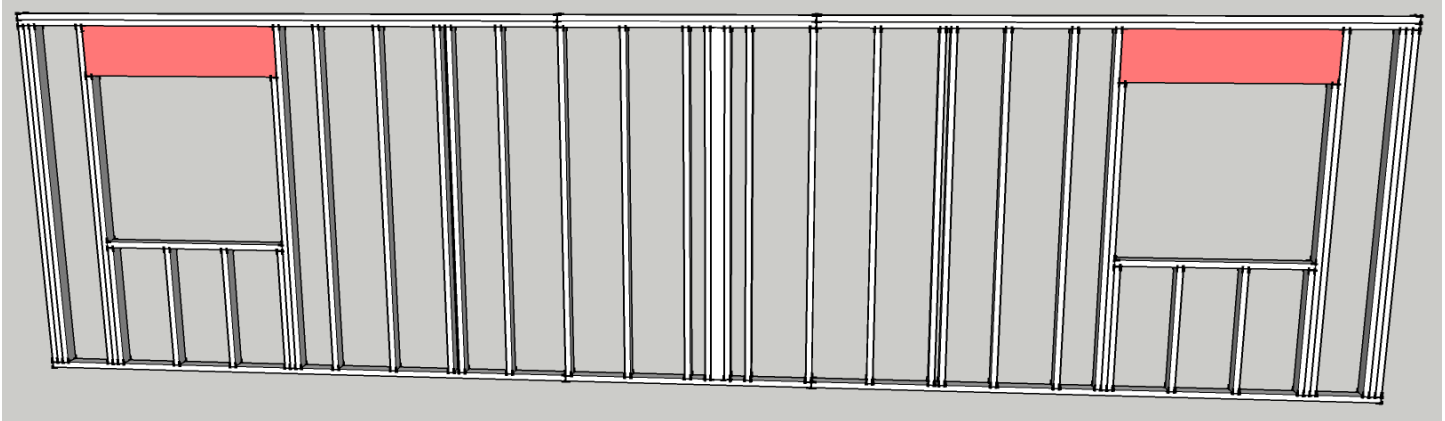
Section 3 requires the use of details that reduce thermal bridging. Several of these details are required by the 2009 IECC, such as extending full height uncompressed insulation over the wall top plate at the eaves, and requiring that access be provided to all equipment in attics that prevents damaging or compressing the insulation beneath.

However, 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, the cost and energy savings associated with the advanced framing option in this Section were estimated using a reduced framing fraction of 19%, rather than the default of 23%, in each home.

Code requires that all headers be insulated, which generally aligns with the Rater-F TES requirement to insulate all headers above windows and doors  $\geq R-3$  for 2x4 framing or equivalent cavity width, and  $\geq R-5$  for all other assemblies (e.g., with 2x6 framing). The remaining advanced framing details are not required by code, including that corners use modified framing or high-density insulation to achieve  $\geq R-6$ , that framing be limited at all windows & doors, that all interior / exterior wall intersections be insulated to the same R-value as the rest of the exterior wall, and that extraneous use of framing be minimized. These details are achieved by reducing the amount of lumber used in the walls, resulting in a reduced framing fraction.

To estimate the impact on framing fraction from these details, a 30'x8' wall was modeled with and without these details. The wall below was modeled without these features and has a framing fraction of 23%.

**30' Long by 8' High 2x4 16" OC Standard Wall with Two Windows (4'-1" x 3'-8.5")**



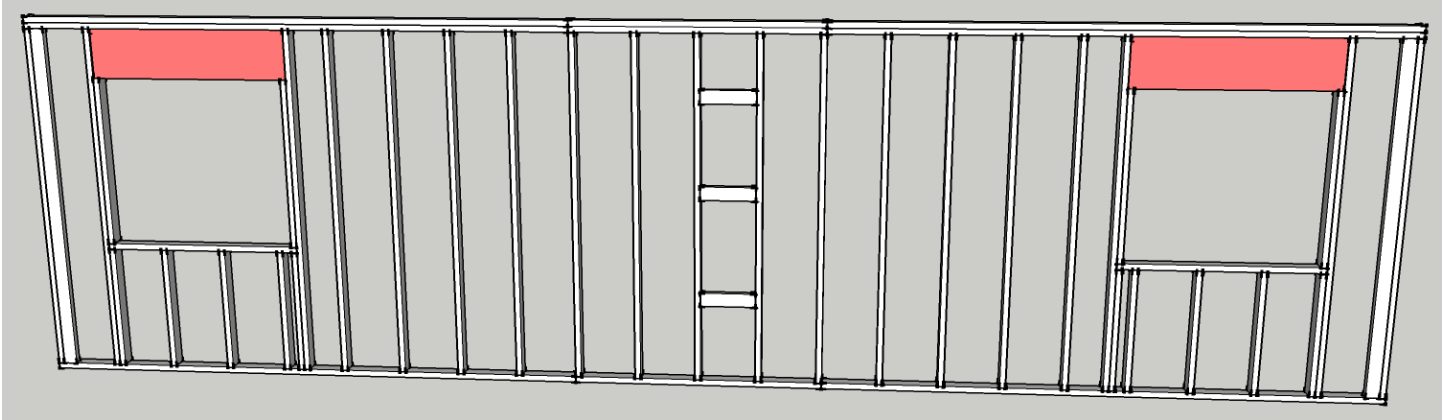
Top & Bottom Plates:	3 * 30' * 1.5"	= 11.3 sq. ft.
King Studs:	23 * 7'-7.5" * 1.5"	= 21.9 sq. ft.
Int. / Ext. Wall Intersection:	7'-7.5" * 3.5"	= 2.2 sq. ft.
Exterior Wall Corner:	4 * 7'-7.5" * 1.5"	= 3.8 sq. ft.
Window Header:	2 * 4'-4" * 11.5"	= 8.3 sq. ft.
Jacks / Trimmers:	4 * 6'-8" * 1.5"	= 6.0 sq. ft.
Window Sills:	2 * 4'-1" * 1.5"	= 1.0 sq. ft.
Cripples:	8 * 2'-8.5" * 1.5"	= 2.7 sq. ft.
Total Wood Area		= 54.6 sq. ft.
Total Wall Area		= 240 sq. ft.
Framing Fraction	= 54.6 / 240	= 23%



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

The wall below was modeled with these features and has a framing fraction of 18%.

**30' Long by 8' High 2x4 16" OC ENERGY STAR Wall with Two Windows (4'-1" x 3'-8.5")**



Top & Bottom Plates:	3 * 30' * 1.5"	= 11.3 sq. ft.
King Studs:	19 * 7'-7.5" * 1.5"	= 18.1 sq. ft.
Int. / Ext. Wall Intersection:	(Insulated Ladder Wall)	= 0 sq. ft.
Exterior Wall Corner:	(Insulated 3-Stud Corner)	= 0 sq. ft.
Window Header:	2 * 4'-4" * 11.5"	= 8.3 sq. ft.
Jacks / Trimmers:	4 * 3'-10" * 1.5"	= 1.9 sq. ft.
Window Sills:	2 * 4'-4" * 1.5"	= 1.1 sq. ft.
Cripples:	10 * 2'-8.5" * 1.5"	= 3.4 sq. ft.
Total Wood Area		= 44.1 sq. ft.
Total Wall Area		= 240 sq. ft.
Framing Fraction	= 44.1 / 240	= 18%

Recognizing that not all walls will achieve the exact same reduction in framing fraction, for this analysis the baseline and improved framing fraction values were aligned with the default framing fractions in ANSI / RESNET / ICC 301-2014, January 2016. Table 4.2.2(6) of this Standard defines a default framing fraction of 23% for 16 inch on-center Standard walls and 19% for 16 inch on-center Advanced walls. Energy savings from this reduction in framing were estimated within REM/Rate. In addition to saving energy, the lower framing fraction will reduce material costs. To estimate the material cost savings, the net wall area of each home modeled in Exhibits 4 through 16 was multiplied by 23% for the baseline home and by 19% for the ENERGY STAR certified home. The resulting lumber area was converted to thousand board-feet and multiplied by the material cost for 2x4 8.5 ft. high studs in Climate Zones 1 through 4 and 2x6 8.5 ft. high studs in Climate Zones 5 through 7. This resulted in material savings of \$120 per home in Climate Zones 1 through 4 and \$188 in Climate Zones 5 through 7.

Section 4 requires air sealing of penetrations, cracks, and other openings in the home's thermal enclosure system. These details largely overlap with the 2009 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. Instead, it was assumed that these requirements will largely be met to achieve the code-required infiltration limit of 7 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 limit of 7 ACH50. However, an incremental cost was estimated in Exhibits 4 through 16 to account for additional air sealing required to reduce the infiltration rate from 7 ACH50 to the level included in the ENERGY STAR Version 3 Reference Design. Included in this cost was the one air



## ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

sealing detail from the Rater-F TES that is not required by code – the inclusion of a gasket between the sill plate and foundation.

Finally, despite the fact that many of the requirements in the Rater-F TES are also required by code, the 2009 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 1.5 hours per home. At a labor rate of \$55 per hour for a Home Energy Rater, this was estimated to cost \$82.

In summary, the costs for the measures that impact the HERS Index are itemized in Exhibits 4 through 16. The additional costs for the reduced thermal bridging requirements and Rater verification of the Rater-F TES sum to -\$38 in Climate Zones 1 through 4 and -\$106 in Climate Zones 5 through 7, and were rounded to the nearest \$25, for a final estimated cost of -\$50 and -\$100 respectively.



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) 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 HERS Index 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 HERS 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 \$209 and \$309, depending on Climate Zone and house configuration, and encompasses both requirements that improve the HERS Index and those that do not.

Excluding the requirements that impact the HERS Index, the remaining checklist requirements address Rater verification of the equipment model numbers, static pressure, bedroom pressure balancing, ventilation system, and filter, which are estimated to cost \$200 for Climate Zones 1-4 as well as electric homes in Climate Zones 4-7, and \$100 for gas homes 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 National HVAC Design Report. It was estimated that the review will take 5 minutes per home. At a labor rate of \$55 per hour for a Home Energy Rater, this was estimated to cost \$5. 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. Therefore, this was estimated to cost \$9 at a labor rate of \$55 per hour.

Section 6 requires, in part, that the duct system be visually inspected for proper installation. It is expected that this visual inspection will occur concurrent with the visual inspections conducted for the Thermal Enclosure System section of Rater-F and therefore no incremental cost was estimated for this task.

Next, Section 6 requires that the bedrooms in the home be pressure-balanced. Assuming that pressure relief is provided by a transfer grille, at a cost of \$31 per grille (including two interior registers, a galvanized frame, and a sound baffle), the total cost for this feature was estimated to be \$93 for a three bedroom home, plus 30 minutes of installation by an HVAC Assistant at a labor rate of \$55 per hour, equal to \$27. In addition, the Rater must verify that the pressure balancing requirements have been met. Estimating 5 minutes per bedroom, at a labor rate of \$55 per hour, the cost for verification was \$14. These three costs add to a total of \$134.

Section 6 also requires that duct insulation levels be visually verified. It is expected that this visual inspection will occur concurrent with the visual inspections conducted for the Thermal Enclosure System section of the Rater-F and therefore no incremental cost was estimated for this task.

Finally, Section 6 requires that ducts be tested and verified to meet air leakage limits. The 2009 IECC also requires this for the baseline home configurations analyzed. Therefore no incremental cost was assumed for testing. However, the duct leakage limits in the 2009 IECC are less stringent than those in the Rater-F. Therefore, the increased effort and cost to achieve the lower leakage limits were accounted for in Exhibits 4 through 16.

Section 7 requires the whole-house mechanical ventilation rate to be measured. Verifying that the Rater-measured ventilation rate is within  $\pm 15$  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. By averaging the two values, a cost of \$11 was estimated. Note that the incremental cost of the whole-house mechanical ventilation system itself is accounted for with the National HVAC Design Report.





# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

Section 7 also defines whole-house mechanical ventilation control, fan efficiency, inlet location, and sound requirements, which are not addressed in the 2009 IRC. Not all of the requirements will apply to all homes. Therefore, these quick visual inspections were estimated to take 5 minutes per home. At a labor rate of \$55 per hour, the cost for verification was \$5.

Section 8 primarily defines airflow requirements for kitchen and bath exhaust fans. While the 2009 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 for ENERGY STAR certified homes, 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. While two bathroom fans are assumed to be present in the home, only one is upgraded to meet this requirement. The other is upgraded as part of the whole-house mechanical ventilation system, as accounted for with the National HVAC Design Report. Estimating that it takes 5 minutes to measure each bath fan, 10 minutes are required to complete this test. Due to the complexity of some kitchen exhaust fan inlets, it was estimated that it will take 10 minutes to verify the kitchen exhaust requirements. In total, this equals 20 minutes. At a labor rate of \$55 per hour, this equates to \$18. Because sound limits are now recommended, rather than required, for all but continuously-running bath fans, no incremental cost was assumed to achieve these limits.

Section 9 defines filtration requirements. The 2009 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. In addition, visual verification of these requirements by the Rater was estimated to take 5 minutes. At a labor rate of \$55 per hour, this equates to \$5.

Section 10 defines combustion safety requirements. Unlike the Rater-F, the 2009 IRC does not explicitly require power-vented or direct-vented combustion appliances, nor does it explicitly require combustion safety testing. However, for homes 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, either into the unconditioned attic or the garage, or to use electric space and water heating equipment. In Climate Zones 4 through 7, 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 homes in Climate Zones 4 through 7. For these home 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.

The remainder of Section 10 defines requirements for fireplaces that are not mechanically-drafted or direct-vented and for unvented combustion appliances other than cooking ranges or ovens. On average, it is not expected that homes will have combustion appliances of these types and, therefore, no incremental cost was assumed for compliance.

In summary, the costs for the measures that impact the HERS Index are itemized in Exhibits 4 through 16. The remaining checklist requirements address Rater verification of the equipment model numbers, static pressure, bedroom pressure balancing, ventilation system, and filter. These sum to \$202 for Climate Zones 1-3 as well as electric homes in Climate Zones 4-7, and to \$102 for gas homes in Climate Zones 4-7. These were rounded to the nearest \$25, for a final estimated cost of \$200 and \$100, respectively.



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) 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 HERS Index 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 HERS rating.

As can be seen in Exhibits 4 through 16, the net cost for complying with the HVAC-D was estimated to range between savings of \$333 and a cost of \$152, depending on Climate Zone and house configuration, and encompasses both requirements that improve the HERS Index and those that do not.

Excluding the requirements that impact the HERS Index, the only remaining requirement is the completion of the HVAC-D by the designer, which is estimated to cost \$5 based upon current labor rates.

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, additional 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**

Section 1 of the HVAC-D requires the designer to provide a basic overview of their design. While not explicitly required by the 2009 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 whole-house mechanical ventilation system be designed and installed, which is not required by the 2009 IRC.

In Climate Zones 1 through 4, costs were estimated for 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. Homes 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 this system, the added costs were the motorized damper, the controller for the motorized damper and bathroom exhaust fan, the ENERGY STAR certified bathroom exhaust fan, and a half hour of installation.

For Climate Zones 5 through 7, the costs were estimated for a ventilation system comprising an ENERGY STAR certified bathroom exhaust fan and bath fan controller. Homes with this system use the bathroom exhaust fan to provide all required ventilation. For this system, the added costs were the incremental cost to upgrade from a non-certified to an ENERGY STAR certified fan and the controller for the bathroom exhaust fan. No incremental labor cost was assumed.

The incremental costs for all of these ventilation systems are included in Exhibits 4 through 16. The energy impact from the ventilation load and the fan power were captured within REM/Rate.

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 2009 IRC. However, while both the baseline home and the ENERGY STAR certified home were assumed to be right-sized per code requirements, the cooling equipment capacity of the ENERGY STAR certified home was assumed to be one half ton smaller. This occurs because of the reduced load resulting from measures such as the insulation installation, infiltration, and fenestration requirements of the program. The cost savings from this half ton reduction in equipment size is included in Exhibits 4 through 16.



## ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

In summary, the costs for the measures that impact the HERS Index are itemized in Exhibits 4 through 16. The additional cost for the completion of the HVAC-D by the designer is estimated to be \$5. EPA has worked to automate this task, such that it requires negligible time or money to complete. However, some designers still complete this task manually. Filling out one report manually is estimated to take 20 minutes. This might be done multiple times for one plan, if multiple designs are needed to accommodate options. On the other hand, one HVAC design might be used multiple times in a production environment where the same house plan and HVAC design is built repeatedly. Assuming that the average HVAC design is used 5 times, the average cost per house is 4 minutes. At a labor rate of \$88 per hour, the total labor cost equates to \$6, which was rounded to the nearest \$5, for a final estimated cost of \$5.



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) 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 HERS Index. As can be seen in Exhibits 4 through 16, the net cost for complying with the Rater-D was estimated to be \$25.

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 is an ENERGY STAR partner and the HVAC contractor is credentialed, to verify that the fenestration and insulation specified in the home energy rating file complies with the program's requirements, to collect the National 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 is an ENERGY STAR partner is 1 minute and the estimated time required to verify that the HVAC contractor is credentialed is 5 minutes. Verification that the fenestration and insulation meets program requirements automatically occurs within the home energy rating software program, so no time is estimated for compliance. Assuming that the same HVAC design is built five times, and that the time required to collect each one-page National HVAC Design Report is one hour, the average time per house to complete this task is estimated to be 12 minutes. Lastly, by again assuming that one report is needed per five homes constructed, and estimating that 30 minutes are required to review each report, the estimated time to review the National HVAC Design Report is 6 minutes per home.

In summary, the tasks on the Rater-D require 24 minutes per home. At a labor rate of \$55 per hour, the total labor cost equates to \$22. This was rounded to the nearest \$25, for a final estimated cost of \$25.



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

## Section 7: Incremental Cost & Savings of the National HVAC Commissioning Checklist

### Average Estimated Incremental Cost

The requirements of the National HVAC Commissioning Checklist (HVAC-C) do not affect the HERS Index. In total, the average incremental cost of the HVAC-C was estimated to be \$75.

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

### Average Estimated Incremental Savings

The only energy savings of the HVAC-C were estimated outside of REM/Rate and account for complying with the commissioning 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

Prior to installation of HVAC systems in ENERGY STAR certified homes and completion of the HVAC-C, contractors are required to be credentialed by an HVAC Quality Installation Oversight Organization (HQUITO). Two HQUITO's are available, each with its own fee structure and an overall cost per home that is dependent on the number of homes that the contractor installs systems in annually. Costs per home can range from less than \$10 to greater than \$100. For a contractor installing systems in 25 homes per year, the costs per home after the first year is approximately \$24, assuming no significant quality assurance issues.

Section 1 of the HVAC-C requires the contractor to provide a basic overview of the system they're commissioning. While not explicitly required by the 2009 IECC, providing this information does not add any incremental cost other than the time required to complete the paperwork.

The remainder of the HVAC-C requires two HVAC commissioning tests to be completed, which are not explicitly required by the 2009 IRC. In Section 2, the contractor is required to verify the refrigerant charge. Using a digital manifold, this is estimated to take 20 minutes. 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. 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. Lastly, it was estimated to take 5 minutes to fill out the checklist with the information gathered in the field. The total time for commissioning (i.e., measuring refrigerant charge, using static pressure and the fan-speed setting to approximate air handler airflow, and completing the checklist) was estimated to take 44 minutes. At a labor rate of \$88 per hour for an HVAC Contractor, this translates to \$59. With the addition of the \$24 per home credential fee, this sums to a total cost of \$83. This was rounded to the nearest \$25, which is \$75.

Energy savings from the HVAC commissioning 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 commissioning 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."

In addition, a savings factor of 2.9% was estimated for the commissioning 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%



## ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

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 Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

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

### **Average Estimated Incremental Cost**

The requirements of the National Water Management System Builder Requirements (Builder-W) do not impact the HERS Index. Furthermore, because they are also required by the 2009 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 Builder-W, as the measures implemented are focused on water management details.

### **Rationale**

Section 1 defines water management details applicable to the site and to the home'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 2009 IRC. Therefore, no incremental cost was estimated for meeting these code-required checklist items. Furthermore, since the Builder-W 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 Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

## Section 9: Cost References

### A. Thermal Enclosure System

#### Air Sealing

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

#### Doors

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

#### Framing

<b>Reference</b>	RS Means Construction Cost Data 2010
<b>Accessed</b>	June 2016
<b>Notes</b>	<ul style="list-style-type: none"> <li>Framing costs based upon RS Means Line Number 06 11 10.40 6145, representing 2x4 8.5 ft. high studs in Climate Zones 1 through 4, and RS Means Line Number 06 11 10.40 6165, representing 2x6 8.5 ft. high studs in Climate Zones 5 through 7.</li> <li>All costs prorated by 12.9% to adjust for inflation between 2010 and 2016 using RS Means 2016 Cost Construction Index.</li> </ul>

#### Insulation Installation

<b>Source</b>	RS Means Construction Cost Data 2010
<b>Accessed</b>	June 2016
<b>Notes</b>	<ul style="list-style-type: none"> <li>Incremental cost for going from Grade III to Grade I wall insulation:             <ul style="list-style-type: none"> <li>In Climate Zones 1-4: Assumed to cost 35% more than labor rate for RS Means Line Number 07 21 16.20 0080, representing batt insulation,</li> <li>In Climate Zones 5-7: Assumed to cost 25% more than labor rate for RS Means Line Number 07 21 26.10 0020, representing blown insulation.</li> </ul> </li> <li>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.</li> <li>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.</li> <li>All labor rates prorated by 12.9% to adjust for inflation between 2010 and 2016 using RS Means 2016 Cost Construction Index.</li> </ul>

#### Radiant Barrier

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





# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

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

## Windows

<b>Reference</b>	NREL National Residential Energy Efficiency Measures Database v3.0.0 <a href="http://www.nrel.gov/ap/retrofits/">http://www.nrel.gov/ap/retrofits/</a>
	Market data from ENERGY STAR Program Requirements for Residential Windows, Doors, and Skylights
<b>Accessed</b>	June 2016
<b>Notes</b>	<ul style="list-style-type: none"> <li>A two-step process was used to estimate the incremental costs for windows, reflecting a dearth of data for this measure.</li> <li>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 <math>\leq 0.32</math>, and is as follows: <math>y = [\text{SHGC}] \times (-0.688) + [\text{U-value}] \times (-96.33) + 54.5</math>. The second equation was created using the NREL data for non-metal frames, representing windows with a U-factor <math>&gt; 0.32</math>, and is as follows: <math>y = [\text{SHGC}] \times (-1.32) + [\text{U-value}] \times (-8.36) + 25.8</math>.</li> <li>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, &amp; 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, &amp; 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, 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.</li> <li>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.</li> </ul>

## B. Space Conditioning Equipment & Filter

### Air-source Heat Pump

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

### Central Air Conditioner

<b>Reference</b>	NREL National Residential Energy Efficiency Measures Database v3.0.0 <a href="http://www.nrel.gov/ap/retrofits/">http://www.nrel.gov/ap/retrofits/</a>
<b>Accessed</b>	June 2016



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

<b>Notes</b>	<ul style="list-style-type: none"> <li>• Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction.</li> <li>• Costs were linearly interpolated by SEER.</li> </ul>
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## Filter

<b>Reference</b>	<p>True Blue 12 in. x 24 in. x 1 in. Fiberglass FPR 1 Air Filter (MERV 2) <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # 112241</p> <p>Honeywell 12 in. X 24 in. X 1 in. Allergen Plus Pleated FPR 7 Air Filter (~MERV 6) <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # 205164337</p>
<b>Accessed</b>	September 2016
<b>Notes</b>	<ul style="list-style-type: none"> <li>• N/A.</li> </ul>

## Gas Furnace

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

## C. Ventilation Equipment

### Exhaust Ventilation System

<b>Reference</b>	<p>SmartExhaust Toggle Controller <a href="http://www.aircyclers.com/products/smartexhaust">http://www.aircyclers.com/products/smartexhaust</a></p> <p>Air King 50 CFM Bath Exhaust Fan Without Light <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # AS54</p> <p>Air King 50 CFM Bath Exhaust Fan With Light <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # ASLC50</p> <p>Air King 80 CFM ENERGY STAR Certified Bath Exhaust Fan Without Light <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # AK80</p> <p>Air King 100 CFM ENERGY STAR Certified Bath Exhaust Fan Without Light <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # AK100L</p>
<b>Accessed</b>	September 2016
<b>Notes</b>	<ul style="list-style-type: none"> <li>• Included in homes in Climate Zones 5-7.</li> <li>• 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.</li> </ul>

### Supply Ventilation System

<b>Reference</b>	<p>AirCycler g2 <a href="http://www.aircyclers.com/products/aircyclers-g2">http://www.aircyclers.com/products/aircyclers-g2</a></p> <p>Honeywell EARD6TZ 6" Round Motorized Fresh Air Damper <a href="http://www.supplyhouse.com/Honeywell-EARD6TZ-6-Round-TrueZONE-Motorized-Fresh-Air-Damper">http://www.supplyhouse.com/Honeywell-EARD6TZ-6-Round-TrueZONE-Motorized-Fresh-Air-Damper</a></p> <p>AirCycler FanConnect <a href="http://www.aircyclers.com/products/fanconnect">http://www.aircyclers.com/products/fanconnect</a></p>
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# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

	<p>Air King 50 CFM Bath Exhaust Fan Without Light <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # AS54</p> <p>Air King 50 CFM Bath Exhaust Fan With Light <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # ASLC50</p> <p>Air King 80 CFM ENERGY STAR Certified Bath Exhaust Fan Without Light <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # AK80</p> <p>Air King 100 CFM ENERGY STAR Certified Bath Exhaust Fan Without Light <a href="http://www.Homedepot.com">http://www.Homedepot.com</a>, Gulfgate Mall Store #6509 (Houston), Model # AK100L</p>
<b>Accessed</b>	September 2016
<b>Notes</b>	<ul style="list-style-type: none"> <li>• Included in homes in Climate Zones 1-4.</li> <li>• 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.</li> </ul>

## D. Ductwork

### Duct sealing

<b>Reference</b>	NREL National Residential Efficiency Measures Database v3.0.0 <a href="http://www.nrel.gov/ap/retrofits/">http://www.nrel.gov/ap/retrofits/</a>
<b>Accessed</b>	June 2016
<b>Notes</b>	<ul style="list-style-type: none"> <li>• Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction.</li> <li>• 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 (3 tons in CZ 1-4 and 2.25 tons in CZ 5-7) 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.</li> <li>• A duct surface area of 576 ft<sup>2</sup> was assumed using the default area reported in REM/Rate v15.7 for a 2,400 sq. ft. 2-story home with one return register.</li> </ul>

### Transfer Grille

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

## E. Domestic Hot Water Equipment

### Electric Water Heater

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



# ENERGY STAR Certified Homes, Version 3 (Rev. 09) Cost & Savings Estimates

## Gas Water Heater

<b>Reference</b>	NREL National Residential Energy Efficiency Measures Database v3.0.0 <a href="http://www.nrel.gov/ap/retrofits/">http://www.nrel.gov/ap/retrofits/</a>
<b>Accessed</b>	June 2016
<b>Notes</b>	<ul style="list-style-type: none"> <li>Because the database represents retrofit costs, the low-end of the cost range was used to approximate the costs for new construction.</li> <li>Costs were linearly interpolated by Energy Factor (EF).</li> <li>Additional incremental cost for power venting capability in CZ 4-7 was estimated to be \$150.</li> </ul>

## F. Appliances & Lighting

### Dishwasher

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

### Lighting

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

### Refrigerator

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

## G. Labor

<b>Source</b>	RS Means Construction Cost Data 2010																
<b>Accessed</b>	June 2016																
<b>Notes</b>	<ul style="list-style-type: none"> <li>Hourly rate listed by position:           <table border="1" data-bbox="313 1551 1276 1755"> <thead> <tr> <th>Cost &amp; 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> </tbody> </table> </li> <li>All labor rates prorated by 12.9% to adjust for inflation between 2010 and 2016 using RS Means 2016 Cost Construction Index.</li> </ul>		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
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