Economic Database in Support of ASHRAE 90.2 (Energy-Efficient Design of Low-Rise Residential Buildings) 1481 RP

Prepared for

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ABSTRACT

The objective of ASHRAE[1] 1481-RP was to obtain an economic database in support of Standing Standards Project Committee 90.2 (SSPC 90.2) because a collection of reliable construction cost data is requisite, yet periphery to, the principal goals of the committee. Cost data has been difficult to obtain in the past. In order for the committee to provide timely technical review of standard updates and meet future ASHRAE goals of increasing building energy efficiency, a library of costs to calculate the economic impact of proposed amendments is required.

To accommodate ASHRAE's requirements as outlined in 1481-RP, the NAHB Research Center worked with four active home builders to produce the database. The Research Center identified builders from different regions with the specific knowledge and expertise to develop costs related to energy-efficiency upgrades, and engaged them as subcontractors on the project. This paper presents the economic database that was compiled for this effort and an overview of the data collection and normalization process.

INTRODUCTION

Following the format outlined by *ASHRAE 1481-RFP – Economic Data Base in Support of Standard 90.2*, the NAHB Research Center teamed with four builders of varying sizes and locations to produce this report. Data has been generated and formatted as matrices titled by principal building systems or assemblies common to the construction of a single-family detached (SFD) house. Each of the matrices presented as Section 1 of this report contains an estimate of the aggregate cost to the consumer for the new construction of the stated, defined assembly. Generally, costs in this economic database are reported per square feet of area so that application may be made to similarly-constructed buildings of varying size. An exception to the reporting unit of square feet was made with 10-inch tubular skylights and HVAC equipment which are reported as cost per unit. Results are meant to capture only the variable subcomponents of the assembly; e.g., foundation wall insulation does not include the foundation wall itself, as the foundation cost remains constant regardless of the location and type of insulation applied.

In addition to this paper, the data that supports the national average costs contained in the matrices are included in eight electronic (Microsoft™ Excel) Appendices – *ASHRAE Cost Book 2008* (Appendix 1); *Unit Prices with Market Adjustment* (Appendices 2a and 2b); *TX Climate zone 3* (Appendix 3); *OK Climate zone 3* (Appendix 4); *MD Climate zone 4* (Appendix 5); and *OH Climate zone 5* (Appendix 6). Appendices 3 through 6 are the workbooks compiled by the builders who participated in this study. Appendix 7 contains the workbook that was compiled with R.S. Means costs. Appendices 8a and 8b contain the matrices that provide the costs for assemblies presented in this report.

Data provided in the builder workbooks was adjusted by location with profit and overhead added. When necessary, data was supplemented by additional costs acquired directly by the NAHB Research Center. The normalized estimates provided in the builder workbooks have been tallied and averaged in Appendix 1, *ASHRAE Cost Book 2008*. Each page in the workbook represents an assembly or component identified by ASHRAE for inclusion in this economic database and deemed commercially viable by the NAHB Research Center. Section 1

[1] American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

of this report covers the data and methodology that was used in the development of aggregated cost of the assemblies at the national level. Appendix 2a, titled *Unit Prices with Market Adjustment SFD,* contains the table of R.S. Means market adjustment factors that provided the method for normalizing costs to a national (or, conversely, a local) marketplace in this study. As the title suggests, Appendix 2a also contains a spreadsheet of the unit prices that were estimated for this study factored for the 43 cities of significance to ASHRAE and the two additional markets selected by the NAHB Research Center.

Section 2 of the report contains factors for extension of the SFD estimates to attached single-family and low-rise multifamily unit (MFU)[2] cost and the matrices that represent the resultant imputed costs. Appendix 2b, *Unit Prices with Market Adjustment MFU*, covers the unit costs of components adjusted by the MFU factor.

Cost Methodology

Builders from four different regions with experience in residential energy-efficient design and construction provided costs for the specific assemblies examined in this study. In addition to their expertise in energy efficiency, the builders were selected because they represent market and scale variation deemed appropriate to a sample of this size. Table 1 covers the business and market characteristics of the builders that supplied the cost data points that support the national cost estimates derived in this study.

Table 1. Cost Data Origin

Climate Zone	Market	Average Annual SFD Starts				Price Range of Average Home (includes land)		
		1-9	10-25	25-100	250-350	$190,000-250,000	$255,000-350,000	$355,000-450,000
3	Fort Worth, TX	X						X
3	Oklahoma City, OK				X	X		
4	Baltimore, MD			X				X
5	Dayton, OH		X				X	

Estimated costs are based on new construction and include builder profit and overhead, which have been applied as an aggregated 28% of the subcontractors' bid price(s) to the builder, netting to a 22.1% gross margin.[3] Operation, financing and maintenance have not been included.

In order to make this data nationally relevant, the Location Factors listed in the *R.S. Means Residential Cost Data 2008*[4] have been applied to the major reporting markets identified by ASHRAE as well as several markets that were selected by the NAHB Research Center to accommodate the builders who supported this study.

[2] Low-rise buildings have been defined in the Request for Proposal (RFP) as three stories or less.

[3] In the 2008 Edition of *The Cost of Doing Business*, a survey prepared by the NAHB Economics Group, survey respondents that built on land that they developed or owned reported an average gross profit margin of 22.1%. Among survey respondents gross margin tended to fall below this average with a drop in revenue below the reported average gross revenue of $27.6 million. Similarly, gross margin increased for builders reporting revenue greater than $27.6 million. Two of the builders in this study had gross revenues exceeding the average and two of the builders had revenue of less than the survey respondent's average, as would be expected based on the known volume of production. All of the builders who participated in the study build on owned lots.

[4] Reed Construction Data Inc. pp. 623-628.

Participating builders were instructed to develop real costs from estimates generated for a single-family detached dwelling within a 25% size range (high or low) of the national average (2,521 square feet)[5].

Costs were compiled in the third quarter of 2008, during a period of economic recession with new housing starts down 33% or more from the previous year and 50-63% from 2006[6], dependent on market location. Sample market indexes from the beginning and end of the reporting period (July 15, 2008-October 15, 2008) are covered in Table 2.

Table 2. Commodity Benchmarks at Beginning and End of Estimation Period[7]

Commodity	International Index		SPF S (Inland West mills) (FOB Mill)		East/Mid-Atlantic (FOB Mill)		Atlanta[8] (Delivered)		Great Lakes/ N Central (FOB Mill)	
	Jul	Oct	Jul	Oct	Jul	Oct	Jul	Oct	Jul	Oct
2x4 - #2&Btr.			282	205	275	268	357	295	340	290
7/16" OSB			172	170	172	147	190	182	187	180
23/32" OSB			315	305	295	268	353	313	325	315
Steel[8]	1,186	940								

In some cases, the numbers submitted by the builders exhibited wide variations in cost and specification, as were anticipated by the characteristics of the builders and marketplaces defined for the study. Outcomes of tabulated builder estimates, which were deemed to be representative of the marketplace, were averaged to produce one national number for each component or assembly. The process of tabulating builders' estimates involved any or all of the following actions; verification of the components and quantities covered by the estimate, cost interpolation for sizes that were not reported (i.e., insulation at stated R-values), conversion to a uniform unit of measurement (typically square foot), calculation and inclusion of the state and local sales taxes on materials[9], application of builder's profit and overhead, and application of the R. S. Means location adjustment factor. To supplement or verify the information provided by the builders, Research Center staff solicited independent bids for some components and entered the data on the builder's sheet associated with the market area where the cost was obtained. For some cases, outlying estimates were excluded from the average. Cost estimates are reported in the *ASHRAE Cost Book* (Appendix 1) spreadsheets at the national level.

The builders who provided the estimates used in this study represented annual production volume centered around 10, 25, 100, and 350 units per year and sale prices ranging from

[5] U.S. Census Bureau, *Highlights of Annual 2007 Characteristics of New Housing*, www.census.gov/const/www/highanncharac2007.html

[6] "Developments in financial markets in the second half of 2007 and early months of 2008 have undermined rather than contributed to recovery in the housing sector. Housing sector activity has been depressed by an additional 30 percent due to the credit market crisis… Single family housing starts are down 63 percent from peak levels of production during the housing boom with some of the most troubled markets down 80 percent or more…" NAHB, *State & Top 100 Metro Report , April 30, 2008.* http://www.nahb.org/generic.aspx?genericContentID=58215&sectionid=872&channelid=311&channelID=311

[7] Lumber numbers as reported in U. S. dollars in *Random Lengths*, the weekly report on North American Lumber Markets. Dimensional lumber numbers are per thousand board feet. Panel numbers are per thousand square feet. All numbers except Atlanta FOB mill. Atlanta number includes delivery to marketplace.

[8] MEPS (International) LTD , a UK-based global steel industry watcher and consultant. www.meps.co.uk/world-price.htm. Cost is in dollars per metric tonne of cold rolled coil product.

[9] State and local sales taxes applied to material are as follows:

TX3	.0825
OK3	.08375
MD4	.06
OH5	.07

$190,000 to $450,000 (Table 1), but there was no consistent indication that the high volume builders were reporting lower cost estimates, with the exception of HVAC equipment costs. Due to a lack of evidence that volume discounts might underlie some of the larger builders' estimates, no builder annual volume adjustment was applied to the builders' cost estimates.

There were several instances of only one builder reporting a cost for a component. These were adjusted by builder profit and overhead and location factor and compared to another source. Where the comparison indicated that the one cost was reasonably representative, the single cost is reported as an average cost. Similarly, for cases where only one cost estimate was received for a component of an assembly, the average cost of the assembly with the component is reported as the average of a similar assembly factored by the cost trend between levels of the component, and noted as such in the builders' workbooks (Appendices 3 through 6). Costs developed using R.S. Means were adjusted with the same stated overhead and profit (O&P) factor of 28% to net the average gross margin of 22.1%.

National average costs shown in the *ASHRAE Cost Book* (Appendix 1) comprise the average of the adjusted builders' costs only and do not include the R.S. Means (RSM) cost. RSM numbers have been developed and represented for a reasonableness test only.

Costs may be extended to attached dwellings and low-rise multifamily dwellings utilizing the adjustment factors covered in Section 2.

Cost Matrix Results

Numbers that are contained in the matrices represent the cost of each assembly, as defined below the matrix, in the aggregate. Cost estimates in each cell of a matrix represent the sum of the appropriate cells (or components of the assembly) in each of the *ASHRAE Cost Book* worksheets that are identified below the matrix.

SECTION 1: SINGLE-FAMILY DETACHED COST ESTIMATES

A. Ceiling Assembly

Ceiling assembly includes trusses/rafters, insulation, labor, and truss placement equipment where applicable. The assembly excludes components that do not vary with the level of insulation installed; e.g., roof sheathing, uplift restraint hardware, and drywall. Assembly includes eave edge baffles with flat ceiling assemblies and/or continuous baffles in raftered or cathedral ceiling assemblies, as noted in the *ASHRAE Cost Book* (Appendix 1).

Matrix A1: Ceiling Assembly

Single Family Detached National Average Cost Per Square Foot 2008							
			Wood truss at 24" oc.				Conventionally Framed
Structural Roof/ Ceiling Type		Unit of Measure	6/12 Flat Clg 2x4 & 2x4 - Std. Heel 4-1/8"	6/12 2x4 over 2x4 Energy Heel - Flat Clg	6/12 over 3/12 Cathedral Ceiling	6/12 over 3/12 Cathedral Energy Heel	2x12 SYP rafters at 24" oc. (cathedral)
R-Value of Insulation	Type of Insulation		14" soffit				
19	Fiberglass batt	sq. ft.	4.61	5.07			
25	Fiberglass batt	sq. ft.	5.02	5.49			
30C	Fiberglass batt- 8 1/2"	sq. ft.	5.66	6.13	5.71	6.08	4.96
30	Fiberglass batt- 10 1/2"	sq. ft.	5.07	5.54	5.15	5.52	4.40
38C	Fiberglass batt- 10 1/2"	sq. ft.	6.17	6.64	6.18	6.56	5.43
38	Fiberglass batt- 13"	sq. ft.	5.31	5.84	5.32	5.69	
49	Fiberglass batt	sq. ft.	6.00	6.53	6.15	6.52	
19	Blown Cellulose	sq. ft.	4.40	4.87	5.46	5.83	4.71
25	Blown Cellulose	sq. ft.	4.56	5.03	5.58	5.95	4.83
30	Blown Cellulose	sq. ft.	4.67	5.14	5.74	6.11	4.99
38	Blown Cellulose	sq. ft.	4.85	5.39	6.03	6.40	
42	Blown Cellulose	sq. ft.	5.07	5.61	6.17	6.55	
49	Blown Cellulose	sq. ft.	5.32	5.86	6.63	7.00	
60	Blown Cellulose	sq. ft.	5.62	6.15	6.83	7.20	

Assembly consists of the national average cost estimates for:
A1. Insulation Flat, or
A2. Insulation Cathedral
A3. Roof System (with 11" heel; all applications).
Note that ceiling R-values less than 30 in any climate zone may not meet prescriptive code minimums.

B. Wood Exterior Walls

Wood exterior walls include the complete assembly of structural frame, sheathing, insulation, and weather resistant barrier (WRB). Builders were instructed to include the cost of bracing the walls where non-structural sheathings were specified. Instructions to account for the added costs for jamb returns where sheathing thickness required these also were given. Three builders participating in this study indicated that drywall returns would finish the added wall depth and believed the cost of jamb extensions was not significant.[10] The aggregate numbers reported in the matrix for the various sheathing choices for wood exterior walls include a WRB for all applications. While it may be possible for some of the foam sheathings to serve as a WRB, if taped, reported costs did not appear to include tape, and it was beyond the scope of this study to ascertain whether each of the alternate sheathings was in code compliance as an alternate weather barrier/drainage plane. Wall costs include any added expense to attach siding to foam sheathing.

These prices cannot assume to be applicable in seismic or high wind zones, in addition to homes with multiple stories above grade.

Because of its recent market introduction and cost competitiveness with traditional insulative sheathings, the cost of an additional sheathing – SIS (structural insulating sheathing) - was added to the list of component costs that were collected.

All four of the builders reported installation costs for an open cell spray foam product.

All builders contributing to this paper were unsuccessful in obtaining reliable bids for mineral or rock wool batts due to the material being unavailable in their marketplace or through their traditional distribution networks. The *MD Climate Zone 4* workbook (Appendix 5) contains some costs for this material; however, it was only available in 2' x 4' batts of 2", 3", and 4" thicknesses, which were deemed impractical for exterior wall cavity application. Because of this, mineral wool insulation is not included in this study.

[10] The fourth builder reported an added cost of $20 per wood window for jamb extensions required with sheathings of 1" or greater thickness. The cost is not reflected in any of the assemblies because vinyl windows are the assumed "base component".

Matrix B1: Wood Exterior Wall with Fiberglass Cavity Insulation

Single Family Detached National Average Cost Per Square Foot 2008													
				2 x 4 Wall at 16" oc			2 x 6 Wall at 16" oc.		2 x 4 Wall at 24" oc			2 x 6 Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Fiberglass Batt, kraft face, stapled									
	7/16"	OSB	sq. ft.	5.64	5.72	5.97	6.72	6.90	5.37	5.45	5.71	6.40	6.58
	1/8"	Structural Laminated Fibrous Board	sq. ft.	5.80	5.88	6.13	6.89	7.06	5.54	5.62	5.87	6.57	6.75
5	1"	SIS Panel (Polyiso and struct. sheathing	sq. ft.	6.49	6.57	6.82	8.52	8.69	6.05	6.13	6.39	8.09	8.27
2	1/2"	EPS	sq. ft.	5.96	6.04	6.29	7.05	7.22	5.68	5.76	6.01	6.70	6.88
3	3/4"	EPS	sq. ft.	6.15	6.23	6.48	7.24	7.42	5.86	5.94	6.19	6.89	7.06
4	1"	EPS	sq. ft.	6.23	6.31	6.56	7.32	7.50	5.94	6.02	6.27	6.97	7.14
2.5	1/2"	XPS	sq. ft.	6.52	6.60	6.85	7.54	7.71	6.20	6.28	6.53	7.18	7.36
4	3/4"	XPS	sq. ft.	6.59	6.67	6.92	7.68	7.85	6.30	6.38	6.63	7.32	7.50
5	1"	XPS	sq. ft.	6.87	6.95	7.20	7.89	8.07	6.54	6.62	6.87	7.52	7.69
3.2	1/2"	Polyisocyanurate	sq. ft.	6.51	6.59	6.84	7.85	8.02	6.17	6.25	6.50	7.45	7.62
5	3/4"	Polyisocyanurate	sq. ft.	7.14	7.22	7.47	8.50	8.67	6.69	6.77	7.02	8.02	8.19
6.5	1"	Polyisocyanurate	sq. ft.	7.41	7.49	7.74	8.77	8.94	6.96	7.04	7.29	8.29	8.46
10	1 1/2"	Polyisocyanurate	sq. ft.	8.07	8.15	8.40	9.42	9.60	7.62	7.70	7.95	8.95	9.12

Assembly consists of the national average cost estimates for:
B1. ExtWoodWalls2x4
B5. Insulation-Walls
B2.ExtWoodWalls2x6
Each assembly includes a WRB. Alternate sheathing includes labor and material for wall bracing in standard wind and non-seismic zones; no OSB.
Based on standard window/door jambs and drywall returns at no cost.

Matrix B2: Wood Exterior Wall with Sprayed Cellulose Cavity Insulation

Single Family Detached National Average Cost Per Square Foot 2008													
				2 x 4 Wall at 16" oc			2 x 6 Wall at 16" oc.		2 x 4 Wall at 24" oc			2 x 6 Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Sprayed Cellulose Insulation									
	7/16"	OSB	sq. ft.		6.15		7.19			5.89		6.86	
	1/8"	Structural Laminated Fibrous Board	sq. ft.		6.32		7.36			6.06		7.03	
5	1"	SIS Panel (Polyiso and struct. sheathing	sq. ft.		7.01		8.98			6.57		8.56	
2	1/2"	EPS	sq. ft.		6.48		7.51			6.19		7.17	
3	3/4"	EPS	sq. ft.		6.67		7.71			6.38		7.35	
4	1"	EPS	sq. ft.		6.75		7.79			6.46		7.43	
2.5	1/2"	XPS	sq. ft.		7.04		8.01			6.72		7.64	
4	3/4"	XPS	sq. ft.		7.11		8.14			6.81		7.79	
5	1"	XPS	sq. ft.		7.39		8.36			7.05		7.98	
3.2	1/2"	Polyisocyanurate	sq. ft.		7.03		8.31			6.69		7.91	
5	3/4"	Polyisocyanurate	sq. ft.		7.66		8.96			7.21		8.48	
6.5	1"	Polyisocyanurate	sq. ft.		7.93		9.23			7.48		8.75	
10	1 1/2"	Polyisocyanurate	sq. ft.		8.59		9.89			8.14		9.41	

B1. ExtWoodWalls2x4
B5. Insulation-Walls
B2.ExtWoodWalls2x6
Each assembly includes a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no cost.

Matrix B3: Wood Exterior Wall with Sprayed Foam Cavity Insulation

Single Family Detached National Average Cost Per Square Foot 2008														
				2 x 4 Wall at 16" oc			2 x 6 Wall at 16" oc.		2 x 4 Wall at 24" oc			2 x 6 Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Sprayed Foam Insulation (open cell)									
	7/16"	OSB	sq. ft.		7.27		9.16			7.01		8.83	
	1/8"	Structural Laminated Fibrous Board	sq. ft.		7.44		9.32			7.18		9.00	
5	1"	SIS Panel (Polyiso and struct. sheathing	sq. ft.		8.13		10.95			7.69		10.52	
2	1/2"	EPS	sq. ft.		7.60		9.48			7.31		9.13	
3	3/4"	EPS	sq. ft.		7.79		9.67			7.50		9.32	
4	1"	EPS	sq. ft.		7.87		9.75			7.58		9.40	
2.5	1/2"	XPS	sq. ft.		8.16		9.97			7.84		9.61	
4	3/4"	XPS	sq. ft.		8.23		10.11			7.93		9.75	
5	1"	XPS	sq. ft.		8.51		10.32			8.17		9.95	
3.2	1/2"	Polyisocyanurate	sq. ft.		8.15		10.28			7.81		9.88	
5	3/4"	Polyisocyanurate	sq. ft.		8.78		10.93			8.33		10.45	
6.5	1"	Polyisocyanurate	sq. ft.		9.05		11.20			8.60		10.72	
10	1 1/2"	Polyisocyanurate	sq. ft.		9.71		11.86			9.26		11.38	

B1. ExtWoodWalls2x4
B5. Insulation-Walls
B2.ExtWoodWalls2x6
Each assembly includes a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no cost.

Steel Exterior Walls

Not one of the builders participating in this study regularly employed cold-formed steel (CFS) studs in the construction practice. As with the wood wall cost effort, the builders were instructed to include wall bracing where non-structural sheathings were specified. Because cold-formed steel frames constructed prescriptively are required to be framed in-line, the only spacing reported is 24", the most commonly used spacing for residential construction with CFS.

Matrix B4: Cold-Formed Steel Exterior Wall with Fiberglass Cavity Insulation

Single Family Detached National Average Cost Per Square Foot 2008								
				2 x 4 CFS (Steel) Wall at 24" oc			2 x 6 CFS Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Fiberglass Batt, kraft face, pressure fit				
	7/16"	OSB	sq. ft.	7.18	7.26	7.49	7.51	7.63
	1/8"	Structural Laminated Fibrous Board						
5	1"	SIS Panel (Polyiso and struct. sheathing						
2	1/2"	EPS						
3	3/4"	EPS					8.45	8.57
4	1"	EPS	sq. ft.	7.76	7.84	8.08	8.55	8.66
2.5	1/2"	XPS	sq. ft.	7.42	7.49	7.73	8.32	8.44
4	3/4"	XPS	sq. ft.	7.58	7.66	7.90	8.47	8.58
5	1"	XPS	sq. ft.	7.95	8.03	8.27	8.66	8.78
3.2	1/2"	Polyisocyanurate	sq. ft.	7.95	8.03	8.26	8.64	8.76
5	3/4"	Polyisocyanurate	sq. ft.	8.23	8.30	8.54	9.01	9.13
6.5	1"	Polyisocyanurate	sq. ft.	8.50	8.58	8.81	9.32	9.43
10	1 1/2"	Polyisocyanurate	sq. ft.	9.30	9.37	9.61	10.11	10.23

Assembly consists of the national average cost estimates for:
B3. ExtSteelWalls2x4
B5. Insulation-Walls
Each assembly includes a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no cost.
All walls represented may not comply with prescriptive energy code.

Matrix B5: Cold-Formed Steel Exterior Walls with Sprayed Cellulose Cavity Insulation

Single Family Detached National Average Cost Per Square Foot 2008								
				2 x 4 CFS (Steel) Wall at 24" oc			2 x 6 CFS Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Sprayed Cellulose Insulation				
	7/16"	OSB	sq. ft.		7.60		7.87	
	1/8"	Structural Laminated Fibrous Board						
5	1"	SIS Panel (Polyiso and struct. sheathing	sq. ft.					
2	1/2"	EPS	sq. ft.		8.03		8.76	
3	3/4"	EPS	sq. ft.		8.09		8.81	
4	1"	EPS	sq. ft.		8.18		8.91	
2.5	1/2"	XPS	sq. ft.		7.83		8.68	
4	3/4"	XPS	sq. ft.		8.00		8.83	
5	1"	XPS	sq. ft.		8.37		9.02	
3.2	1/2"	Polyisocyanurate	sq. ft.		8.37		9.00	
5	3/4"	Polyisocyanurate	sq. ft.		8.64		9.37	
6.5	1"	Polyisocyanurate	sq. ft.		8.91		9.68	
10	1 1/2"	Polyisocyanurate	sq. ft.		9.71		10.47	

Assembly consists of the national average cost estimates for:
B3. ExtSteelWalls2x4
B5. Insulation-Walls
Each assembly includes a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no cost.
All walls represented may not comply with prescriptive energy code.

Matrix B6: Cold-Formed Steel Exterior Wall with Sprayed Foam Cavity Insulation

Single Family Detached National Average Cost Per Square Foot 2008								
				2 x 4 CFS (Steel) Wall at 24" oc			2 x 6 CFS Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Sprayed Foam Insulation				
	7/16"	OSB	sq. ft.		8.72		9.83	
	1/8"	Structural Laminated Fibrous Board						
5	1"	SIS Panel (Polyiso and struct. sheathing						
2	1/2"	EPS			9.15		10.72	
3	3/4"	EPS	sq. ft.		9.21		10.78	
4	1"	EPS	sq. ft.		9.30		10.87	
2.5	1/2"	XPS	sq. ft.		8.95		10.65	
4	3/4"	XPS	sq. ft.		9.12		10.79	
5	1"	XPS	sq. ft.		9.49		10.99	
3.2	1/2"	Polyisocyanurate	sq. ft.		9.49		10.97	
5	3/4"	Polyisocyanurate	sq. ft.		9.76		11.33	
6.5	1"	Polyisocyanurate	sq. ft.		10.03		11.64	
10	1 1/2"	Polyisocyanurate	sq. ft.		10.83		12.44	

Assembly consists of the national average cost estimates for:
B3. ExtSteelWalls2x4
B5. Insulation-Walls
Each assembly includes a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no cost.
All walls represented may not comply with prescriptive energy code.

C. Wood Framed Floors

Based on the builders surveyed, *Builder Practices Survey* results[11], and minimum requirements for insulation in floor assemblies above unconditioned spaces, 2x6 dimensional lumber floor systems were not included in the costs reported for this study.

Because of evidence from the same source that the practice of spacing joists at 19.2” on center is not the norm, as well as the lack of market availability of insulation batts sized for the spacing, only 16”- and 24”-spaced floor assemblies appear in the matrix.

[11] NAHB Research Center, *Builder Practices Survey, 2007*. Survey results indicate that less than 8% of the new residential construction market report using 2x8, or smaller, lumber as floor joists. Survey results indicate that 18% of all first or second floor assemblies are spaced on 19.2” centerlines.

Matrix C1. Wood Framed Floor with Fiberglass Batt Cavity Insulation

Single Family Detached National Average Cost Per Square Foot 2008										
			Joists at 16" oc				Joists at 24" oc			
			2 x 8 Joist	2 x 10 or 9 1/4" I-J	2 x 12 or 11 7/8 I-J	14" or 16" I-Joist	2 x 8	2 x 10	2 x 12	14" or 16" I-Joist
Cavity Insulation R-Value	Thickness (inches)	Unit of Measure	Fiberglass Batt, Kraft Face, secured in place							
13	3 1/2	sq. ft	3.49	3.72	4.45	4.78	3.55	3.69	4.59	5.48
19	5 1/2	sq. ft	3.59	3.81	4.55	5.01	3.69	3.82	4.69	5.59
25	8	sq. ft	3.82	4.09	4.80	5.20	3.84	4.02	4.94	5.86
30	10	sq. ft		4.30	5.03	5.56		4.25	5.17	6.09
30C*	8.25	sq. ft		4.67	5.10	5.77		4.75	5.66	6.43
38	12	sq. ft				5.62				6.28
38C*	10.5	sq. ft			5.53	6.20			6.09	6.86
49	15	sq. ft				7.16				6.99

Assembly consists of the national average cost estimates for:
C. Wood framed floor assembly - fiberglass batt insulation, joists, and labor. Does not include subfloor.

D. Foundation Insulation

The builders participating in this study did not find a source for R-4 foil-faced insulation, so that cost estimate is not reported. No costs were obtained for foil-faced (flamespread) insulation batts in excess of R-13.

Expanded polystyrene may not be suitable for sub-grade installations without a continuous protective covering; therefore, EPS is not reported as a slab exterior foundation insulation.

Matrix D1: Foundation Insulation – Exterior and Core Fill Applications

Single Family Detached National Average Cost Per Square Foot 2008						
8"or 12" Subgrade Masonry Wall			Core Fill		Exterior	
R-Value of Insulation	Thickness	Unit of Measure	Perlite Core Fill[1]	Spray Foam Core Fill[1]	XPS	Polyisocyanurate
10	5.125	sq. ft.	4.52			
15	7.625	sq. ft.	5.94			
18	5.125	sq. ft.		4.84		
27	7.625	sq. ft.		6.63		
2.5	0.5	sq. ft.			2.63	
5.0	1	sq. ft.			3.02	
10.0	2	sq. ft.			3.84	
3.5	0.5	sq. ft.				2.91
7.0	1	sq. ft.				3.28
10.5	1.50	sq. ft.				3.94

1. Perlite and Spray foam thickness and R-Value only applies to core, not overall wall average
Assembly consists of the national average cost estimates for:
D. Foundation Ins
Cost of foundation not included:
Damproof consists of one coat of sprayed bituminous coating on concrete/block surface.
Exterior bituminous damproofing is excluded when rigid foam is applied.
Exterior rigid foam applications include taping seams.

Matrix D2: Foundation Insulation - Interior Applications

Single Family Detached National Average Cost Per Square Foot 2008						
8"or 12" Subgrade Masonry Wall - Interior Insulation						
R-Value of Insulation	Thickness	Unit of Measure	Foil-faced FG Insulation, draped	2x4 at 24" kraft faced FG & gypsum, taped	2x6 at 24" kraft faced FG & 1/2" gypsum, taped	Expanded Polystyrene & 1/2" gypsum, taped
11	3	sq. ft.	1.87			
13	3.5	sq. ft.	2.07			
13.0	3.5	sq. ft.		3.66		
19.0	5.5	sq. ft.			4.59	
4.0	1	sq. ft.				2.49
8.0	2	sq. ft.				3.96

Assembly consists of the national average cost estimates for:
D. Foundation Ins
Cost of foundation NIC.
Damproof consists of one coat of sprayed bituminous coating on concrete/block surface.
Exterior bituminous damproofing is included with all of the costs of the interior insulation applications.

Matrix D3: Foundation Insulation Slab - Exterior Applications

Single Family Detached National Average Cost Per Square Foot 2008								
Slab - Exterior or Core Fill Insulation								
R-Value of Insulation	Thickness	Unit of Measure	Perlite Core Fill[1]	Spray Foam Core Fill[1]	XPS		Polyisocyanurate	
					Sub-grade	Above grade	Sub-grade	Above grade
10	5.125	sq. ft.	4.52					
15	7.625	sq. ft.	5.94					
18	5.125	sq. ft.		4.84				
27	7.625	sq. ft.		6.63				
2.5	0.5	sq. ft.			1.66	9.43		
5.0	1	sq. ft.			2.05	9.83		
10.0	2	sq. ft.			2.87	10.64		
3.5	0.5	sq. ft.					1.93	9.71
7.0	1	sq. ft.					2.31	10.08
10.5	1.50	sq. ft.					2.97	10.75

1. Perlite and Spray foam thickness and R-Value only applies to core, not overall wall average
Assembly consists of the national average cost estimates for:
D. Foundation Ins
Cost of foundation not included:
Damproof consists of one coat of sprayed bituminous coating on concrete/block surface.
Exterior bituminous damproofing is excluded when rigid foam is applied.
Exterior rigid foam applications include taping seams.

F. Windows

Window costs in a range of U-values and solar heat gain coefficients (SHGC) that were available through the builders' traditional distribution channels have been captured in the cost workbooks (Appendices 3 through 6). The three graphs below, Figures 1-3, indicate plotted relationships between Cost vs. V-Value, cost vs. SHGC, and U-Value vs. SHGC of the windows reported in this study.

Each of the builders participating in this study had similar experiences in their attempts to locate high-performance windows, sliding glass doors, and skylight glass options. Typically, the window that the builder was pricing was available in two double-insulated glass types – clear or low-E. In cold climates, the low-E version of the window was also available with argon gas between the panes to enhance the window's U-Value. Follow-up by both the builders and the NAHB Research Center did not produce any assurance that there is a definitive market availability of windows with low (below .30) SHGC ratings in any of the market areas addressed by the study. Often, window performance characteristics meeting the high-performance criteria were posted on national manufacturer's websites; however, inquiries of the manufacturer's listed distribution network failed to offer a product for sale with the low numbers that were listed in the website specifications.

Additional data collected by Research Center analysts were reported in local jurisdictions and compiled with the *ASHRAE Cost Book* in order to generate the graphs below. These graphs show the change in cost (increase) per square foot from a basic window to a window of higher

thermal-resistive performance. Data points cover various window styles, manufacturers, frame types, and performance ratings.

Figures 1 and 2 used a similar approach in trying to capture the cost of obtaining lower U-factors and SHGC levels. The scatter plot in figure 1 was populated with the windows U-Value and additional cost per square foot to go beyond the base line of a double-glazed clear glass window. The equation for the trend line that best represents distribution can be used to determine the cost for windows within the data range. The additional cost is always referenced to a window within the same series in order to eliminate differences in window construction.

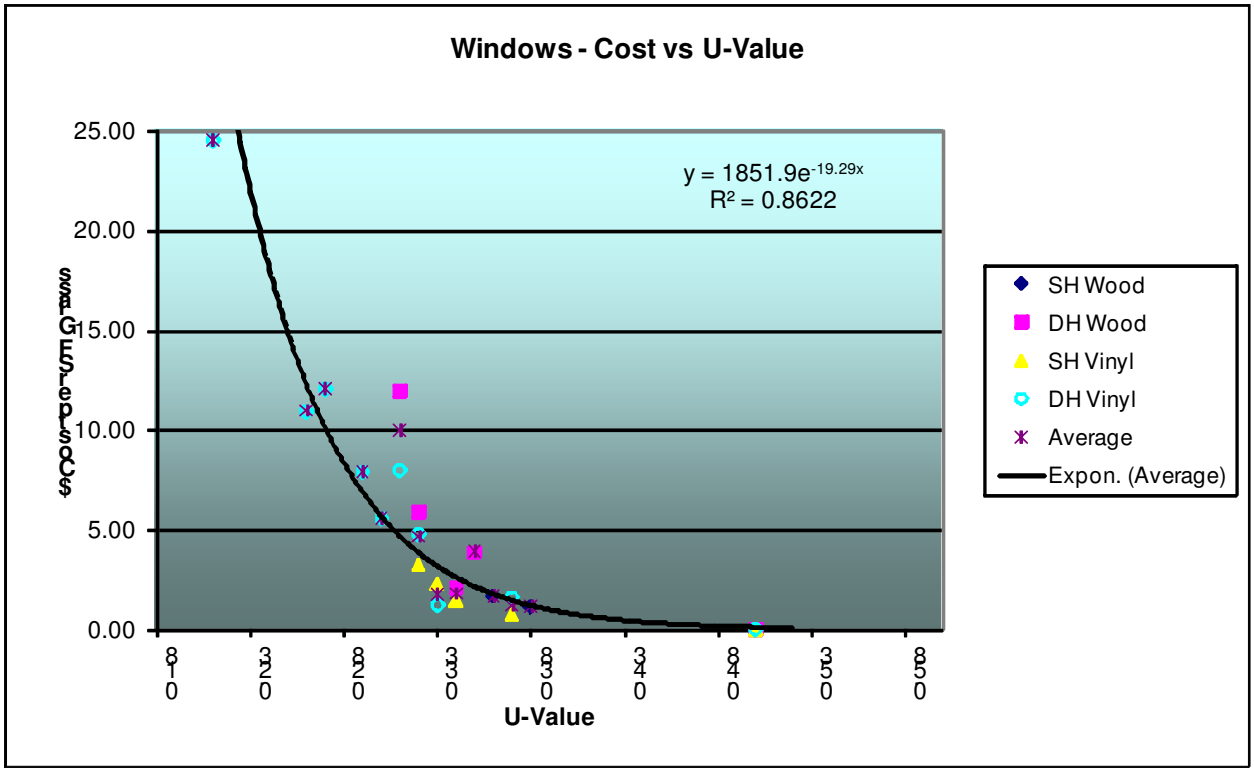

Figure 1. Window Cost vs. U-Value

From the window figures it can be seen that there is a relatively small variance in the cost per square foot of window relative to the U-Value resulting in an R-Squared or 0.86. This variance is significantly higher when looking at cost compared to U-Value. Meaning that U-Value is the determinate factor in window pricing with SHGC still being a factor, but much less predictable.

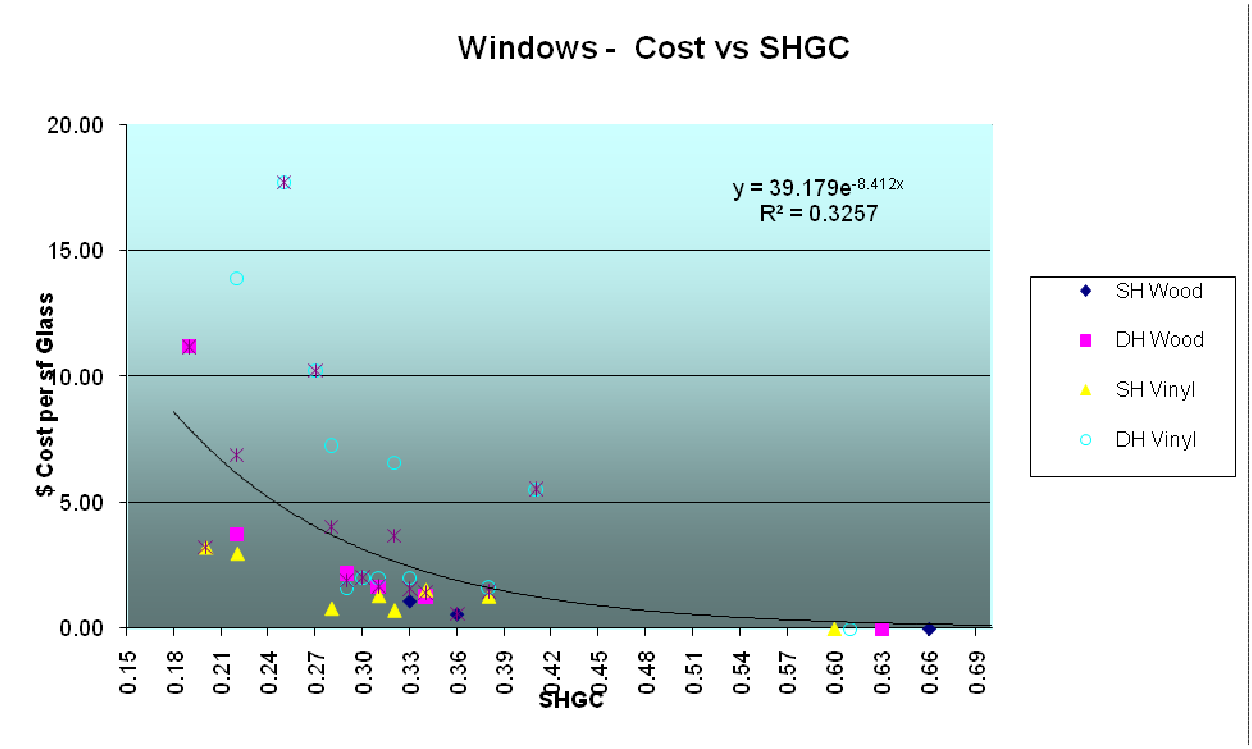

Figure 2. Window Cost vs. SHGC

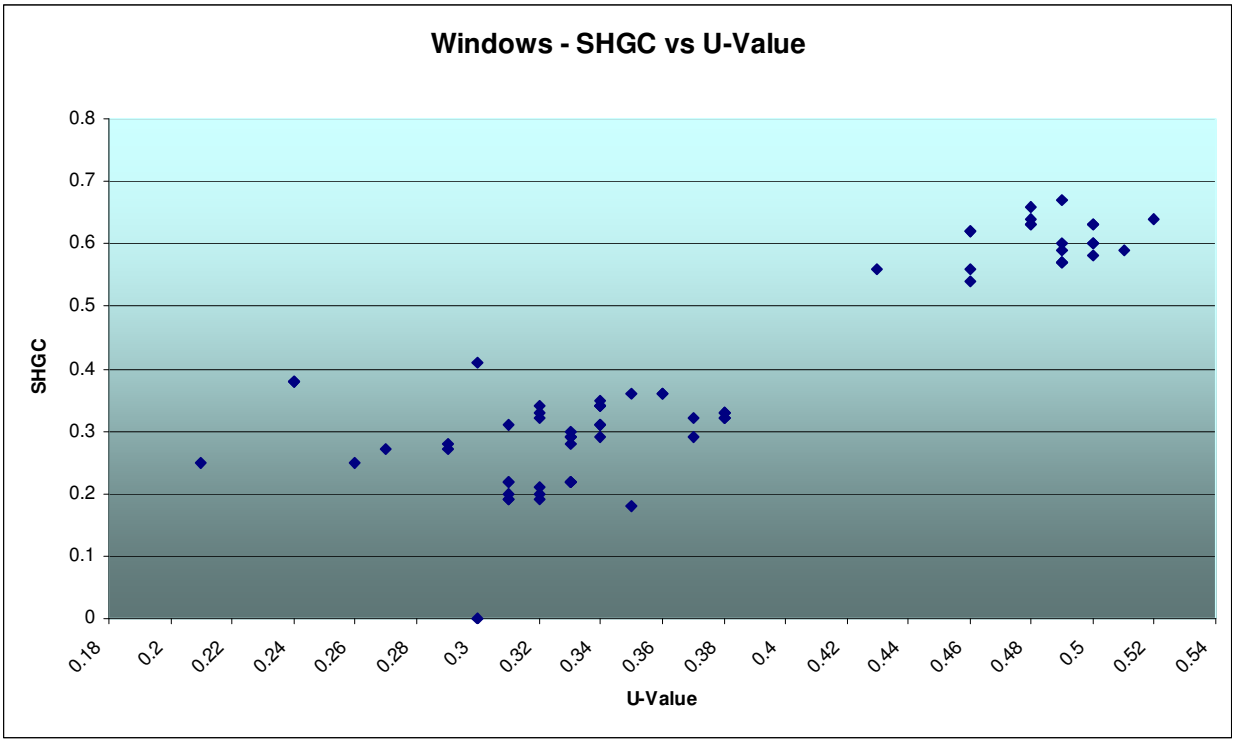

Figure 3. Window SHGC vs. U-Value

Window Size and Type	Grade	Frame Material	Location	U-value	SH GC	VT	Mfgr	Cost per SqFt
3050 SH 7/16" glass	Std	Vinyl	OH	0.51	0.59	0.62	#7	$13.76
3050 SH 7/16" glass	Std	Vinyl	MD	0.49	0.57	0.59	#6	$14.17
3050 SH 7/16" glass	Std	Vinyl	MD	0.49	0.57	0.60	#4	$14.47
3050 SH 7/16" glass, Low-E	Std	Vinyl	OH	0.37	0.32	0.55	#7	$14.50
3050 SH 7/16" glass, Low-E	Std	Vinyl	MD	0.33	0.28	0.51	#6	$14.98
3050 SH 7/16" glass, Low-E 272	Std	Vinyl	MD	0.34	0.31	0.52	#4	$15.78
3050 SH 7/16" glass	Std	Vinyl	OK	0.48	0.63	0.66	#4	$15.85
3050 SH 7/16" glass	Std	Vinyl	OK	0.50	0.58	0.59	#5	$17.22
3050 SH 7/16" glass, Low-E 272	Std	Vinyl	OK	0.34	0.34	0.58	#4	$17.38
3050 SH	Std	Wood	OK	0.49	0.67	0.70	#4	$17.57
3050 SH 7/16" glass, Low-E	Std	Vinyl	TX	0.34	0.35	0.54	#7	$17.67
3050 SH 7/16" glass, Low-E 272, argon	Std	Vinyl	MD	0.32	0.20	0.47	#4	$17.69
3050 SH 7/16" glass, Low-E	Std	Vinyl	OK	0.24	0.38	0.54	#5	$18.50
3050 SH 7/16", Low-E	Std	Wood	OK	0.36	0.36	0.61	#4	$19.21
3050 SH 7/16" glass, Low-E 366	Std	Vinyl	OK	0.33	0.22	0.52	#4	$19.43
3050 DH 7/16" insulated glass	Pre	Vinyl	MD	0.49	0.59	0.60	#6	$19.70
3050 SH Low-E 272	Std	Vinyl	TX	0.34	0.34	0.58	#4	$20.51
3050 DH	Pre	Vinyl	MD	0.49	0.59		#3	$20.61
3050 DH, 7/16" ins. Glass	Pre	Vinyl	MD	0.49	0.60	0.83	#2	$20.72
3050 DH 7/16" ins. glass, Low-E	Pre	Vinyl	MD	0.37	0.29	0.53	#6	$21.31
3050 DH insulated glass	Pre	Vinyl	TX	0.46	0.62	0.65	#7	$21.88
3050 DH 7/16" ins. glass, Low-E	Pre	Vinyl	TX	0.33	0.22	0.50	#7	$22.27
3050 DH 7/16" ins. Glass	Pre	Vinyl	MD	0.31	0.30		#3	$22.62
3050 DH, 7/16" ins. glass, Low-E, Argon	Pre	Vinyl	MD	0.33	0.30	0.71	#2	$22.73
3050 SH Low-E 366	Std	Vinyl	TX	0.33	0.22	0.52	#4	$22.88
3050 DH 7/16" insulated glass	Pre	Vinyl	OH	0.46	0.62	0.65	#7	$23.31
3050 DH 7/16" insulated glass	Pre	Vinyl	OK	0.52	0.64	0.66	#5	$24.24
3050 DH 7/16" ins. glass, Low-E	Pre	Vinyl	OH	0.32	0.33	0.57	#7	$25.32
3050 DH 7/16" ins. glass, Low-E	Pre	Vinyl	OK	0.24	0.38	0.58	#5	$25.88
3050 DH 7/16" ins. glass, Titanium Low-E, Argon	Pre	Vinyl	MD	0.30	0.41	0.72	#3	$26.13
3050 DH, insulated Low-E 240	Pre	Vinyl	TX	0.32	0.21	0.32	#7	$27.54
3050 DH, 3- 7/16" ins. glass, Low-E, Argon	Pre	Vinyl	MD	0.29	0.28	0.65	#2	$28.01
3050 DH, insulated Low e-5 w/ Argon	Pre	Vinyl	TX	0.32	0.32	0.54	#7	$28.48
3050 DH, 3- 7/16" ins. glass, Titanium Low-E, Argon	Pre	Vinyl	MD	0.29	0.27	0.66	#3	$29.05
3050 DH 3- 7/16" ins. glass, Low-E, Krypton	Pre	Vinyl	MD	0.26	0.25	0.55	#2	$31.65
3050 DH 7/16" insulated glass	Pre	Wood	OH	0.46	0.56	0.59	#8	$32.30
3050 DH, 3- 7/16" ins. glass, Titanium Low-E, Krypton	Pre	Vinyl	MD	0.27	0.27		#3	$32.67
3050 DH 7/16" ins. glass, Low-E	Pre	Wood	OH	0.34	0.31	0.52	#8	$33.95

Window Size and Type	Grade	Frame Material	Location	U-value	SH GC	VT	Mfgr	Cost per SqFt
3050 DH, insulated Low-e-6 w/ Argon	Pre	Vinyl	TX	0.31	0.22	0.51	#7	$35.81
3050 DH 7/16" insulated glass	Pre	Wood	OK	0.48	0.64	0.67	#4	$36.77
3050 DH 7/16" ins. glass, Low-E	Pre	Wood	OK	0.34	0.34	0.58	#4	$37.00
3050 SH	Pre	Wood	OH	0.50	0.63	0.65	#4	$39.27
3050 SH 7/16", Low-E	Pre	Wood	OH	0.38	0.33	0.57	#4	$40.37
3050 SH 7/16", Low-E	Pre	Wood	TX	0.36	0.36	0.50	#9	$40.54
3050 DH insulated glass	Pre	Wood	TX	0.46	0.54	0.57	#9	$42.09
3050 DH 7/16" ins. glass, Low-E	Pre	Wood	MD	0.33	0.29	0.48	#1	$43.02
3050 DH 3- 7/16" ins. glass, Low-E, Krypton	Pre	Vinyl	MD	0.21	0.25	0.55	#2	$45.24
3050 DH 7/16" ins. glass, Low-E	Pre	Wood	TX	0.35	0.18	0.28	#9	$45.96
3050 DH, insulated Low-E 240	Pre	Wood	TX	0.34	0.29	0.50	#9	$46.49
3050 DH 7/16" insulated glass	Pre	Wood	OK	0.48	0.63	0.66	#4	$46.51
3050 DH 7/16" glass, Low-E, Argon	Pre	Wood	OK	0.32	0.34	0.58	#4	$48.85
3050 DH 7/16" glass, Low-E 366, Argon	Pre	Wood	OK	0.31	0.22	0.52	#4	$50.26
3050 DH, insulated Low-e-6 w/ Argon	Pre	Wood	TX	0.32	0.19	0.44	#9	$51.56
3050 DH, insulated Low e-5 w/ Argon	Pre	Wood	TX	0.31	0.19	0.45	#9	$62.30

Table 3: Window Installed Cost Table

G. Sliding Glass Doors

In an approach similar to that taken with window costs, sliding glass door costs were acquired over a range of U-values in the builders' marketplaces. Figure 4 details the U-value and cost relationship. There is considerably more scatter in Figure 4 (R^2=0.799) placing the trendline high at the lower U-values.

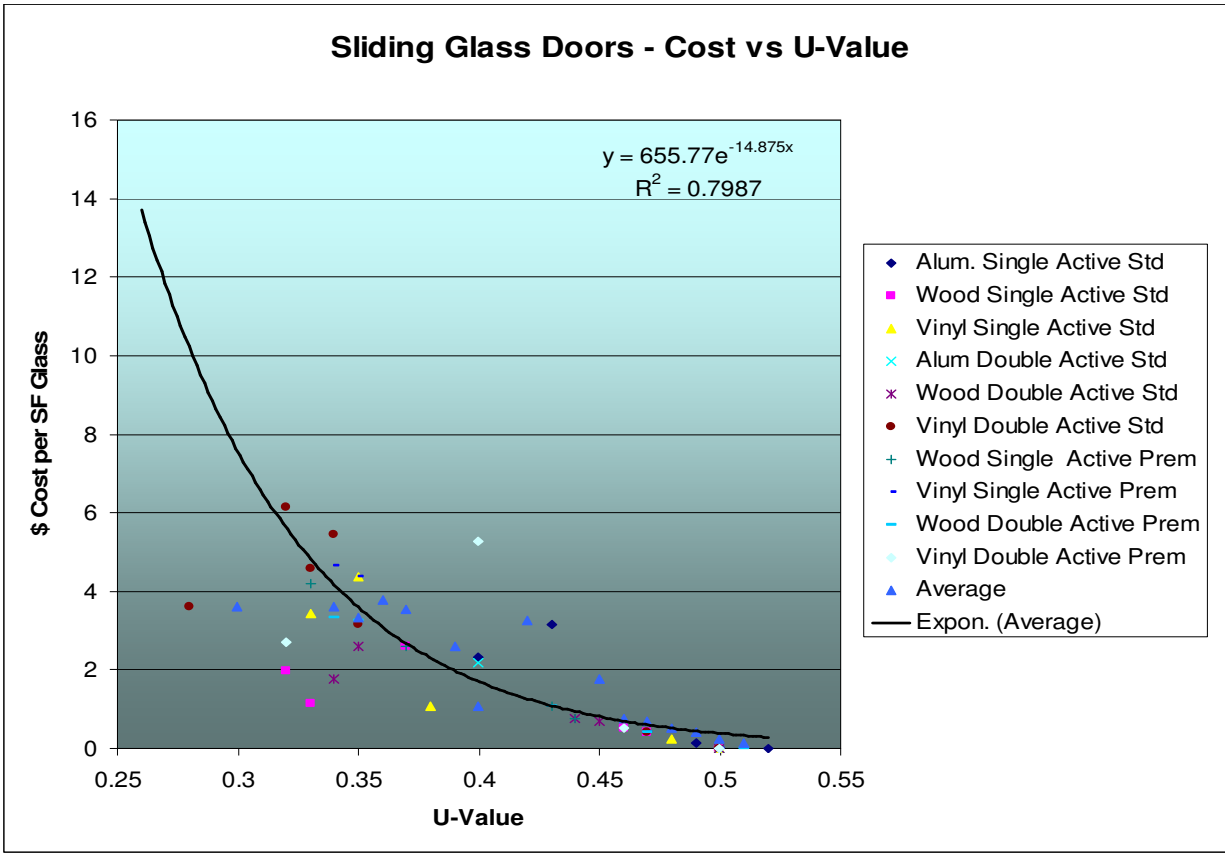

Figure 4. Sliding Glass Doors – Cost vs U-Value

H. Entry Doors

Builders were consistent in providing costs for national brands of exterior pre-hung doors. All of the manufacturers use products with double-pane glass, so single-glazed units have been omitted from this report. Actual U-values of the entry doors are captured in the builder cost workbooks (Appendices 3-6). Average U-values of reported classes are reported in Appendix 1, the *ASHRAE Cost Book*.

Matrix H1: Entry Doors

Single Family Detached National Average Cost Per Square Foot 2008							
Door Type	**Grade**	**No Glass**		**>50% Glazing**		**<50% Glazing**	
		U-Value	Cost sq ft	U-Value	Cost sq ft	U-Value	Cost sq ft
Wood Slab & Frame	Standard	0.48	$ 25.14	0.48	$ 32.42	0.47	$ 31.78
Foam Insulated Metal	Standard	0.16	$ 13.08	0.32	$ 21.33	0.37	$ 19.20
Fiberglass Insulated	Standard	0.15	$ 19.46	0.31	$ 30.15	0.35	$ 26.67
Wood Slab & Frame	Premium	0.48	$ 35.12	0.46	$ 35.31	0.46	$ 36.28
Foam Insulated Metal	Premium	0.17	$ 17.90	0.29	$ 27.53	0.37	$ 24.47
Fiberglass Insulated	Premium	0.14	$ 32.01	0.28	$ 37.03	0.36	$ 39.27

I. Skylights

Investigation by the builders who participated in this effort and Research Center analysts could not locate plastic skylights for residential application so these were omitted from this analysis. Tubular skylight costs are reported as each unit rather than square footage due to the size (less than 12") of the whole unit. Costs include a roof-mounted flashing kit and some length of tubing. Builders and retailers were not very specific about the length of pipe or skylight shaft liner that came with the base installation setup.

Matrix I1: Skylights

Single Family Detached National Average Cost Per Square Foot 2008[A]				
Average Values	**U-Value**	**0.54**	**0.52**	**0.49**
	SHGC	**0.68**	**0.35**	**0.32**
Skylight Type	**Unit of Measure**			
Builder Grade Flat Glass Skylight - Wood/alum.	sq. ft.	54.93		
Mid-Grade Flat Glass Skylight - Wood	sq. ft.		63.81	
Prem. Grade Flat Glass Skylight - Wood/comp.	sq. ft.			72.24
Tubular Skylight - 10"	Each	766		

[A]**Exception: Tubular Skylight is reported as each; including flashing kit and 3-5' of ducting.**

J. Air Infiltration Sealing

Air infiltration testing has been defined at three levels, measured as $ACH_{N,}$ – less than .35 (defined as code minimum), .16 -.25, and less than .15. It is expected that achievement of the two superior levels would also include compliance with the ENERGY STAR® thermal bypass checklist.

Matrix J1: Air Infiltration Sealing

Single Family Detached National Average Cost Per Square Foot 2008		
Level of Performance	**Unit of Measure**	**Cost**
Basic, code minimum, ACH_{NAT} approx. .35	sq. ft.	0.12
Better, ENERGYSTAR, ACH_{NAT} .25 - .16	sq. ft.	0.23
Best, High Performance, ACH_{NAT} less than .15	sq. ft.	0.36

Assembly consists of the national average cost estimates for:
J. Air Infiltration Seal

K., L., M. Heating Air Conditioning and Ventilation Systems (HVAC)

Worksheets denoted as K, L, M in the *ASHRAE Cost Book* and Matrices contain average cost estimates for HVAC equipment and performance upgrades. Builders reported these costs in many formats and were sometimes unable to isolate labor/controls/equipment/commissioning costs. Unlike the findings for other components in this study, results indicated a wide range of equipment costs and labor directly associated with the installation and/or commissioning of the equipment.

The volume builders that participated in the study – located in Oklahoma and Maryland – reported similar and significantly lower costs for HVAC equipment than the other two builders, indicating that volume pricing is potentially a factor with mechanical equipment. This would explain why builders did not report similar trends in the incremental costs of increased efficiency; e.g., there was an approximate $1,000 dollar increase from 13 to 14 SEER in OH whereas that same cost to OK and MD (the high volume builders) was approximately $150. And, small builder HVAC cost estimates for similar equipment and efficiency were nearly two times that of the volume builder. Because of these observations, HVAC costs have been reported in two columns – national average for high annual volume builders and the national average for small builders (low volume), covered in Matrices K1, L1, and M1. Figures 5 through 8 graph the relationships between costs and equipment efficiency.

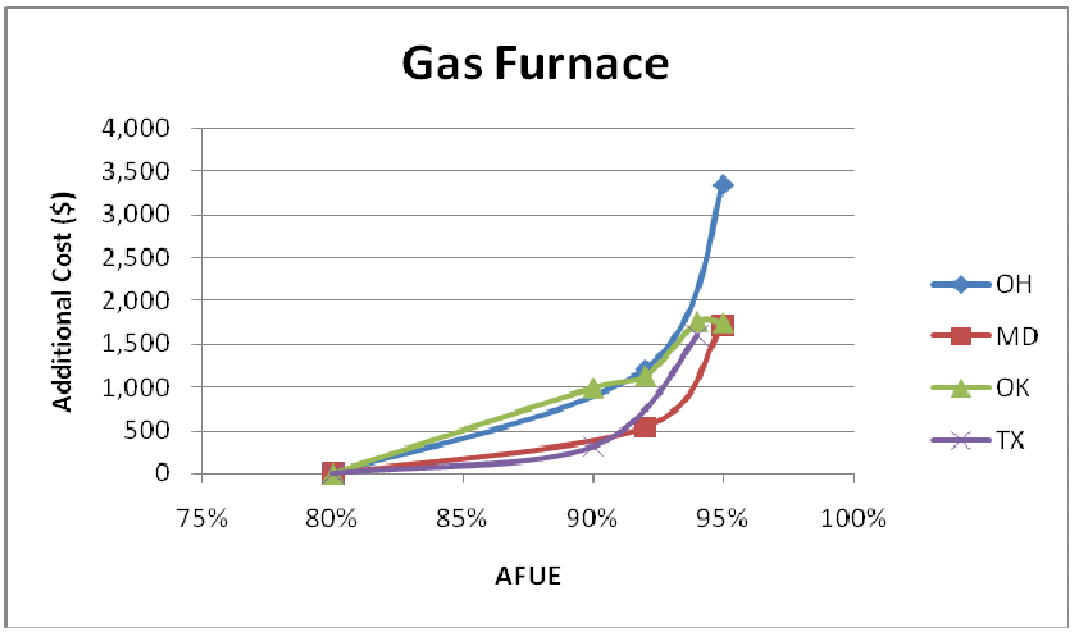

Figure 5: Gas Furnace Cost Comparison

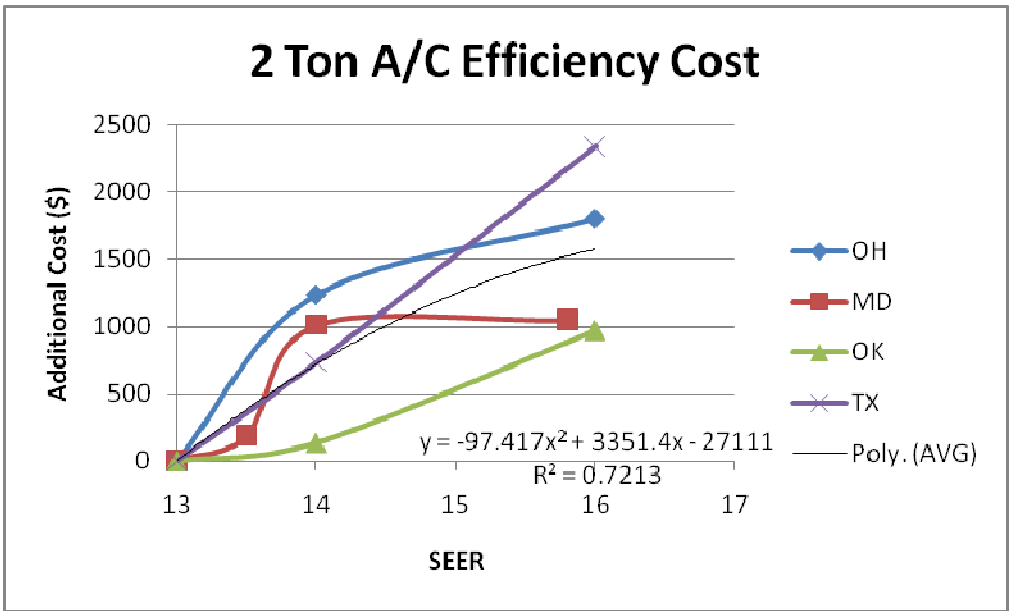

Figure 6: A/C Cost Comparison

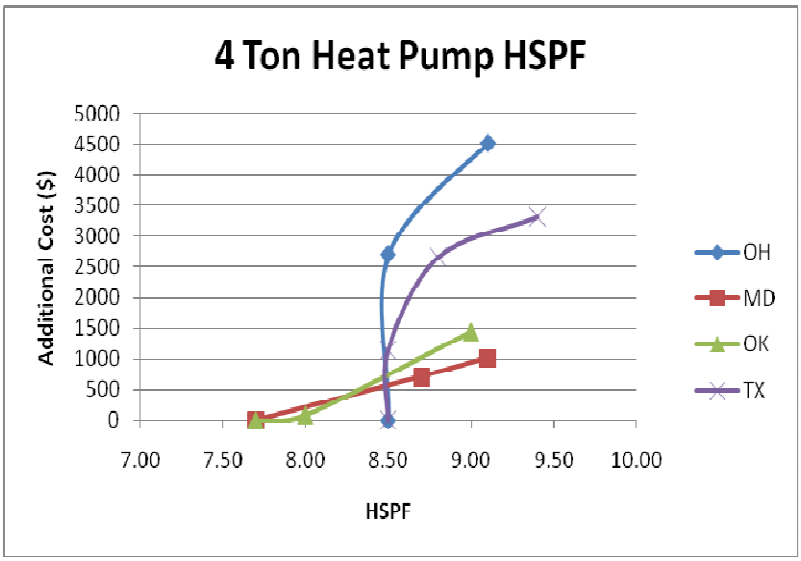

Figure 7: Heat Pump Cost Comparison - HSPF

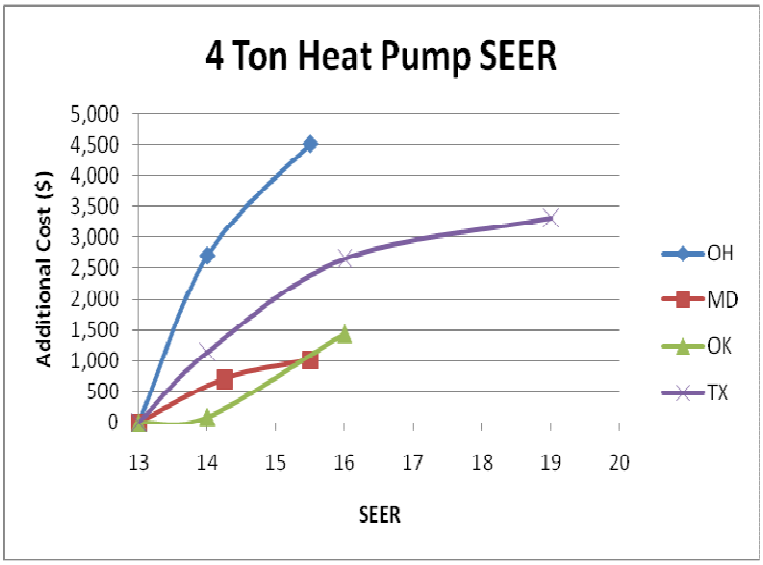

Figure 8: Heat Pump Cost Comparison – SEER

Matrix K1: Gas Furnaces

Single Family Detached National Average Cost Per Unit 2008				
Element	Efficiency	Approx. Input Capacity	Cost per Unit - (volume = 100-350 per yr.)	Cost per Unit - (volume = 10-25 per yr.)
Gas Furnace				
Upright, upflow	80 AFUE	40-50K BTU	697	1,795
Upright, upflow	80 AFUE	60-64K BTU	718	1,879
Upright, upflow	80 AFUE	78-80K BTU	735	2,122
Upright, upflow	80 AFUE	96-100K BTU	926	2,275
Horizontal, downflow	80 AFUE	40-50K BTU	788	2,140
Horizontal, downflow	80 AFUE	60-64K BTU	820	2,140
Horizontal, downflow	80 AFUE	78-80K BTU	844	2,188
Horizontal, downflow	80 AFUE	96-100K BTU	957	2,188
Upright, upflow	90 AFUE	40-50K BTU		1,876
Upright, upflow	90 AFUE	60-64K BTU		2,240
Upright, upflow	90 AFUE	78-80K BTU		2,811
Upright, upflow	90 AFUE	96-100K BTU		3,165
Horizontal, downflow	90 AFUE	40-50K BTU		3,372
Horizontal, downflow	90 AFUE	60-64K BTU		3,379
Horizontal, downflow	90 AFUE	78-80K BTU		3,448
Horizontal, downflow	90 AFUE	96-100K BTU		3,585
Upright, upflow	92 AFUE	40-50K BTU	1,474	
Upright, upflow	92 AFUE	60-64K BTU	1,513	
Upright, upflow	92 AFUE	78-80K BTU	1,566	
Upright, upflow	92 AFUE	96-100K BTU		
Horizontal, downflow	92 AFUE	40-50K BTU	1,368	
Horizontal, downflow	92 AFUE	60-64K BTU	1,802	
Horizontal, downflow	92 AFUE	78-80K BTU	1,923	
Horizontal, downflow	92 AFUE	96-100K BTU		
Upright, upflow	94 AFUE	40-50K BTU	2,400	
Upright, upflow	94 AFUE	60-64K BTU		3,213
Upright, upflow	94 AFUE	78-80K BTU	2,497	4,607
Upright, upflow	94 AFUE	96-100K BTU		5,932
Horizontal, downflow	94 AFUE	40-50K BTU	2,400	5,281
Horizontal, downflow	94 AFUE	60-64K BTU		5,505
Horizontal, downflow	94 AFUE	78-80K BTU	2,497	5,739
Horizontal, downflow	94 AFUE	96-100K BTU		6,056
Upright, upflow	96 AFUE	40-50K BTU	2,445	
Upright, upflow	96 AFUE	60-64K BTU	2,400	
Upright, upflow	96 AFUE	78-80K BTU	2,461	
Upright, upflow	96 AFUE	96-100K BTU	2,487	
Horizontal, downflow	96 AFUE	40-50K BTU		
Horizontal, downflow	96 AFUE	60-64K BTU	2,601	
Horizontal, downflow	96 AFUE	78-80K BTU	2,638	
Horizontal, downflow	96 AFUE	96-100K BTU	2,691	

Matrix L1: Air Conditioner

Single Family Detached National Average Cost Per Unit 2008				
Element		Approx. Capacity	Cost per Unit - (volume = 100-350 per yr.)	Cost per Unit - (volume = 10-25 per yr.)
Electric Air Conditioner	SEER	Tons		
Electric A/C	13	1	N/A	N/A
Electric A/C	13	1.5	1,055	
Electric A/C	13	2	1,560	2,922
Electric A/C	13	2.5	1,729	3,702
Electric A/C	13	3	1,995	3,200
Electric A/C	13	4	2,309	3,758
Electric A/C	13	5	2,607	4,112
Electric Air Conditioner	14	1	N/A	N/A
Electric A/C	14	1.5	1,319	
Electric A/C	14	2	1,723	4,872
Electric A/C	14	2.5	1,948	4,146
Electric A/C	14	3	2,182	5,615
Electric A/C	14	4	2,372	
Electric A/C	14	5	2,765	
Electric Air Conditioner	15	1	N/A	
Electric A/C	15	1.5	2,102	
Electric A/C	15	2	2,215	
Electric A/C	15	2.5	2,830	
Electric A/C	15	3	2,697	
Electric A/C	15	4	2,839	
Electric A/C	15	5	2,839	
Electric A/C	16	1	N/A	
Electric A/C	16	1.5		
Electric A/C	16	2	2,490	
Electric A/C	16	2.5		
Electric A/C	16	3	2,546	
Electric A/C	16	4	3,273	
Electric A/C	16	5	3,784	
Electric Air Conditioner	18	1		
Electric A/C	18	1.5		
Electric A/C	18	2		
Electric A/C	18	2.5		
Electric A/C	18	3		
Electric A/C	18	4		
Electric A/C	18	5		

Matrix M1. Heat Pump

Single Family Detached National Average Cost Per Unit 2008					
Element	Approximate Efficiency		Approx. Capacity	Cost per Unit (volume = 100-350 per yr.)	Cost per Unit (volume = 10-25 per yr.)
Electric Heat Pump and Air Handler	**HSPF**	**SEER**	**Tons**		
Air Source Heat Pump (indoor & outdoor units)	7.7	13	1	1,865	
Heat Pump	7.7	13	1.5	2,143	
Heat Pump	7.7	13	2	2,398	4,428
Heat Pump	7.7	13	2.5	2,639	4,785
Heat Pump	7.7	13	3	3,087	5,262
Heat Pump	7.7	13	4	3,673	6,324
Heat Pump	7.7	13	5	4,122	7,450
Air Source Heat Pump (indoor & outdoor units)	8.0	14	1	2,063	
Heat Pump	8.0	14	1.5	2,198	
Heat Pump	8.0	14	2	2,362	4,022
Heat Pump	8.0	14	2.5	2,643	4,432
Heat Pump	8.0	14	3	2,959	4,913
Heat Pump	8.0	14	4	3,324	6,505
Heat Pump	8.0	14	5	3,789	7,330
Air Source Heat Pump (indoor & outdoor units)	8.5	15	1		
Heat Pump	8.5	15	1.5	4,034	
Heat Pump	8.5	15	2	4,241	
Heat Pump	8.5	15	2.5	4,422	
Heat Pump	8.5	15	3	4,334	
Heat Pump	8.5	15	4	4,824	
Heat Pump	8.5	15	5	5,427	
Air Source Heat Pump (indoor & outdoor units)	9.0	16	1		
Heat Pump	9.0	16	1.5		
Heat Pump	9.0	16	2	4,077	5,692
Heat Pump	9.0	16	2.5		
Heat Pump	9.0	16	3	4,485	6,560
Heat Pump	9.0	16	4	4,899	8,019
Heat Pump	9.0	16	5	5,412	9,185
Air Source Heat Pump (indoor & outdoor units)	9.5	18	1		
Heat Pump	9.5	18	1.5		
Heat Pump	9.5	18	2		
Heat Pump	9.5	18	2.5		6,920
Heat Pump	9.5	18	3		7,243
Heat Pump	9.5	18	4		8,682
Heat Pump	9.5	18	5		9,838

SECTION 2: ATTACHED AND MULTIFAMILY CONSTRUCTION COSTS

Cost-estimate adjustment factors to SFD costs are provided in R. S. Means Square Foot Costs 2008.[12] These adjustment factors were informally reviewed with the National Multi Housing Council, and consensus was reached to use a commonly-applied factor of .94, which represents the high end of those compiled by R.S. Means for townhouses of average construction quality. The same factor has been deemed representative for low-rise multifamily construction.

This factor has been applied to the national average costs aggregated in the matrices in Section 1 of this report to produce the Multifamily Unit (MFU) estimated cost matrices that follow.

An exception to this standard application will be noted for Matrix Multi-B1 through Matrix Multi-B-6, wood and steel exterior walls. The assemblies in those matrices include foam sheathing over OSB wall sheathing, where noted.

[12] Reed Construction Data, Inc. p. 32, inner unit .88 and end unit .94.

Matrix Multi-A1: Ceiling Assembly

Multifamily National Average Cost Per Square Foot 2008							
	Factor applied to SFD	0.94	Wood truss at 24" oc.				Conventionally Framed
Structural Roof/ Ceiling Type			6/12 Flat Clg 2x4 & 2x4 - Std. Heel 4-1/8"	6/12 2x4 over 2x4 Energy Heel - Flat Clg	6/12 over 3/12 Cathedral Ceiling	6/12 over 3/12 Cathedral Energy Heel - 11"	2x12 SYP rafters at 24" oc. (cathedral)
R-Value of Insulation	Type of Insulation	Unit of Measure	14" soffit				
13	Fiberglass batt						
19	Fiberglass batt	sq. ft.	4.33	4.77			
25	Fiberglass batt	sq. ft.	4.72	5.16			
30C	Fiberglass batt - 8 1/2"	sq. ft.	5.32	5.76	5.37	5.72	4.66
30	Fiberglass batt - 10 1/2"	sq. ft.	4.77	5.21	4.84	5.19	4.13
38C	Fiberglass batt- 10 1/2"	sq. ft.	5.80	6.24	5.81	6.16	5.10
38	Fiberglass batt-13"	sq. ft.	4.99	5.49	5.00	5.35	
49	Fiberglass batt	sq. ft.	5.64	6.14	5.78	6.13	
13	Blown Cellulose						
19	Blown Cellulose	sq. ft.	4.14	4.58	5.13	5.48	4.42
25	Blown Cellulose	sq. ft.	4.29	4.73	5.24	5.60	4.54
30	Blown Cellulose	sq. ft.	4.39	4.83	5.40	5.75	4.69
38	Blown Cellulose	sq. ft.	4.56	5.07	5.67	6.02	
42	Blown Cellulose	sq. ft.	4.77	5.27	5.80	6.15	
49	Blown Cellulose	sq. ft.	5.00	5.50	6.23	6.58	
60	Blown Cellulose	sq. ft.	5.28	5.79	6.42	6.77	

Assembly consists of the national average cost estimates for:
A1. Insulation Flat, or
A2. Insulation Cathedral
A3. Roof System (with 11" heel; all applications).
Note that ceiling R-values less than 30 in any climate zone may not meet prescriptive code minimums.

Matrix Multi-B1: Wood Exterior Walls with Fiberglass Insulation

Multifamily National Average Cost Per Square Foot 2008													
		Factor Applied to SFD	0.94	2 x 4 Wall at 16" oc			2 x 6 Wall at 16" oc.		2 x 4 Wall at 24" oc			2 x 6 Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Fiberglass Batt, kraft face, stapled									
	7/16"	OSB	sq. ft.	6.24	6.32	6.56	7.27	7.43	6.00	6.07	6.31	6.96	7.13
	1/8"	Structural Laminated Fibrous Board	sq. ft.	6.40	6.47	6.71	7.42	7.59	6.16	6.23	6.47	7.12	7.29
5	1"	SIS Panel (Polyiso and struct. sheathing	sq. ft.	7.04	7.12	7.36	8.95	9.12	6.64	6.71	6.95	8.55	8.72
2	1/2"	EPS	sq. ft.	6.55	6.62	6.86	7.57	7.74	6.28	6.36	6.60	7.25	7.42
3	3/4"	EPS	sq. ft.	6.73	6.81	7.04	7.75	7.92	6.46	6.53	6.77	7.42	7.59
4	1"	EPS	sq. ft.	6.80	6.88	7.12	7.83	7.99	6.53	6.61	6.84	7.50	7.66
3	1/2"	XPS	sq. ft.	7.07	7.15	7.38	8.03	8.20	6.78	6.85	7.09	7.70	7.86
4.5	3/4"	XPS	sq. ft.	7.14	7.22	7.45	8.16	8.33	6.87	6.94	7.18	7.83	8.00
6	1"	XPS	sq. ft.	7.40	7.48	7.71	8.36	8.53	7.09	7.17	7.40	8.01	8.18
3.2	1/2"	Polyisocyanurate	sq. ft.	7.07	7.15	7.38	8.32	8.49	6.75	6.83	7.06	7.95	8.11
5	3/4"	Polyisocyanurate	sq. ft.	7.66	7.73	7.97	8.93	9.10	7.24	7.31	7.55	8.48	8.65
6.5	1"	Polyisocyanurate	sq. ft.	7.91	7.99	8.22	9.19	9.35	7.49	7.57	7.80	8.74	8.90
7	1 1/2"	Polyisocyanurate	sq. ft.	8.53	8.61	8.84	9.80	9.97	8.11	8.19	8.42	9.36	9.52

Assembly consists of the national average cost estimates for:
B1. ExtWoodWalls2x4
B5. Insulation-Walls
B2.ExtWoodWalls2x6
Each assembly includes structural sheathing (OSB) and a weather-resistant barrier (WRB).
Based on standard window/door jambs and drywall returns at no additional cost.
Costs do not account for the usable space lost to the thicker 2x6 wall dimension.

Matrix Multi-B2. Wood Exterior Walls with Sprayed Cellulose Insulation

Multifamily National Average Cost Per Square Foot 2008													
		Factor Applied to SFD	0.94	2 x 4 Wall at 16" oc			2 x 6 Wall at 16" oc.		2 x 4 Wall at 24" oc			2 x 6 Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Sprayed Cellulose Insulation									
	7/16"	OSB	sq. ft.		6.73		7.71			6.48		7.40	
	1/8"	Structural Laminated Fibrous Board	sq. ft.		6.89		7.86			6.64		7.56	
5	1"	SIS Panel (Polyiso and struct. sheathing	sq. ft.		7.53		9.39			7.12		8.99	
2	1/2"	EPS	sq. ft.		7.04		8.01			6.77		7.69	
3	3/4"	EPS	sq. ft.		7.22		8.19			6.94		7.86	
4	1"	EPS	sq. ft.		7.29		8.27			7.02		7.93	
3	1/2"	XPS	sq. ft.		7.56		8.47			7.26		8.13	
4.5	3/4"	XPS	sq. ft.		7.63		8.60			7.35		8.27	
6	1"	XPS	sq. ft.		7.89		8.80			7.58		8.45	
3.2	1/2"	Polyisocyanurate	sq. ft.		7.56		8.76			7.23		8.38	
5	3/4"	Polyisocyanurate	sq. ft.		8.15		9.37			7.72		8.92	
6.5	1"	Polyisocyanurate	sq. ft.		8.40		9.63			7.98		9.17	
7	1 1/2"	Polyisocyanurate	sq. ft.		9.02		10.24			8.59		9.79	

B1. ExtWoodWalls2x4
B5. Insulation-Walls
B2.ExtWoodWalls2x6
Each assembly includes structural sheathing (OSB) and a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no additional cost.
Costs do not account for the usable space lost to the thicker 2x6 wall dimension.

Matrix Multi-B3: Wood Exterior Walls with Sprayed Foam Insulation

Multifamily National Average Cost Per Square Foot 2008													
		Factor Applied to SFD	0.94	2 x 4 Wall at 16" oc			2 x 6 Wall at 16" oc.		2 x 4 Wall at 24" oc			2 x 6 Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Sprayed Foam Insulation									
	7/16"	OSB	sq. ft.		7.79		9.56			7.54		9.25	
	1/8"	Structural Laminated Fibrous Board	sq. ft.		7.94		9.71			7.69		9.41	
5	1"	SIS Panel (Polyiso and struct. sheathing	sq. ft.		8.59		11.24			8.17		10.84	
2	1/2"	EPS	sq. ft.		8.09		9.86			7.82		9.53	
3	3/4"	EPS	sq. ft.		8.27		10.04			7.99		9.71	
4	1"	EPS	sq. ft.		8.35		10.12			8.07		9.78	
3	1/2"	XPS	sq. ft.		8.61		10.32			8.31		9.98	
4.5	3/4"	XPS	sq. ft.		8.68		10.45			8.40		10.12	
6	1"	XPS	sq. ft.		8.94		10.65			8.63		10.30	
3.2	1/2"	Polyisocyanurate	sq. ft.		8.61		10.61			8.29		10.23	
5	3/4"	Polyisocyanurate	sq. ft.		9.20		11.22			8.78		10.77	
6.5	1"	Polyisocyanurate	sq. ft.		9.45		11.47			9.03		11.02	
7	1 1/2"	Polyisocyanurate	sq. ft.		10.07		12.09			9.65		11.64	

B1. ExtWoodWalls2x4
B5. Insulation-Walls
B2.ExtWoodWalls2x6
Each assembly includes structural sheathing (OSB) and a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no additional cos.
Costs do not account for the usable space lost to the thicker 2x6 wall dimension.

Matrix Multi-B4: Steel Exterior Walls with Fiberglass Insulation

Multifamily National Average Cost Per Square Foot 2008								
		Factor Applied to SFD	0.94	2 x 4 CFS (Steel) Wall at 24" oc			2 x 6 CFS Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Fiberglass Batt, kraft face, pressure fit				
	7/16"	OSB	sq. ft.	7.81	7.88	8.10	8.11	8.22
	1/8"	Structural Laminated Fibrous Board						
5	1"	SIS Panel (Polyiso and struct. sheathing						
2	1/2"	EPS						
3	3/4"	EPS					9.00	9.11
4	1"	EPS	sq. ft.	8.35	8.43	8.65	9.09	9.20
3	1/2"	XPS	sq. ft.	8.03	8.10	8.32	8.88	8.99
4.5	3/4"	XPS	sq. ft.	8.18	8.26	8.48	9.01	9.13
6	1"	XPS	sq. ft.	8.53	8.60	8.83	9.20	9.31
3.2	1/2"	Polyisocyanurate	sq. ft.	8.53	8.60	8.82	9.18	9.29
5	3/4"	Polyisocyanurate	sq. ft.	8.79	8.86	9.08	9.52	9.63
6.5	1"	Polyisocyanurate	sq. ft.	9.04	9.12	9.34	9.81	9.92
7	1 1/2"	Polyisocyanurate	sq. ft.	9.79	9.87	10.09	10.56	10.67

Assembly consists of the national average cost estimates for:
B3. ExtSteelWalls2x4
B5. Insulation-Walls
Each assembly includes structural sheathing (OSB) and a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no additional cost.
All walls represented may not comply with prescriptive energy code.
Costs do not account for the usable space lost to the thicker 2x6 wall dimension.

Matrix Multi-B5. Steel Exterior Walls with Sprayed Cellulose Insulation

Multifamily National Average Cost Per Square Foot 2008								
		Factor Applied to SFD	0.94	2 x 4 CFS (Steel) Wall at 24" oc			2 x 6 CFS Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Sprayed Cellulose Insulation				
	7/16"	OSB	sq. ft.		8.20		8.45	
	1/8"	Structural Laminated Fibrous Board						
5	1"	SIS Panel (Polyiso and struct. sheathing	sq. ft.					
2	1/2"	EPS	sq. ft.					
3	3/4"	EPS	sq. ft.		8.66		9.34	
4	1"	EPS	sq. ft.		8.74		9.43	
3	1/2"	XPS	sq. ft.		8.42		9.22	
4.5	3/4"	XPS	sq. ft.		8.57		9.35	
6	1"	XPS	sq. ft.		8.92		9.53	
3.2	1/2"	Polyisocyanurate	sq. ft.		8.92		9.52	
5	3/4"	Polyisocyanurate	sq. ft.		9.18		9.86	
6.5	1"	Polyisocyanurate	sq. ft.		9.43		10.15	
7	1 1/2"	Polyisocyanurate	sq. ft.		10.18		10.90	

Assembly consists of the national average cost estimates for:
B3. ExtSteelWalls2x4
B5. Insulation-Walls
Each assembly includes structural sheathing (OSB) and a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no additional cost.
All walls represented may not comply with prescriptive energy code.
Costs do not account for the usable space lost to the thicker 2x6 wall dimension.

Matrix Multi-B6. Steel Exterior Walls with Sprayed Foam Insulation

Multifamily National Average Cost Per Square Foot 2008								
		Factor Applied to SFD	0.94	2 x 4 CFS (Steel) Wall at 24" oc			2 x 6 CFS Wall at 24" oc.	
			Cavity Insulation R-Value	11	13	15	19	21
Approx. R-Value of Insulation	Thickness	Continuous Sheathing Type	Unit of Measure	Sprayed Foam Insulation				
	7/16"	OSB	sq. ft.		9.25		10.30	
	1/8"	Structural Laminated Fibrous Board						
5	1"	SIS Panel (Polyiso and struct. sheathing						
2	1/2"	EPS						
3	3/4"	EPS	sq. ft.		9.71		11.19	
4	1"	EPS	sq. ft.		9.80		11.28	
3	1/2"	XPS	sq. ft.		9.47		11.07	
4.5	3/4"	XPS	sq. ft.		9.63		11.20	
6	1"	XPS	sq. ft.		9.98		11.38	
3.2	1/2"	Polyisocyanurate	sq. ft.		9.97		11.36	
5	3/4"	Polyisocyanurate	sq. ft.		10.23		11.71	
6.5	1"	Polyisocyanurate	sq. ft.		10.49		12.00	
7	1 1/2"	Polyisocyanurate	sq. ft.		11.24		12.75	

Assembly consists of the national average cost estimates for:
B3. ExtSteelWalls2x4
B5. Insulation-Walls
Each assembly includes structural sheathing (OSB) and a weather-resistant barrier.
Based on standard window/door jambs and drywall returns at no additional cost.
All walls represented may not comply with prescriptive energy code.
Costs do not account for the usable space lost to the thicker 2x6 wall dimension.

Matrix Multi-C1: Wood Framed Floor with Fiberglass Batt Insulation

Multifamily National Average Cost Per Square Foot 2008										
Factor Applied to SFD		0.94	Joists at 16" oc				Joists at 24" oc			
			2 x 8 Joist	2 x 10 or 9 1/4" I-J	2 x 12 or 11 7/8 I-J	14" or 16" I-Joist	2 x 8	2 x 10	2 x 12	14" or 16" I-Joist
Cavity Insulation R-Value	Thickness (inches)	Unit of Measure	Fiberglass Batt, Kraft Face, Stapled							
13	3 1/2	sq. ft	3.28	3.50	4.19	4.49	3.33	3.47	4.32	5.15
19	5 1/2	sq. ft	3.37	3.58	4.27	4.71	3.47	3.59	4.41	5.25
25	8	sq. ft	3.59	3.84	4.51	4.89	3.61	3.78	4.64	5.51
30	10	sq. ft		4.04	4.73	5.23		4.00	4.86	5.72
30C*	8.25	sq. ft		4.39	4.79	5.42		4.47	5.32	6.05
38	12	sq. ft				5.28				5.91
38C*	10.5	sq. ft			5.20	5.83			5.72	6.45
49	15	sq. ft				6.73				6.57

Assembly consists of the national average cost estimates for:
C. Insulation, joists and labor - floor assembly. Does not include subflooring.

Matrix Multi-D1. Foundation and Slab Insulation - Exterior and Core Fill Applications

Multifamily National Average Cost Per Square Foot 2008						
Factor Applied to SFD	0.94					
8"or 12" Subgrade Masonry Wall - Exterior or Core Fill Insulation						
R-Value of Insulation	Thickness	Unit of Measure	Perlite Core Fill[1]	Spray Foam Core Fill[1]	XPS	Polyisocyanurate
10	5.125	sq. ft.	4.25			
15	7.625	sq. ft.	5.58			
18	5.125	sq. ft.		4.55		
27	7.625	sq. ft.		6.23		
2.5	0.5	sq. ft.			2.47	
5.0	1	sq. ft.			2.84	
10.0	1.5"	sq. ft.			3.61	
3.5	0.5	sq. ft.				2.73
7.0	1	sq. ft.				3.08
10.5	1.50	sq. ft.				3.71

1. Perlite and Spray foam thickness and R-Value only applies to core, not overall wall average
Assembly consists of the national average cost estimates for:
D. Foundation Ins
Cost of foundation not included.
Damproof consists of one coat of sprayed bituminous coating on concrete/block surface.
Exterior bituminous damproofing is excluded when rigid foam is applied.
Exterior rigid foam applications include taping seams.

Matrix Multi-D2: Foundation Insulation - Interior Applications

Multifamily National Average Cost Per Square Foot 2008						
Factor Applied to SFD	0.94					
8"or 12" Subgrade Masonry Wall - Interior Insulation						
R-Value of Insulation	**Thickness**	**Unit of Measure**	**Foil-faced FG Insulation, draped**	**2x4 at 24" kraft faced FG & gypsum, taped**	**2x6 at 24" kraft faced FG & 1/2" gypsum, taped**	**Expanded Polystyrene & 1/2" gypsum, taped**
11	**3**	sq. ft.	1.76			
13	**3.5**	sq. ft.	1.95			
13.0	**3.5**	sq. ft.		3.44		
19.0	**5.5**	sq. ft.			4.32	
4.0	**1**	sq. ft.				2.34
8.0	**2**	sq. ft.				3.72

Assembly consists of the national average cost estimates for:
D. Foundation Ins
Cost of foundation NIC.
Damproof consists of one coat of sprayed bituminous coating on concrete/block surface.
Exterior bituminous damproofing is included with all of the costs of the interior insulation applications.
Foil-faced fiberglass was costed where it met the local interpretation of the building code.

Matrix Multi-D3: Foundation Insulation Slab - Exterior Applications

Multifamily National Average Cost Per Square Foot 2008								
Factor Applied to SFD	0.94							
Slab - Exterior or Core Fill Insulation								
R-Value of Insulation	**Thickness**	**Unit of Measure**	**Perlite Core Fill[1]**	**Spray Foam Core Fill[1]**	**XPS**		**Polyisocyanurate**	
					Sub-grade	**Above grade**	**Sub-grade**	**Above grade**
10	**5.125**	sq. ft.	4.25					
15	**7.625**	sq. ft.	5.58					
18	**5.125**	sq. ft.		4.55				
27	**7.625**	sq. ft.		6.23				
2.5	**0.5**	sq. ft.			1.56	8.87		
5.0	**1**	sq. ft.			1.93	9.24		
10.0	**2**	sq. ft.			2.70	10.00		
3.5	**0.5**	sq. ft.					1.82	9.13
7.0	**1**	sq. ft.					2.17	9.48
10.5	**1.50**	sq. ft.					2.79	10.10

1. Perlite and Spray foam thickness and R-Value only applies to core, not overall wall average
Assembly consists of the national average cost estimates for:
D. Foundation Ins
Cost of foundation not included.
Damproof consists of one coat of sprayed bituminous coating on concrete/block surface.
Exterior bituminous damproofing is excluded when rigid foam is applied.
Exterior rigid foam applications include taping seams.

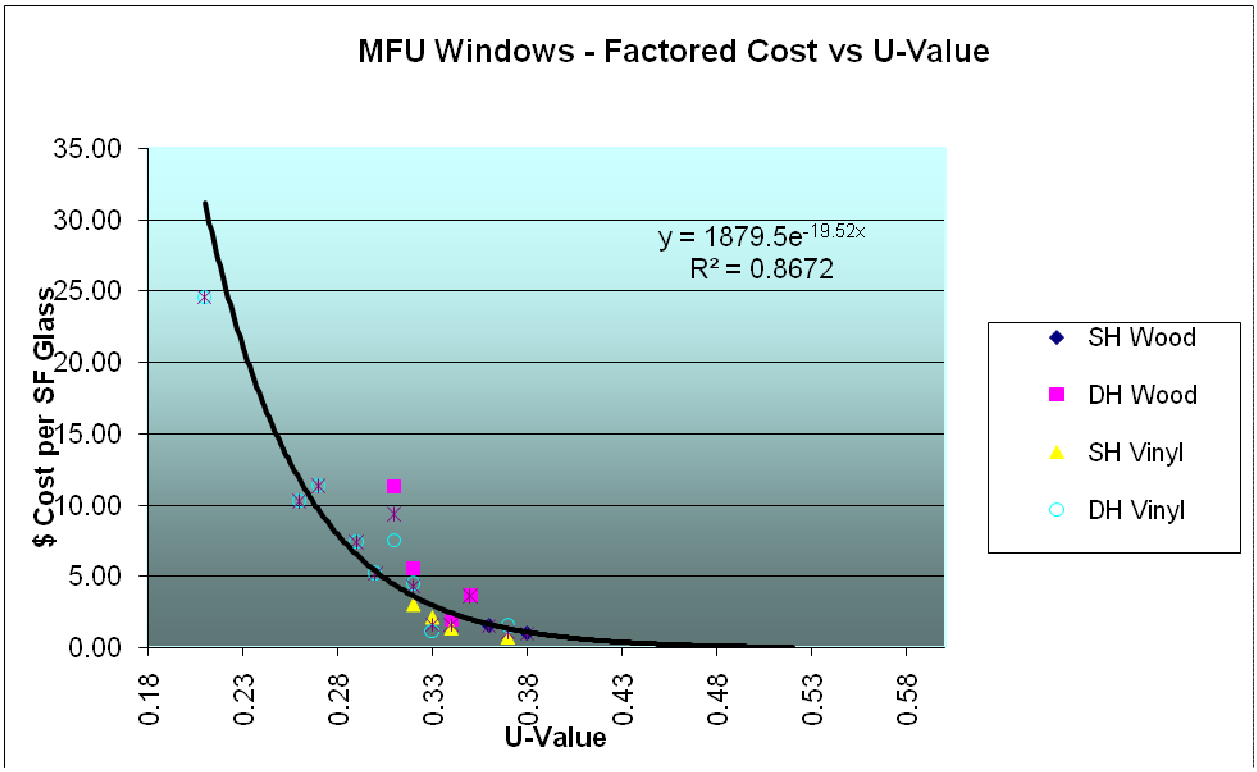

Figure 9. Window Cost Vs. U-Value

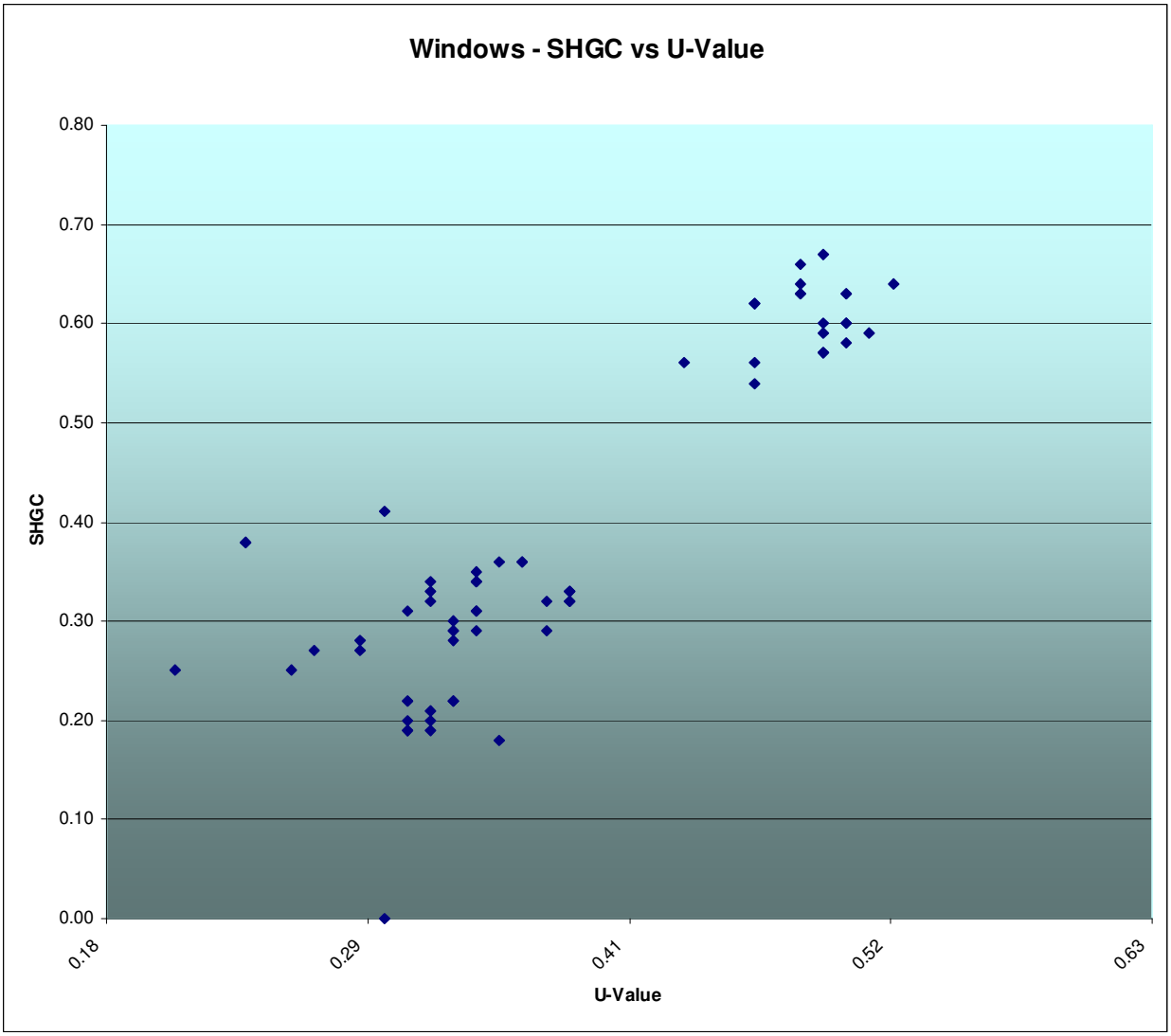

Figure 10. Window Cost Vs SHGC

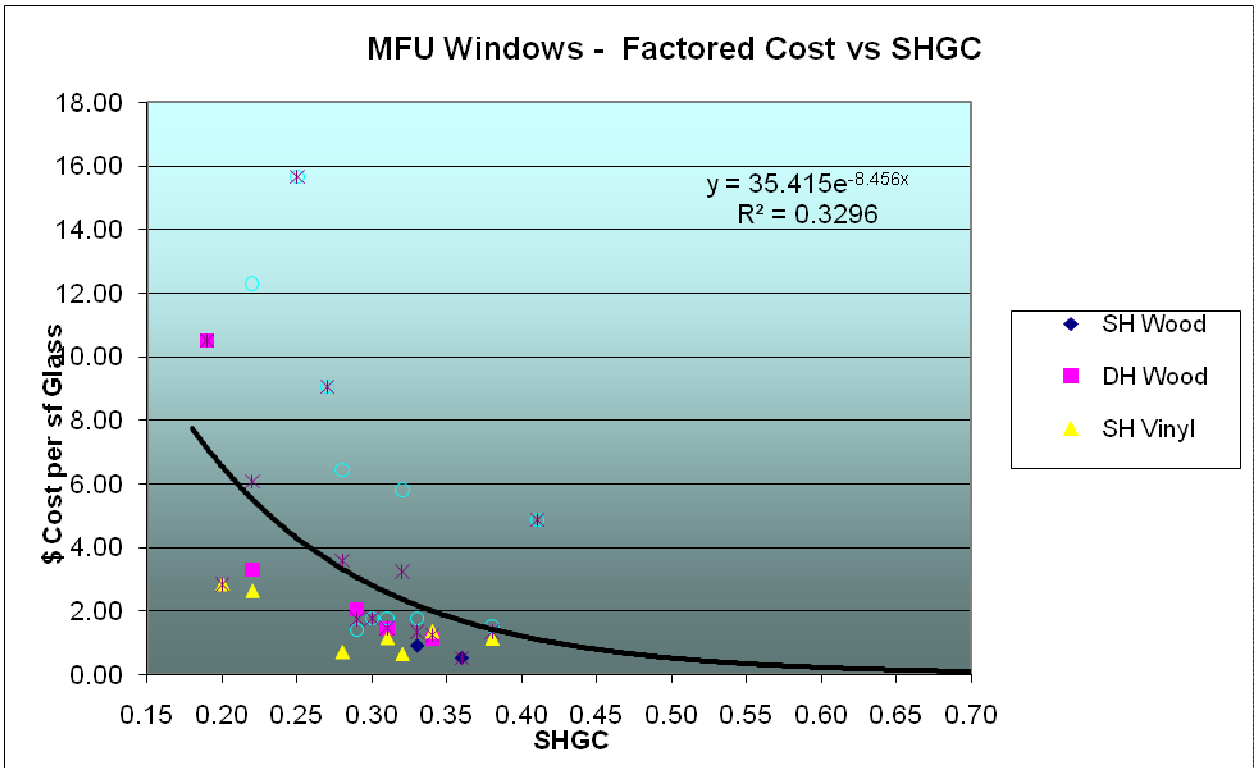

Figure 11. Window SHGC vs U-value

G. Sliding Glass Doors

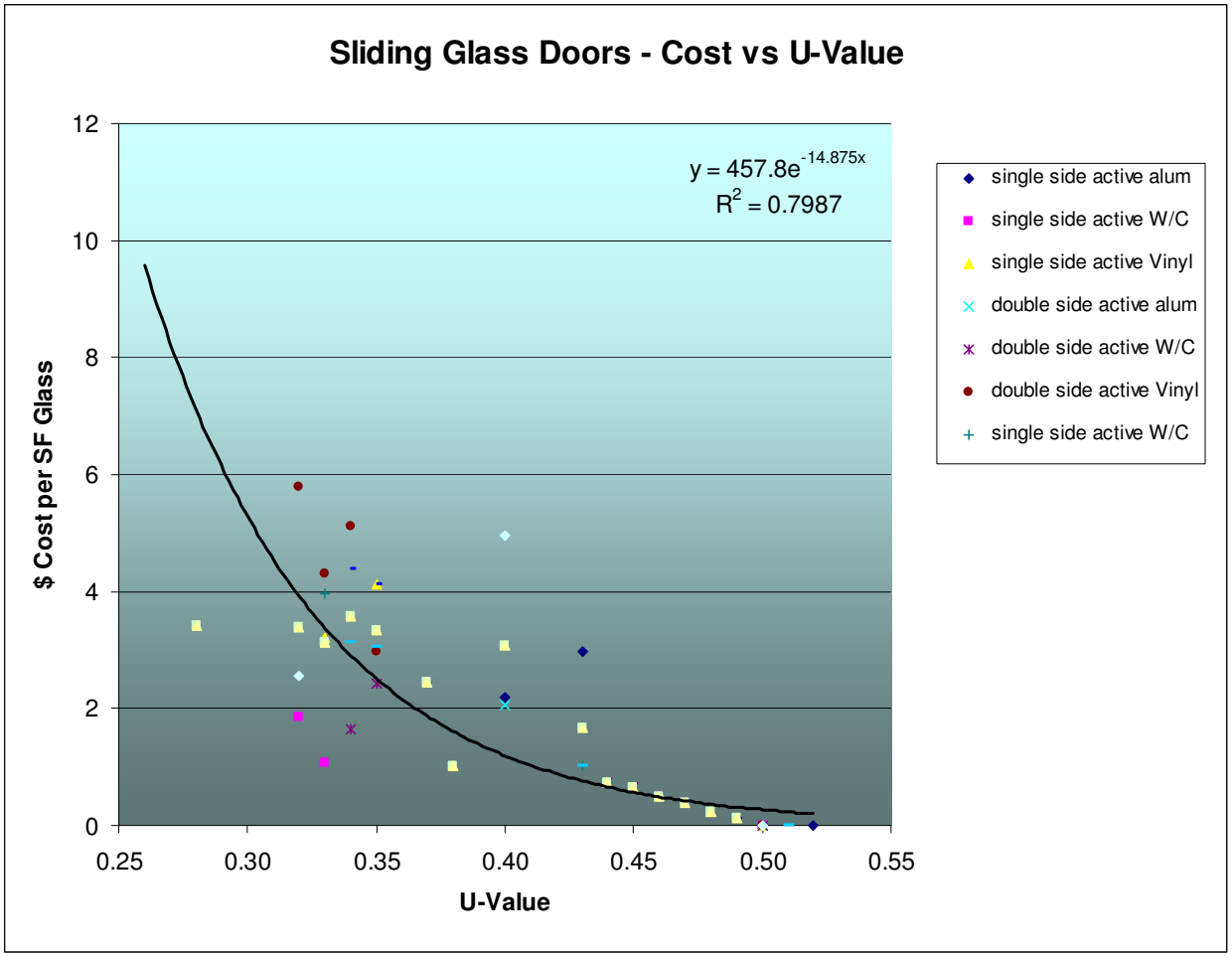

Figure 12. Sliding Glass Doors – Cost vs. SHGC

Matrix Multi-H1: Entry Doors

Multifamily National Average Cost Per Square Foot 2008							
Factor Applied to SFD	0.94						
Door Type	**Grade**	**No Glass**		**>50% Glazing**		**<50% Glazing**	
		U-Value	Cost sq ft	U-Value	Cost sq ft	U-Value	Cost sq ft
Wood Slab & Frame	Standard	0.48	$ 23.63	0.48	$ 30.48	0.47	$ 29.87
Foam Insulated Metal	Standard	0.16	$ 12.30	0.32	$ 20.05	0.37	$ 18.04
Fiberglass Insulated	Standard	0.15	$ 18.30	0.31	$ 28.34	0.35	$ 25.07
Wood Slab & Frame	Premium	0.48	$ 33.01	0.46	$ 33.19	0.46	$ 34.10
Foam Insulated Metal	Premium	0.17	$ 16.82	0.29	$ 25.88	0.37	$ 23.00
Fiberglass Insulated	Premium	0.14	$ 30.09	0.28	$ 34.80	0.36	$ 36.91

Matrix Multi-I1. Skylights

Multifamily National Average Cost Per Square Foot 2008				
Factor Applied to SFD	0.94			
Average Values	**U-Value**	**0.54**	**0.52**	**0.49**
	SHGC	**0.68**	**0.35**	**0.32**
Skylight Type	**Unit of Measure**			
Builder Grade Flat Glass Skylight - Wood/alum.	sq. ft.	51.63		
Mid-Grade Flat Glass Skylight - Wood	sq. ft.		59.98	
Prem. Grade Flat Glass Skylight - Wood/comp.	sq. ft.			67.90
Tubular Skylight - 10"	each	720		

Matrix Multi-J1. Air Infiltration Sealing

Multifamily National Average Cost Per Square Foot 2008		
Factor Applied to SFD	0.94	
Level of Performance	**Unit of Measure**	**Cost**
Basic, code minimum, ACH_{NAT} approx. .35	sq. ft.	0.11
Better, ENERGYSTAR, ACH_{NAT} .25 - .16	sq. ft.	0.22
Best, High Performance, ACH_{NAT} less than .15	sq. ft.	0.34

Assembly consists of the national average cost estimates for:
J. Air Infiltration Seal

Matrix Multi-K1. Gas Furnace

Multifamily National Average Cost Per Square Foot 2008				
Factor Applied to SFD	0.94			
Element	**Efficiency**	**Input Capacity**	**Cost per Unit (volume = 100-350 per yr.)**	**Cost per Unit (volume = 10-25 per yr.)**
Gas Furnace				
Upright, upflow	**80 AFUE**	**40-50K BTU**	655	1,687
Upright, upflow	**80 AFUE**	**60-64K BTU**	675	1,766
Upright, upflow	**80 AFUE**	**78-80K BTU**	691	1,995
Upright, upflow	**80 AFUE**	**96-100K BTU**	871	2,138
Horizontal, downflow	**80 AFUE**	**40-50K BTU**	740	2,012
Horizontal, downflow	**80 AFUE**	**60-64K BTU**	771	2,012
Horizontal, downflow	**80 AFUE**	**78-80K BTU**	794	2,057
Horizontal, downflow	**80 AFUE**	**96-100K BTU**	900	2,057
Upright, upflow	**90 AFUE**	**40-50K BTU**		1,763
Upright, upflow	**90 AFUE**	**60-64K BTU**		2,106
Upright, upflow	**90 AFUE**	**78-80K BTU**		2,643
Upright, upflow	**90 AFUE**	**96-100K BTU**		2,976
Horizontal, downflow	**90 AFUE**	**40-50K BTU**		3,170
Horizontal, downflow	**90 AFUE**	**60-64K BTU**		3,176
Horizontal, downflow	**90 AFUE**	**78-80K BTU**		3,241
Horizontal, downflow	**90 AFUE**	**96-100K BTU**		3,370
Upright, upflow	**92 AFUE**	**40-50K BTU**	1,386	
Upright, upflow	**92 AFUE**	**60-64K BTU**	1,422	
Upright, upflow	**92 AFUE**	**78-80K BTU**	1,472	
Upright, upflow	**92 AFUE**	**96-100K BTU**		
Horizontal, downflow	**92 AFUE**	**40-50K BTU**	1,286	
Horizontal, downflow	**92 AFUE**	**60-64K BTU**	1,694	
Horizontal, downflow	**92 AFUE**	**78-80K BTU**	1,808	
Horizontal, downflow	**92 AFUE**	**96-100K BTU**		
Upright, upflow	**94 AFUE**	**40-50K BTU**	2,256	
Upright, upflow	**94 AFUE**	**60-64K BTU**		3,021
Upright, upflow	**94 AFUE**	**78-80K BTU**	2,347	4,330
Upright, upflow	**94 AFUE**	**96-100K BTU**		5,576
Horizontal, downflow	**94 AFUE**	**40-50K BTU**	2,256	4,964
Horizontal, downflow	**94 AFUE**	**60-64K BTU**		5,175
Horizontal, downflow	**94 AFUE**	**78-80K BTU**	2,347	5,395
Horizontal, downflow	**94 AFUE**	**96-100K BTU**		5,693
Upright, upflow	**96 AFUE**	**40-50K BTU**	2,298	
Upright, upflow	**96 AFUE**	**60-64K BTU**	2,256	
Upright, upflow	**96 AFUE**	**78-80K BTU**	2,314	
Upright, upflow	**96 AFUE**	**96-100K BTU**	2,338	
Horizontal, downflow	**96 AFUE**	**40-50K BTU**		
Horizontal, downflow	**96 AFUE**	**60-64K BTU**	2,445	
Horizontal, downflow	**96 AFUE**	**78-80K BTU**	2,480	
Horizontal, downflow	**96 AFUE**	**96-100K BTU**	2,530	

Matrix Multi-L1: Air Conditioner

Multifamily National Average Cost Per Square Foot 2008				
Factor Applied to SFD	0.94			
Element	Approximate Efficiency	Approx. Capacity	Cost per Unit (volume = 100-350 per yr.)	Cost per Unit (volume = 10-25 per yr.)
Electric Heat Pump and Air Handler	**SEER**	**Tons**		
Air Source Heat Pump (indoor & outdoor units)	13	1	N/A	N/A
Heat Pump	13	1.5	992	
Heat Pump	13	2	1,467	4,162
Heat Pump	13	2.5	1,626	4,497
Heat Pump	13	3	1,876	4,946
Heat Pump	13	4	2,170	5,945
Heat Pump	13	5	2,450	7,003
Air Source Heat Pump (indoor & outdoor units)	14	1	N/A	N/A
Heat Pump	14	1.5	1,240	
Heat Pump	14	2	1,620	3,781
Heat Pump	14	2.5	1,831	4,166
Heat Pump	14	3	2,052	4,618
Heat Pump	14	4	2,230	
Heat Pump	14	5	2,600	
Air Source Heat Pump (indoor & outdoor units)	15	1	N/A	
Heat Pump	15	1.5	1,976	
Heat Pump	15	2	2,082	
Heat Pump	15	2.5	2,660	
Heat Pump	15	3	2,535	
Heat Pump	15	4	2,668	
Heat Pump	15	5	2,668	
Air Source Heat Pump (indoor & outdoor units)	16	1	N/A	
Heat Pump	16	1.5		
Heat Pump	16	2	2,341	
Heat Pump	16	2.5		
Heat Pump	16	3	2,393	
Heat Pump	16	4	3,076	
Heat Pump	16	5	3,556	
Air Source Heat Pump (indoor & outdoor units)	18	1		
Heat Pump	18	1.5		
Heat Pump	18	2		
Heat Pump	18	2.5		
Heat Pump	18	3		
Heat Pump	18	4		
Heat Pump	18	5		

Matrix Multi-M 1. Heat Pump

Multifamily National Average Cost Per Square Foot 2008					
Factor Applied to SFD	0.94				
Element	Approximate Efficiency		Approx. Capacity	Cost per Unit (volume = 100-350 per yr.)	Cost per Unit (volume = 10-25 per yr.)
Electric Heat Pump and Air Handler	**HSPF**	**SEER**	**Tons**		
Air Source Heat Pump (indoor & outdoor units)	**7.7**	**13**	**1**	1,753	
Heat Pump	**7.7**	**13**	**1.5**	2,015	
Heat Pump	**7.7**	**13**	**2**	2,254	4,162
Heat Pump	**7.7**	**13**	**2.5**	2,481	4,497
Heat Pump	**7.7**	**13**	**3**	2,902	4,946
Heat Pump	**7.7**	**13**	**4**	3,453	5,945
Heat Pump	**7.7**	**13**	**5**	3,874	7,003
Air Source Heat Pump (indoor & outdoor units)	**8.0**	**14**	**1**	1,939	
Heat Pump	**8.0**	**14**	**1.5**	2,067	
Heat Pump	**8.0**	**14**	**2**	2,220	3,781
Heat Pump	**8.0**	**14**	**2.5**	2,484	4,166
Heat Pump	**8.0**	**14**	**3**	2,781	4,618
Heat Pump	**8.0**	**14**	**4**	3,125	6,115
Heat Pump	**8.0**	**14**	**5**	3,562	6,890
Air Source Heat Pump (indoor & outdoor units)	**8.5**	**15**	**1**		
Heat Pump	**8.5**	**15**	**1.5**	3,792	
Heat Pump	**8.5**	**15**	**2**	3,986	
Heat Pump	**8.5**	**15**	**2.5**	4,156	
Heat Pump	**8.5**	**15**	**3**	4,074	
Heat Pump	**8.5**	**15**	**4**	4,535	
Heat Pump	**8.5**	**15**	**5**	5,102	
Air Source Heat Pump (indoor & outdoor units)	**9.0**	**16**	**1**		
Heat Pump	**9.0**	**16**	**1.5**		
Heat Pump	**9.0**	**16**	**2**	3,832	5,350
Heat Pump	**9.0**	**16**	**2.5**		
Heat Pump	**9.0**	**16**	**3**	4,216	6,167
Heat Pump	**9.0**	**16**	**4**	4,605	7,538
Heat Pump	**9.0**	**16**	**5**	5,087	8,634
Air Source Heat Pump (indoor & outdoor units)	**9.5**	**18**	**1**		
Heat Pump	**9.5**	**18**	**1.5**		
Heat Pump	**9.5**	**18**	**2**		
Heat Pump	**9.5**	**18**	**2.5**		6,505
Heat Pump	**9.5**	**18**	**3**		6,809
Heat Pump	**9.5**	**18**	**4**		8,161
Heat Pump	**9.5**	**18**	**5**		9,248

DISCUSSION OF RESULTS

Economic Database

This work provides a sound basis on which the costs of energy efficient upgrades can be estimated. The pricing can be applied to construction techniques and products that are available in the market; however, there are some limitations to the contracted level of effort that became evident during the initial analysis. For example, four costs averaged for one assembly followed by two costs comprising the average of the next higher performing assembly can misstate the true price delta between these assemblies. This type of incongruity was particularly apparent for high-density fiberglass batts in floor and roof assemblies because only two of the four builders were able to locate a supply source for the products and provide costs. In such an instance, data points were dropped, narrowing the sample size while preserving the cost relationship between levels of upgraded performance. Larger data samples would be expected to decrease the variance of the data and increase the confidence in the relationship between cost and performance level reported.

Costs were derived primarily by surveying builders from four different regions and, as necessary, supplemented by directly obtaining costs from suppliers. The data was compiled and analyzed, but some of the data points deviated significantly from the average. This can be a frequent problem with small data samples. The consistent approach taken was to eliminate obvious outlying data points when differences could not be reconciled.

Builders participating were given the same set of instructions and templates. Notes included specific reference to often overlooked components that contribute to the upward creep of costs for specialty assemblies, such as window jamb extensions at thick wall/sheathing applications. The limited scope of this effort did not allow finite verification of the subcontractor bids that underlie these cost estimates.

Product Availability and Marketplace Limitations

A specific list of energy efficient products was provided by the ASHRAE SSPC 90.2 Committee to be priced for this study. There were a few gaps in the responses from the builders due to a lack of local product availability with their established suppliers. These gaps included vermiculite core fill insulation used in foundation block, plastic skylights and very high efficiency air conditioning systems (17 SEER+). In addition some smaller subsets of data had little or no reporting from the responding builders such as 19.2” fiberglass batt products for floors over unconditioned space, mineral wool batts to fit typical exterior wall cavities and high density fiberglass batts (e.g., R-30C and R-38C).

Windows are widely available with thermal performance levels down to a U-Value of about 0.30 and SHGC of 0.29. Below those levels, there are often many windows listed by the manufacturers, but very few of them could be priced by a supplier or ordered. Soliciting supplemental costs directly from suppliers was necessary to obtain a representative sample at the higher performing levels.

HVAC equipment pricing varied widely among the builders. Higher costs were associated with the low-volume builders and lower costs with the high-volume builders. Because it is probable

that the larger builders engage in contracts directly with product manufacturers who provide the opportunity for equipment cost advantages, HVAC equipment costs were averaged and displayed differently than other cost estimates in this report.

HVAC costs and efficiencies are presented as reported by the builders without interpolation of intermediate sizes or efficiencies. It is known that one ton air conditioning units were unavailable in the marketplace, but inquiry into other voids in the spreadsheets did not produce definitive results as to product availability in certain sizes and efficiencies.

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