How Much More Does It Cost to Build an ENERGY STAR[®] Home? Incremental Cost Estimation Process

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ABSTRACT

The incremental costs for building ENERGY STAR-certified homes over baseline homes have changed recently. ENERGY STAR certification now sets duct leakage maximums and mandates completion of the Thermal Bypass Checklist (TBC), which increase builders' costs. At the same time, raising the standards of local building codes and baseline practices reduce energy efficiency incremental costs. This paper discusses the methodology used in developing incremental cost estimates for the Massachusetts New Homes with ENERGY STAR Program. The project estimates the incremental costs involved in building a home to minimum ENERGY STAR requirements (HERS Index of 85) and to higher efficiency levels that achieve HERS scores of 70 and 65.

The project determines the incremental cost of implementing various measures and practices necessary for achieving ENERGY STAR and higher efficiency levels, such as improving insulation, air sealing, duct sealing, HVAC equipment, windows and water heating, and passing the TBC. The project incorporates cost information from several sources including RS Means data, HVAC and insulation contractors, builders, and builder supply companies. Ten builders who have constructed ENERGY STAR homes under the most recent standards, five insulation contractors, and five HVAC contractors were interviewed.

Building contractors with experience in energy-efficient construction are the preferred source of incremental costs estimates; the challenge is to get them to devote time calculating the incremental cost of upgrading specific measures and implementing new construction practices. This paper discusses the strategies used to estimate incremental costs and also provides the incremental costs of building homes to various ENERGY STAR levels.

Introduction

The incremental costs involved in building an ENERGY STAR-certified home over a baseline home in Massachusetts were last estimated in 2002. Since then, various forces have pushed incremental costs in both upward and downward directions. ENERGY STAR certification now sets duct leakage minimums and mandates completion of the Thermal Bypass Checklist (TBC), which increase builders' costs. At the same time, raising the standards of local building codes and baseline practices reduce energy efficiency incremental costs. This is because incremental costs are calculated by considering energy efficient measures and practices that builders are not already implementing.

Since many ENERGY STAR-certified homes in Massachusetts surpass minimum requirements, this study estimates the incremental costs involved in building a home to minimum ENERGY STAR requirements (HERS Index of 85) and to higher efficiency levels that achieve HERS indices of 70 and 65. Incremental costs are estimated for both single family homes and multifamily units at the HERS 85

and 70 levels and for single family homes at the HERS 65 level. Furthermore, since a substantial minority of Massachusetts new homes use boilers and many of those heat with oil, incremental costs are estimated for homes with three different types of heating systems: natural gas furnaces, natural gas boilers, and oil boilers. Thus there are fifteen sets of incremental costs estimated in all: six at the HERS 85 level (two housing types times three heating systems), six at the HERS 70 level (two housing types times three at the HERS 65 level (single family homes with three heating systems).

Methodology

The first step in estimating incremental costs is to determine what upgrades a baseline home would require to reach the HERS levels considered. Several packages for reaching each HERS level were developed for single family homes and multifamily units through use of the RemRate model. The program implementer, ICF International, Inc., was asked to develop realistic packages of measures for reaching each targeted HERS index level based on what builders in the program are installing. Therefore, some highly efficient measures, such as instantaneous water heaters, are not included in the upgrade packages if they are not measures builders in the program are typically installing. Additionally, packages going from the baseline to minimum ENERGY STAR requirements often called for mix of "upgrades" and "downgrades" involving cost trade-offs. For example, a builder could install a more efficient heating system and use less efficient windows. The values for various components were compared to the baseline values developed in a 2005 baseline study and used to define the User Defined Reference Home (UDRH). The components requiring modifications to reach the various HERS levels, and thus contributing to incremental costs, are listed in Table 1.

0
Ceiling Insulation
Floor Insulation
Slab Insulation
Wall Sheathing Insulation (HERS 70 and 65 Packages only)
Insulation Installation Grade
Duct Leakage
Duct Insulation
Windows
Air Infiltration
Mechanical Ventilation
Heating System Size
Heating System Efficiency
Cooling System Size
Cooling System Efficiency
Water Heater Efficiency
Thermal Bypass Checklist

 Table 1: Measures Addressed in All Packages

In order to estimate incremental costs for these components, it is also necessary to define the parameters of a "typical" newly constructed home. These parameters, shown in Table 2, are developed from averages reflecting the homes and multifamily units certified through the program.

	Average Area by Housing Type (Sq. Ft.)		
Building Parameters	Single-Family	Multi-Family	
Conditioned Floor Area	2,425	1,504	
Exterior Wall Area	2,517	1,506	
Ceiling Area - Attic	1,114	510	
Ceiling Area - Cathedral	249	182	
Window Area	316	191	
Door Area	59	34	
Slab Floor Area	406	316	
Floor Over Unconditioned Area	922	342	
Duct Supply Area	232	121	
Duct Return Area	116	44	
Foundation Wall Area	2,135	513	

 Table 2: Building Parameters Used for Incremental Cost Estimates

One of the goals of the study was to base incremental cost estimates, to the extent possible, on data provided by building contractors with experience in energy-efficient construction. Builders who had constructed ENERGY STAR-certified homes under the new standards specifying duct leakage maximums and completion of the Thermal Bypass Checklist (TBC), as well as insulators and HVAC contractors who had worked on such homes were contacted for this purpose. While the project team has had a great deal of experience interviewing building professionals on energy-efficient new construction, having the respondents provide actual cost estimates based on the parameters in Table 2 proved to be much more difficult than conducting more qualitative interviews. Accordingly, a multi-step process was used.

Interviews with insulation and HVAC contractors were initiated before builder interviews. For some of the measure upgrades considered, the respondents were provided with preliminary estimates of incremental costs based on information from interviews completed to date, the RS Means Guide and/or HVAC distributor web sites. We then asked the respondents whether these estimates were too high, too low, or about right; respondents who chose one of the first two options then provided their own estimates. In the case of insulator interviews, the RS means Guide provided the initial estimates for ceiling insulation upgrades from R-30 using fiberglass batts to R-38 using blown-in cellulose. In the case of HVAC distributor websites provided the initial estimates for downsizing heating and cooling systems and increasing heating and cooling system efficiency levels. All respondents were contacted at least twice: once to explain the purpose of the study and to provide them with the building parameters and any initial estimates available, and then again to obtain their final estimates. In all, we completed ten contractor interviews; five with insulators and five with HVAC contractors.

The cost estimates sent to builders were an average of estimates from insulation and HVAC contractors, RS Means, builder supply companies, and HVAC distributor websites, as appropriate. For example, the initial ceiling insulation costs provided to builders were an average of estimates from the RS Means Guide and the five insulator interviews. Builders were also provided initial cost estimates for

upgrading slab insulation from uninsulated to R-10 and upgrading wall sheathing insulation from uninsulated to R-3 from RS Means Guide data.

Builders provided cost estimates for all measure upgrades except windows, installing mechanical ventilation, floor insulation, and upgrades of slab insulation from uninsulated to R-2 and R-7. We did not obtain cost estimates from builders for these measures since we found that the respondents' experience with these measures was not sufficient to provide reliable estimates. In all, we completed ten builder interviews; however, as was the case with insulators and HVAC contractors, not all builders could provide incremental cost estimates for each measure requested.

Table 3 summarizes the methodology used showing the sources for all incremental cost estimates and, in the cases where incremental costs are based on averages, the number of observations used. In cases where averages are calculated from interview data and a source such as the RS Means Guide, the RS Means Guide is treated as one observation; each builder or contractor interview is likewise treated as one observation.

As may be noted from Table 3, calculating incremental costs for each package involved the summation of many measure upgrade costs (or, in a few cases, subtracting costs associated with downsizing HVAC equipment, eliminating floor insulation, etc.). Tables 4a and 4b present examples of incremental cost calculation for two packages: single family homes with gas furnaces going from the baseline to the minimum ENERGY STAR or HERS 85 level and from the baseline to the HERS 65 level.

Results

Table 5 shows incremental costs for all the heating system combinations considered with single and multifamily averages at the different HERS levels. Estimated incremental costs for building homes meeting the minimum ENERGY STAR requirements (HERS Index 85) in Massachusetts average \$2,599 or \$1.07 per square foot for single family homes and \$1,286 or \$0.85 per square foot for multifamily units. The incremental costs per square foot to reach the minimum ENERGY STAR level calculated in 2007 are somewhat lower than the costs calculated in 2002; the 2007 average single family cost of \$1.07 per square foot is 18% lower than the \$1.31 per square foot calculated in 2002; similarly, the 2007 average multifamily unit cost of \$0.85 per square foot is 11% lower than the \$0.95 per square foot calculated in 2002. These lower costs are to be expected since baseline practices, as identified in the 2005 baseline study, are more energy efficient than baseline practices identified in the previous baseline study.

Incremental costs increase substantially at higher efficiency levels; single family incremental costs to reach the HERS 70 level are more than two-and-one-half times the incremental costs of meeting minimum ENERGY STAR requirements; multifamily unit incremental costs are almost four times as high.

Measure	Data Sources	Number of Observations
Upgrade ceiling insulation R-30	Average of RS Means data, insulator	
to R-38	interview data and builder interview data.	16
Downgrade floor insulation R-19	RS Means data	
to R-11 or to uninsulated		1
Upgrade slab insulation uninsulated to R-2	Building supply house data	1
Upgrade slab insulation	RS Means data	
uninsulated to R-7		1
Upgrade slab insulation	Average of RS Means data and builder	
uninsulated to R-10	interview data	8
Upgrade wall sheathing	Average of RS Means data and builder	_
insulation uninsulated to R-3	interview data	7
Upgrade insulation install grade	Average of insulator interview data and	
from III to I	builder interview data.	13
Reduce duct leakage from 22%	Average of HVAC contractor interview data	10
to 6% or lower	and builder interview data	12
Upgrade duct insulation R-5 to	Average of HVAC contractor interview data	
R-6	and builder interview data	11
Upgrade or downgrade windows	Building supply house data	1
Reduce air infiltration	Average of insulator interview data and	5 (air seal to 2.0 ACH50)
	builder interview data	8 (air seal to 3.0 ACH50)
		10 (air seal to 4.0 ACH50)
		11 (air seal to 5.0 ACH50)
Install mechanical ventilation	Building supply house data	1
Change in heating system size	Average of HVAC contractor interview data,	5 (oil boilers)
	builder interview data and prices from HVAC	11 (gas furnaces)
	distributor websites	13 (gas boilers)
Change in heating system	Average of HVAC contractor interview data,	3 (65,000 BTUH Oil Boiler)
efficiency	builder interview data and prices from HVAC	5 (110,000 BTUH Oil Boiler)
	distributor websites	7 (65,000 BTUH Gas Boiler or
		110,000 Gas Furnace)
		8 (110,000 BTUH Gas Boiler)
		9 (110,000 BTUH Gas
		Furnace)
Change in cooling system size	Average of HVAC contractor interview data,	
	builder interview data and prices from HVAC	10
		12
officiency	Average of HVAC contractor interview data,	
enciency	distributor wobsites	9 (2.0 ton Unit)
Lingrade water boater officiency	Average of HVAC contractor interview date	11 (3.2 ton unit)
opgrade water neater eniciency	and builder interview data	11
Thermal bypass checklist	Average of builder interview data	9

 Table 3: Data Sources for Incremental Costs by Measure

Package	Baseline	HERS 85	Cost Estimate	Per Sq. Foot Cost
Duct Leakage	21.7%	6.0%	\$621	\$0.26
Duct Insulation R-Value	4.7	6.0	\$181	\$0.07
Air Infiltration	6.72 ACH50	5.0 ACH50	\$393	\$0.16
Mechanical Ventilation	None	100 CFM/40 Watts	\$143	\$0.06
Windows U-Value	0.37	0.35	\$316	\$0.13
Ceiling Insulation R-Value	31	38	\$228	\$0.09
Insulation Installation Grade	III	ļ	\$620	\$0.26
Slab Insulation R-Value	0.11	Uninsulated	\$0	\$0.00
Floor Insulation R-Value	19.4	11.0	-\$175	-\$0.07
Downsize Furnace (BTUH)	130,000	110,000	-\$208	-\$0.09
Downsize Central AC (Tons)	4.0	3.2	-\$142	-\$0.06
Water Heater Energy Factor	0.59	0.62	\$73	\$0.03
Thermal Bypass Checklist			\$886	\$0.37
		Total	\$2,936	\$1.21

Table 4a : Single Family Package to Reach HERS Index of 85 (ENERGY STAR) with GasFurnace

Table 4b: Single Family Package to Reach HERS Index of 65 with Gas Furnace

Package	Baseline	HERS 65	Cost Estimate	Per Sq. Foot Cost
Duct Leakage	21.7%	1.0%	\$621	\$0.26
Duct Insulation R-Value	4.7	6.0	\$181	\$0.07
Air Infiltration	6.72 ACH50	2.0 ACH50	\$1,460	\$0.60
Mechanical Ventilation	None	100 CFM/40 Watts	\$143	\$0.06
Windows U-Value	0.37	0.25	\$1,368	\$0.56
Ceiling Insulation R-Value	31	38	\$228	\$0.09
Insulation Installation Grade	III		\$620	\$0.26
Exterior Wall Insulation R-Value	0.0	3.0	\$2,244	\$0.93
Slab Insulation R-Value	0.11	10.0	\$532	\$0.22
Floor Insulation R-Value	19.4	11.0	-\$175	-\$0.07
Downsize Furnace (BTUH)	130,000	110,000	-\$208	-\$0.09
Furnace Efficiency—AFUE	90	96	\$826	\$0.34
Downsize Central AC (Tons)	4.0	3.2	-\$142	-\$0.06
Central AC SEER	13	17	\$629	\$0.26
Water Heater Energy Factor	0.59	0.62	\$73	\$0.03
Thermal Bypass Checklist			\$886	\$0.37
		Total	\$9,286	\$3.83

	ENERGY STAR Minimum (HERS 85)	HERS 70	HERS 65
Single Family Home with Gas Furnace	\$2,869	\$7,136	\$9,286
total and per square foot cost	\$1.18	\$2.94	\$3.83
Single Family Home with Gas Boiler	\$2,646	\$6,570	\$8,160
total and per square foot cost	\$1.09	\$2.71	\$3.36
Single Family Home with Oil Boiler	\$2,371	\$6,325	\$7,914
total and per square foot cost	\$0.98	\$2.61	\$3.26
Average for all single family	\$2,599	\$6,677	\$8,453
total and per square foot cost	\$1.07	\$2.75	\$3.49
Multifamily Unit with Gas Furnace	\$1,068	\$5,314	
total and per square foot cost	\$0.71	\$3.53	NA
Multifamily Unit with Gas Boiler	\$1,470	\$4,756	
total and per square foot cost	\$0.98	\$3.16	NA
Multifamily Unit with Oil Boiler	\$1,246	\$4,697	
total and per square foot cost	\$0.83	\$3.12	NA
Average for all multifamily	\$1,286	\$4,922	
total and per square foot cost	\$0.85	\$3.27	NA

Table 5: Incremental Costs from Baseline to Specific HERS Levels

While the incremental costs for reaching a HERS level of 70 or 65 from baseline building practices are quite steep, it must be noted that most builders truly interested in achieving a HERS index of 70 or 65 are likely already building homes that would achieve a HERS index lower than 85. Table 6 thus shows the incremental costs associated with stepping up energy efficiency: going from HERS 85 to HERS 70 and from HERS 70 to HERS 65. The incremental costs for going from HERS 85 to HERS 70 for an average single family home are about 50% greater than the incremental costs of going from a baseline home to HERS 85; going from HERS 70 to HERS 65 for an average single family home has incremental costs less than half those required to go from HERS 85 to HERS 70.

	Baseline To HERS 85	HERS 85 To HERS 70	HERS 70 To HERS 65
Single Family Home with Gas Furnace	\$2,869	\$4,267	\$2,150
total and per square foot cost	\$1.18	\$1.76	\$0.89
Single Family Home with Gas Boiler	\$2,646	\$3,924	\$1,590
total and per square foot cost	\$1.09	\$1.62	\$0.65
Single Family Home with Oil Boiler	\$2,371	\$3,954	\$1,589
total and per square foot cost	\$0.98	\$1.63	\$0.65
Average for all single family	\$2,599	\$4,078	\$1,776
total and per square foot cost	\$1.07	\$1.68	\$0.74
Multifamily Unit with Gas Furnace	\$1,068	\$4,246	ΝΔ
total and per square foot cost	\$0.71	\$2.82	NA NA
Multifamily Unit with Gas Boiler	\$1,470	\$3,286	ΝΔ
total and per square foot cost	\$0.98	\$2.18	INA
Multifamily Unit with Oil Boiler	\$1,246	\$3,451	ΝΔ
total and per square foot cost	\$0.83	\$2.29	INA
Average for all multifamily	\$1,286	\$3,636	ΝΑ
total and per square foot cost	\$0.85	\$2.42	INA

Table 6: Incremental Costs Between HERS Levels

Detailed Findings

The incremental cost packages, as noted in Table 1, addressed 16 different measures or types of costs. This section explores some of the more interesting findings on individual cost categories.

Insulation

The ceiling insulation upgrade assumes the use of R-38 blown-in cellulose instead of R-30 fiberglass batts; this makes sense since blown-in cellulose is used by most of the builders interviewed for the incremental cost study and is recommended by the Massachusetts New Homes with ENERGY STAR Program. Builders and insulation contractors were also asked to estimate incremental costs going from R-30 fiberglass batts to R-38 fiberglass batts and from R-30 fiberglass batts to R-38 spray foam. Using R-38 fiberglass batts instead of R-38 blown-in cellulose would cost an average of \$92 less per single family home or 4% of HERS 85 incremental costs and \$42 less per multifamily home or 3% of HERS 85 incremental costs. Spray foam is much more expensive; using spray foam instead of R-38 blown-in cellulose would cost an average of \$4,129 more per single family home or 159% of HERS 85 incremental costs and \$1,895 more per multifamily home or 147% of HERS 85 incremental costs. While some insulation contractors argued that spray foam is recommended to achieve the low air infiltration levels (2.0 ACH50) required for some HERS 65 packages, most builders maintain that these levels are doable with blown-in cellulose. Thus, the blown-in cellulose incremental cost was used for attic insulation upgrades in all packages.

Thermal Bypass Checklist

Builders are the sole source of incremental cost estimates involved in meeting the TBC. The TBC, required for ENERGY STAR certification on all homes in 2007, consists of a visual inspection of framing areas where air barriers are commonly missed and ensuring proper alignment of the insulation with the air barriers; over twenty areas need to be inspected before the walls are completed. The TBC incremental cost estimates displayed the greatest amount of variation of all of the estimates obtained. Estimates for single family homes range from \$0 by a builder who said that his contractors already followed "good practices" to \$2,500. According to ICF, the program's implementer, the variation in builders' estimates of the cost of meeting the TBC is reasonable given the differences in individual builders' standard practices and experience.

Builders were asked if they thought TBC incremental costs would decrease after they had completed the first home, since less additional planning and contractor oversight might be required for subsequent projects. However, most of the respondents did not have enough experience with the TBC to estimate reduced costs for subsequent homes, so the initial home average estimates of \$886 for single family homes and \$549 for multifamily units were used. These costs may be reduced as builders gain more experience with the TBC.

Labor Costs

Four out of five insulation contractors interviewed say they charge more to work on ENERGY STAR homes; five out of ten builders interviewed also report that they pay more for insulation jobs on ENERGY STAR homes. (Four builders said they do not pay more for ENERGY STAR jobs, but probably pay more for choosing better quality insulation companies than those doing quick-and-dirty jobs, and one builder did not know.) Builders were also asked to estimate how much more time they spent overseeing the insulation contractor's work to ensure ENERGY STAR standards are met and to put a dollar value on that time. The incremental labor costs paid to insulators are calculated as an average of the builder and insulator estimates; incremental costs for builder oversight are then added to these costs to calculate total incremental insulation labor costs. Incremental builder oversight costs averaged 18% of total incremental insulation labor costs. In total, incremental labor costs for homes at all three HERS levels averaged \$620 for single family homes and \$341 for multifamily units.

HVAC Related Costs

HVAC related incremental costs come from downsizing equipment (these are actually savings which are subtracted from total costs), increasing unit efficiencies, and duct sealing. In most cases the range of HVAC related incremental cost estimates are reasonably consistent. The heating system upgrades with the widest ranges of estimates are upgrades to very high efficiency systems. Estimates for central air conditioning upgrades from SEER 13 to SEER 17 also varied widely, ranging from \$492 to \$1,100 for a 3.2 ton unit and from \$493 to \$850 for a two ton unit.

Sealing ducts to ENERGY STAR levels is one of the more expensive upgrade measures. Individual upgrade packages called for reaching specific duct leakage levels of one, four or six percent. The HVAC contractors said they could not provide different cost estimates for achieving different specific duct leakage levels—they say they simply seal the ducts to meet ENERGY STAR standards. Given that the average duct leakage in homes certified in 2006 that met the new six percent duct leakage requirement was less than three percent, it seems reasonable to use one cost estimate for reducing duct leakage from the baseline level of 21.7% to six percent or less.

Cost estimates for sealing ducts to ENERGY STAR levels vary widely. HVAC contractors' cost estimates for duct sealing to ENERGY STAR levels range from \$650 to \$1,000 for a single family home. Builders' estimates tend to be lower: two builders say it does not cost more to seal ducts to ENERGY STAR levels if the contractor is following the building code, and the others provided estimates ranging from \$400 to \$965. Average incremental costs of \$621 for single family homes and \$370 for multifamily units were used for all packages achieving the selected HERS levels. Of course, a minority of homes, using boilers with no central air conditioning (some affordable housing and some homes in the western part of the state fall into this category) will not need duct sealing; this can reduce incremental costs for meeting ENERGY STAR requirements by about 25%.

Conclusions

Estimating incremental building costs is a time-consuming but necessary component of planning for the Massachusetts New Homes with ENERGY STAR Program. The toughest part was getting twenty busy contractors (ten builders, five HVAC contractors, and five insulators) to provide cost estimates on multiple measures for a hypothetical job. By sending them a questionnaire with detailed parameters after the initial contact, we tried to make it clear that we hoped to get back realistic estimates. Some contractors took up to a month, with repeated phone reminders, to provide their data. Assembling all the contractor data took about three months.

The study provided valuable insights into cost structures that affect residential new construction as energy efficiency is stepped up. First, incremental costs for reaching the minimum ENERGY STAR level from baseline building practices are slightly lower than five years ago. This is as expected; it means that the rise in baseline energy efficiency over that period more than makes up for the increased costs inherent in new ENERGY STAR requirements. The more important finding is the steep rise in incremental costs to achieve higher levels of energy efficiency, the HERS 70 and HERS 65 levels. These incremental costs need to be considered when developing strategies, such as tiered incentives, to encourage builders to continually strive for lower HERS indices. For some builders, particularly those who already surpass ENERGY STAR requirements, incremental costs for lower HERS indices may be manageable. For those builders just meeting minimum ENERGY STAR standards, achieving lower HERS indices will require more financial support.

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