CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

2008 California Energy Commission Title 24 Building Energy Efficiency Standards
March 20, 2007

Final Report
Insulation Requirements

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Overview

The nonresidential insulation levels were last updated in 1992 and very few changes have been made to the prescriptive envelope requirements in the last 12 years. The main changes came with the Title 24 2005 Standards as U-factors were pre-calculated for all common construction assemblies and published as Joint Appendix IV for both the residential and nonresidential Alternative Calculation Method (ACM) manuals. Another change with the Title 24 2005 Standards applies to metal buildings; the R-value method was eliminated as a compliance option for metal building roofs.

The approach in this analysis is to calculate the cost effective level of insulation for separate classes of construction. The analysis is based on time dependent valued (TDV) energy, which replaced source energy with the 2005 update to the Standards. TDV electric energy weights consumption and savings by time of day. TDV gas energy weights consumption by season.

The approach is to identify a list of reasonable constructions for each class of construction, estimate the cost for each construction assembly, estimate the TDV energy for each construction assembly in the list, and calculate the life-cycle cost of each construction assembly using the Energy Commission approved life-cycle cost methodology. The criterion is then to get to the U-Factor of the construction with the lowest life-cycle cost (LCC). A secondary criterion is to ensure, where appropriate, that the prescriptive criteria is at least as stringent as the 2005 Standard. A minimum requirement is that the U-factor selected have a life cycle cost that is at or lower than the life cycle cost for the minimum prescriptive requirement assembly for Title 24 2005. In cases where the U-factor corresponding to the minimum life-cycle cost is higher than the 2005 Title 24 prescriptive requirement, an alternate assembly may be chosen provided that its total life cycle cost does not exceed the LCC for the 2005 assembly.

Description

The proposed change is a modification to the prescriptive insulation requirements for nonresidential and high-rise residential buildings, which are contained in Tables 143-A, 143-B, and 143-C. The standards for relocatable school buildings in Table 143-C are for buildings that can be relocated to any climate zone, and so the insulation requirements correspond to those of the most severe climate zones in Table 143-A. Since the prescriptive standards set the baseline for the performance method, the performance method would become more stringent also.

Energy Benefits

The energy benefits are calculated using DOE-2.1E, the California Energy Commission (CEC) reference method for nonresidential buildings. A separate analysis is performed for each opaque construction type (roof, wall, and floor) and class of construction within that type (mass, metal buildings, metal framing and wood framing). The life-cycle cost optimum insulation is determined for each type/class in the sixteen climate zones. The evaluation is performed using a life-cycle cost approach based on TDV energy and the CEC methodology. U-factors from Joint Appendix IV are used in the analysis. Tables IV.2 and IV.7 were used for roof constructions, tables IV.9, IV.11, IV.16 and IV.19 were used for wall constructions and tables IV.21 and IV.25 were used for floor constructions.

Non-energy Benefits

Non-energy benefits from improved insulation levels include improved comfort and environmental benefits - environmental benefits are discussed in the next section.

Statewide Energy Impacts

Annual energy simulations produced linear regressions relating HVAC electricity and gas use to U-factor. Thus, for any prescriptive U-factor, the annual electricity use in kWh/ft^2 and gas use in therm/ft^2 can be calculated. This provides an estimate of energy savings per ft^2 of area of the applicable building component (roof area, wall area, or floor area). To estimate statewide energy impacts, average annual construction data from the Dodge nonresidential new construction survey for program years 2000 through 2003 was applied, which estimated annual new construction at 157,800,000 ft^2. This data included construction estimates by climate zone and by building type. A weighted average of kWh, therm and TDV energy savings, per ft^2 of construction, for each construction type was developed from the results. An example is shown in the table below, for wood-framed walls, daytime occupancy.

Statewide Impact Calculation Example, Wood-Framed Walls, Daytime Occupancy

CZ	2005 U	2008 U	2005 kWh/ft^2	2008 kWh/ft^2	Diff.	Weighting Factor	Savings, kWh/ft^2-y
1	0.102	0.102	6.887982	6.887982	0	0.002562	0
2	0.102	0.059	15.08962	14.75101	0.338604	0.057684	0.019532
3	0.110	0.110	10.87995	10.87995	0	0.128873	0
4	0.110	0.059	16.2356	15.9195	0.316093	0.04659	0.014727
5	0.110	0.102	11.94763	11.90805	0.039573	0.014202	0.000562
6	0.110	0.110	13.95597	13.95597	0	0.066377	0
7	0.110	0.110	15.6444	15.6444	0	0.071838	0
8	0.110	0.102	18.07775	18.02132	0.056431	0.09321	0.00526
9	0.110	0.059	19.93894	19.50984	0.429098	0.114591	0.049171
10	0.102	0.059	21.12777	20.7026	0.42517	0.084135	0.035772
11	0.102	0.059	18.89083	18.50074	0.390085	0.025361	0.009893
12	0.102	0.059	18.00621	17.64738	0.358831	0.175092	0.062828
13	0.102	0.059	22.47148	22.00099	0.470495	0.072343	0.034037
14	0.102	0.059	19.98305	19.53763	0.445427	0.02247	0.010009
15	0.102	0.041	32.30146	31.42654	0.874924	0.018918	0.016552
16	0.102	0.059	12.25608	11.98516	0.270924	0.005753	0.001559
Total						1	**0.260**

The Dodge data also included construction by occupancy type. A composite annual energy savings level, that is a weighted average of the different occupancy types, was developed. Finally, nonresidential new construction by building type was estimated by applying data from the Nonresidential New Construction database conducted for the California Energy Commission. This database includes building details for 990 commercial buildings that span different utility service territories. Since wall energy savings were determined per ft^2 of wall area, a relation must be developed to determine the ft^2 of new wall construction, based on floor area. Similarly, roof area of new construction must be determined. Roof and wall area estimates were determined by applying wall-floor area ratios and roof-floor area ratios from data in the Nonresidential New Construction database. For 157.8 million ft^2 of floor area of new construction, wall area is estimated at 45.3 million ft^2 and roof area at 109.7 million ft^2. Statewide energy impacts are shown in Tables 1-3 below.

Table 1 – Statewide Electricity Impact Analysis from 2008 Prescriptive Envelope Requirements

Energy Savings (kWh/ft^2-y)							
	Daytime	Retail	24 hour	Weighted Avg.	% of NC*	Area ($x10^6$ ft^2)	Savings (GWh/yr)
Metal Bldg Roof	0.0104	0.0154	0.0392	0.0137	59.4	109.7	0.89
Wood Fr Roof	0.0273	0.0667	0.0843	0.0383	40.6	109.7	1.70
Metal Bldg Wall**	0.2520	0.3229	0.5605	0.2892	9.5	45.3	1.24
Metal Fr Wall	0.8213	1.1381	1.5214	0.9298	21.1	45.3	8.89
Mass Light Wall	0.1246	0.5066	0.5003	0.2156	34.0	45.3	3.32
Mass Heavy Wall	0.0480	0.3654	0.1587	0.1065	18.9	45.3	0.91
Wood Fr Wall	0.1601	0.2599	0.4191	0.1976	16.5	45.3	1.48
Mass Floor	0.2597	0.4720	-0.0109	0.2695	20.0	157.8	8.51
Wood Fr Floor	0.0050	0.1427	0.0580	0.0308	10.0	157.8	0.49
Total							**27.42**

** Percentage estimates of new construction were derived from the Nonresidential New Construction Database.*
*** For metal building walls, it was assumed that 40% of new construction that is Storage is Dodge DB are metal buildings.*

Table 2 – Statewide Gas Impact Analysis from 2008 Prescriptive Envelope Requirements

Energy Savings (therm/ft2-y)							
	Daytime	Retail	24 hour	Weighted Avg.	% of NC	Area (x10^6 ft2)	Savings ($x10^6$ therms/yr)
Metal Bldg Roof	0.0001	0.0004	0.0058	0.0006	59.4	109.7	0.04
Wood Fr Roof	0.0023	0.0054	0.0129	0.0036	40.6	109.7	0.16
Metal Bldg Wall	0.0123	0.0123	0.0381	0.0145	9.5	45.3	0.06
Metal Fr Wall	0.0435	0.0452	0.1027	0.0488	21.1	45.3	0.47
Mass Light Wall	0.0407	0.0404	0.1175	0.0472	34.0	45.3	0.73
Mass Heavy Wall	0.0250	0.0378	0.1327	0.0362	18.9	45.3	0.31
Wood Fr Wall	0.0072	0.0095	0.0281	0.0094	16.5	45.3	0.07
Mass Floor	-0.0288	-0.0260	0.0506	-0.0216	20.0	157.8	-0.68
Wood Fr Floor	0.0020	-0.0101	0.0287	0.0024	10.0	157.8	0.04
Total							**1.19**

Table 3 – Statewide TDV Impact Analysis from 2008 Prescriptive Envelope Requirements

TDV Savings (TDV/ft2-y)							
	Daytime	Retail	24 hour	Weighted Avg.	% of NC	Area (x10^6 ft2)	Savings (x10^6 TDV/yr)
Metal Bldg Roof	0.2316	0.3168	1.3581	0.3406	59.4	109.7	22.19
Wood Fr Roof	0.8376	1.7998	2.9654	1.1674	40.6	109.7	51.98
Metal Bldg Wall	5.3356	5.9232	10.6419	5.8780	9.5	45.3	25.29
Metal Fr Wall	17.5012	20.3821	28.9088	18.9173	21.1	45.3	180.77
Mass Light Wall	9.2988	12.6027	23.3439	11.0047	34.0	45.3	169.45
Mass Heavy Wall	5.6315	10.5408	23.6138	7.9207	18.9	45.3	67.80
Wood Fr Wall	3.3893	4.7901	8.0317	4.0009	16.5	45.3	29.90
Mass Floor	0.4216	6.2140	7.7916	1.9445	20.0	157.8	61.37
Wood Fr Floor	0.4276	2.3070	5.1904	1.1235	10.0	157.8	17.73
Total							626.48

Environmental Impact

Insulation will reduce heat loss and gain through building envelopes and this will reduce the use of heating and cooling system energy that negatively impacts the environment. The primary environmental impact is the reduction in air emissions from the reduction in furnace or boiler emissions due to reduced heating fuel (natural gas) consumption and power plants due to reduced electricity consumption.[1]

Type of Change

This report recommends changes to the prescriptive requirements. As the prescriptive standards change, the baseline for performance calculations also changes. The Title 24 Standards and Nonresidential ACM Manual will need to be modified accordingly.

Technology Measures

Measure Availability and Cost

There are numerous manufacturers of insulation products, and products are widely distributed through contractors, wholesale distributors, and retail. The market place for insulation is competitive and healthy. Products being considered in this study are already available in the marketplace, and increasing the minimum insulation requirement should not cause a shortage, if ample time is given before implementation of the requirements so that manufacturers have time to shift production output. Increasing the minimum insulation requirement should not affect the manufacturing process materially.

The cost of insulation is directly related to the quantity that is purchased and installed in the building. Shifting from one type (fiberglass batts) to another (foamed plastic) will change the cost per unit of thermal resistance (R-value). The cost of insulation products is well documented in the literature. More information is provided later in the report on insulation costs, since this is a key input to the analysis.

Performance verification or commissioning of insulation systems is not common in nonresidential buildings. With the 2005 update to the Standards, field verification and diagnostic testing of insulation systems was added as a compliance option for low-rise residential buildings to recognize that research has shown insulation is commonly installed with construction defects. For low-rise residential buildings, the thermal performance of insulation is assumed to be installed according to standard practice methods unless a HERS rater performs field verification and diagnostic testing to demonstrate that high quality installation has been achieved. This report does not propose a similar approach at this time for basing nonresidential insulation performance on the presence of construction defects unless the work is independently verified to insure a high quality installation is achieved.

Useful Life, Persistence and Maintenance

The life-cycle cost analysis uses a 30 year life for insulation. This is the current standard and common practice for envelope requirements. There is no significant persistence or maintenance issues related to increasing insulation levels. The only potential issue is the degradation over time of insulation performance due to the possible condensation of water within a construction assembly. Condensation could result at walls adjacent to moisture laden spaces when there is an inadequate or discontinuous vapor barrier.

Analysis Tools

Energy savings and peak electricity demand reductions can be quantified using the current reference method or approved ACMs.

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[1] The reduction in emissions due to reduced electricity could occur anywhere throughout the Western United States whereas the reduction in emissions due to reductions in heating will occur at the building site.

Relationship to Other Measures

Heating and cooling loads will be impacted by improved insulation levels and heating and cooling systems may possibly be downsized. A key input into this analysis was whether the HVAC systems have an air-side economizer. All the models used to develop insulation level recommendations assume that air-side economizers are used on all new buildings. However, Title 24 Section 144(e) requires air side economizers on HVAC units that have a cooling capacity greater than 75,000 Btu/hr (6.25 tons). A sensitivity analysis was performed in climate zones 3, 6, and 12 to determine the effect of economizers. This is detailed in the 2005 versus 2008 Insulation Level Comparisons section under Economizers. A cool roof sensitivity analysis was also performed for this study since the optimal cool roof coating was determined using the 2005 insulation standards as a baseline.

Methodology

Approach

A component approach is used for the development of the recommended insulation levels. With this approach, the stringency of each category of construction is determined independently from the others. Construction assemblies addressed in this report are organized by type, class and category, as defined below:

Types	The three types of constructions are roofs, walls and floors. These are defined in the standards.
Classes	A separate performance criterion is recommended for each class of construction. A class of construction can be a consolidation of more than one category, as defined in the next bullet.
Categories	Categories are consolidated into classes. The categories of construction used in this analysis are the same as those used to group information in Joint Appendix IV.

A separate life-cycle cost analysis was performed for each category and then the data was consolidated into classes. The construction assemblies considered in the life-cycle cost analysis are those that are included in each table of Joint Appendix IV specified below. The initial cost of each construction assembly was estimated from nationally published data[2] but cross checked against regional data for California[3]. Roof insulation costs for high-density batt insulation were revised from values used in the May 2006 report based on feedback from industry.

The energy consumption of each construction assembly is calculated for three occupancy types, which capture the principal variation within the occupancy schedules referenced in the nonresidential ACM manual. These include occupancy schedules for daytime only, 24-hour (i.e., high-rise residential and hotel/motel), and retail. The schedules of operation, occupant loads, lighting loads, plug loads and other modeling assumptions for these three occupancies are taken from the Nonresidential ACM Manual. Details on these and other modeling assumptions are provided later in this section.

Once the energy use and the initial cost were determined for each construction category, the life-cycle cost is calculated for each construction assembly using the CEC recommended methodology. The approach is to find the construction assembly that minimizes life-cycle cost.

Categories of Construction

[2] RSMeans, *Means CostWorks 2005, Building Construction Cost Data*, 7th Edition, 2005.

[3] California Public Utilities Commission and California Energy Commission, *2004-05 Database for Energy Efficient Resources (DEER) Version 2.0*, 2005.

The categories of construction used in the analysis are determined from Joint Appendix IV, as shown below. The tables in Joint Appendix IV present the U-factors and other thermal performance data for just about all levels of insulation. The tables are comprehensive and are intended to provide performance data for all levels of insulation. Every cell in the Joint Appendix IV data tables listed below was evaluated. The categories considered are shown below.

Roofs

Table IV.1 – U-factors of Wood Framed Attic Roofs

Table IV.2 – U-factors of Wood Framed Rafter Roofs

Table IV.4 – U-factors of Metal Framed Attic Roofs

Table IV.5 – U-factors of Metal Framed Rafter Roofs

Table IV.6 – U-factors for Span Deck and Concrete Roofs

Table IV.7 – U-factors for Metal Building Roofs

Walls

Table IV.9 – U-factors of Wood Framed Walls

Table IV.11 – U-factors of Metal Framed Walls

Table IV.16 – U-factors for Metal Building Walls

Table IV.19 – Effective R-values for Interior or Exterior Insulation Layers (Note that this table has insulation levels that apply to base mass wall constructions. These are combined with the standard design light and heavy mass walls as defined in the nonresidential ACM manual.)

Floors

Table IV.20 – Standard U-factors for Wood Framed Floors with a Crawl Space

Table IV.21 – Standard U-factor for Wood Framed Floors without a Crawl Space

Table IV.23 – Standard U-factor for Metal Framed Floors with a Crawl Space

Table IV.24 – Standard U-factor for Metal Framed Floors without a Crawl Space

Table IV.25 – Standard U-factors for Concrete Raised Floors

Cost Data

Cost assumptions are critically important to the life-cycle cost. The higher the initial cost, the less likely a measure will be cost effective. However, only the incremental cost of adding insulation or otherwise improving the thermal performance of the construction assembly is of significance for each category of construction (see above).

In order to remain consistent, the analysis used data from one source, *Means CostWorks 2005*. However, as a cross reference and check, the Means data was compared to the *2005 Database for Energy Efficient Resources (DEER)*, where data is available from both sources. When more than one insulation product can be used for a particular application, the product with the lowest cost was used. Incremental costs include both material and labor.

Specific values for certain insulation levels and framing sizes that are not available in the Means database was determined by regression analysis. Values determined through regression are *italicized* and highlighted in yellow. In Table 4 through Table 11 a separate regression analysis was performed for both the material cost and labor cost. For cavity insulation, no regression was performed for labor cost because the cost is assumed to be fixed to the framing size. In other words, all cavity insulation for 2x4 framing have the same labor cost, and all cavity insulation for 2x6 framing have the same labor cost.

The final cost used in the life-cycle cost analysis includes a 1.09 multiplier to adjust the national figures to California and a 30% markup for contractors' overhead and profit. Tables 1 through 8 show installed costs before contractor markup and before the adjustment to California costs.

Insulation Costs

Table 4 – Cavity Insulation Costs

R-value	Material Cost ($/ft^2)	16" Labor Cost ($/ft^2)	24" Labor Cost ($/ft^2)	Total 16" Cost ($/ft^2)	Total 24" Cost ($/ft^2)	DEER Cost ($/ft^2)
11	0.24	0.20	0.17	0.44	0.41	
13	0.31	0.20	0.17	0.51	0.48	
15*	0.558	0.20	0.17	0.758	0.728	0.61
19	0.46	0.24	0.20	0.70	0.66	0.65
21*	0.644	0.24	0.20	0.884	0.844	0.68
22	*0.46*	*0.24*	*0.20*	*0.70*	*0.66*	
25	*0.51*	*0.24*	*0.20*	*0.75*	*0.71*	
30	0.60	0.27	0.24	0.87	0.84	0.76
38	0.70	0.27	0.24	0.97	0.94	0.86
CostWorks description: wall or ceiling insulation, non-rigid, fiberglass, unfaced, batts or blankets						
* Costs for R-15 and R-21 high-density batt insulation were revised per industry feedback						

Table 5 – Rigid Insulation Costs

R-value	Material Cost ($/ft^2)	Labor Cost ($/ft^2)	Total Cost ($/ft^2)
3.9	0.29	0.34	0.63
4.5	0.30	0.34	0.64
5.4	0.24	0.34	0.58
7.2	0.33	0.34	0.67
10.8	0.35	0.38	0.73
14.4	0.46	0.38	0.84
21.6	1.11	0.38	1.49
28.8	1.37	0.38	1.75
CostWorks description: wall insulation, rigid, polyisocyanurate, foil faced, both sides, 4' x 8' sheet			

Table 6 – Rigid Insulation Costs from Regression Only

R-value	Material Cost ($/ft^2)	Labor Cost ($/ft^2)	Total Cost ($/ft^2)
2	*0.09*	*0.34*	*0.43*
4	*0.18*	*0.34*	*0.52*
6	*0.28*	*0.34*	*0.62*
7	*0.32*	*0.34*	*0.66*
8	*0.37*	*0.34*	*0.71*
10	*0.46*	*0.38*	*0.84*
14	*0.64*	*0.38*	*1.02*
12	*0.55*	*0.38*	*0.93*
15	*0.69*	*0.38*	*1.07*
20	*0.92*	*0.38*	*1.30*
25	*1.15*	*0.38*	*1.53*
30	*1.38*	*0.38*	*1.76*
CostWorks description: wall insulation, rigid, isocyanurate, foil faced, both sides, 4' x 8' sheet			

Table 7 – Metal Building Insulation Costs

R-value	Material Cost ($/ft^2)	Labor Cost ($/ft^2)	Total Cost ($/ft^2)
None	0	0	0
R-10	0.38	0.24	0.62
R-11	0.42	0.24	0.66
R-13	0.47	0.24	0.71
R-19	0.61	0.24	0.85
CostWorks description: pre-engineered steel building access, insulation, foil/scrim/kraft (FSK) faced			

Wall Framing Costs

Wall framing costs were determined by assuming a 10' high wall, which is typical of nonresidential buildings. 16 in. O.C. and 24 in. O.C. framing are compared as separate categories in the analysis, however, the code recommendation used the 16 in. O.C. framing as the basis.

Table 8 – Wood Framing Costs

	Frame Size	Material Cost	Labor Cost	Total Cost	Square Foot Cost ($/ft^2)	Total Incremental Cost ($/ft^2)
16 in. O.C	2x4	3.56	5.5	9.06	0.91	0
	2x6	5.65	6.1	11.75	1.18	0.269
	2x8	*7.74*	*6.70*	*14.44*	*1.44*	*0.54*
	2x10	*9.83*	*7.30*	*17.13*	*1.71*	*0.81*
	2x12	*11.92*	*7.90*	*19.82*	*1.98*	*1.08*
24 in. O.C	2x4	2.71	4.38	7.09	0.71	0
	2x6	4.30	4.77	9.07	0.91	0.20
	2x8	*5.89*	*5.16*	*11.05*	*1.11*	*0.40*
	2x10	*7.48*	*5.55*	*13.03*	*1.30*	*0.59*
	2x12	*9.07*	*5.94*	*15.01*	*1.50*	*0.79*
Wall framing is assumed to be 10' high as the least cost to the contractor.						
CostWorks description: wood framing, partitions, standard & better lumber, 10' high, includes single bottom plate and double bottom plate, excludes waste						

Table 9 – Metal Framing Costs

	Frame Size	Material Cost	Labor Cost	Total Cost	Square Foot Cost ($/ft^2)	Total Incremental Cost ($/ft^2)
16 in. O.C.	2x4	11.15	7.40	18.55	1.86	0
	2x6	14.15	7.50	21.65	2.17	0.31
	2x8	17.30	7.60	24.9	2.49	0.65
	2x10	*20.28*	*7.82*	*28.10*	*2.81*	*0.96*
	2x12	*23.31*	*8.00*	*31.31*	*3.13*	*1.26*
24 in. O.C.	2x4	8.20	5.3	13.5	1.35	0
	2x6	10.45	5.45	15.9	1.59	0.24
	2x8	12.85	5.5	18.35	1.835	0.48
	2x10	*15.06*	*5.69*	*20.75*	*2.08*	*0.73*
	2x12	*17.33*	*5.84*	*23.17*	*2.32*	*0.97*

Wall framing is assumed to be 10' high as the least cost to the contractor.

CostWorks reference: partition, galv LB studs, 18 ga, 10' high, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging

Roof Framing Cost

Rafter roof framing costs were determined by assuming a square foot of framing and applying the framing factor specified in the Title 24 2005 Standards, 10% for 16 in. O.C. and 7% for 24 in. O.C. The same process was used to determine costs for metal rafter roofs. 16 in. O.C. and 24 in. O.C. framing are compared as separate categories in the analysis, however, the code recommendation used the 24 in. O.C. framing as the basis. Metal building roofs that utilize rigid insulation include an additional metal deck (screw down roof) to sandwich the rigid insulation.

Table 10 – Wood Rafters Roof Costs

Framing Size	Material Cost	Labor Cost	Total Cost	16" Total Cost ($/ft^2)	24" Total Cost ($/ft^2)	16" Incremental Cost ($/ft^2)	24" Incremental Cost ($/ft^2)
2x6	3.21	3.30	6.51	0.65	0.46	0	0
2x8	4.96	3.48	8.44	0.84	0.59	0.19	0.13
2x10	*7.05*	*4.35*	*11.4*	*1.14*	*0.80*	*0.49*	*0.34*
2x12	*9.60*	*5.22*	*14.83*	*1.48*	*1.04*	*1.83*	*1.58*
2x14	*12.96*	*6.09*	*19.05*	*1.90*	*1.33*	*0.87*	*0.87*

Roof framing is determined by multiplying the total square foot framing cost by the framing factor of 10% for 16 in. O.C. and 7% for 24 in. O.C.

CostWorks description: rafters, roof framing, to 14 in 12 pitch

Table 11 – Metal Rafter Roof Costs

Framing Size	Material Cost	Labor Cost	Total Cost	16" Total Cost ($/ft^2)	24" Total Cost ($/ft^2)	16" Incremental Cost ($/ft^2)	24" Incremental Cost ($/ft^2)
2x6	5.6	3.43	9.03	0.90	0.63	0	0
2x8	6.2	3.65	9.85	0.99	0.69	0.09	0.06
2x10	7.55	3.91	11.46	1.15	0.80	0.25	0.17
2x12	8.3	4.22	12.52	1.25	0.88	0.35	0.25
2x14	*9.28*	*4.46*	*13.74*	*1.37*	*0.96*	*0.47*	*0.33*

Roof framing is determined by multiplying the total square foot framing cost by the framing factor of 10% for 16 in. O.C. and 7% for 24 in. O.C.

CostWorks description: boxed ridge beam, for CF metal rafters, w/ galv joist & track, double, 18 ga

Table 12 – Metal Building Roof Costs

Framing Size	Material Cost ($/ft^2)	Labor Cost ($/ft^2)	Total Cost ($/ft^2)
Screw Down (no thermal blocks)	0.77	0.97	1.74
Standing Seam (thermal blocks at supports)	1.75	1.07	2.82
Metal building roofs including screw down and standing seam include an addition screw down roof cost for rigid insulation.			
CostWorks description (screw): steel roofing, on steel frame, corrugated or ribbed, galvanized, 30 gauge			
CostWorks description (standing seam): steel roofing, on steel frame, flat profile, 1-3/4" standing seams, zinc alluminum alloy finish, 12" wide, 26 gauge			

Floor Framing Cost

Floor framing costs were excluded from the calculation because additional insulation may be added to the floor without altering the framing.

Cost Adjustments

The cost is adjusted for California and a markup is added for the contractors' overhead and profit.

The Means data either specifies a national average or a local city average cost; however, the Means data does not provide a weighting factor for the State of California as a whole. In order to determine a reasonable California adjustment factor, we specified a representative city for each of California's sixteen climate zones. Next, we determined the local adjustment factor for each city and weighted the adjustment factor against the percentage of new construction for the representative city and climate zone. The cost adjustment factors were taken from the Means data and the new construction weighting percentages were taken from the 2005 Title 24 Impact Analysis[4] using the nonresidential new construction database. Table 13 shows the representative city, local adjustment factor, and weighting factor for each of the sixteen climate zones. The weighted markup for each climate zone was determined by multiplying the percent floor area by the local markup. The California adjustment factor or total markup is the sum of the weighted markup.

[4] California Energy Commission by Eley Associates. Impact Analysis, 2005 Update to the California Energy Efficiency Standards, 2003

Table 13 – California Adjustment Factor

Zone	City	Percent Floor Area	Real Area	Local Markup	Weighted Markup
1	Arcata	0.0031	492,900	1.04	0.003224
2	Santa Rosa	0.0701	11,145,900	1.124	0.0787924
3	Oakland	0.1586	25,217,400	1.166	0.1849276
4	San Jose	0.0713	11,336,700	1.169	0.0833497
5	San Louis Obispo	0.0187	2,973,300	1.05	0.019635
6	Los Angeles	0.0602	9,571,800	1.068	0.0642936
7	San Diego	0.0746	11,861,400	1.044	0.0778824
8	Santa Ana	0.0876	13,928,400	1.032	0.0904032
9	Pasadena	0.1036	16,472,400	1.04	0.107744
10	Riverside	0.0843	13,403,700	1.059	0.0892737
11	Redding	0.0140	2,226,000	1.084	0.015176
12	Sacramento	0.1450	23,055,000	1.097	0.159065
13	Fresno	0.0596	9,476,400	1.078	0.0642488
14	Mojave	0.0240	3,816,000	1.021	0.024504
15	Palm Springs	0.0198	3,148,200	1.029	0.0203742
16	Truckee	0.0055	874,500	1.084	0.005962
Totals		1	159,000,000		1.0888556

Energy Use for Each Construction Assembly

The energy use for each construction assembly was calculated using the DOE-2.1E reference method. For each construction type, one or more sets of computer runs were made to establish the relationship between changes in U-factor and TDV energy. The runs include three points that represent high, medium and low U-factors that correspond to no insulation, some insulation (similar to that of the current Standard), and full insulation. The exact DOE-2 inputs can be found in Table 15 through Table 17 below. From these runs, a simple equation was developed to give TDV energy use per square foot of surface area.

TDV = C0 + C1 x U-factor

where:

C0: constant

C1: coefficient

U-factor: U-factor is the overall heat transfer coefficient for the assembly including both the inside and outside air film resistance taken from Joint Appendix IV.

The constants and coefficients, along with the R^2 for the coefficient can be found in Table 52 – TDV DOE-2 Coefficients of the Appendix. Separate coefficients are calculated for each construction assembly, occupancy type and climate zone. For each construction assembly, a case with no insulation, medium insulation close to the current standard, and high insulation is used in an hourly DOE-2 simulation to determine TDV energy consumption for each case, and a regression was performed on the results to determine the constant and coefficient for each climate zone and each occupancy type in TDV. After the constant and coefficient were determined, the U-factor was applied to the TDV equation above to determine TDV energy use for all assemblies.

Energy Model and Assumptions

DOE-2.1E version 119 developed by Lawrence Berkeley Laboratory was used to create a database of heating and cooling energy for a wide variety of inputs. For all cases, a simple five-zone model was used. The arrangement for thermal zoning was intentionally designed so that perimeter zones are connected only to the interior zone and not to other perimeter zones. This tends to isolate solar effects on the building. Windows are modeled only on each perimeter zone.

A set of coefficients is developed for each class of construction, climate zone and occupancy type. The following are important factors in the energy model:

- Geometry
    - A 5-zone model
    - Four exterior zones (100 ft X 15 ft) with windows on the long facades, no skylights
    - One interior zone (100 ft X 100 ft) without windows
    - Space height 13 ft
- Fenestration: The fenestration area is set to 30% of window to wall ratio (WWR) for daytime and 24-hour occupancy and 10% WWR for retail occupancy. The fenestration used is DOE-2 code 2204: double tint bronze with a U-factor of 0.48 and a SHGC of 0.49.

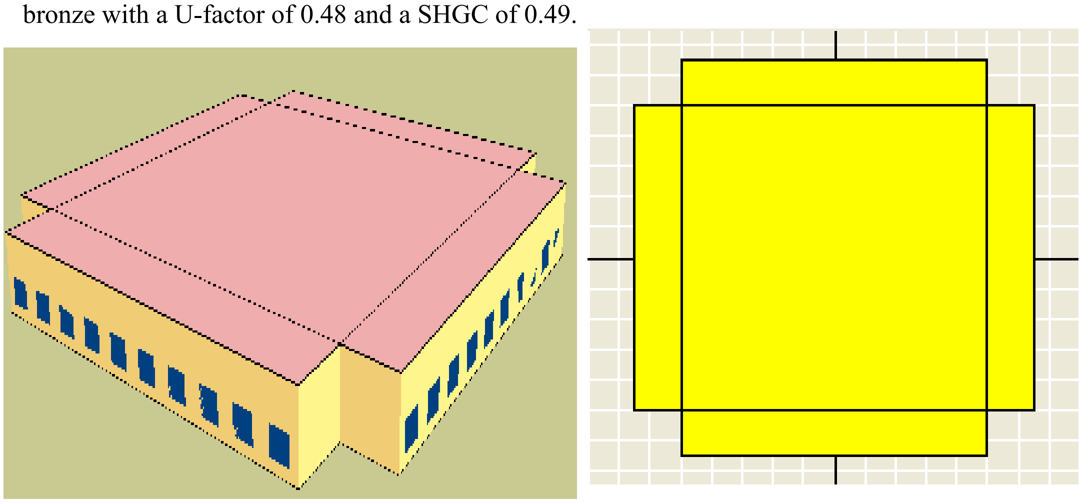

Figure 1 – Five-Zone DOE-2 Model

- Internal loads

Table 14 – Internal Loads

Internal Gain	Daytime	Retail	24-hour
Lighting Power Density	1.25	1.5	0.50
Equipment Power Density	0.75	0.94	0.50
Occupancy	29 persons / 1,000 ft^2	29 persons / 1,000 ft^2	5 persons / 1,000 ft^2

- HVAC systems
  - One packaged single zone (PSZ) system for each zone. No plenum.
  - Cooling EER 9.5, fan power at 0.35 W/cfm
  - Integrated air-side economizer
  - Outside air 15 cfm/person
  - Heating temperature is set to 70°F; cooling temperature is set to 73°F
  - Electricity is used cooling and gas is used for heating
- Operation schedules
  - Daytime only (typical for office buildings). Annual operating hours 4300
  - Retail (typical for retail stores). Annual operating hours 5475
  - 24-hour (typical high-rise residential). Annual operating hours 8760
- Envelope Construction Assemblies Modeled

Table 15 – Roof Construction Assemblies Modeled

Roof Class	ID	DOE-2 Construction Materials	U-factor (Btu/h-sf-°F)
Light	Low	(AR02, BP01, PW03, RWF49, GP01)	0.020
Light	Medium	(AR02, BP01, PW03, RWF19, GP01)	0.045
Light	High	(AR02, BP01, PW03, AL33, GP01)	0.285
Mass	Low	(RG01, BR01, CC14, IN47, GP01)	0.037
Mass	Medium	(RG01, BR01, CC14, IN74, GP01)	0.130
Mass	High	(RG01, BR01, CC14, AL33, GP01)	0.324
Attic	Low	Roof: (RG01, BR01, PW05) Ceiling: (GP02, RWF49)	0.019
Attic	Medium	Roof: (RG01, BR01, PW05) Ceiling: (GP02, RWF19)	0.043
Attic	High	Roof: (RG01, BR01, PW05) Ceiling: (GP02)	0.284

Table 16 – Wall Construction Assemblies Modeled

Wall Class	ID	DOE-2 Materials	U-factor (Btu/h-sf-°F)
Light	Low	(SC01, BP01, WWF30, GP01)	0.032
Light	Medium	(SC01, BP01, WWF11, GP01)	0.076
Light	High	(SC01, BP01, WMF00, GP01)	0.417
Mass7	Low	(SC01, CB49, IN36)	0.065
Mass7	Medium	(SC01, CB49, IN33)	0.143
Mass7	High	(SC01, CB29)	0.379
Mass15	Low	(SC01, CB32, IN36)	0.066
Mass15	Medium	(SC01, CB32, IN33)	0.147
Mass15	High	(CC05)	0.510

Table 17 – Floor Construction Assemblies Modeled

Floor Class	ID	DOE-2 Materials	U-factor (Btu/h-sf-°F)
Light	Low	(RWF49, PW04, CP01)	0.019
Light	Medium	(RWF19, PW04, CP01)	0.042
Light	High	(RWF00, PW04, CP01)	0.151
Mass	Low	(RWF49, CC14, CP01)	0.019
Mass	Medium	(RWF11, CC14, CP01)	0.063
Mass	High	(RWF00, CC14, CP01)	0.162

Life Cycle Cost Model

The CEC life-cycle cost method[5] was used. Measures are assumed to have a 30 year life and the TDV net present values for 30 years were used in this analysis.

This is summarized in the following equation:

LCC = Initial_Cost + PV_{TDV} x TDV

where:

LCC: life cycle cost in dollars

Initial_Cost: incremental cost of the construction assembly from the base case

PV_{TDV}: net present value of TDV nominal kBtu for 30-year nonresidential measures, $0.145972/kBtu in 2008 PV dollars

TDV: annual electricity and natural gas use for HVAC fan, cooling and heat per square foot of construction (wall, roof or floor) area, TDV kBtu..

The objective of this analysis is to select an insulation level that minimizes total life cycle costs. Figure 2 and Figure 3 illustrate how to select insulation levels for wood-framed walls in climate zones 3 and 12. As insulation levels are increased (U-factor decreases), the life-cycle costs decrease until a point of optimal insulation, and then start to increase again. As can be seen on the graph in Figure 2, the minimum life cycle cost point corresponds to a U-factor of 0.110 Btu/hr·ft^2·°F (frame wall with R-11 cavity insulation) and on the graph in Figure 3, the minimum life cycle cost point corresponds to a U-factor of 0.059 Btu/hr·ft^2·°F (frame wall with R-14 rigid insulation). At higher insulation levels the initial cost jumps disproportionately as compared to energy impacts because thicker studs are required. Maintenance costs are assumed to be constant across insulation levels.

The points represent all 104 different discrete insulation combinations for this particular construction assembly according to Joint Appendix IV. (For metal building walls, rigid insulation was excluded from the analysis, as this is not a common method of insulation for this particular construction type.) Table 18 and Table 19 show the top 10 insulation combinations that minimize life-cycle cost and represent the bottom of the J-curve. In some cases the construction assembly corresponding to the lowest total LCC in this analysis would result in a U-factor that is less stringent (higher) than the 2005 prescriptive requirement. This issue is addressed in Table 20 in the discussion of the results of the analysis.

[5] *Life Cycle Cost Methodology, 2008 California Building Energy Efficiency Standards*

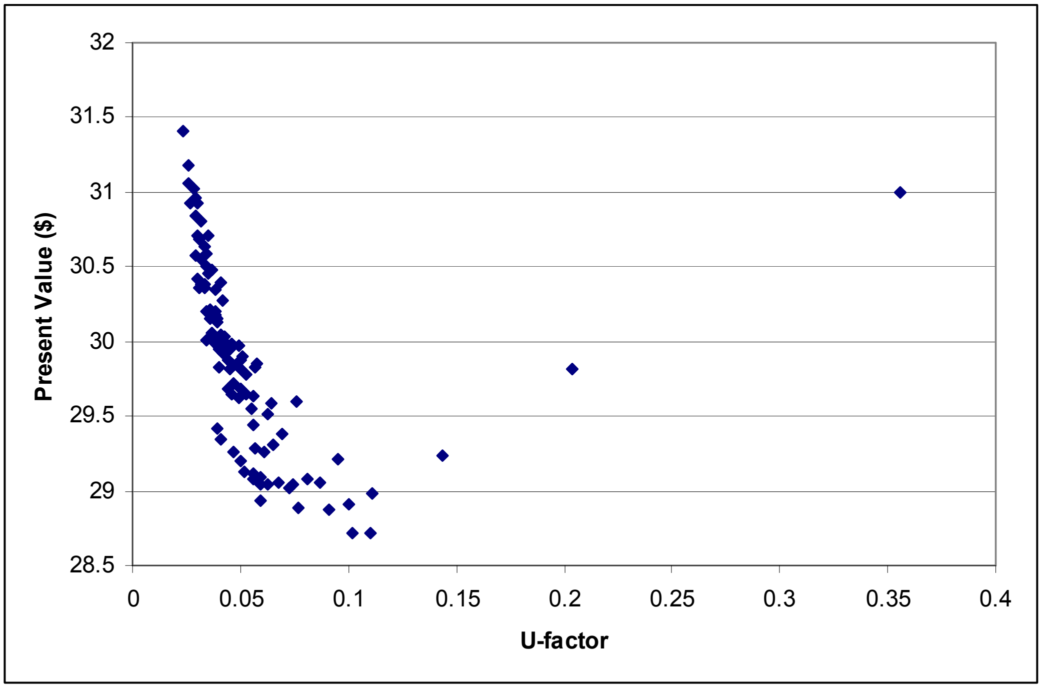

Figure 2 – Life-cycle Cost versus U-factor Curve of Wood-framed Walls in CZ 3

Table 18 – Life-cycle Cost for Daytime Wood-framed Walls CZ 3

Cavity R	Sheathing R	U-factor	Incremental Cost	TDV Total	TDV cost	LCC	Rank
R-11	None	0.11	0.622825403	192.4521584	28.09263	28.71545	1
R-13	None	0.102	0.721911263	191.8038807	27.998	28.71991	2
None	R-8	0.091	1.005013719	190.912499	27.86788	28.87289	3
None	R-10	0.077	1.189030315	189.7780132	27.70228	28.89131	4
None	R-7	0.1	0.934238105	191.6418113	27.97434	28.90858	5
None	R-14	0.059	1.443822526	188.3193886	27.48936	28.93318	6
None	R-6	0.111	0.877617614	192.5331931	28.10446	28.98207	7
R-11	R-4	0.073	1.358891789	189.4538744	27.65496	29.01385	8
R-11	R-6	0.063	1.500443017	188.6435274	27.53667	29.03712	9
R-19	None	0.074	1.371631399	189.5349091	27.66679	29.03842	10

Notice that for wood-framed walls in climate zone 3, the constructions for R-11 (U=0.110) and R-13 (U=0.102) have a nearly identical total life-cycle cost. In this particular case, the second lowest life-cycle cost choice (R-13) can be selected to match the 2005 Title 24 prescriptive requirement. The difference in total life-cycle cost between the first two assemblies is likely within the margin of error for the analysis.

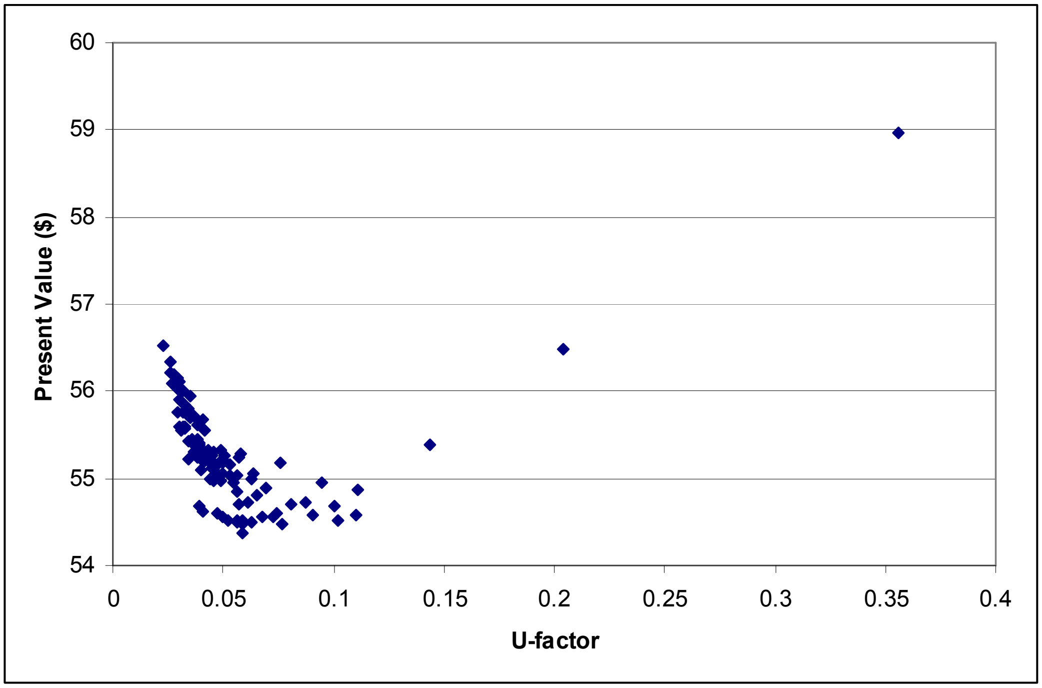

Figure 3 – Life-cycle Cost versus U-factor Curve of Wood-framed Walls in CZ 12

Table 19 – Life-cycle Cost for Daytime Wood-framed Walls CZ 12

Cavity R	Sheathing R	U-factor	Incremental Cost	TDV Total	TDV cost	LCC	Rank
None	R-14	0.059	1.443822526	362.5624047	52.92396	54.36778	1
None	R-10	0.077	1.189030315	365.0726246	53.29038	54.47941	2
R-11	R-7	0.059	1.557063508	362.5624047	52.92396	54.48102	3
R-11	R-8	0.056	1.627839122	362.1440347	52.86289	54.49073	4
R-11	R-6	0.063	1.500443017	363.1202313	53.00539	54.50583	5
R-13	R-8	0.052	1.726924982	361.586208	52.78146	54.50839	6
R-13	R-7	0.056	1.656149368	362.1440347	52.86289	54.51904	7
R-13	None	0.102	0.721911263	368.5590411	53.7993	54.52121	8
R-13	R-6	0.059	1.599528876	362.5624047	52.92396	54.52349	9
R-11	R-10	0.05	1.811855718	361.3072947	52.74075	54.5526	10

Results

2005 versus 2008 Insulation Level Comparisons

The figures below provide a comparison between the current standard and the proposed standard for all sixteen climate zones. For both roofs and walls, the proposed standard is usually more stringent than the current standard. This may be due to the Commission's policy to use a longer building life expectancy of 30-years for envelope measures, a change in the cost of natural gas and electricity TDV energy, and a change in insulation price since 1992, the latest update to the envelope criteria.

The figure title also includes statewide energy impacts for the proposed standard for a particular construction assembly. The statewide energy impacts are on an annual per square foot basis and represent a general estimation of savings weighted by climate zone new construction data and occupancy type. A more detailed breakdown can be found in the Appendices under Energy Impacts.

Comparison of 2008 to 2005 Recommendations

The primary goal of the LCC analysis is to minimize total life-cycle cost, which includes both the first cost of the construction and life-cycle energy costs, in TDV terms. In most cases, the construction corresponding to the lowest total LCC has a more stringent (lower) U-factor than the 2005 Title 24 prescriptive requirements. However, in some cases, this approach would result in a recommended U-factor that is less stringent than the 2005 Title 24 Standard. However, there is not a requirement to use the U-factor corresponding to the lowest life-cycle cost. By state law, measures must result in a life-cycle cost that is equal to or lower costs associated with current requirements. Each of these cases was examined, and some alternate selections were made to keep the 2008 recommendation at or lower than 2005. The recommendations and the rationale behind the recommendations are listed in Table 20. For retail occupancy constructions, there was no basis for comparison with 2005, but the recommendations are similar to daytime occupancy values. In some cases where two constructions had nearly the same total LCC, a judgment was made to use the more stringent U-factor.

Table 20 – Stringency Comparison between T24-2005 and 2008 LCC Analysis and Recommendations

Occupancy	Construction Class/Type	Climate Zone(s)	T24-2005	2008 lowest LCC U-factor	Recommendation	Justification
Daytime	Metal building roofs	1,3,4,5	0.051	0.063	0.063	No specific class for M.B. for 2005; 0.063 already stringent
Daytime	Metal building roofs	6	0.076	0.078	0.078	See reason above
Daytime	Wood Framed roofs	1,3,5	0.051	0.067	0.049	Stay with 2005, R-19, with 24" o.c., small LCC increment (<$0.10/ft2)
Daytime	Wood Framed wall	1	0.102	0.110	0.102	Stay with 2005; very small LCC increment ($0.014/ft2)
Daytime	Light mass wall	5-9	0.430	0.910	0.50	Use 8" LW CMU, assembly JA IV.12-B8
Daytime	Heavy mass wall	2-5,10	0.650	0.690	0.650	Stay with 2005, uninsulated but with diff assembly assumption (JA IV.12-A9/10)
Daytime	Mass Floors	3-10	0.139	0.315	0.315	Adding insulation to mass floors increases energy cost in temperate climates
Daytime	Mass Floors	12,13	0.090	0.109	0.090	0.090 is 2nd lowest LCC choice with an incremental cost less than $0.02/ft2
Daytime	Wood Floors/other	1	0.048	0.071	0.048	Small incremental cost to go to 0.048
Daytime	Wood Floors/other	6,7	0.071	0.238	0.071	Stay with 2005 level to include insulation
24 Hour	Metal building roofs	1	0.036	0.048	0.039	0.039 is 2nd lowest LCC choice with an incremental LCC less than $0.01/ft2
24 Hour	Metal building roofs	2,10-13,15	0.036	0.039	0.039	No specific class for M.B. roofs for 2005
24 Hour	Wood framed roofs	1	0.036	0.039	0.034	0.034 is 2nd lowest LCC with an incremental LCC less than $0.01/ft2

Coefficient Graphs

The coefficient graphs display the results of the regression analysis for each assembly by climate zone and occupancy. Each column (daytime, retail and 24-hour) represents the corresponding coefficient for that assembly determined by the regression analysis. For example, in Figure 12*,* the daytime coefficient for climate zone 1 is the same as the coefficient determined for light weight roofs for climate zone 1 (which can be found in Appendices) as opposed to attic roofs or mass roofs. The Y-axis represents the coefficient threshold for each insulation level. If the coefficient falls within a certain threshold, the corresponding U-Value and R-Value found on the right hand side was determined to have the lowest life cycle cost. For example, in Figure *4*, if the coefficient were 100 for a particular assembly then a U-Value of 0.067 with R-13 insulation would be the most cost effective.

The coefficient used in these graphs is the threshold at which the lowest LCC changes from one construction (A) to a more stringent construction (B). On the graphs this threshold is represented as a horizontal line. The coefficients for any two assemblies follow the simple mathematical derivation below:

LCC_A = Initial Cost of A + Energy Cost A = $IC_A + (C0 + C1 \times U_A)$

LCC_B = Initial Cost of B + Energy Cost B = $IC_B + (C0 + C1 \times U_B)$

$\Delta LCC = LCC_A - LCC_B = (IC_A - IC_B) + C1\ (U_A - U_B)$

At the threshold, the life-cycle costs of the two assemblies A and B are equal:

$IC_A - IC_B = C1 \times (U_A - U_B)$

$$C1 = \frac{IC_B - IC_A}{U_A - U_B}$$

The coefficients represent the change in TDV energy per change in U-factor (TDV/ft^2). Therefore, the higher the coefficient, the more incremental energy savings will be achieved from increasing insulation levels. A negative coefficient represents an increase in energy consumption from increased insulation. Negative coefficients occurred for some floor constructions in temperate climates; the added floor insulation limits nighttime cooling when the space is unoccupied.

Only a small subset of the assemblies is represented on the coefficient graphs. For any given U-factor, there will be one assembly with the lowest cost. The graphs are a good way to visually see how close an assembly is to being the lowest LCC. Where the coefficient for a particular climate zone and construction type is close to one of the horizontal lines on the graph, the life cycle costs between competing assemblies are close to equal.

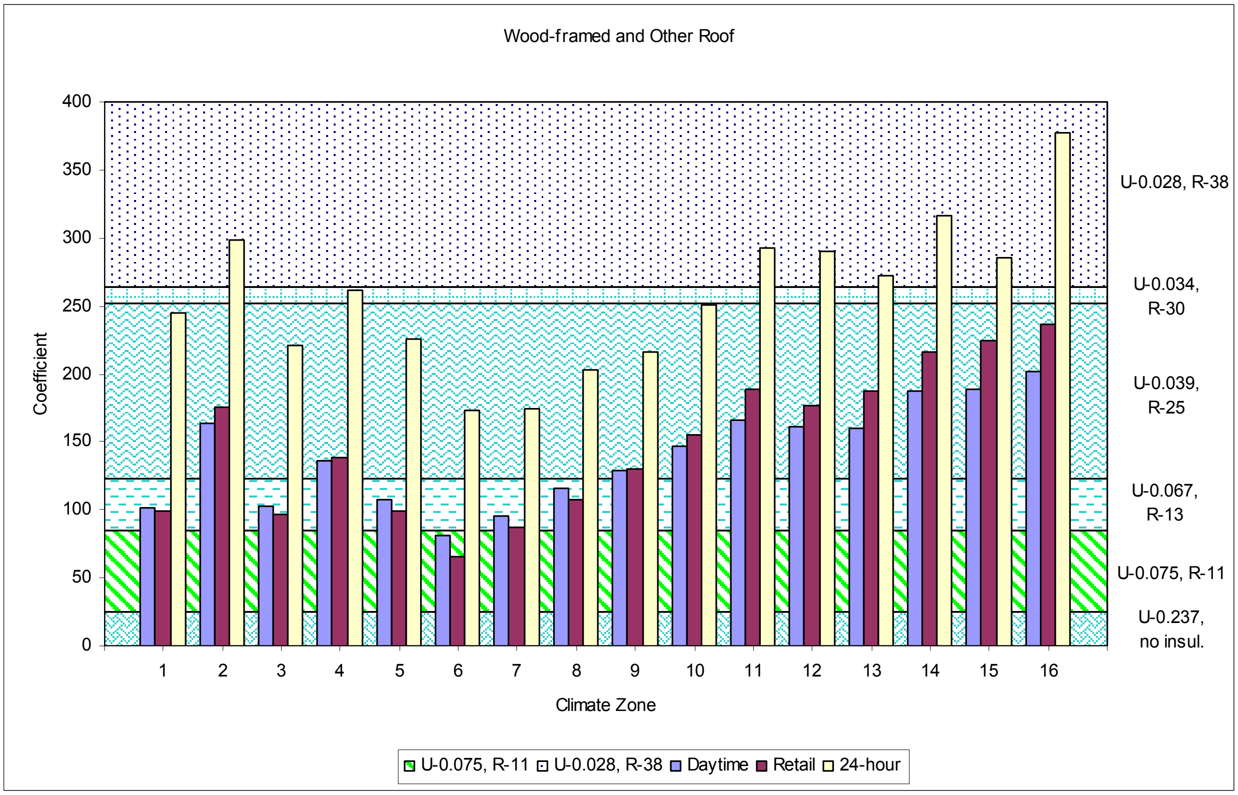

Figure 4 –Coefficient Graph for Wood-Framed Roof (daytime occupancy)

Wood-framed and Other Roof, if the coefficient were 100 for a particular assembly then a U-Value of 0.067 with R-13 insulation would be the most cost effective. The coefficients represent the change in TDV energy per change in U-factor (TDV/ft^2). Therefore, the higher the coefficient, the more energy savings from insulation will be. A negative coefficient represents an increase in energy consumption from increased insulation.

Cool Roofs

A sensitivity analysis was performed for cool roofs in all sixteen climate zones. The sensitivity analysis determined the optimal insulation levels without a cool roof using the model described above. One caveat to the sensitivity analysis is that a previous version of the 2008 TDV curves, dated January 5, 2006, was used. The older curves should have minimal impact on the outcome. Other than the cool roofs and economizers sensitivity analyses performed in this report, all other results are using the most updated 2008 TDV curves, dated April 18, 2006.

Optimal insulation levels for high-rise residential buildings (24-hour occupancies) assume no cool roofs. Optimal insulation levels for low-rise nonresidential buildings and retail occupancies, in most climates, assume that the building has a cool roof, since cool roofs are a prescriptive requirement in the 2005 Standards. An updated cost study of cool roof incremental costs has shown that cool roofs may not be cost effective for low-sloped non-residential buildings in climate zones 1, 3, 5 and 16. The current recommendation is to remove the prescriptive requirement for cool roofs for those climate zones. Buildings using a cool roof may still obtain credit for cool roofs using either the overall envelope tradeoff or performance compliance methods. Therefore, the recommended U-factors for climate zones 1,3,5 and 16 for daytime occupancies assume no cool roof.

The effect of the removal of prescriptive cool roof requirements is to increase required insulation levels for metal building roofs for climate zone 5 and for wood framed roofs for climate zone 3. Other assemblies were not affected by the removal of the cool roof requirement.

Economizers

A sensitivity analysis was performed for economizers in climate zones 3, 6, and 12. The sensitivity analysis determined the optimal insulation level for all envelope assemblies without an economizer using the model described above. The optimal insulation levels remain consistent when no economizers are modeled except floors. One caveat to the sensitivity analysis is that a previous version of the 2008 TDV curves, dated January 5, 2006, was used. The older curves should have minimal impact on the outcome. A second caveat is the mass walls used in the sensitivity analysis were taken from as the default constructions from the ACM Manual and differ by climate zone. For the 2008 Proposed Standard, we selected one default mass wall construction type for $7 \leq HC < 15$ mass wall (8" normal weight CMU wall with solid grout, U-Factor 0.69) and one default mass wall construction type for $15 \leq HC$ mass wall (4" solid concrete wall, U-Factor 0.91).

The "(no) cool roof" figures show the current roof insulation standards as well as the proposed standards with and without a cool roof for roofs only. The "economizer sensitivity" figures show the optimal U-factors for climate zones 3, 6, and 12 when no economizer is modeled.

Metal Building Roof

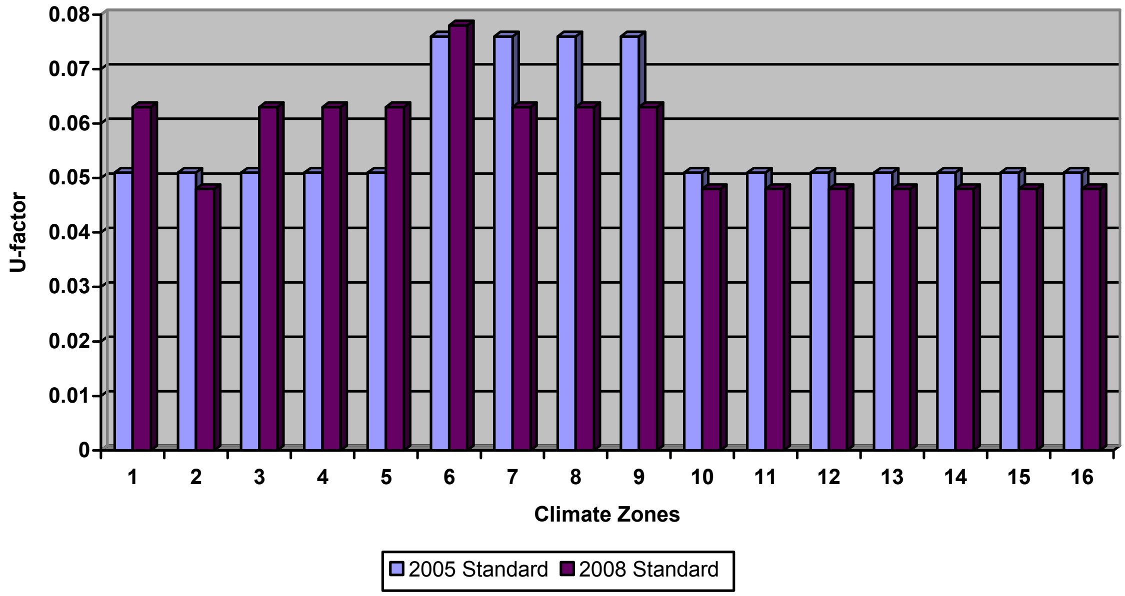

Figure 5 –Metal Building Roof (Daytime)
Statewide Energy Impacts (ft^2-yr): TDV=0.232, kWh=0.010, therm=0.0001

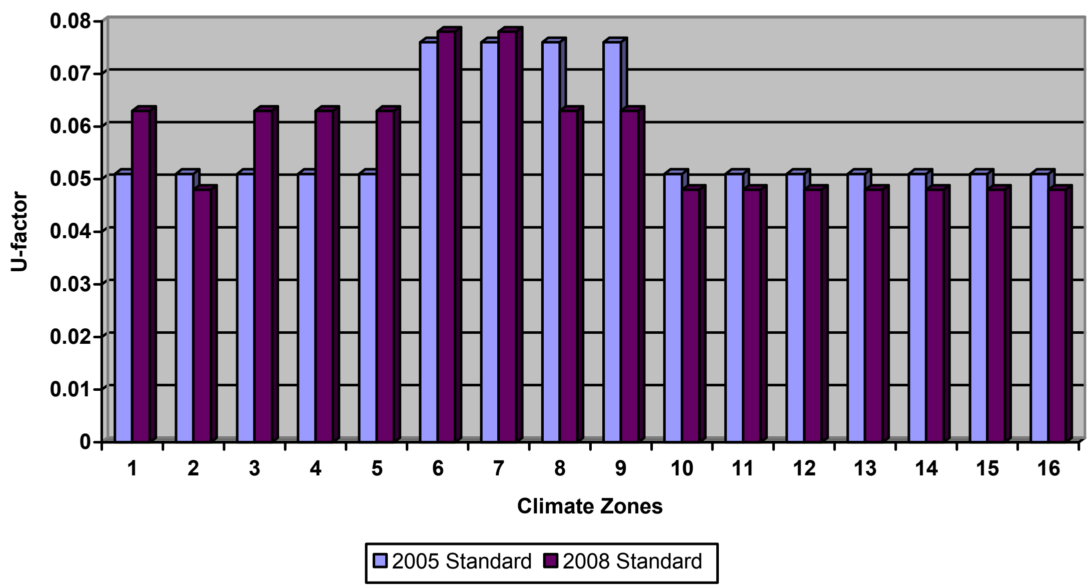

Figure 6 –Metal Building Roof (Retail)
Statewide Energy Impacts (ft2-yr): TDV=0.317, kWh=0.0154, therm=0.0004

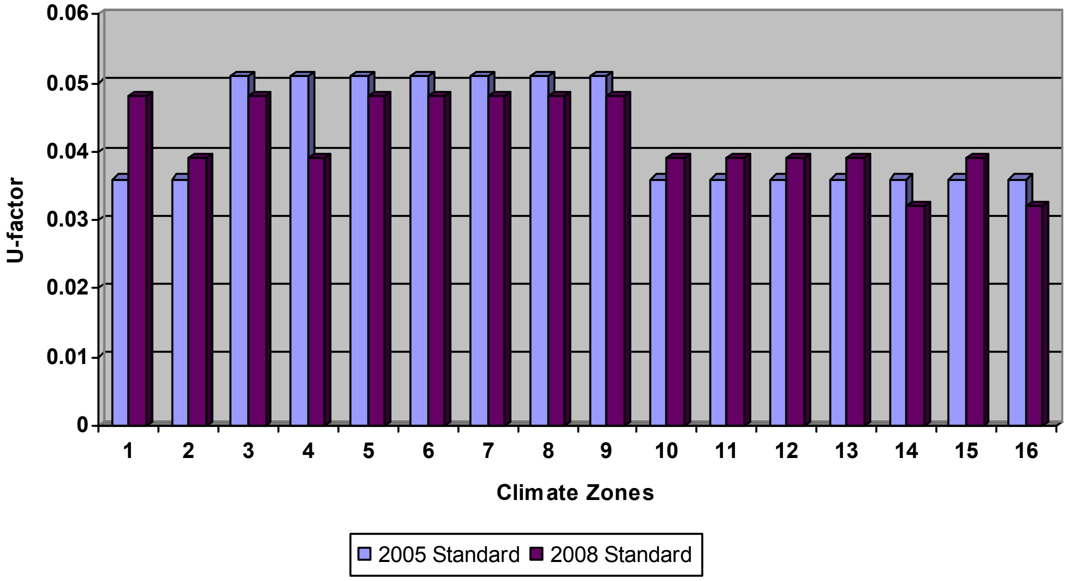

Figure 7 – Metal Building Roof (24-hour)
Statewide Energy Impacts (ft^2-yr): TDV=1.358, kWh=0.0392, therm=0.0058

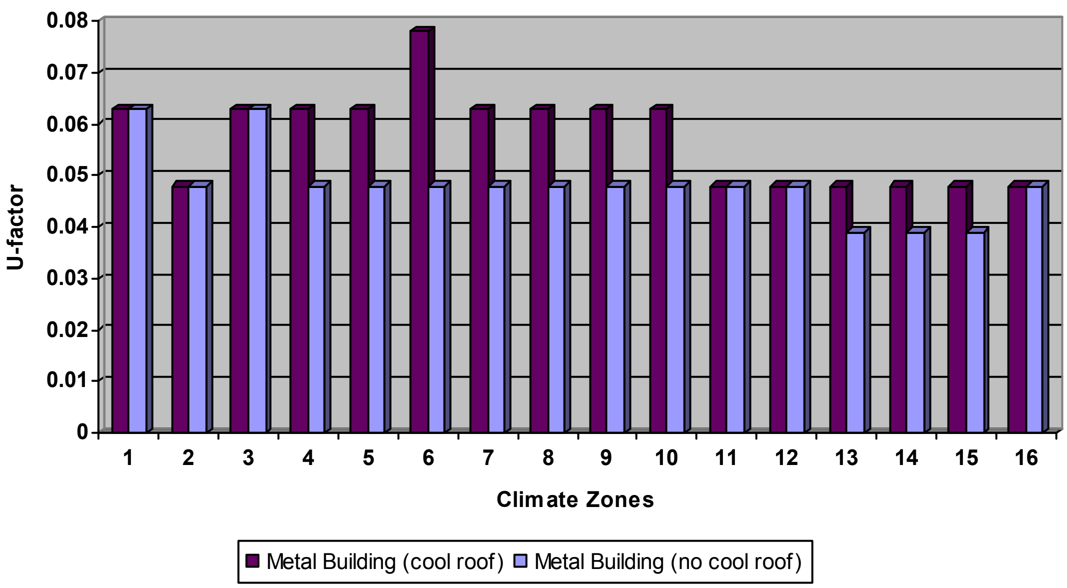

Figure 8 – Daytime Roof Insulation Cool Roof Sensitivity Analysis for Metal Buildings

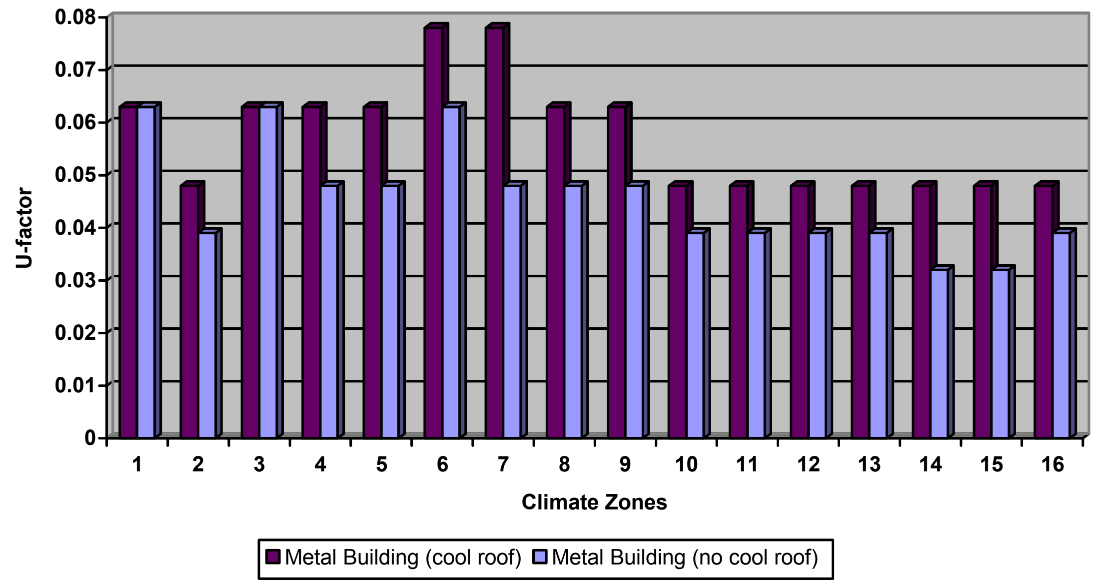

Figure 9 – Retail Roof Insulation Cool Roof Sensitivity Analysis for Metal Buildings

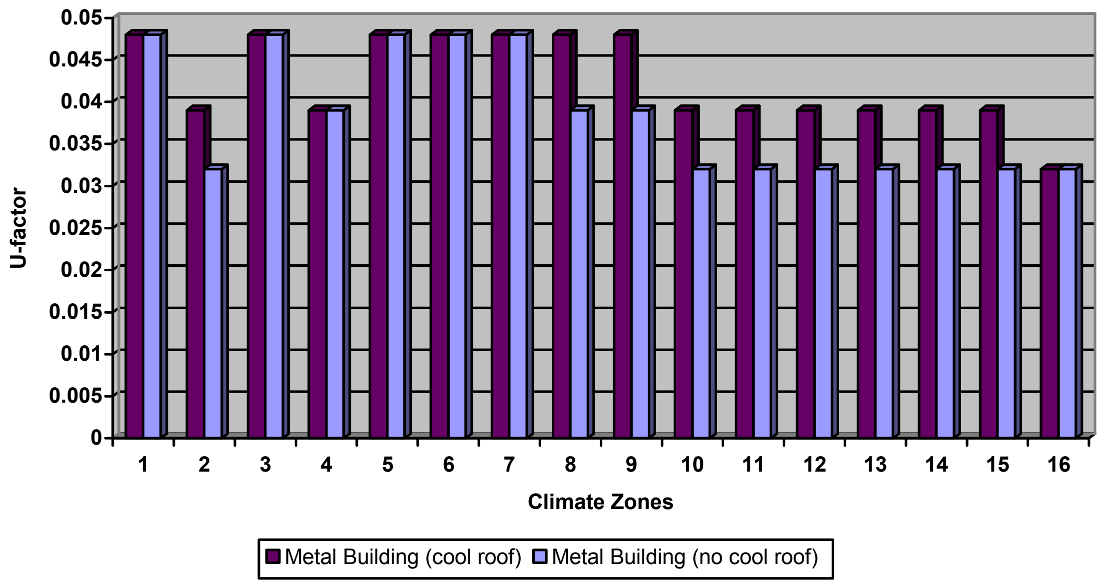

Figure 10 – 24-hour Roof Insulation Cool Roof Sensitivity Analysis for Metal Buildings

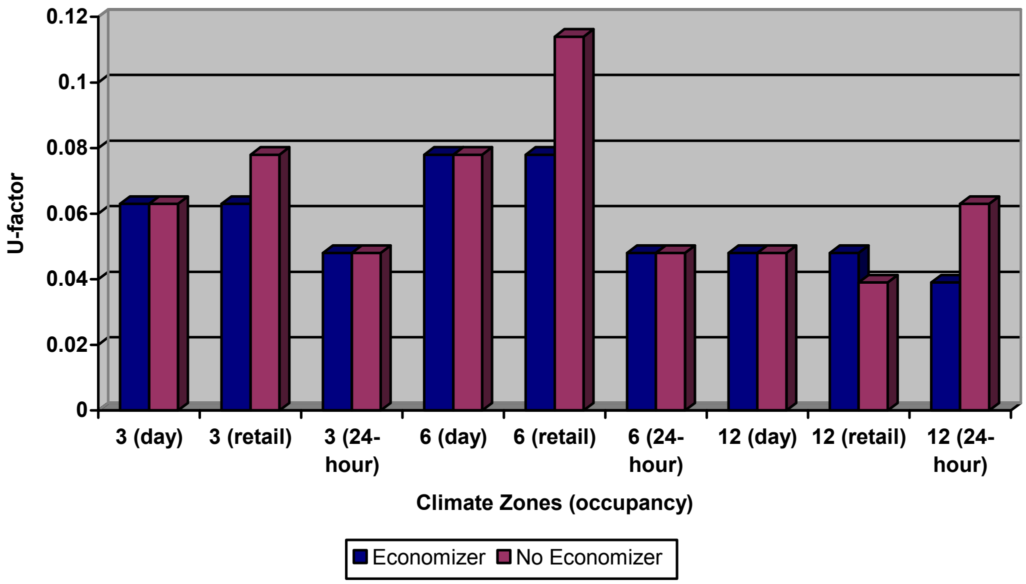

Figure 11 – Economizer Insulation Sensitivity Analysis for Metal Building Roof

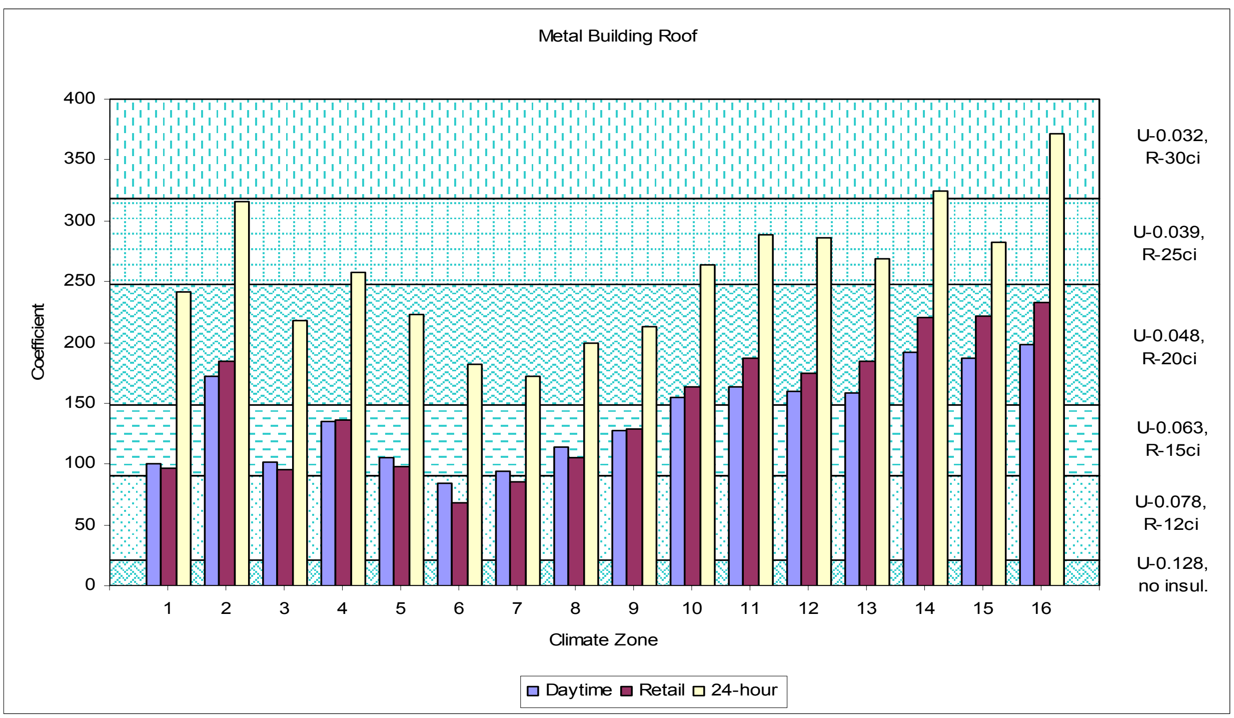

Figure 12 – Metal Building Roof Coefficients (cool roofs)

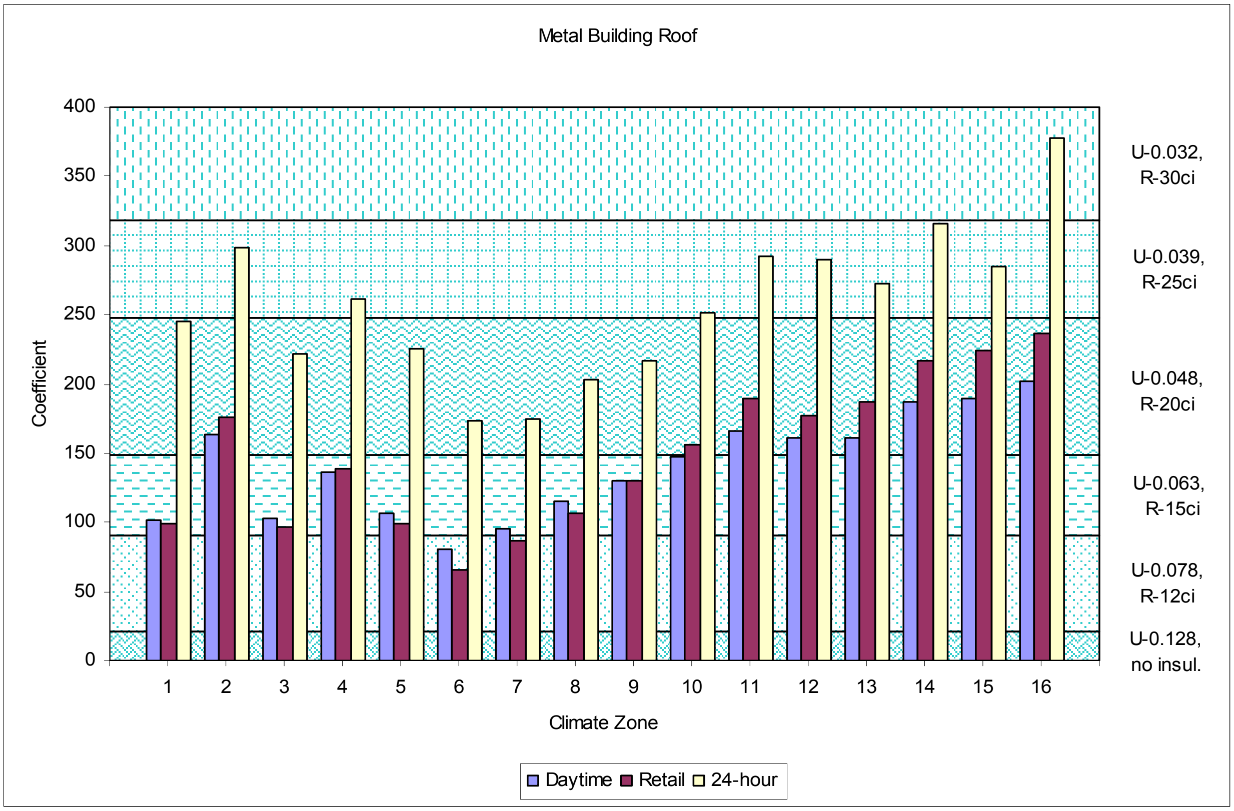

Figure 13 – Metal Building Roof Coefficients (no cool roof)

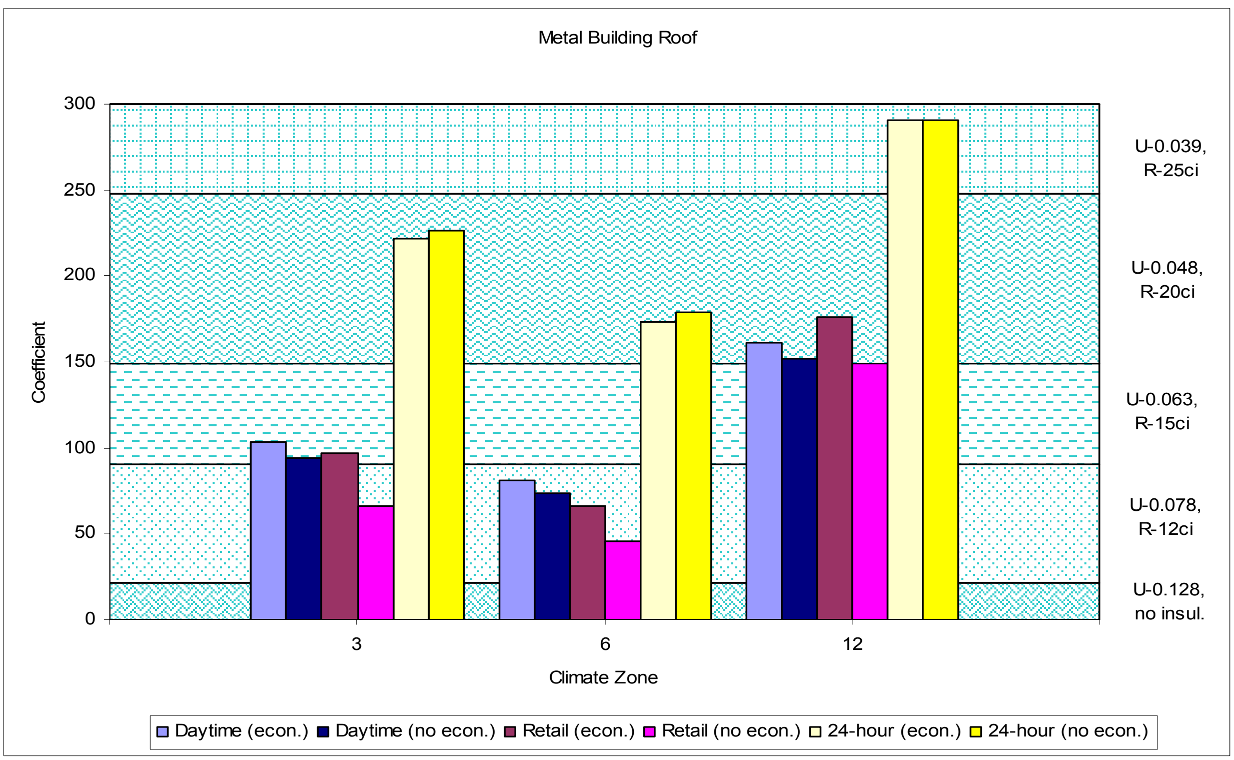

Figure 14 – Metal Building Roof Coefficients (economizer sensitivity)

Wood-framed and Other Roof

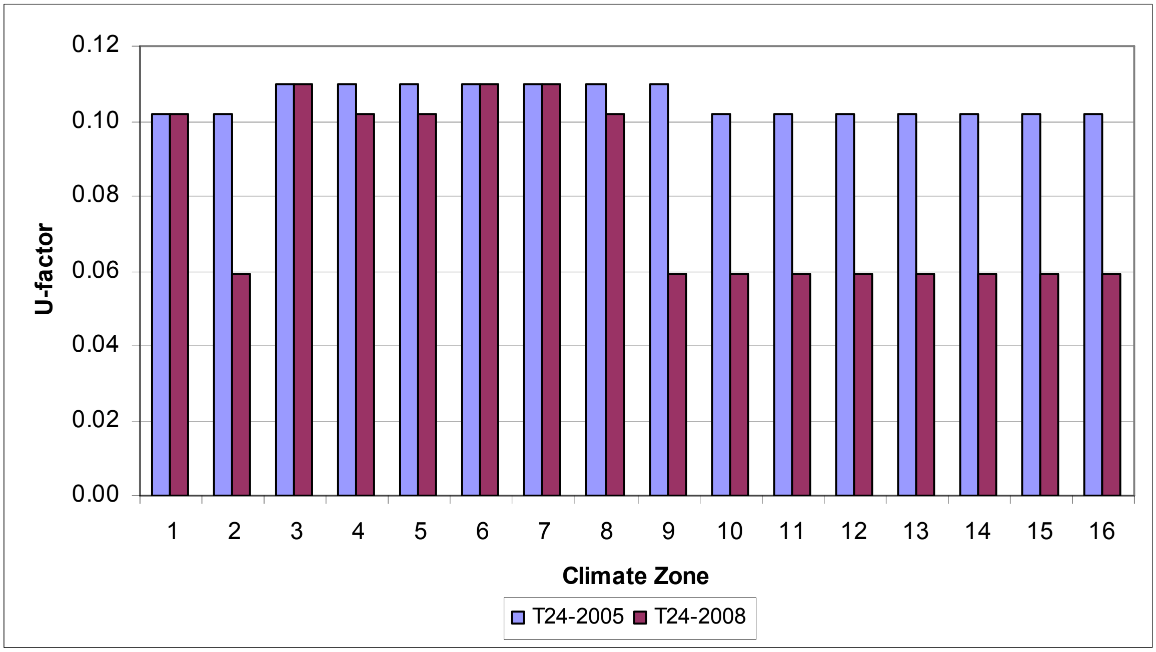

Figure 15 – Wood-framed and Other Roof (Daytime)
Statewide Energy Impacts (ft^2-yr): TDV=0.8376, kWh=0.0273, therm=0.0023

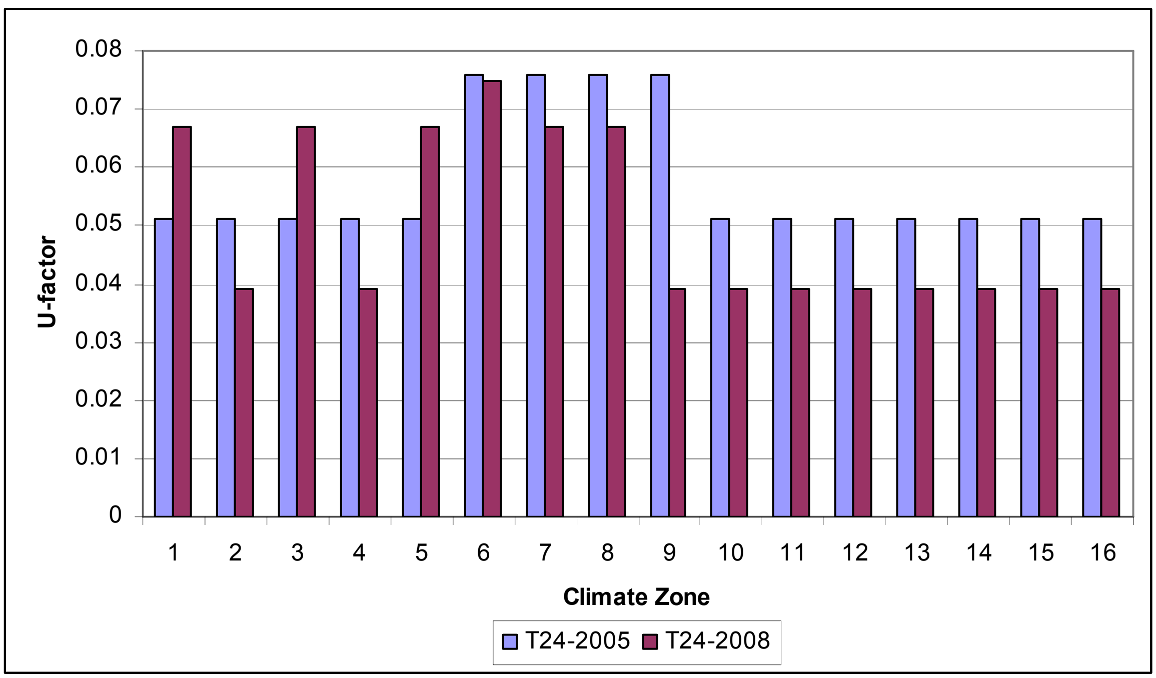

Figure 16 – Wood-framed and Other Roof (Retail)
Statewide Energy Impacts (ft^2-yr): TDV=1.780, kWh=0.0667, therm=0.0054

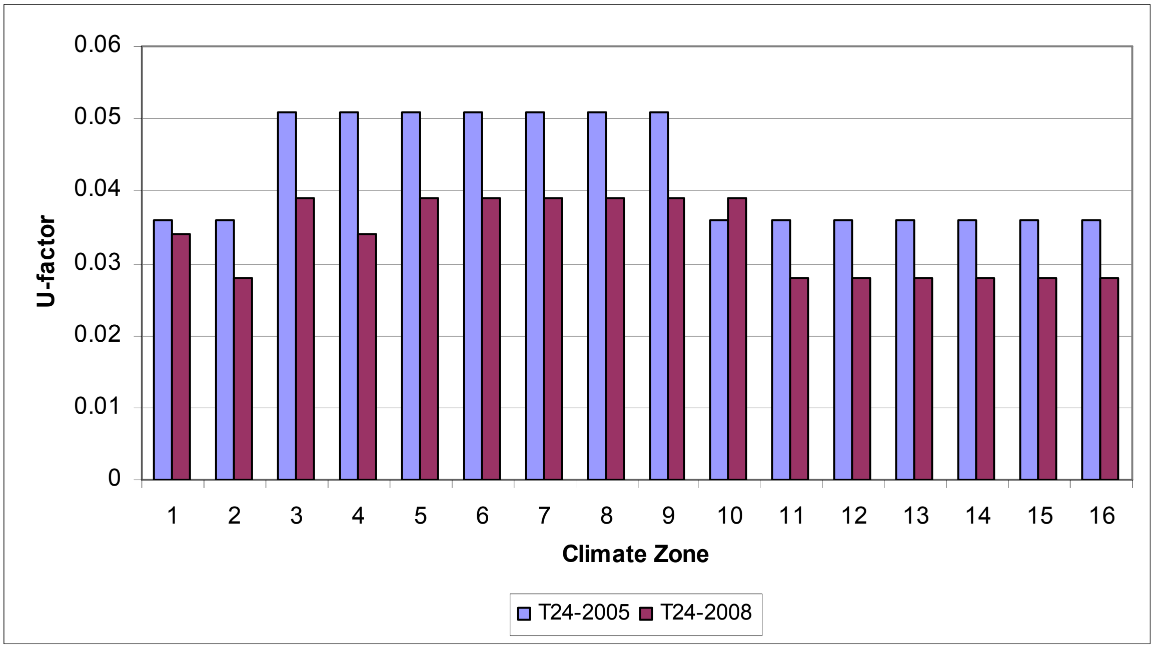

Figure 17 – Wood-framed and Other Roof (24-hour)
Statewide Energy Impacts (ft^2-yr): TDV=2.965, kWh=0.0843, therm=0.013

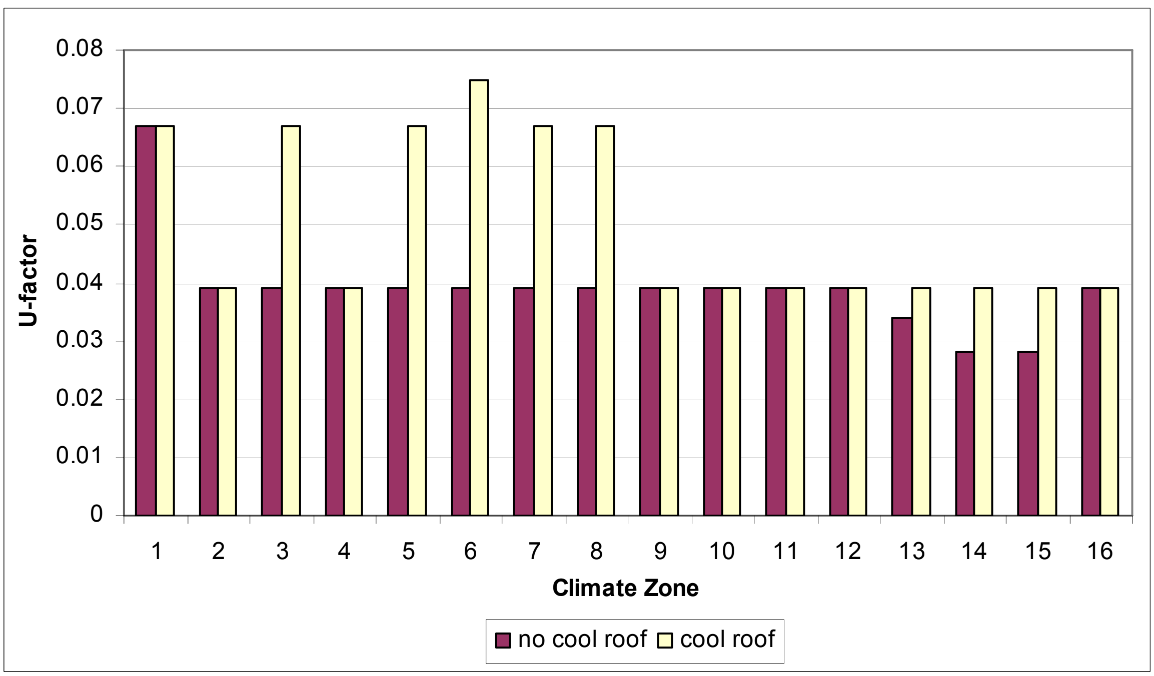

Figure 18 – Daytime Roof Insulation Cool Roof Sensitivity Analysis for Wood-framed and Other

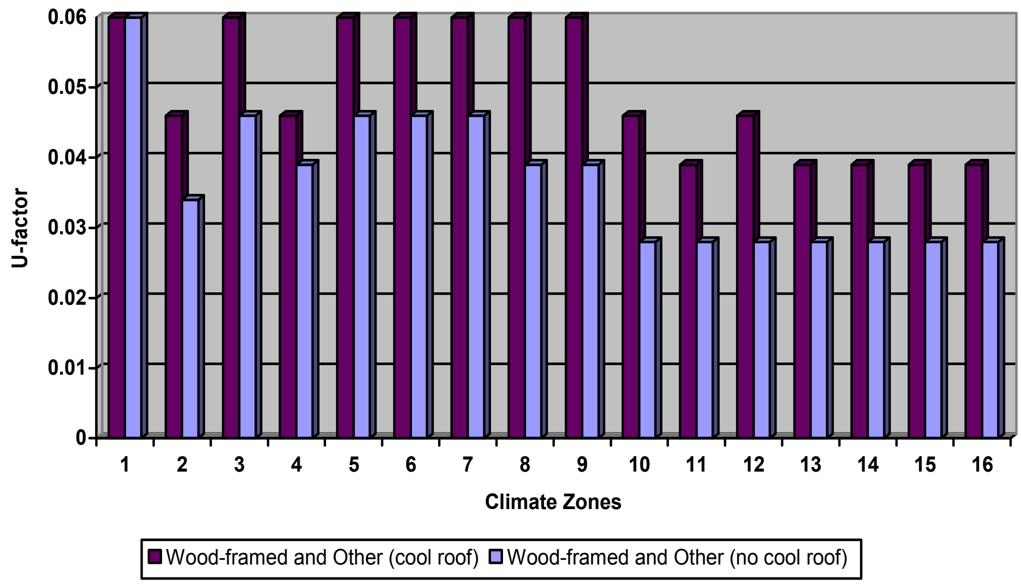

Figure 19 – Retail Roof Insulation Cool Roof Sensitivity Analysis for Wood-framed and Other

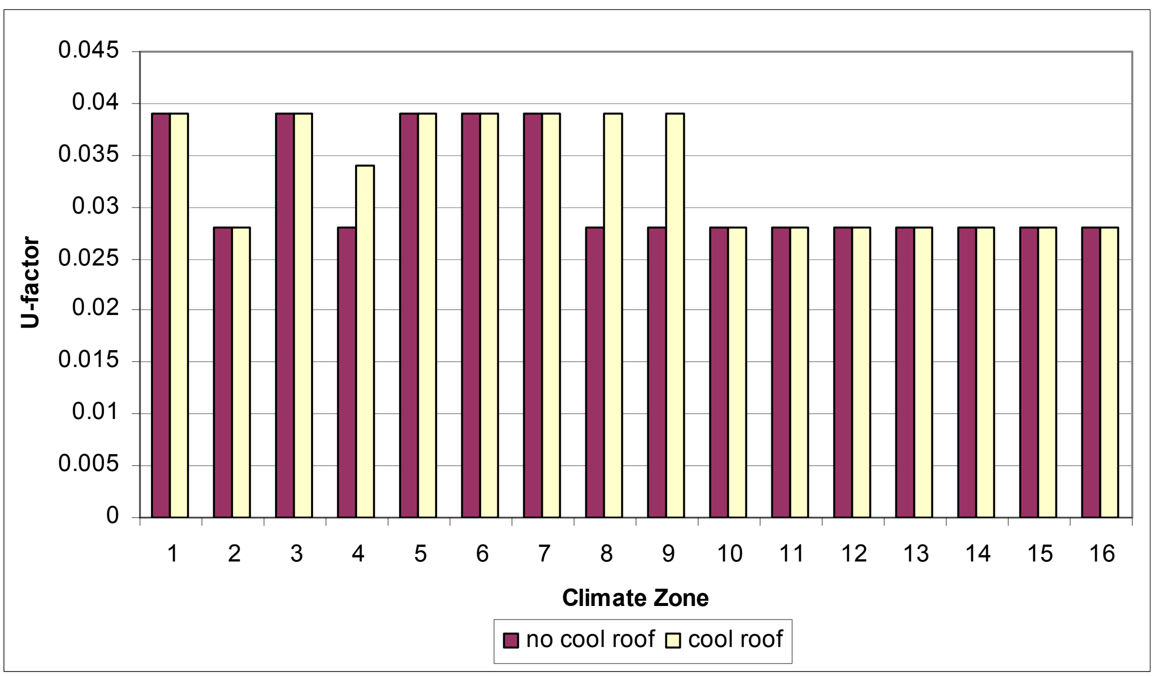

Figure 20 – 24-hour Roof Insulation Cool Roof Sensitivity Analysis for Wood-framed and Other

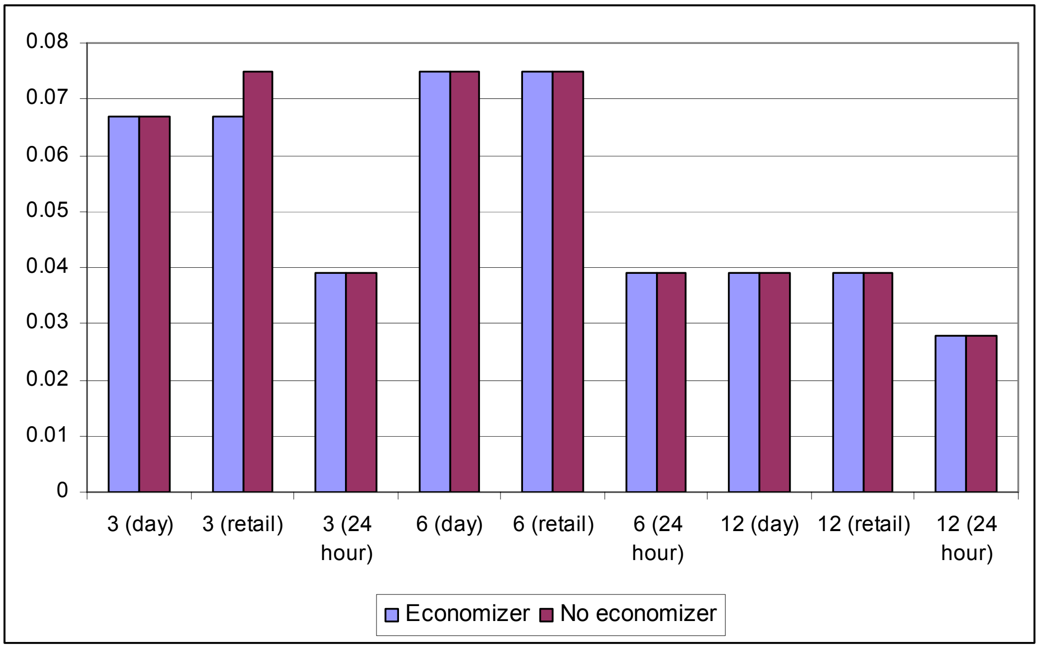

Figure 21 – Economizer Insulation Sensitivity Analysis for Wood-framed and Other Roof

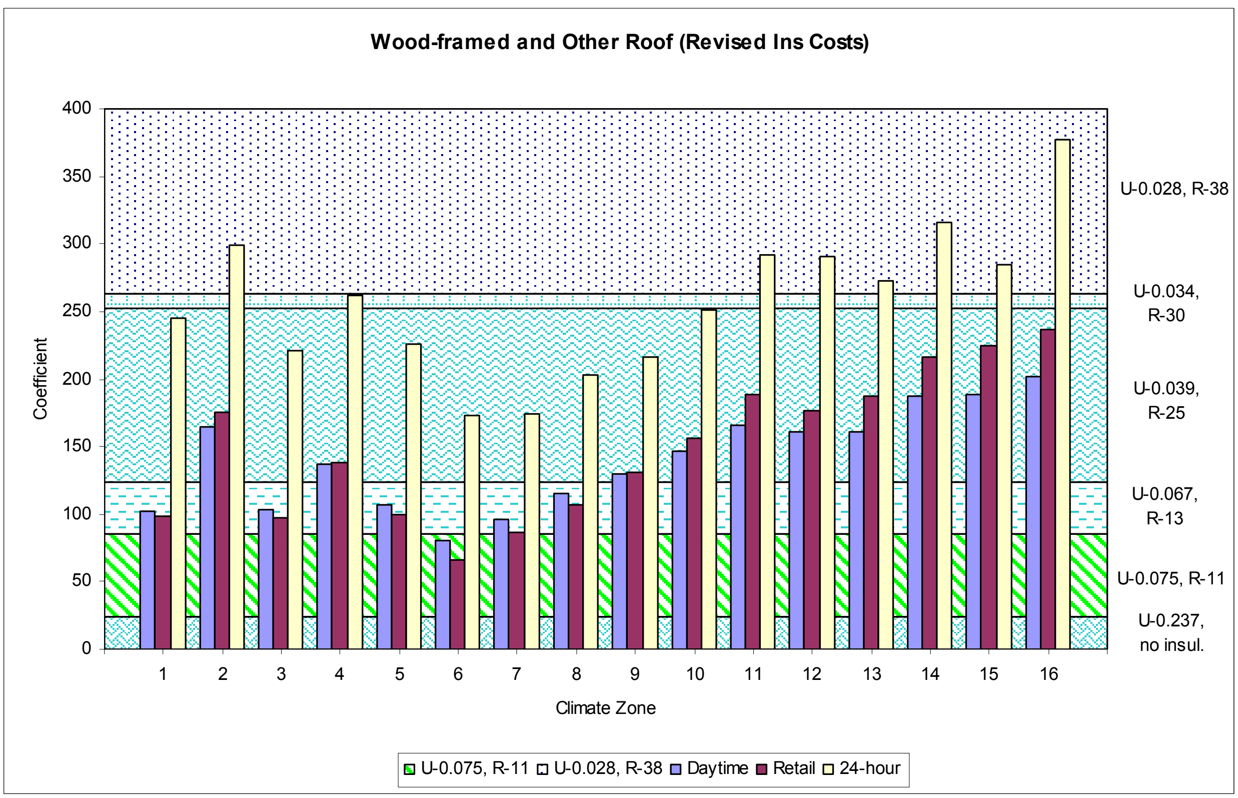

Figure 22 – Wood-framed and Other Roof Coefficients

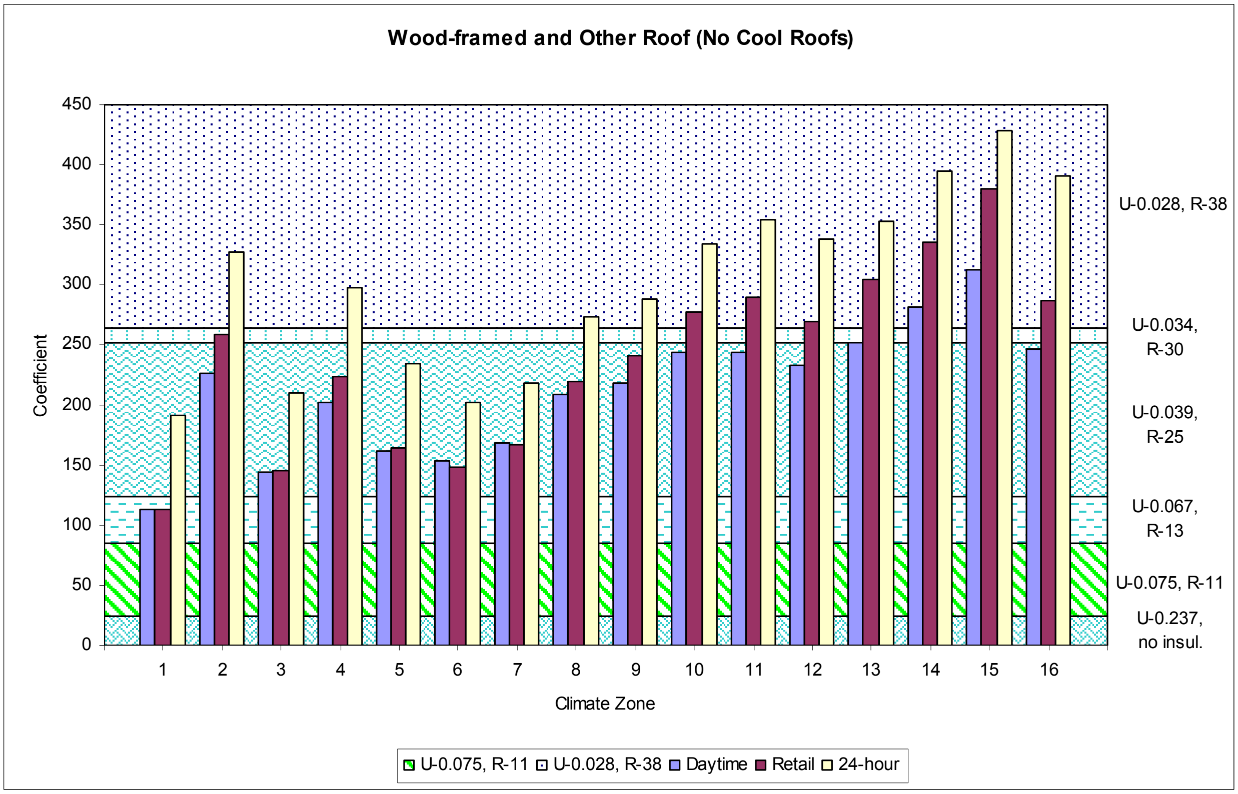

Figure 23 – Wood-framed and Other Roof Coefficients (no cool roof)

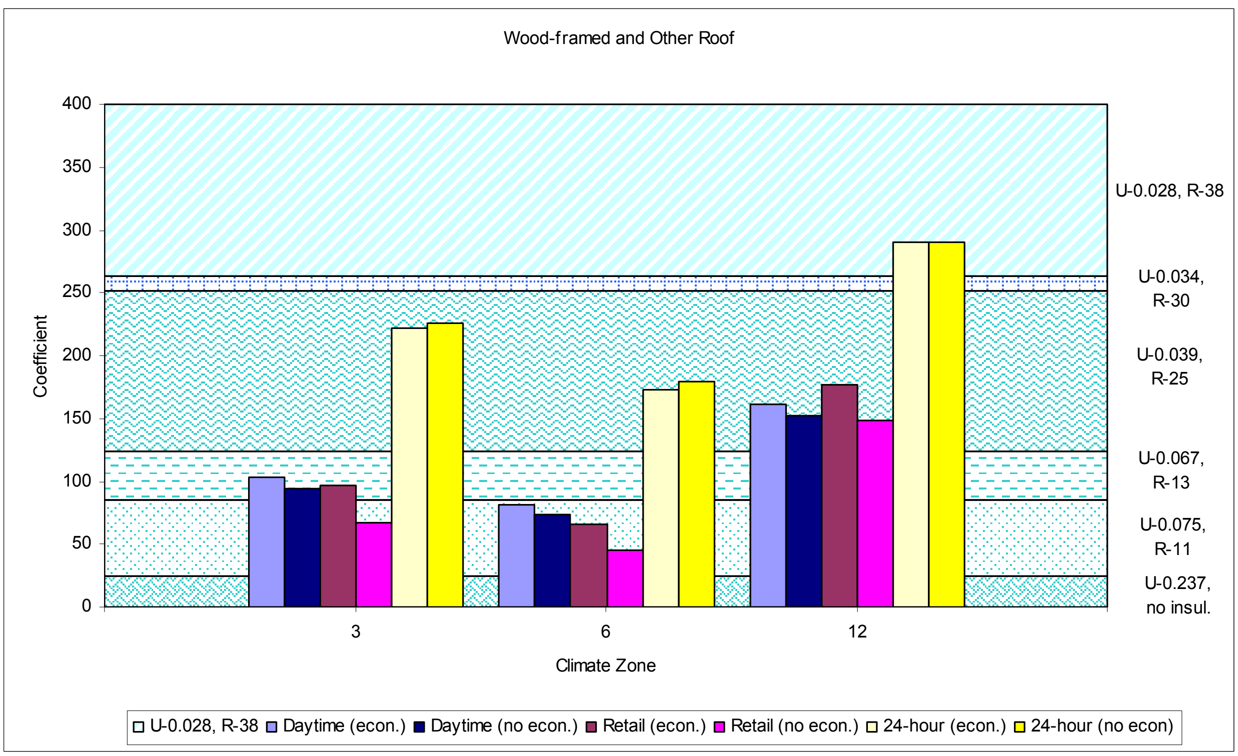

Figure 24 – Wood-framed and Other Roof Coefficients (economizer sensitivity)

Metal Building Wall

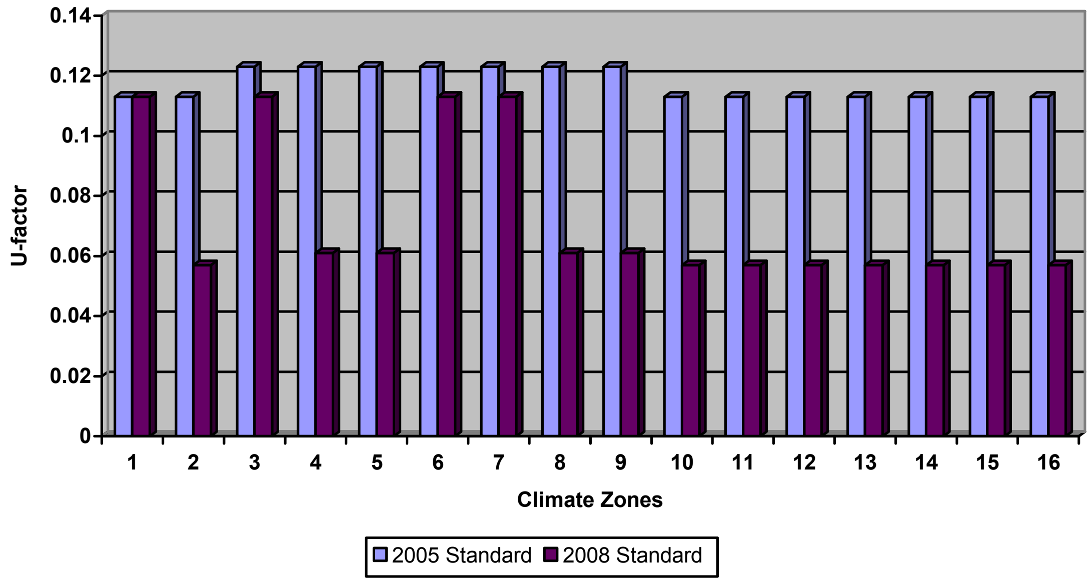

Figure 25 – Metal Building Wall (Daytime)
Statewide Energy Impacts (ft^2-yr): TDV=5.336, kWh=0.252, therm=0.0123

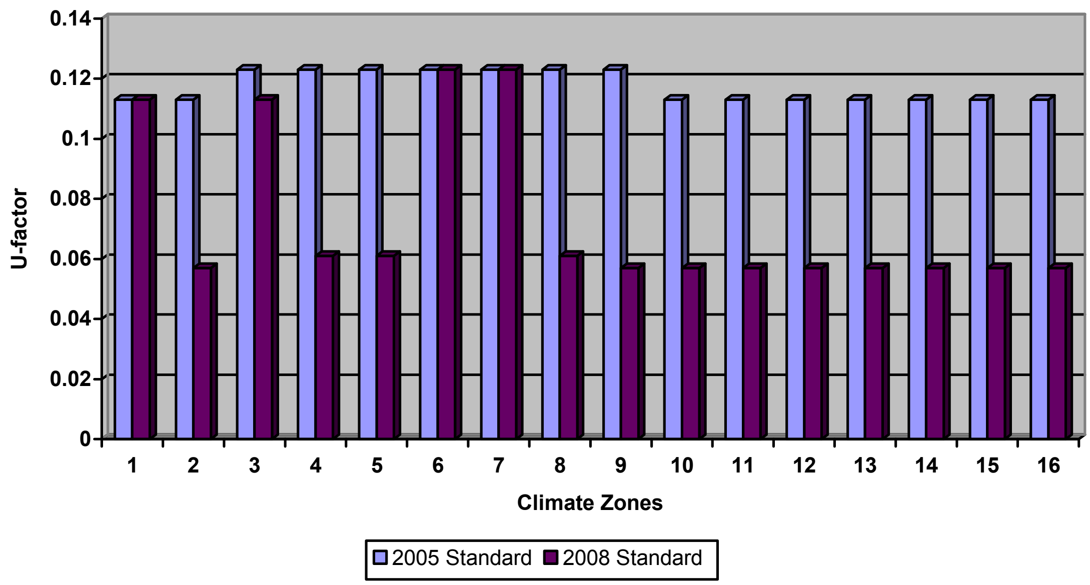

Figure 26 – Metal Building Wall (Retail)
Statewide Energy Impacts (ft^2-yr): TDV=5.923, kWh=0.323, therm=0.0123

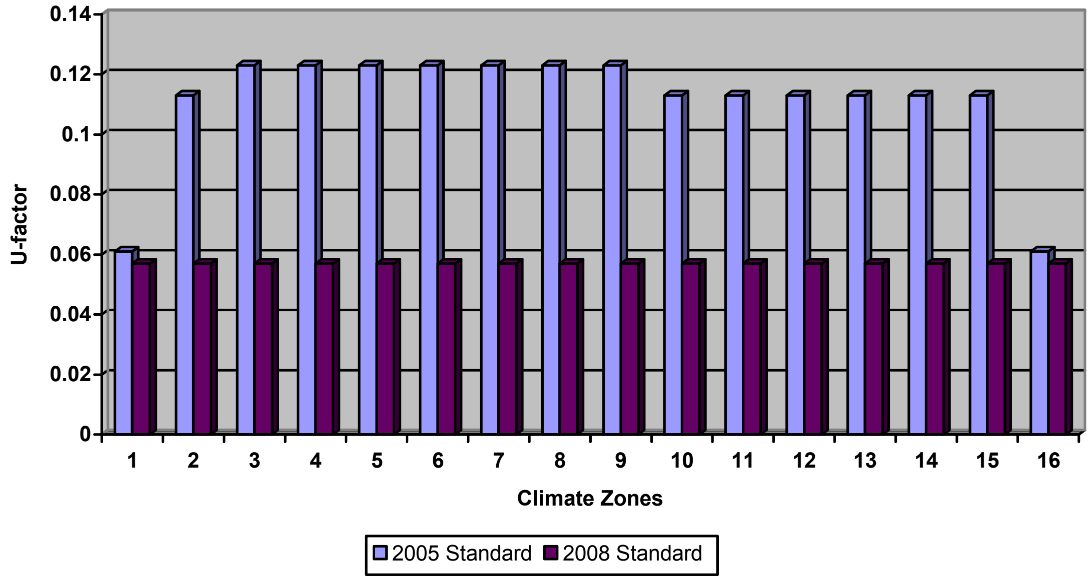

Figure 27 – Metal Building Wall (24-hour)
Statewide Energy Impacts (ft^2-yr): TDV=10.642, kWh=0.561, therm=0.038

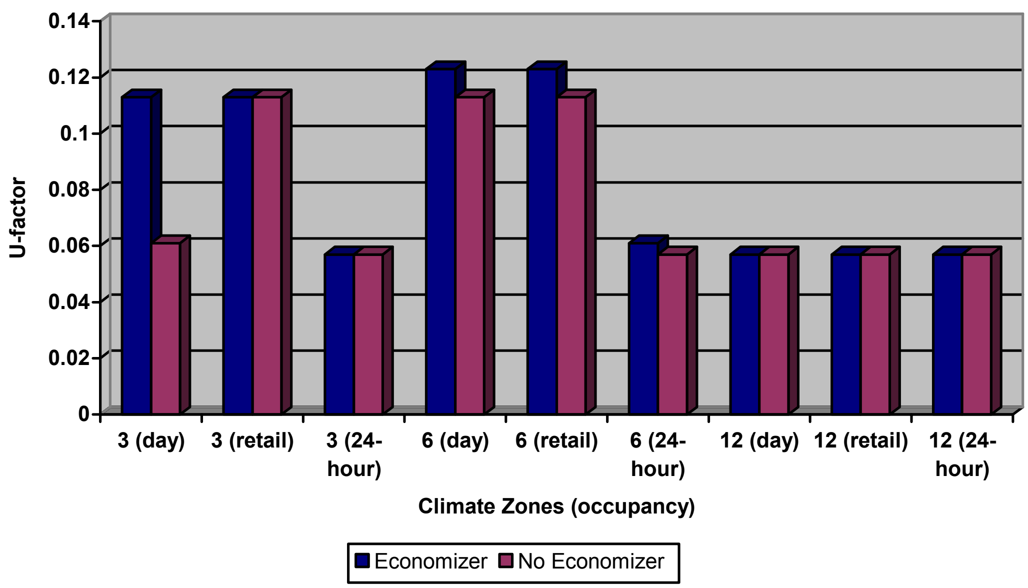

Figure 28 – Economizer Insulation Sensitivity Analysis for Metal Building Wall

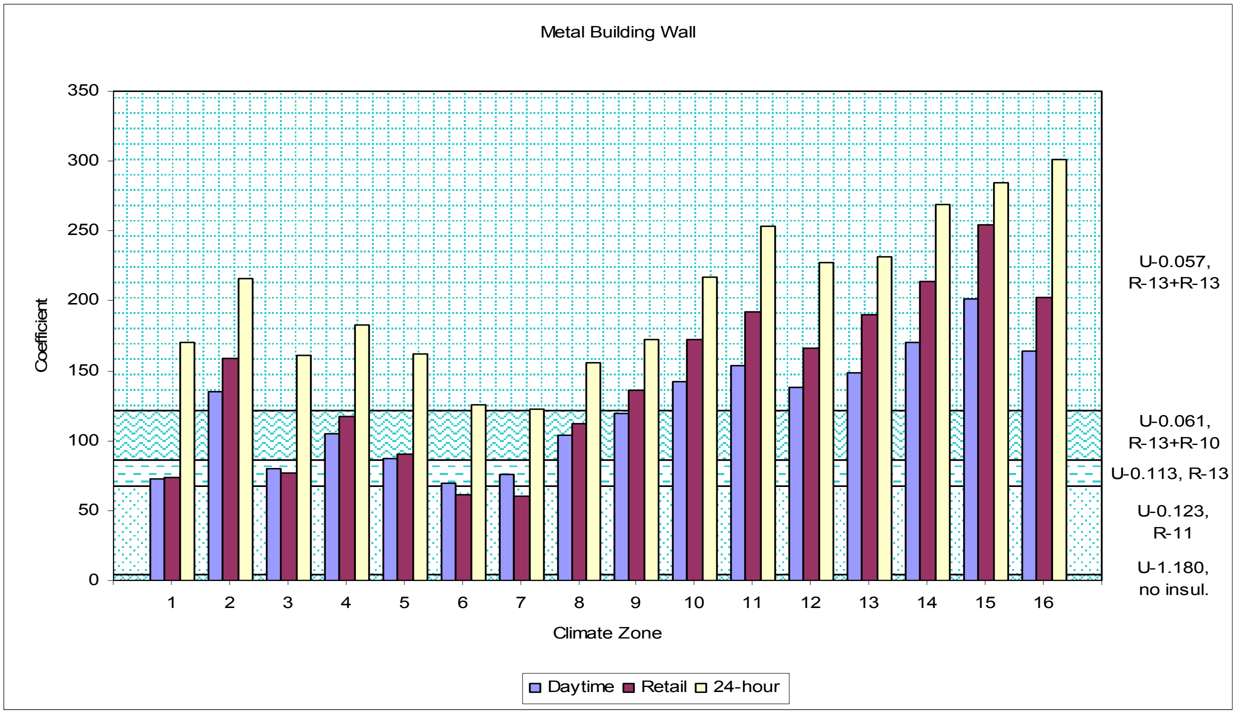

Figure 29 – Metal Building Wall Coefficients

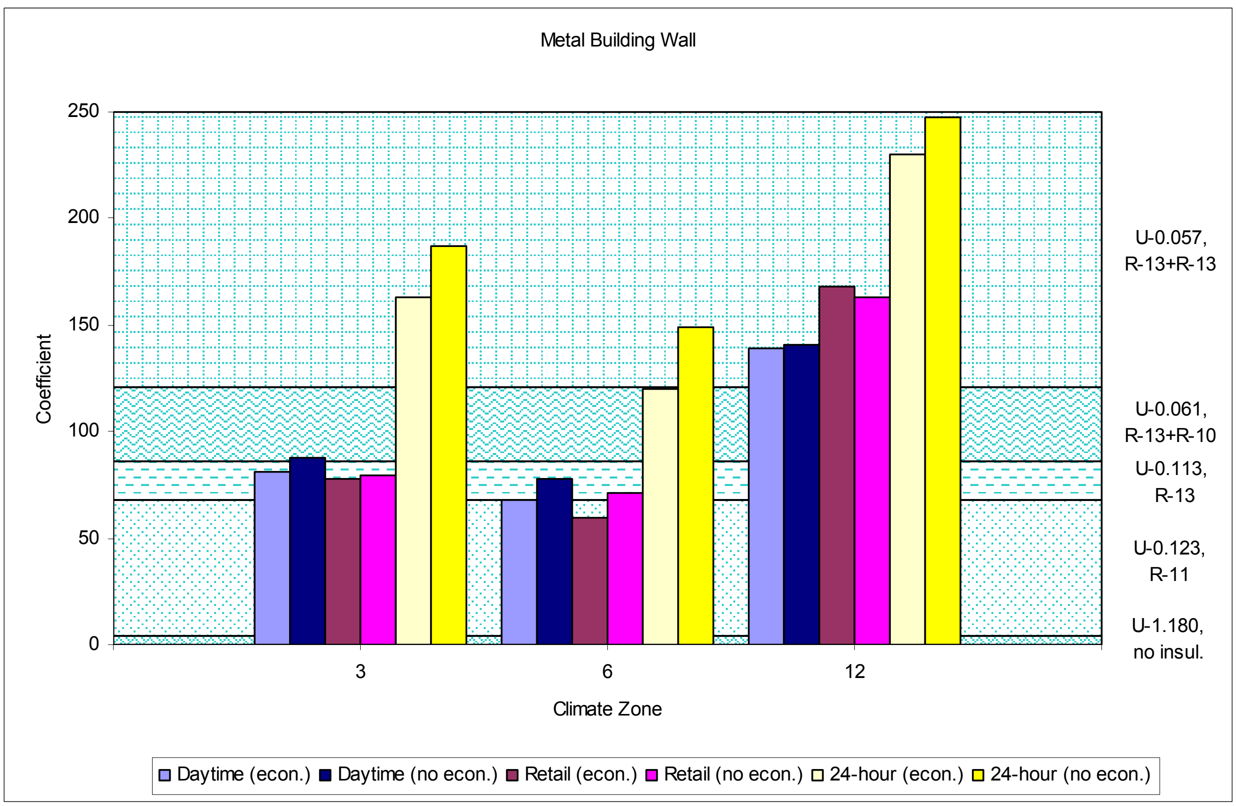

Figure 30 – Metal Building Wall Coefficients (economizer sensitivity)

Metal-framed Wall

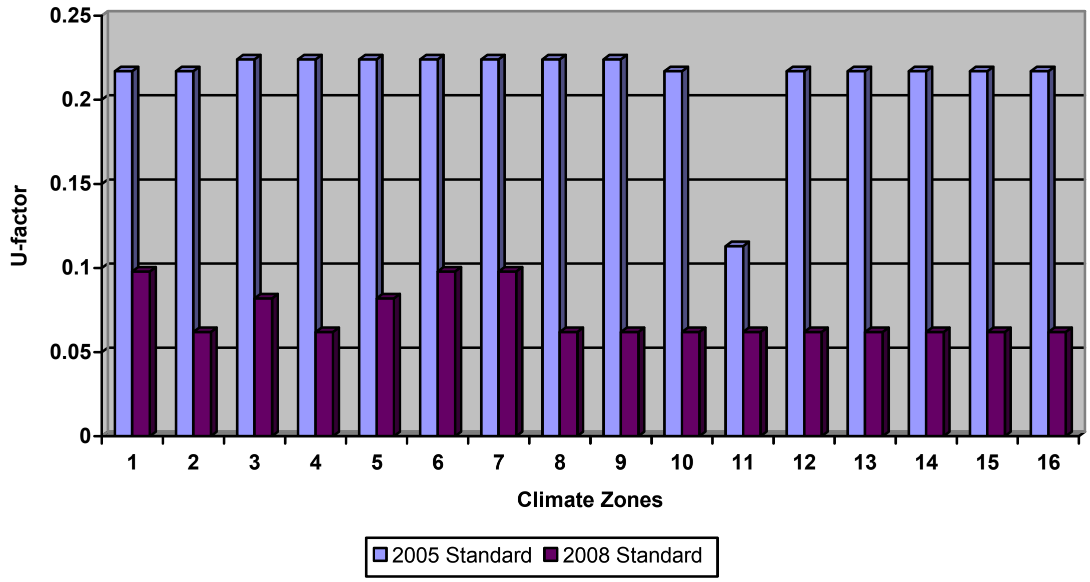

Figure 31 – Metal-framed Wall (Daytime)
Statewide Energy Impacts (ft^2-yr): TDV=17.505, kWh=0.821, therm=0.044

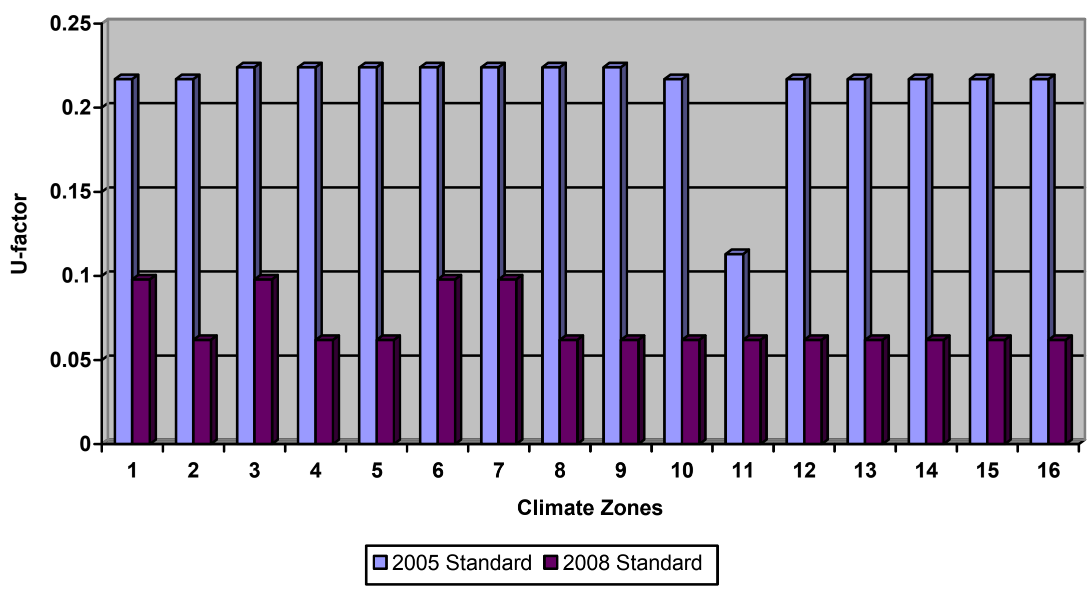

Figure 32 – Metal-framed Wall (Retail)
Statewide Energy Impacts (ft^2-yr): TDV=20.382, kWh=1.138, therm=0.045

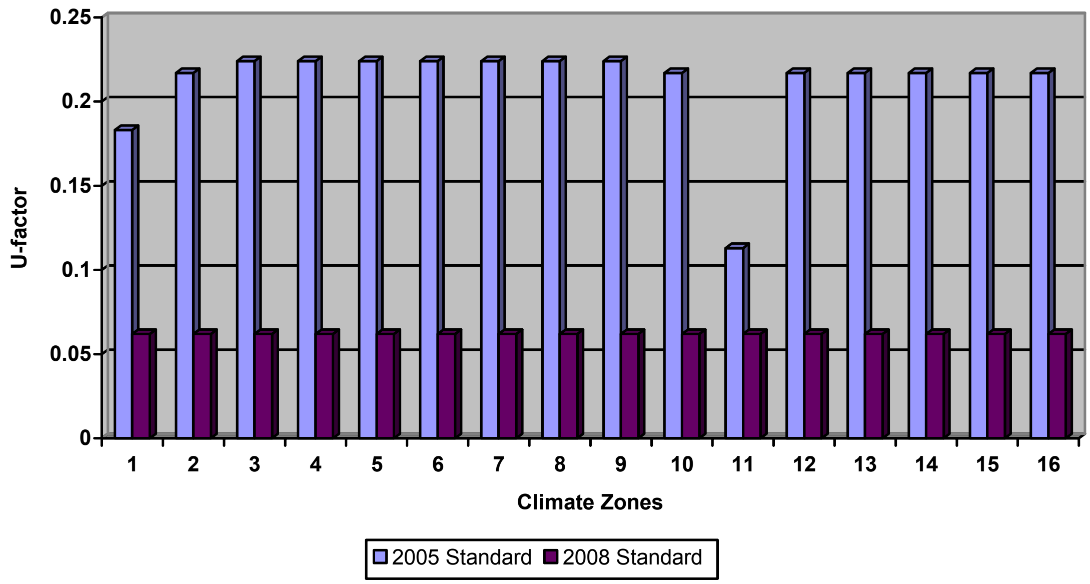

Figure 33 – Metal-framed Wall (24-hour)
Statewide Energy Impacts (ft^2-yr): TDV=28.909, kWh=1.521, therm=0.103

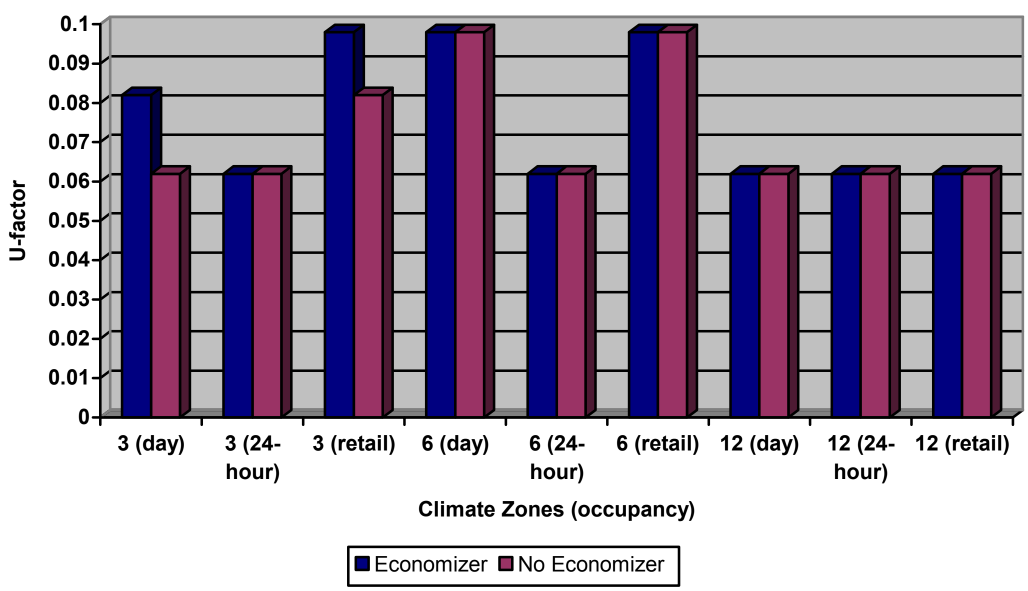

Figure 34 – Economizer Insulation Sensitivity Analysis for Metal-framed Wall

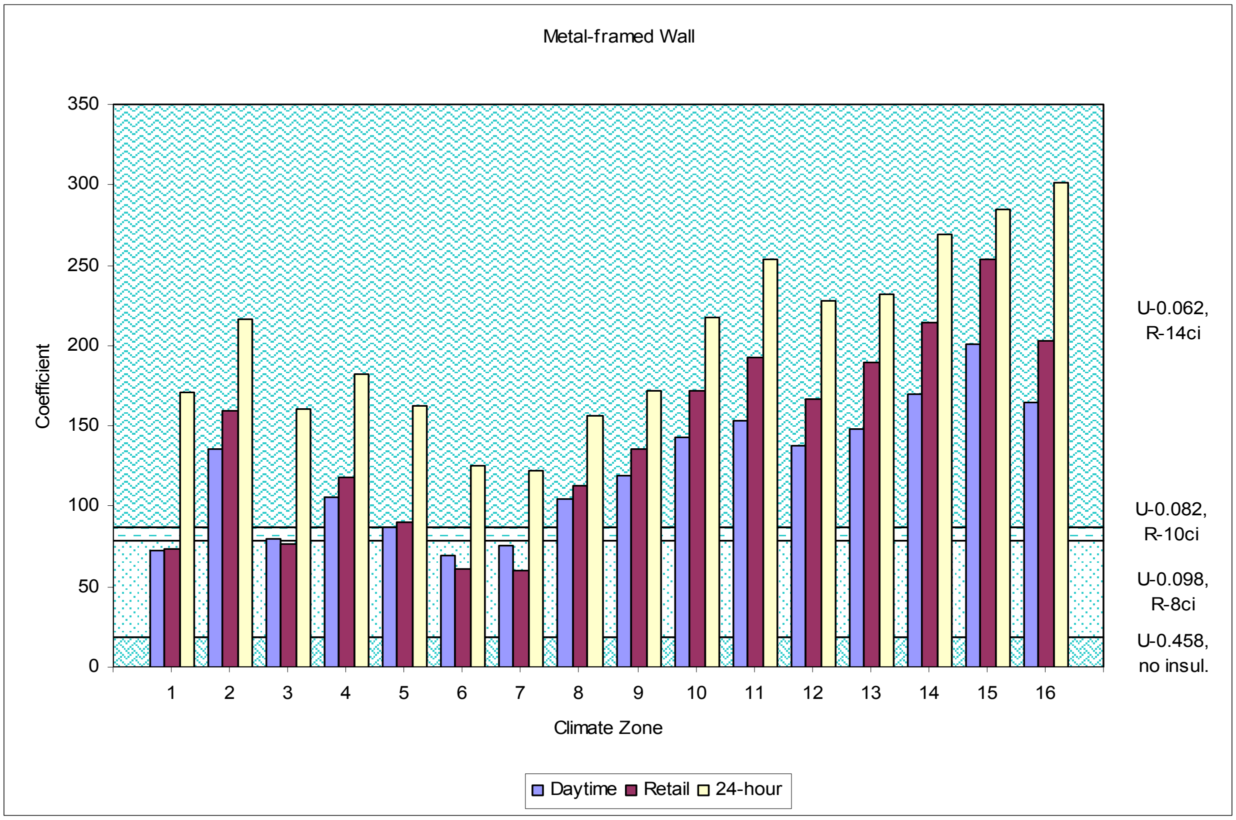

Figure 35 – Metal-framed Wall Coefficients

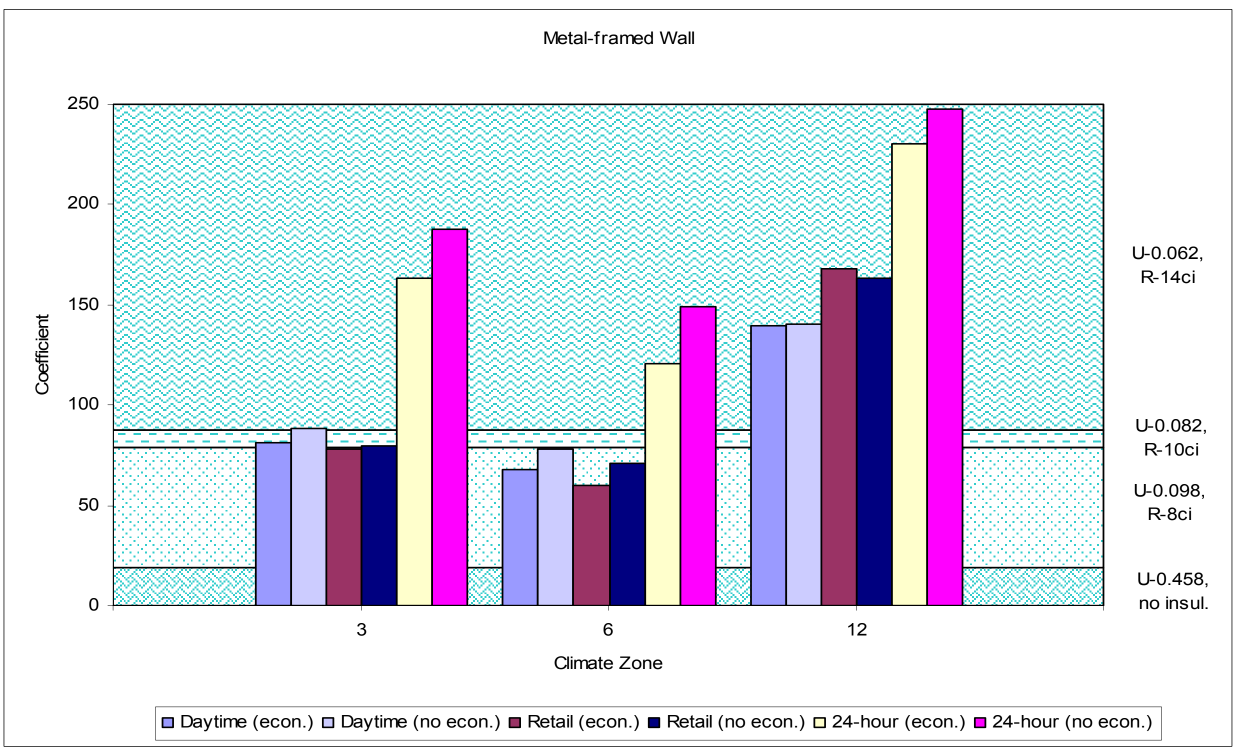

Figure 36 – Metal-framed Wall Coefficients (economizer sensitivity)

Mass (7.0≤HC<15.0) Wall

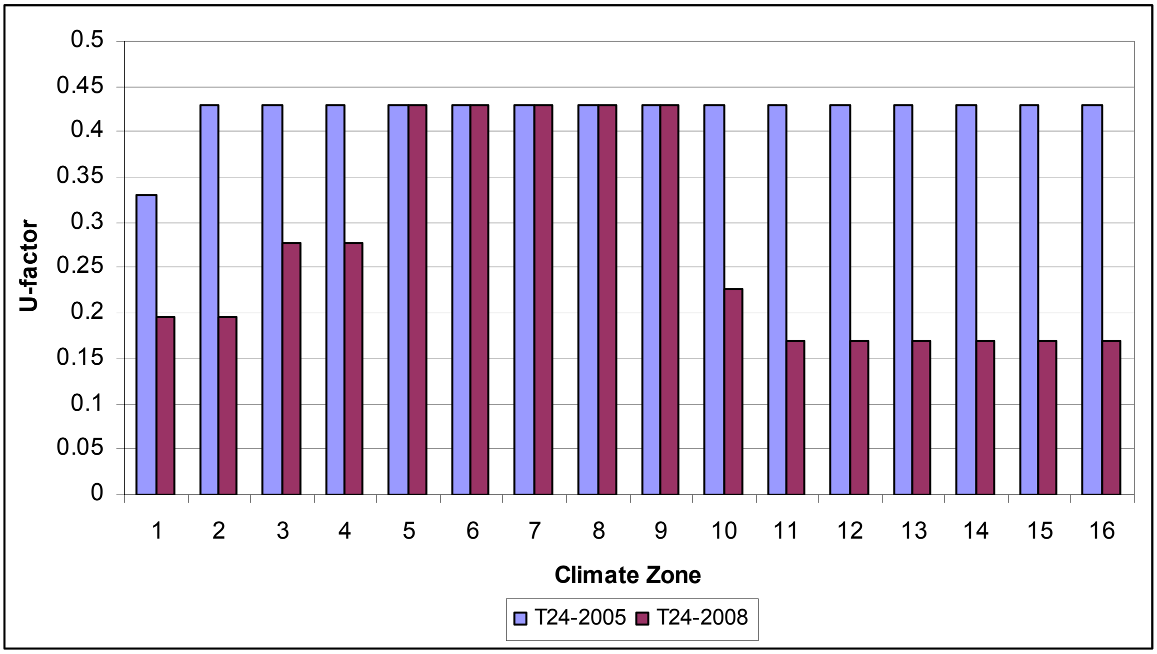

Figure 37 – Mass (7.0≤HC<15.0) Wall (Daytime)
Statewide Energy Impacts (ft^2-yr): TDV=9.299, kWh=0.1246, therm=0.0407

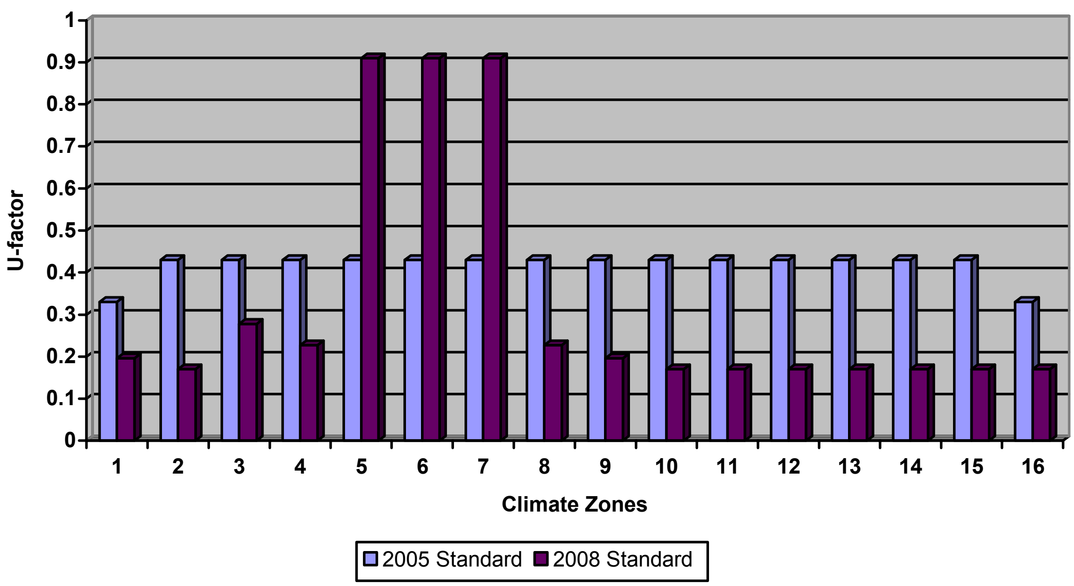

Figure 38 – Mass (7.0≤HC<15.0) Wall (Retail)
Statewide Energy Impacts (ft^2-yr): TDV=12.603, kWh=0.5066, therm=0.0404

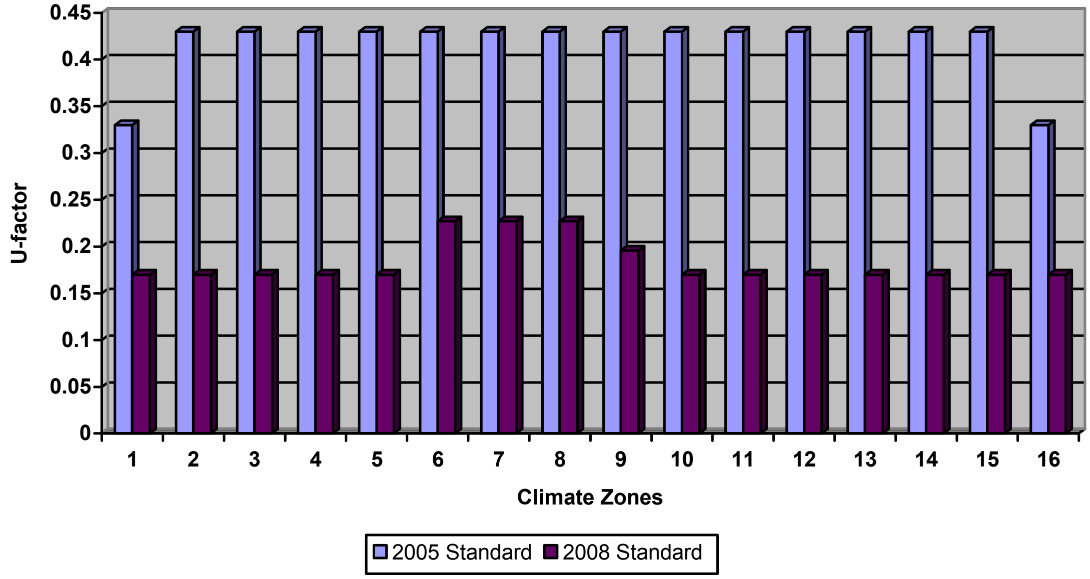

Figure 39 – Mass (7.0≤HC<15.0) Wall (24-hour)
Statewide Energy Impacts (ft²-yr): TDV=23.344, kWh=0.500, therm=0.118

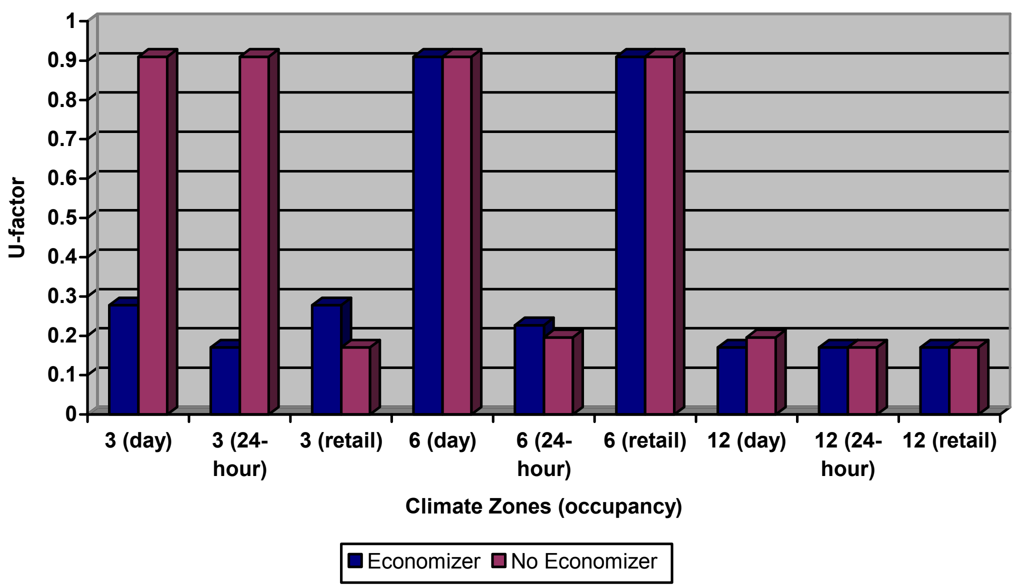

Figure 40 – Economizer Insulation Sensitivity Analysis for Mass (7.0≤HC<15.0) Wall

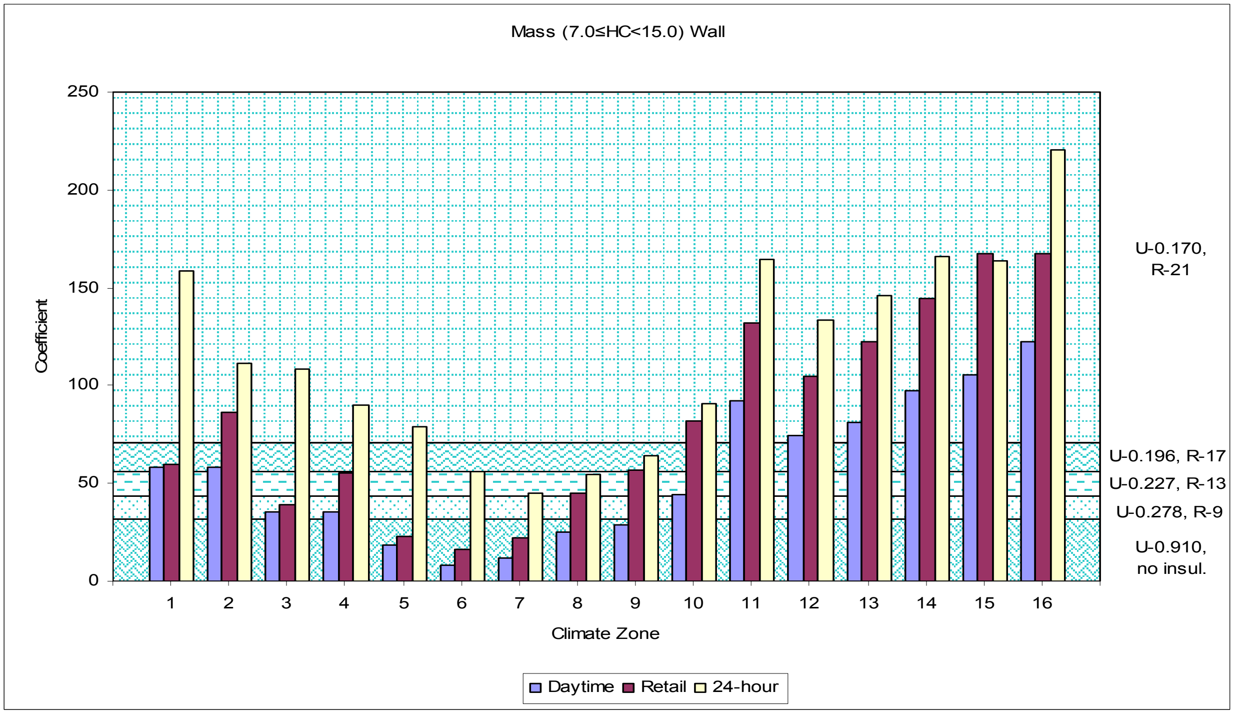

Figure 41 – Mass (7.0≤HC<15.0) Wall Coefficients

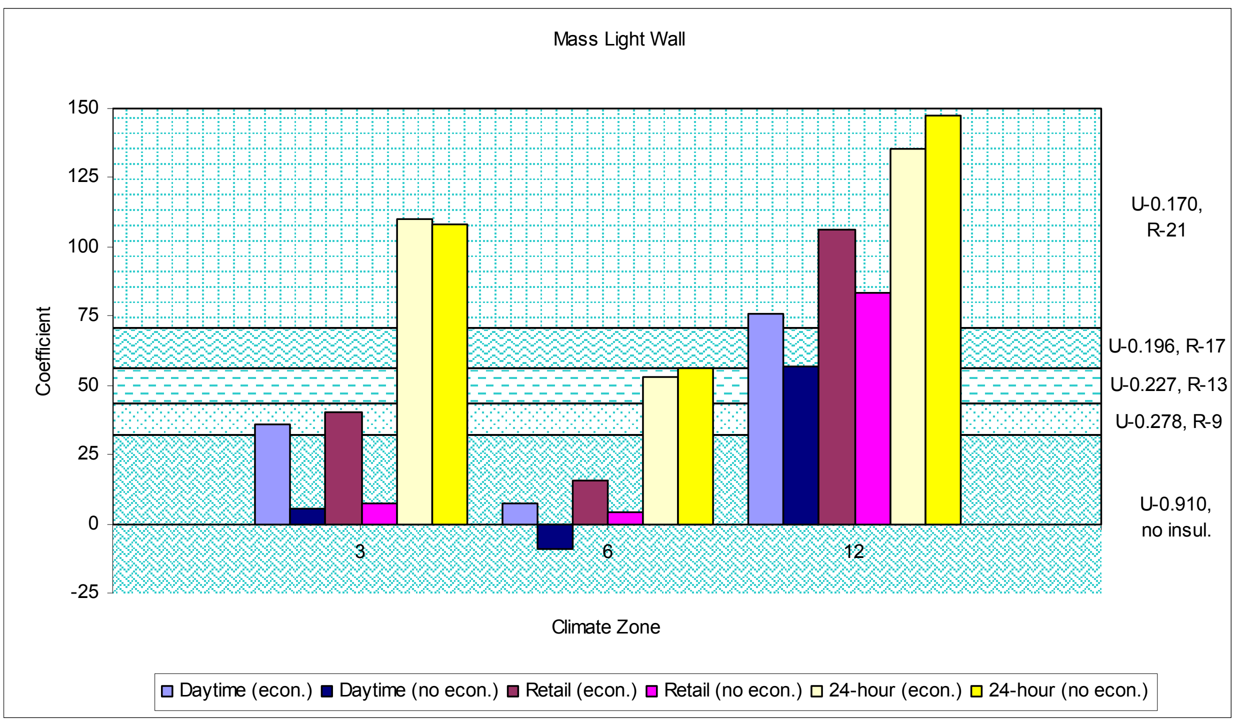

Figure 42 – Mass (7.0≤HC<15.0) Wall Coefficients (economizer sensitivity)

Mass (15.0≤HC) Wall

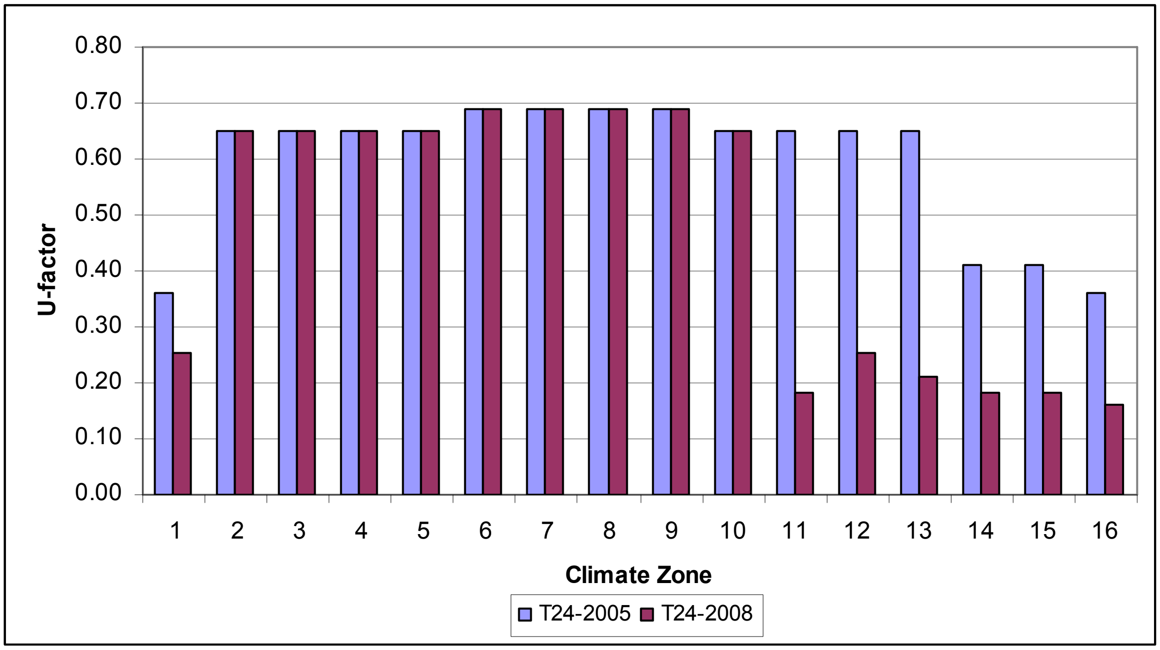

Figure 43 – Mass (15.0≤HC) Wall (Daytime)
Statewide Energy Impacts (ft^2-yr): TDV=5.632, kWh=0.048, therm=0.025

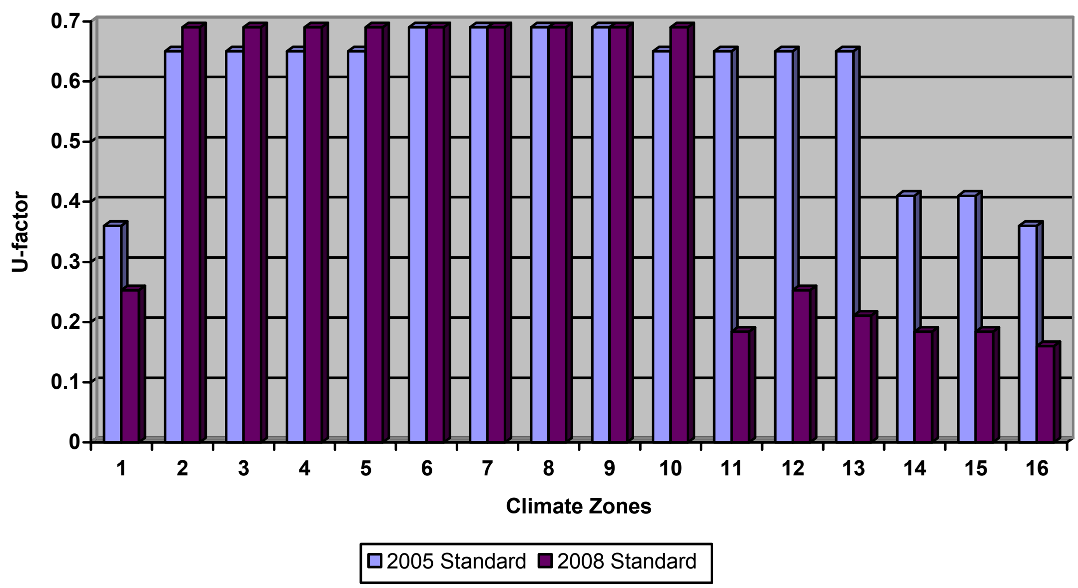

Figure 44 – Mass (15.0≤HC) Wall (Retail)
Statewide Energy Impacts (ft^2-yr): TDV=10.541, kWh=0.365, therm=0.0378

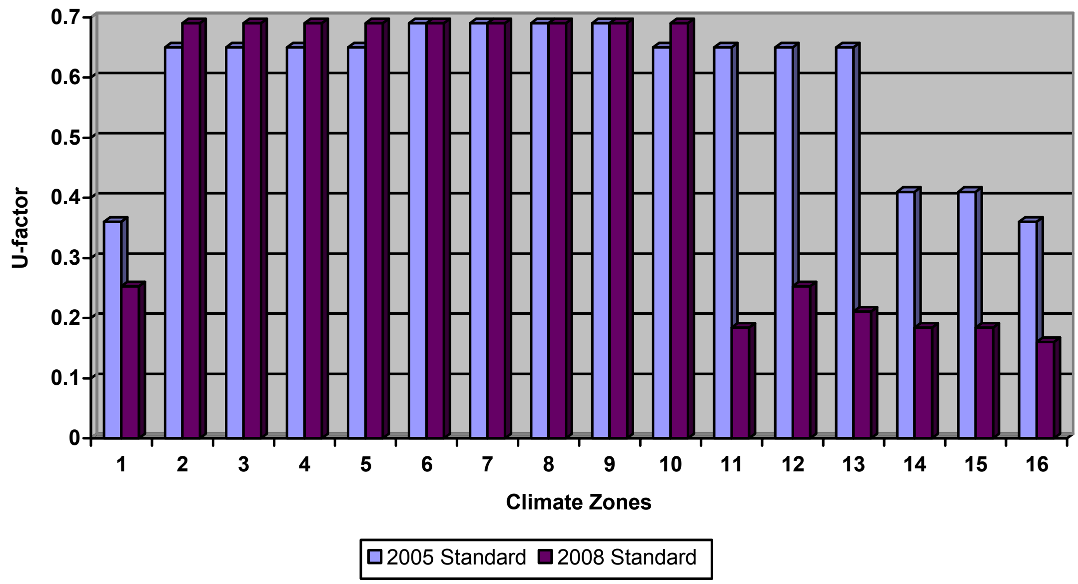

Figure 45 – Mass (15.0≤HC) Wall (24-hour)
Statewide Energy Impacts (ft^2-yr): TDV=23.614, kWh=0.1587, therm=0.1327

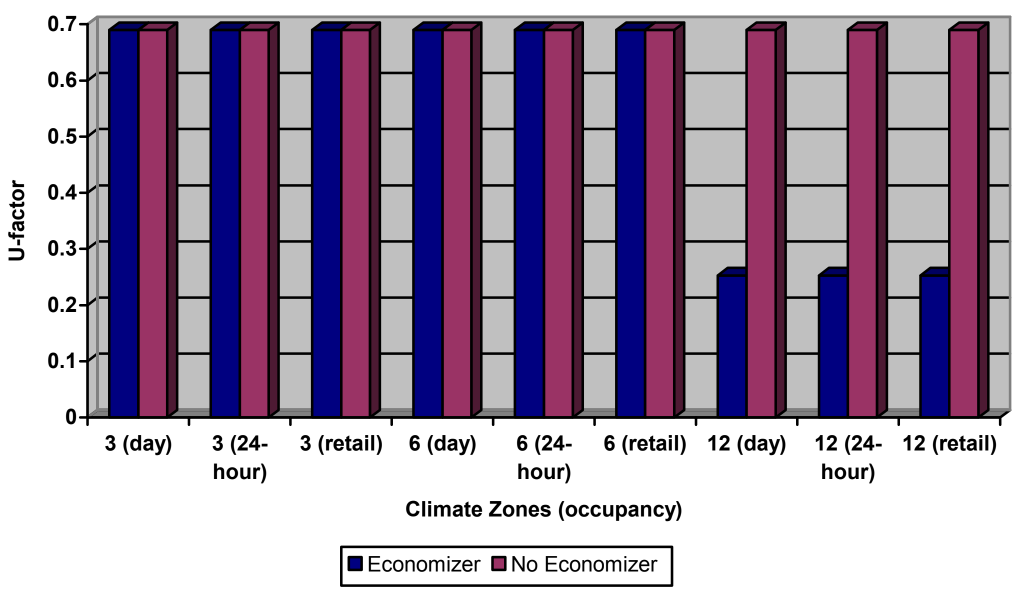

Figure 46 – Daytime Economizer Insulation Sensitivity Analysis for Mass (15.0≤HC) Wall

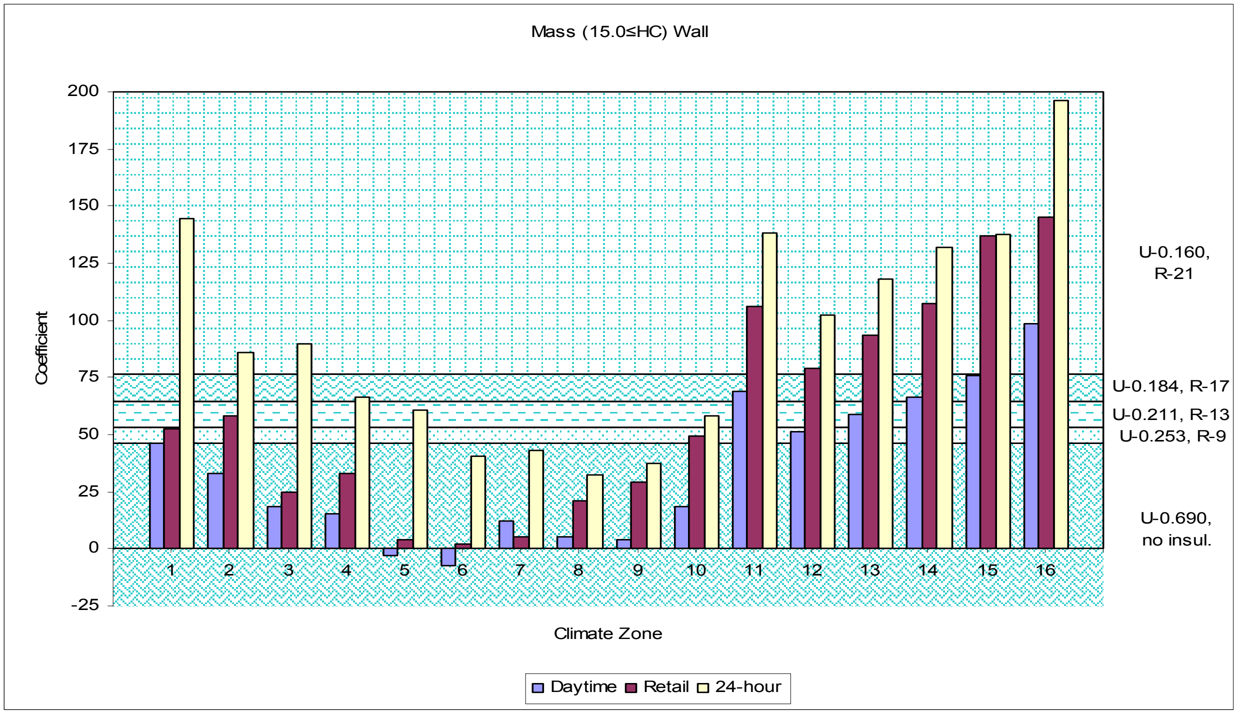

Figure 47 – Mass (15.0≤HC) Wall Coefficients

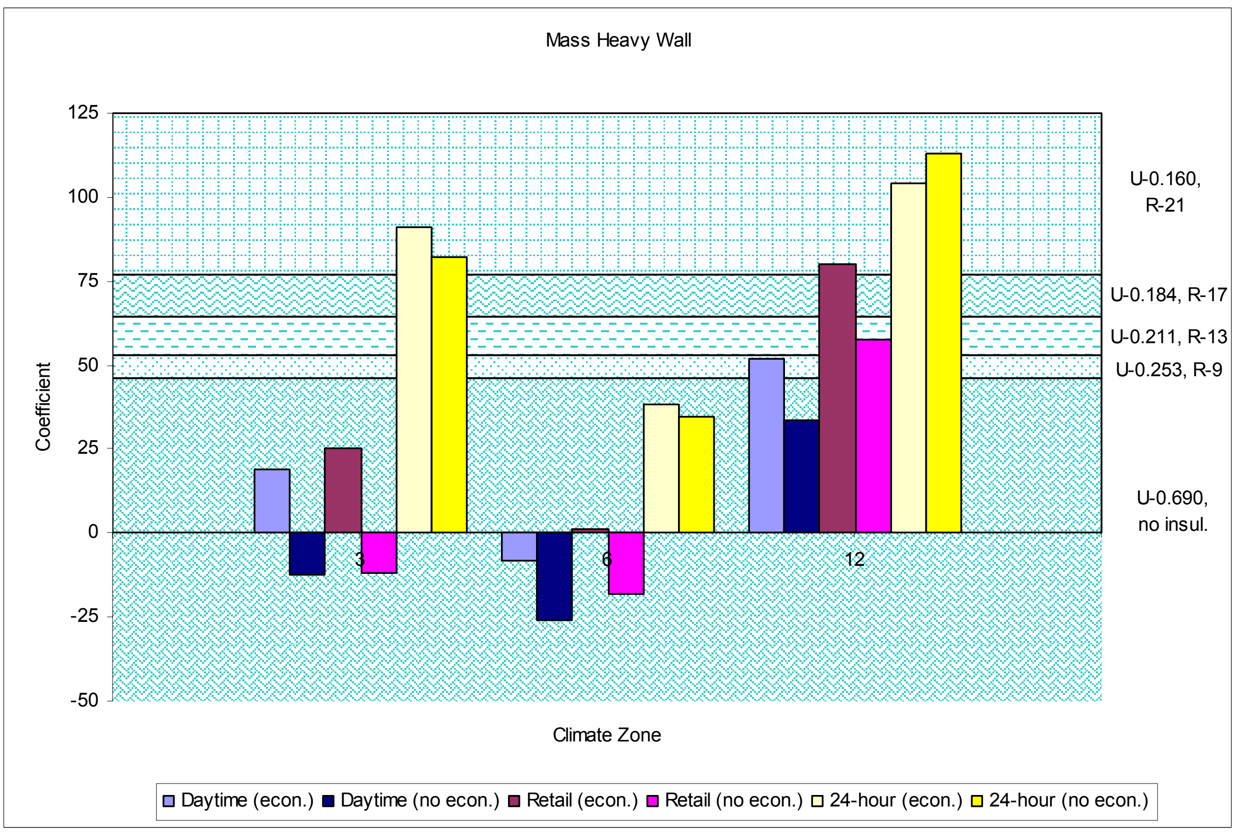

Figure 48 – Mass (15.0≤HC) Wall Coefficients (economizer sensitivity)

Wood-framed and Other Wall

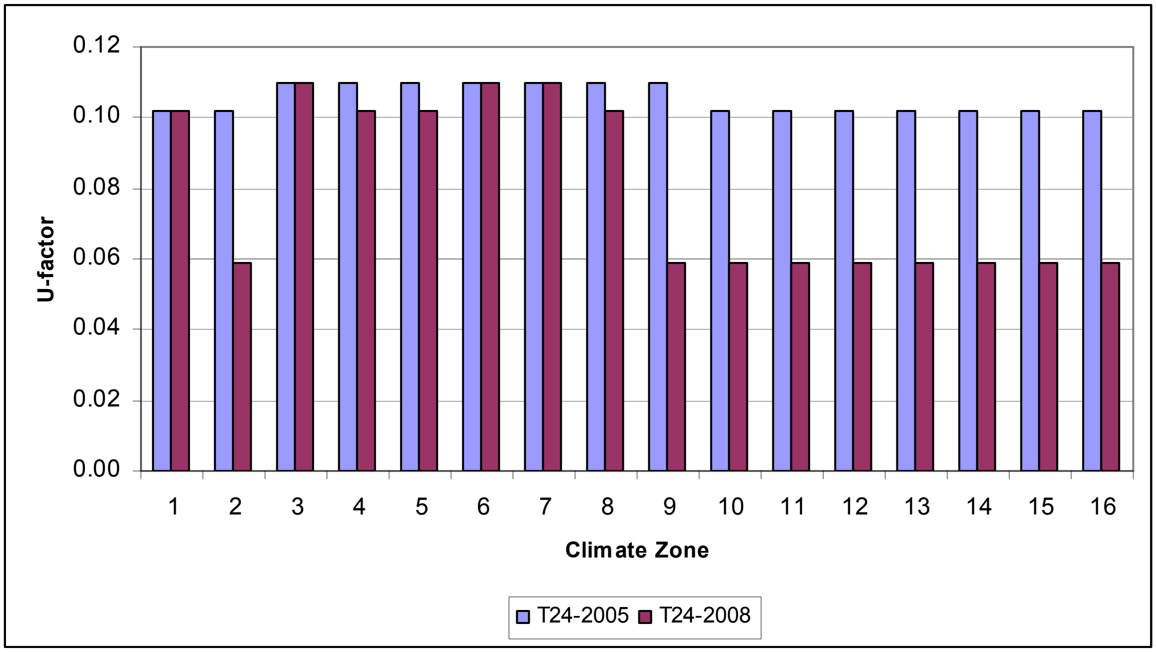

Figure 49 – Wood-framed and Other Wall (Daytime)
Statewide Energy Impacts (ft^2-yr): TDV=3.389, kWh=0.160, therm=0.0072

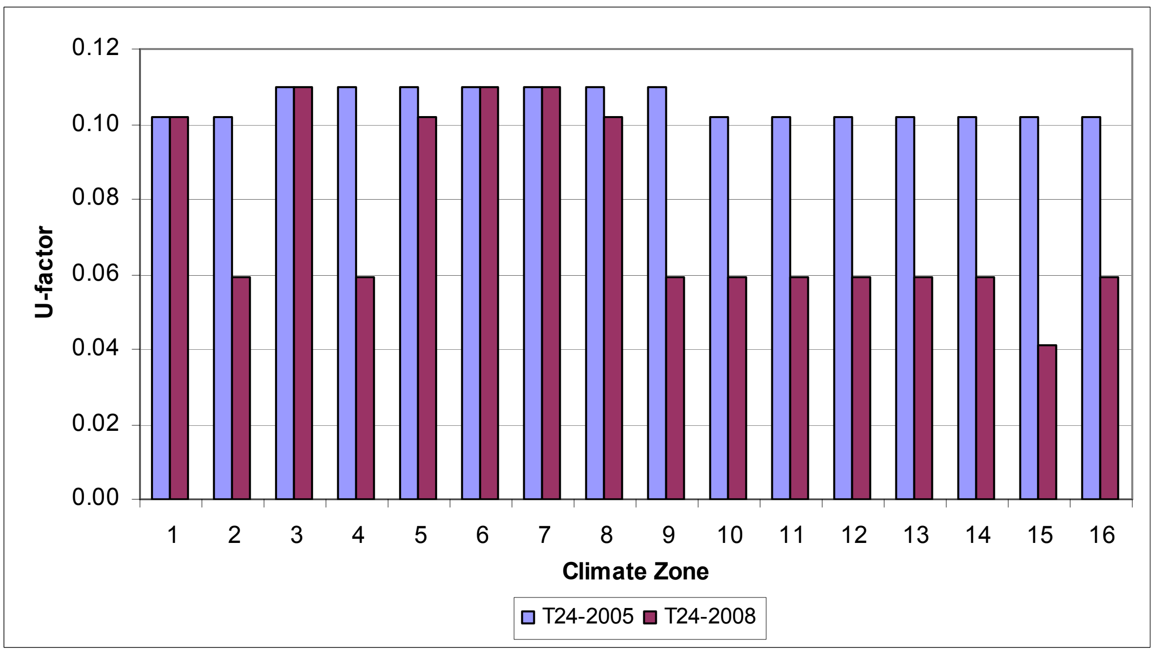

Figure 50 – Wood-framed and Other Wall (Retail)
Statewide Energy Impacts (ft^2-yr): TDV=4.790, kWh=0.260, therm=0.0095

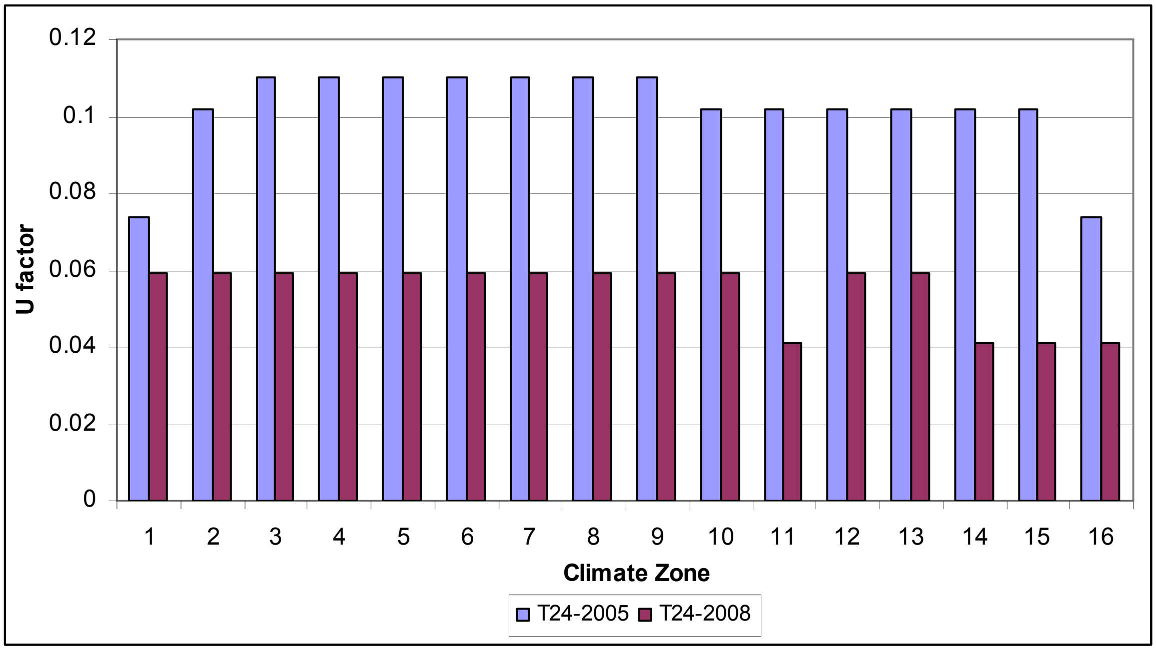

Figure 51 – Wood-framed and Other Wall (24-hour)
Statewide Energy Impacts (ft^2-yr): TDV=8.032, kWh=0.419, therm=0.0281

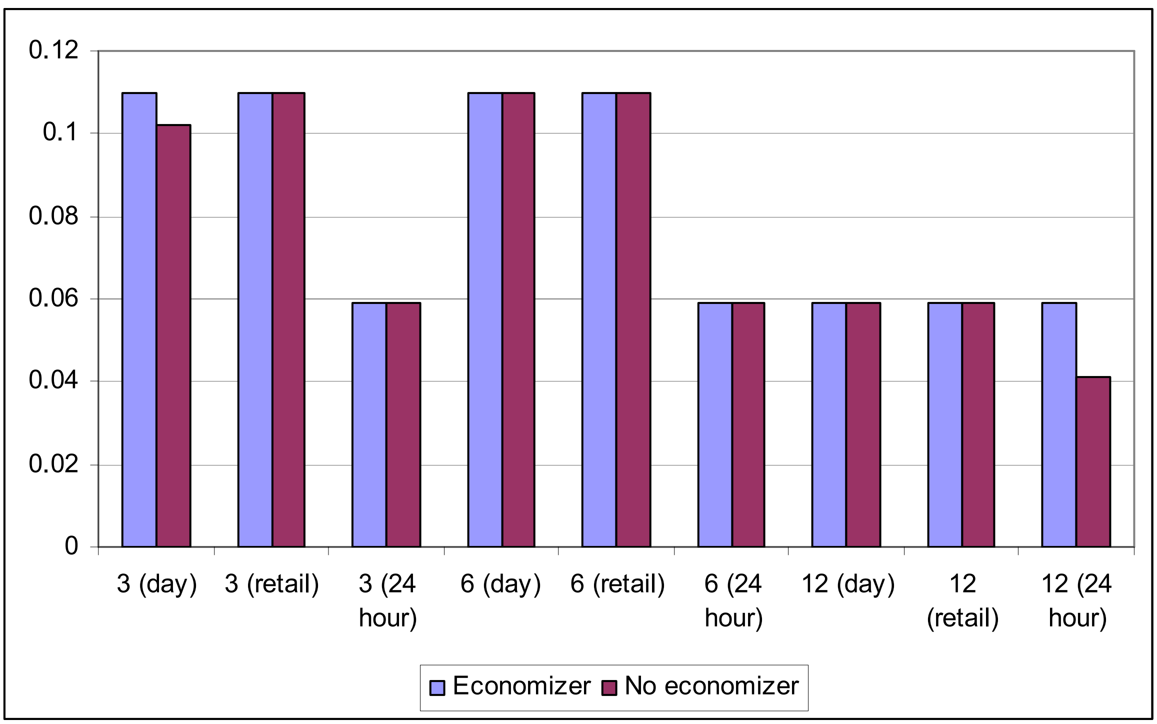

Figure 52 – Daytime Economizer Insulation Sensitivity Analysis for Wood-framed and Other Wall

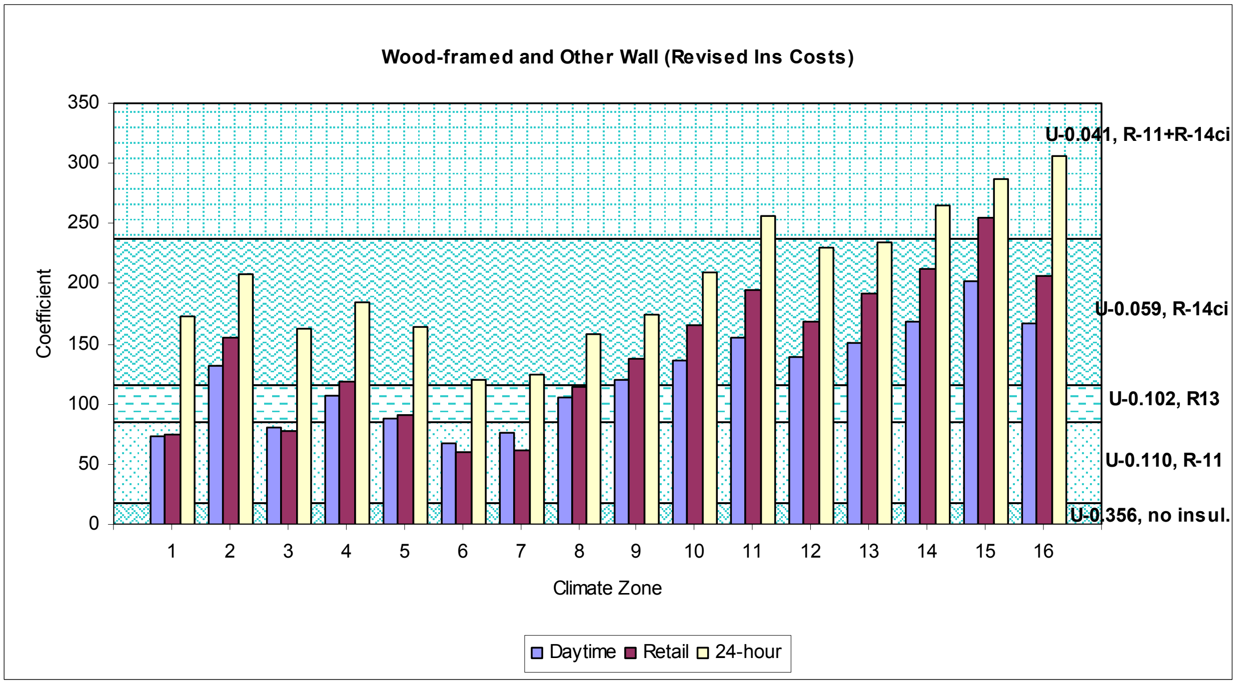

Figure 53 – Wood-framed and Other Wall Coefficients

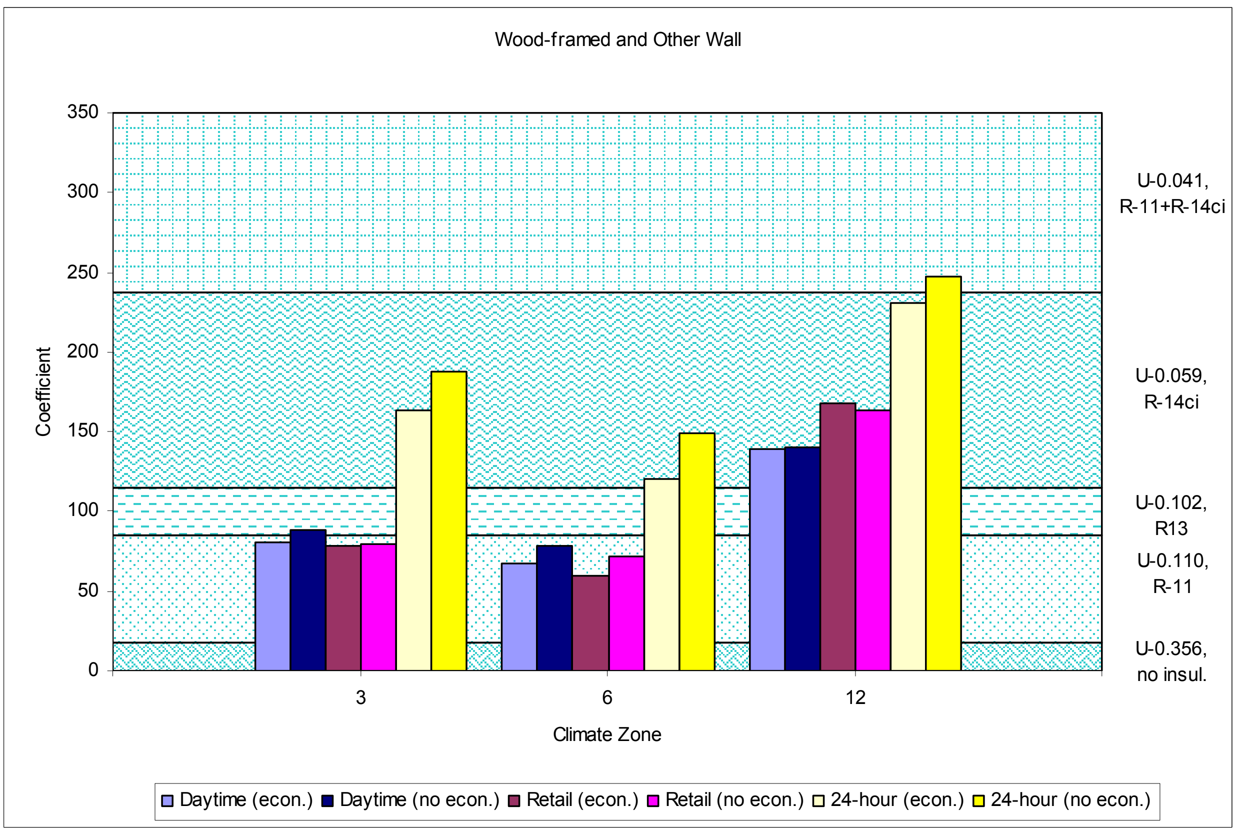

Figure 54 – Wood-framed and Other Wall Coefficients (economizer sensitivity)

Mass Floor

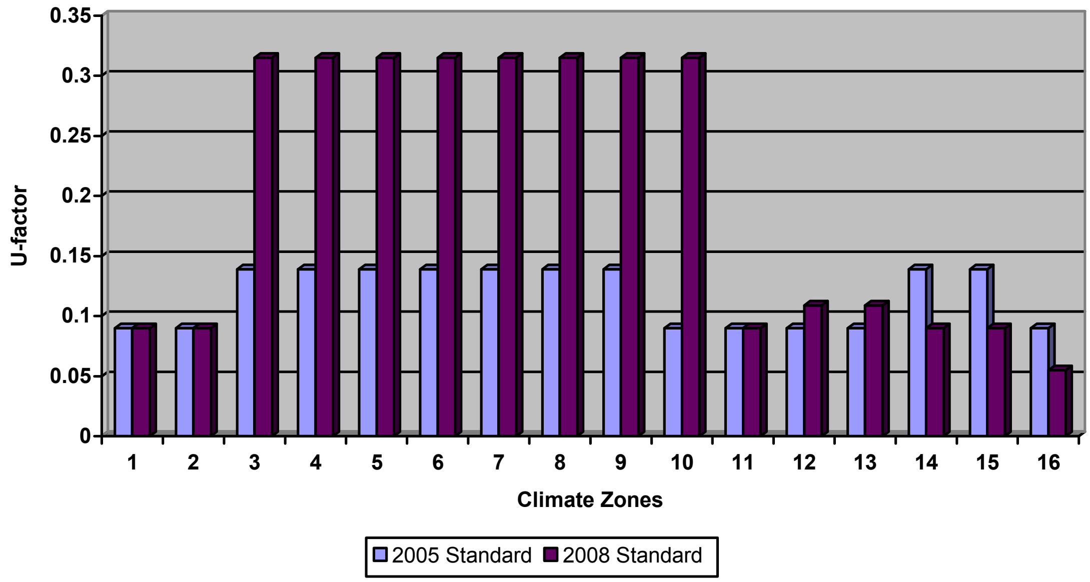

Figure 55 – Mass Floor (Daytime)
Statewide Energy Impacts (ft^2-yr): TDV=0.4216, kWh=0.260, therm=-0.029

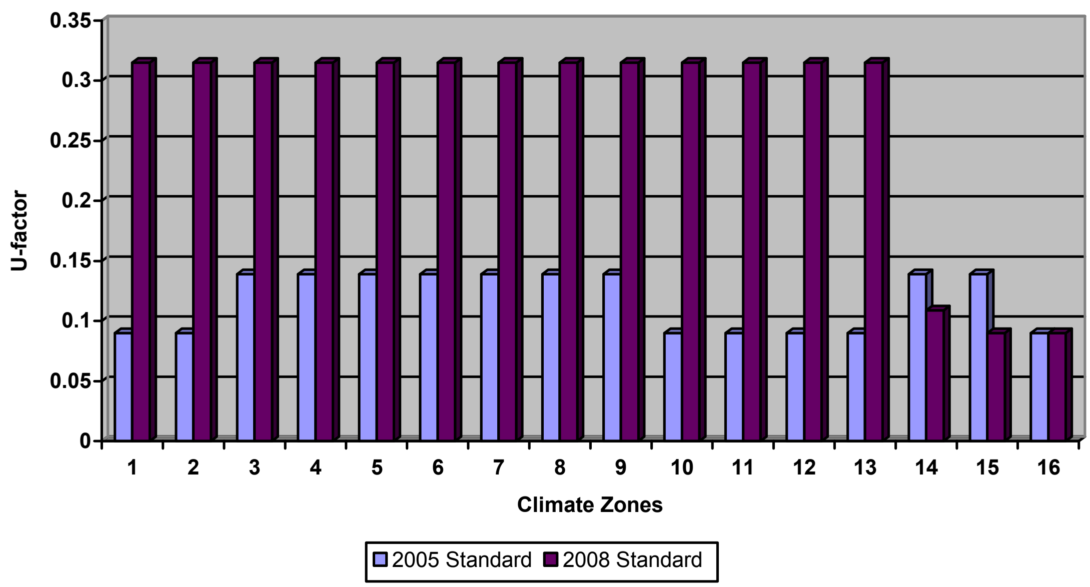

Figure 56 – Mass Floor (Retail)
Statewide Energy Impacts (ft^2-yr): TDV=6.214, kWh=0.472, therm=-0.026

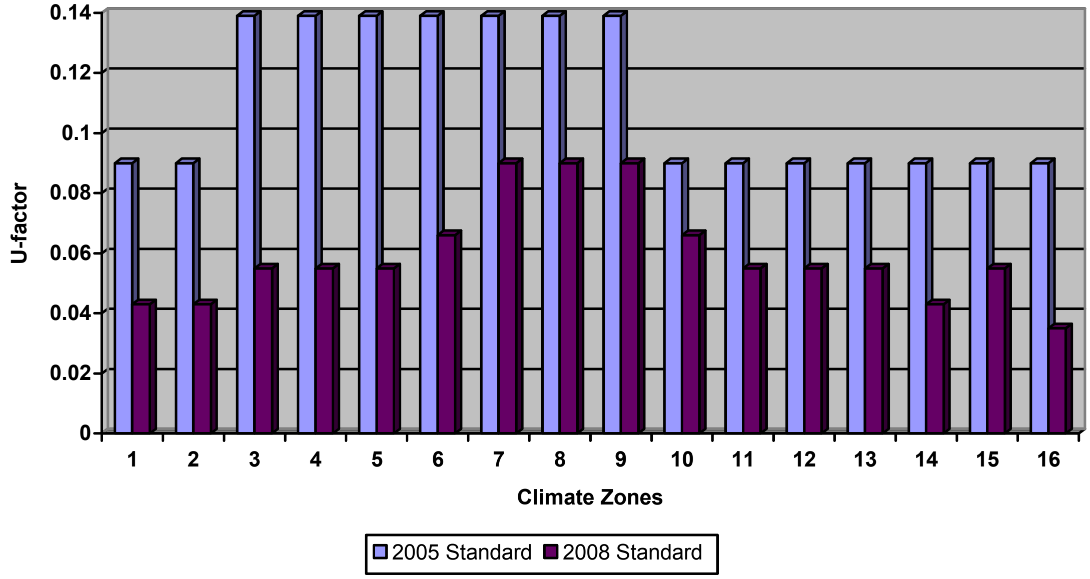

Figure 57 – Mass Floor (24-hour)
Statewide Energy Impacts (ft^2-yr): TDV=7.791, kWh=-0.010, therm=0.050

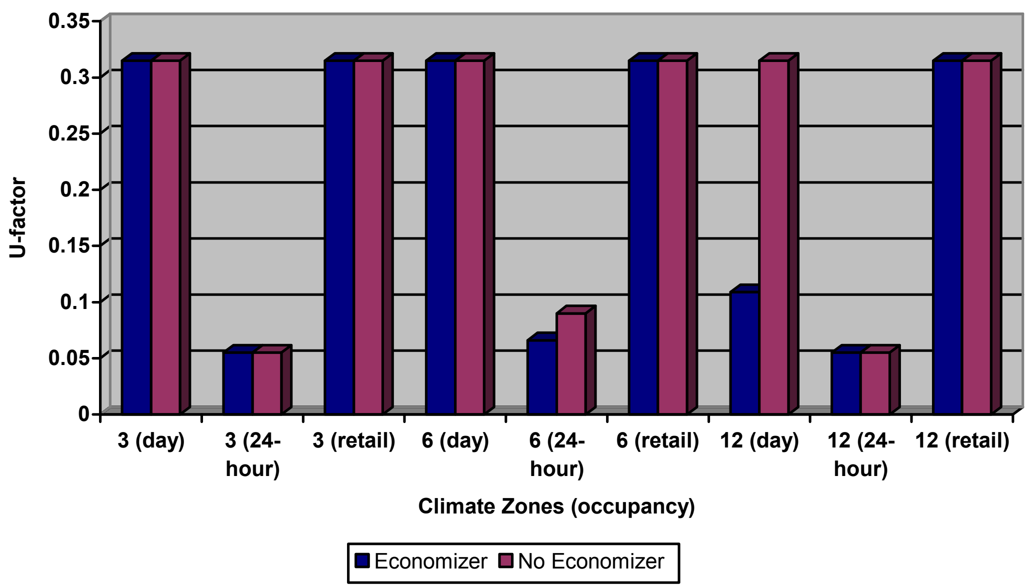

Figure 58 – Daytime Economizer Insulation Sensitivity Analysis for Mass Floor

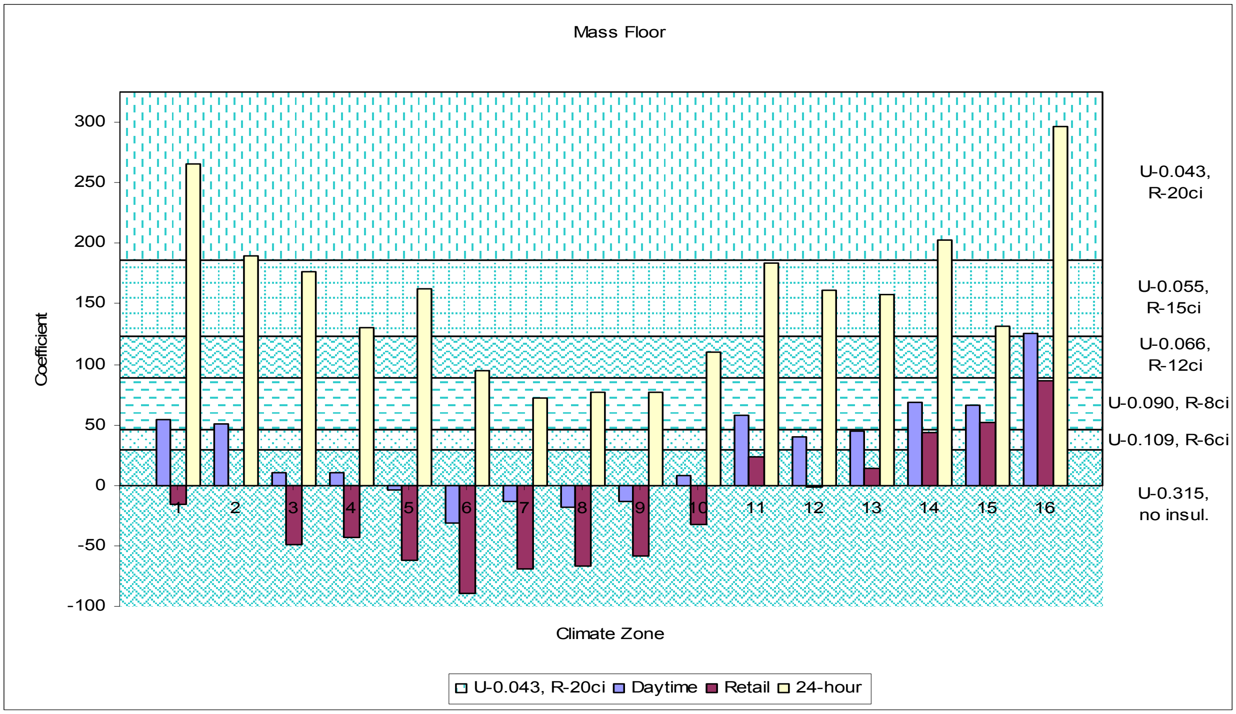

Figure 59 – Mass Floor Coefficients

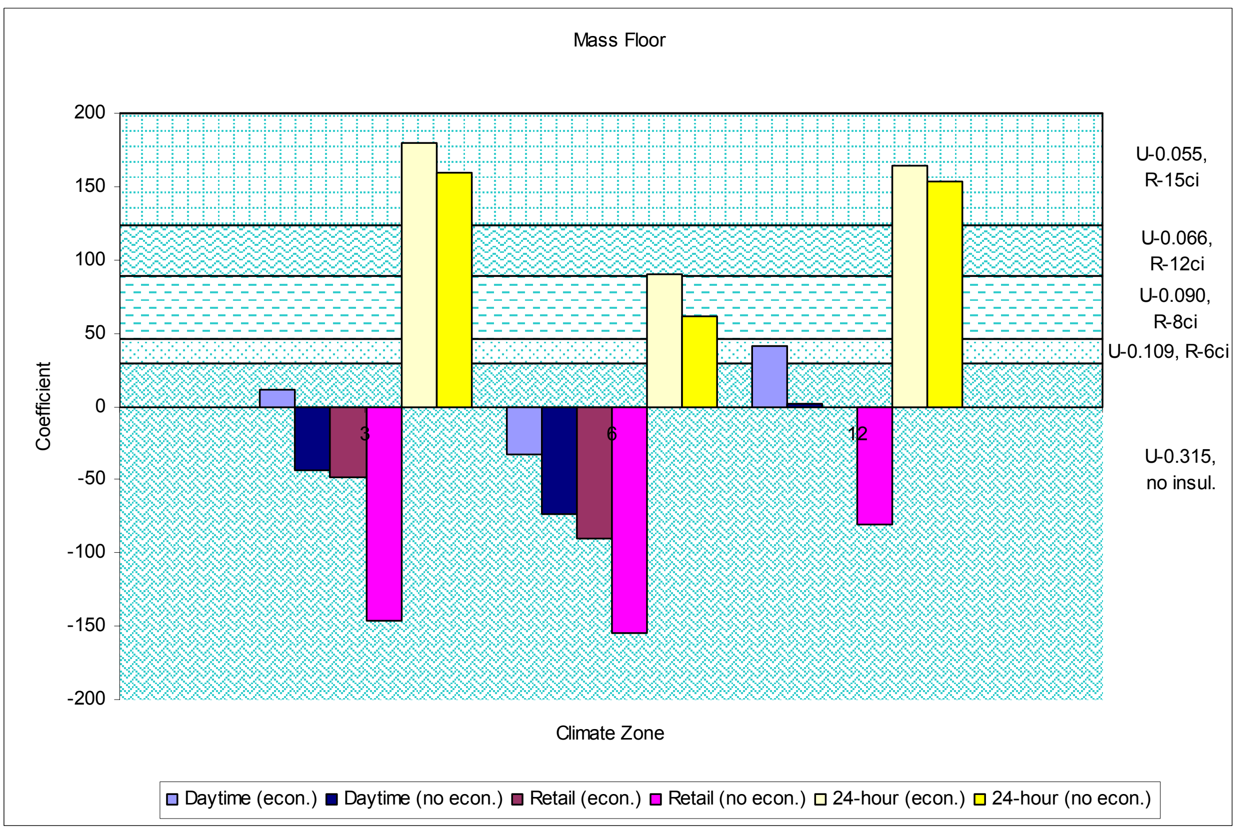

Figure 60 – Mass Floor Coefficients (economizer sensitivity)

Other Floor

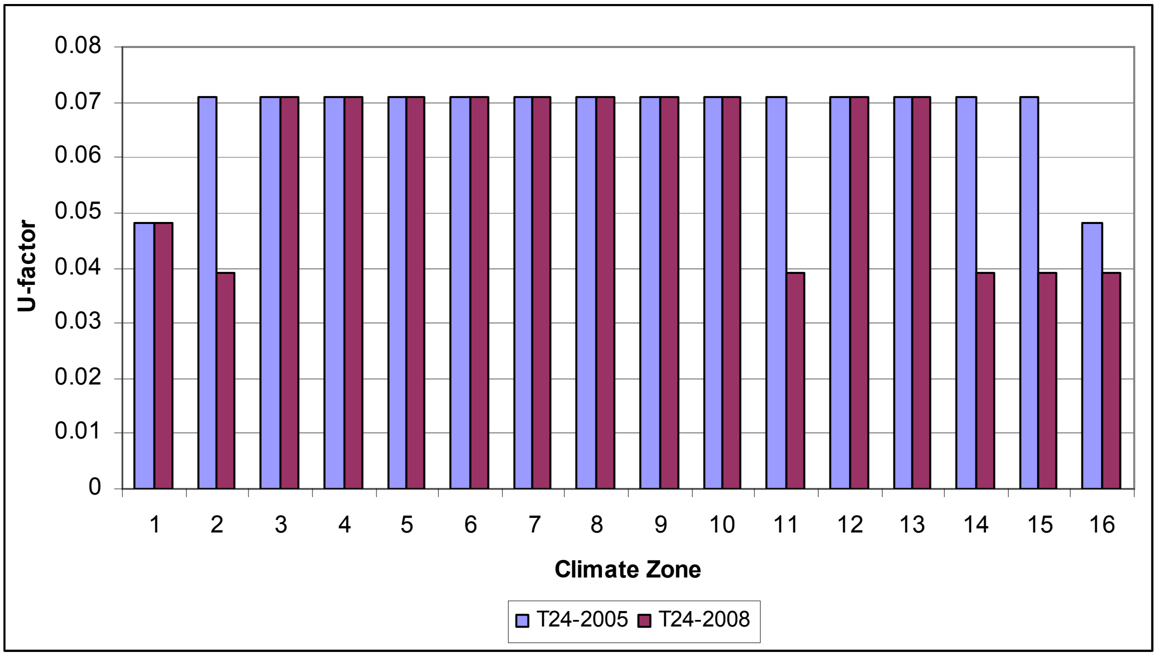

Figure 61 – Other Floor (Daytime)
Statewide Energy Impacts (ft²-yr): TDV=0.4276, kWh=0.005, therm=0.0020

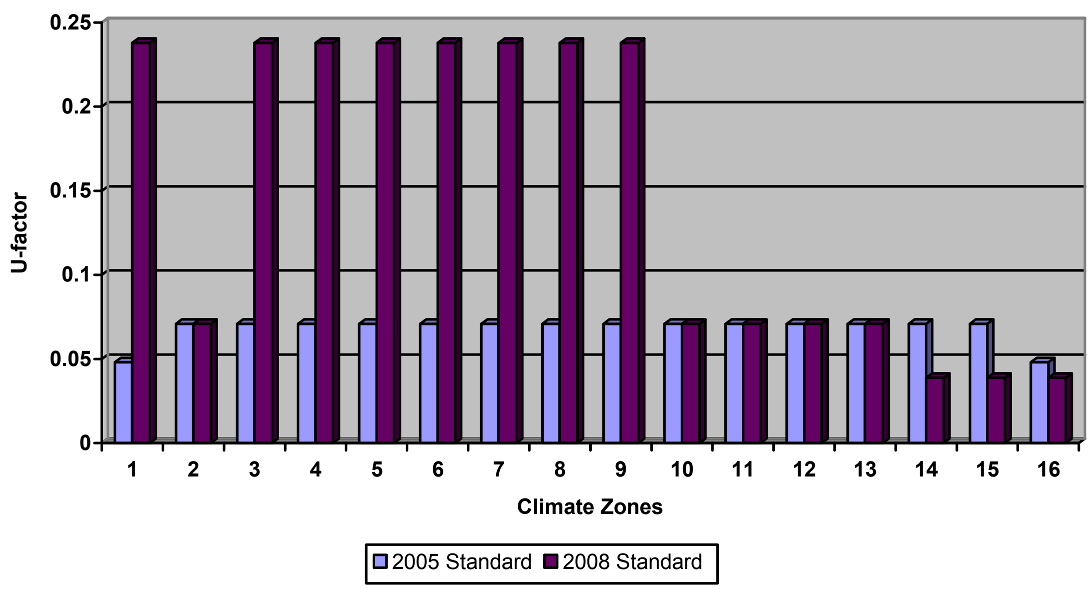

Figure 62 – Other Floor (Retail)
Statewide Energy Impacts (ft²-yr): TDV=2.307, kWh=0.143, therm=-0.0101

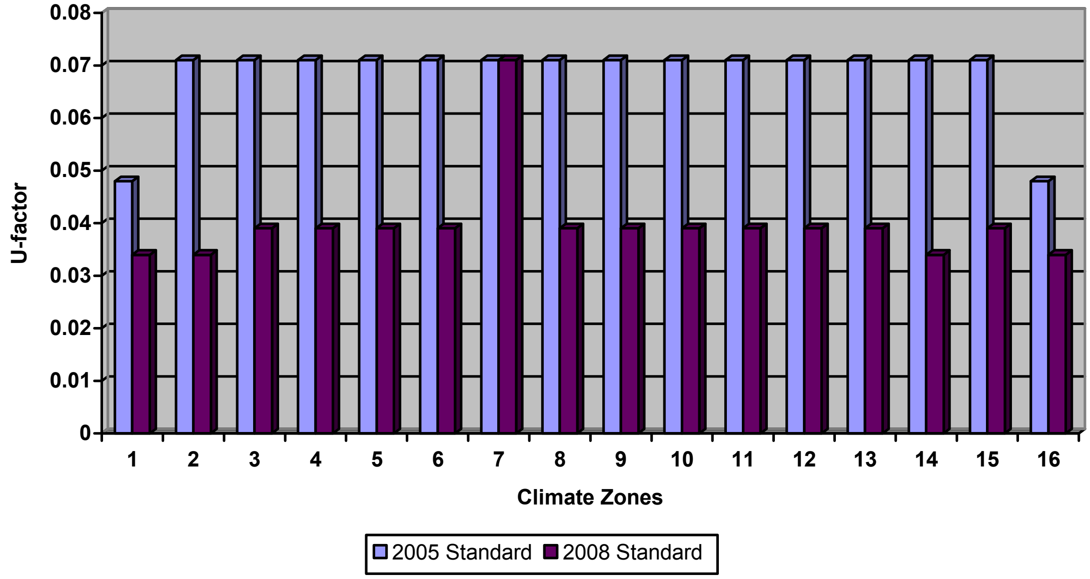

Figure 63 – Other Floor (24-hour)
Statewide Energy Impacts (ft^2-yr): TDV=5.190, kWh=0.058, therm=0.029

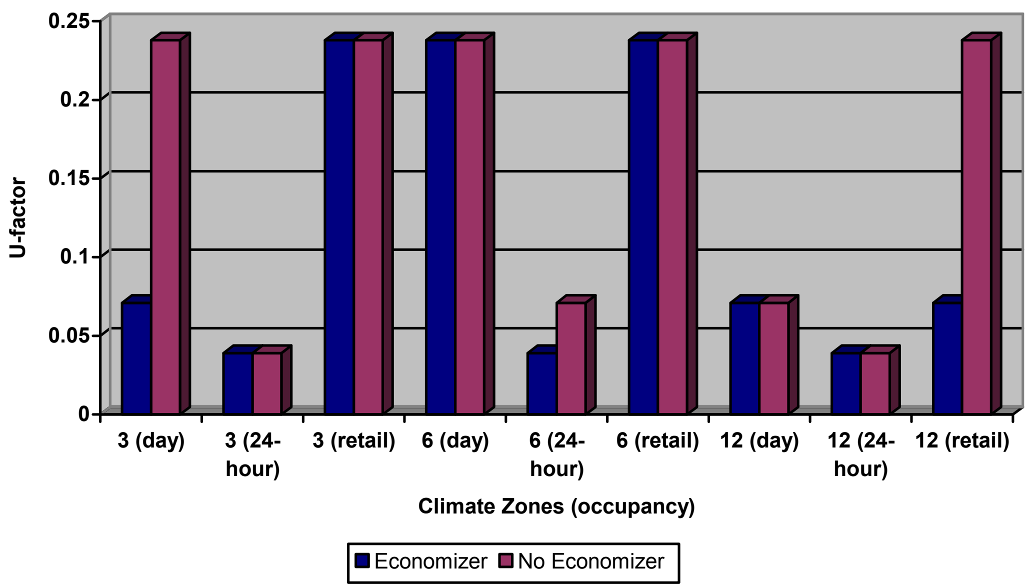

Figure 64 – Daytime Economizer Insulation Sensitivity Analysis for Other Floor

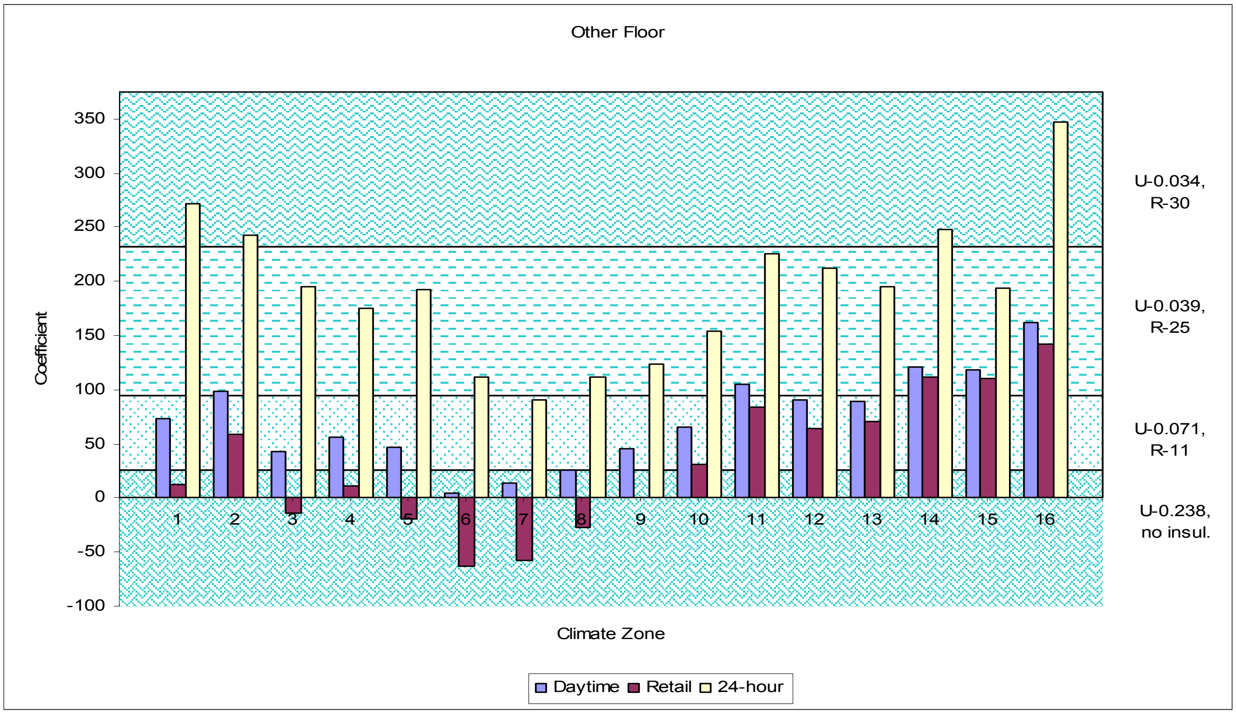

Figure 65 – Other Floor Coefficients

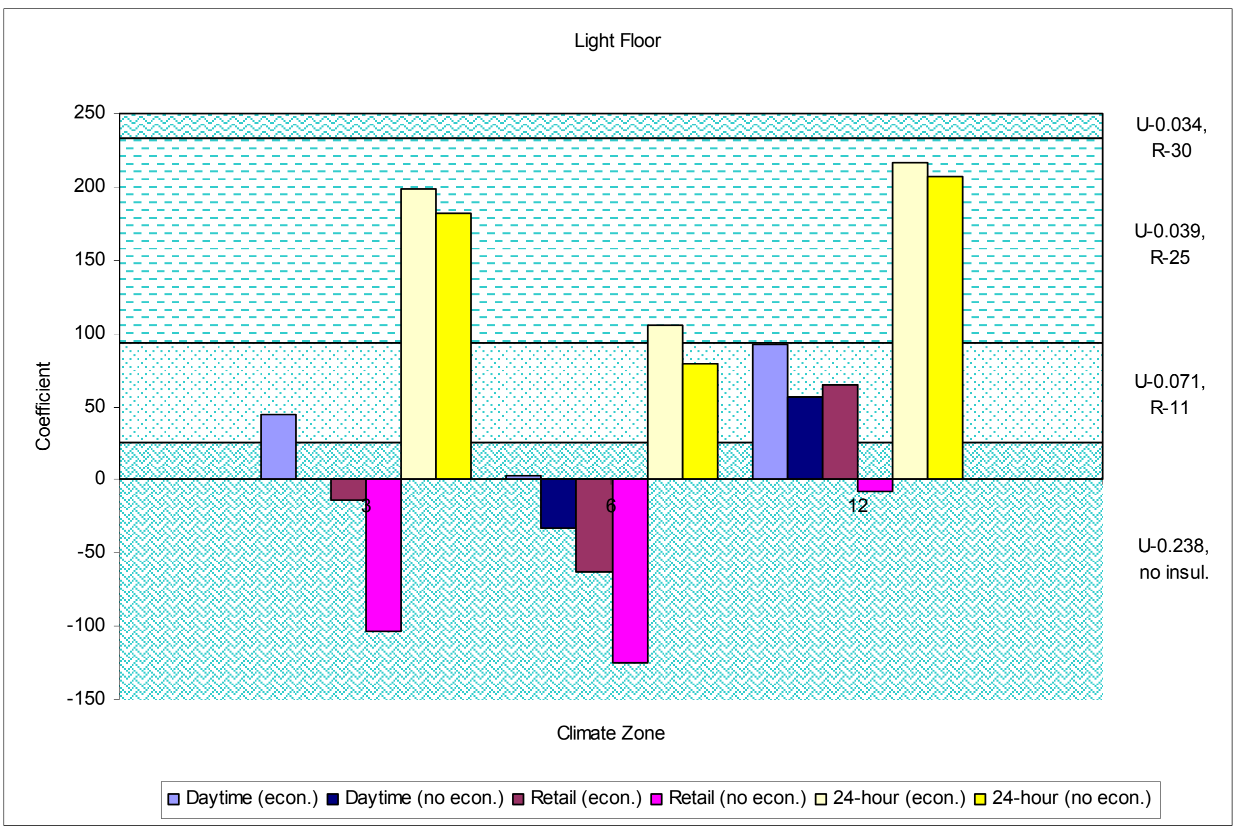

Figure 66 – Other Floor Coefficients (economizer sensitivity)

Cost-effectiveness

A spreadsheet listing the life-cycle cost values for all evaluated construction assemblies can be found at the http link below. The data in the spreadsheets are accessible by downloading an Excel macro, which extracts the 10 lowest life-cycle costs for a particular construction type, class, category and climate zone. You may download a zipped file of this Excel macro from the following website:

https://zurich.archenergy.com/remote/data/1203/Version__1/CASE%20Insulation%20Data%20Extractor.zip

Instructions on accessing the data files are provided in a short document in this zip file.

Table 21 – Life-cycle Cost Spreadsheet Definitions

Column	Definition
Occupancy	Occupancy Type (Daytime, 24-hour, retail)
CZ	Climate Zone (1-16)
Type	Type of Construction (roof, wall, floor)
Class	Class of Construction (wood, metal, metal building, mass, etc.)
Category	Category of Construction (heavy mass, light mass, 16” o.c., 24” o.c., etc.)
Cavity R	Cavity R-value (non-rigid insulation)
Sheathing R	Sheathing R-value (rigid insulation)
U-factor	U-factor of combined cavity and sheathing R-value (U-factor)
LCC	Life-cycle cost
Rank	Rank (Rank=1 is the lowest life-cycle cost among class and category of construction)

Note: The column and definition used in this table and the corresponding spreadsheet may be different than the definitions used in the rest of the report; however, the definition should still be self-explanatory.

Recommendations

These are the recommended code changes based on the TDV life-cycle cost analysis. Since the U-factors were used from Joint Appendix IV to calculate the life cycle cost, we recommend that only the U-factors be listed for compliance purposes in the Standards. As long as the construction meets the U-factor requirement, it does not matter whether the requirement is met through non-rigid insulation, rigid insulation, or a combination thereof.

The recommended classes of construction are as follows:

- Roofs: Metal Building and Wood-framed and Others
  - Metal buildings that utilize rigid insulation include a second deck to sandwich the insulation.
  - Wood-framed and others are wood framed rafter roofs 24 in. OC.
- Walls: Metal Building, Metal-framed, Mass Light, Mass Heavy, and Wood-framed and Other
  - Metal-framed and wood-framed walls are 16 in. OC.
  - Mass light and heavy walls assume interior insulation with metal furring clips
- Floors: Mass and Other

- Mass floor is concrete raised floors or concrete on a metal deck.
- Other is wood-framed floors without a crawl space 16 in. OC.

The recommended U-factors for daytime occupancies were very similar to those for retail occupancies. Therefore, the two tables were combined into a single table. Where the recommended U-factors for daytime and retail occupancies differed for a particular construction, the lower, more stringent U-factor was selected. This selection still results in a life-cycle cost that is lower than the LCC corresponding to the 2005 Title 24 prescriptive assembly.

Table 22 – Daytime Occupancy Recommended Standard (corresponds to Table 143-A)

	Climate Zones															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Roof/Ceiling																
Metal Building	0.063	0.048	0.063	0.063	0.048	0.078	0.063	0.063	0.063	0.048	0.048	0.048	0.048	0.048	0.048	0.048
Wood-framed and other	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Wall																
Metal Building	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
Metal-framed	0.098	0.062	0.082	0.062	0.062	0.098	0.098	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Mass Light	0.196	0.170	0.278	0.227	0.43	0.43	0.43	0.43	0.43	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Mass Heavy	0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
Wood-framed and Other	0.102	0.059	0.110	0.059	0.102	0.110	0.110	0.102	0.059	0.059	0.059	0.059	0.059	0.059	0.041	0.059
Floor/Soffit																
Mass	0.090	0.090	0.315	0.315	0.315	0.315	0.315	0.315	0.315	0.315	0.090	0.090	0.090	0.090	0.090	0.055
Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039

Table 23 – 24-Hour Occupancy Recommended Standard (corresponds to Table 143-B)

	Climate Zones															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Roof/Ceiling																
Metal Building	0.039	0.032	0.048	0.039	0.048	0.048	0.048	0.039	0.039	0.032	0.032	0.032	0.032	0.032	0.032	0.032
Wood-framed and other	0.034	0.028	0.039	0.028	0.039	0.039	0.039	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Wall																
Metal Building	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.057	0.057	0.057	0.057	0.057
Metal-framed	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Mass Light	0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227	0.196	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Mass Heavy	0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690	0.690	0.690	0.184	0.253	0.211	0.184	0.184	0.160
Wood-framed and Other	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.041	0.059	0.059	0.041	0.041	0.041
Floor/Soffit																
Mass	0.043	0.043	0.055	0.055	0.055	0.066	0.090	0.090	0.090	0.066	0.055	0.055	0.055	0.043	0.055	0.035
Other	0.034	0.034	0.039	0.039	0.039	0.039	0.071	0.039	0.039	0.039	0.039	0.039	0.039	0.034	0.039	0.034

Retail occupancy prescriptive requirements are very similar to daytime occupancy requirements, with the exception of mass floors, where no insulation is recommended in most climates.

Proposed Standards Language

The proposed changes to the Standards are the substitution of the tables shown above for Tables 143-A and 143-B. Table 143-C would be changed to include the new values for the most severe climate zone to allow for relocatable school buildings to be located throughout the state.

Alternate Calculation Manual

Table N2-1 of the nonresidential ACM will need to be modified to reflect the choices from Joint Appendix IV that are recommended.

Bibliography and Other Research

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Appendices

Energy Impacts

Table 24 through Table 50 below provide a comparison of energy impacts between the current standard and the proposed standard for all sixteen climate zones. The delta (Δ) TDV, kWh and therm represents the absolute change between the current standard and the proposed standard on an annual per square foot basis. The weighted (wt.) TDV, kWh and therm represents the weighted change by climate zone, occupancy type and square foot of construction. Therefore, the weighted totals represent the average statewide savings on an annual per square foot basis. A positive number represents lower energy consumption (savings) from the proposed standard, whereas a negative number represents higher energy consumption. In certain instances, the proposed standard results in higher energy consumption in certain climate zones, however, the statewide impact is a reduction in energy consumption measured in TDV.

Table 24 – Metal Building Roof (Daytime) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	-1.200	0.516	-1.218	-1.615	-1.265	-0.168	1.227	1.478	1.661	0.466	0.491	0.478	0.475	0.574	0.561	0.595	3.058
Wt. TDV	-0.004	0.035	-0.202	-0.126	-0.024	-0.010	0.087	0.126	0.168	0.041	0.006	0.069	0.027	0.014	0.011	0.003	0.222
Δ kWh	-0.015	0.011	-0.025	-0.042	-0.027	-0.004	0.038	0.048	0.055	0.015	0.014	0.013	0.017	0.017	0.023	0.010	0.150
Wt. kWh	0.000	0.001	-0.004	-0.003	-0.001	0.000	0.003	0.004	0.006	0.001	0.000	0.002	0.001	0.000	0.000	0.000	0.010
Δ therm	-0.007	0.002	-0.006	-0.006	-0.006	-0.001	0.004	0.004	0.005	0.001	0.002	0.002	0.001	0.002	0.001	0.003	-0.001
Wt. therm	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 25 – Metal Building Roof (Retail) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	-1.165	0.552	-1.144	-1.633	-1.170	-0.137	-0.171	1.369	1.674	0.490	0.559	0.523	0.555	0.661	0.667	0.697	2.328
Wt. TDV	-0.003	0.032	-0.147	-0.076	-0.017	-0.009	-0.012	0.128	0.192	0.041	0.014	0.092	0.040	0.015	0.013	0.004	0.305
Δ kWh	-0.017	0.015	-0.026	-0.050	-0.028	-0.004	-0.006	0.054	0.068	0.020	0.019	0.018	0.024	0.023	0.032	0.013	0.155
Wt. kWh	0.000	0.001	-0.003	-0.002	0.000	0.000	0.000	0.005	0.008	0.002	0.000	0.003	0.002	0.001	0.001	0.000	0.015
Δ therm	-0.008	0.002	-0.006	-0.007	-0.006	-0.001	-0.001	0.004	0.005	0.001	0.002	0.002	0.001	0.002	0.001	0.003	-0.005
Wt. therm	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 26 – Metal Building Roof (24-hour) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	0.724	3.785	0.654	3.093	0.667	5.095	4.815	5.595	5.975	3.166	3.459	3.437	3.225	6.172	3.386	7.064	60.313
Wt. TDV	0.003	0.433	0.097	0.180	0.014	0.350	0.529	0.549	0.641	0.148	0.045	0.348	0.207	0.118	0.066	0.031	3.761
Δ kWh	0.007	0.084	0.012	0.080	0.013	0.114	0.156	0.183	0.205	0.106	0.099	0.094	0.120	0.185	0.153	0.112	1.723
Wt. kWh	0.000	0.010	0.002	0.005	0.000	0.008	0.017	0.018	0.022	0.005	0.001	0.010	0.008	0.004	0.003	0.000	0.112
Δ therm	0.004	0.017	0.004	0.014	0.004	0.024	0.020	0.023	0.023	0.011	0.014	0.015	0.011	0.022	0.007	0.036	0.250
Wt. therm	0.000	0.002	0.001	0.001	0.000	0.002	0.002	0.002	0.003	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.016

Table 27 – Wood-framed and Other Roof (Daytime) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	-0.900	0.860	-0.914	0.673	-0.949	1.342	1.510	1.819	2.045	0.776	0.818	0.797	0.792	2.296	2.246	2.382	15.594
Wt. TDV	-0.003	0.058	-0.152	0.052	-0.018	0.078	0.107	0.155	0.206	0.069	0.010	0.115	0.045	0.057	0.045	0.013	0.838
Δ kWh	-0.011	0.018	-0.019	0.018	-0.020	0.032	0.047	0.059	0.068	0.025	0.024	0.022	0.028	0.069	0.092	0.041	0.494
Wt. kWh	0.000	0.001	-0.003	0.001	0.000	0.002	0.003	0.005	0.007	0.002	0.000	0.003	0.002	0.002	0.002	0.000	0.027
Δ therm	-0.005	0.003	-0.005	0.003	-0.005	0.005	0.005	0.005	0.006	0.002	0.003	0.003	0.002	0.006	0.003	0.011	0.042
Wt. therm	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002

Table 28 – Metal Building Roof (Retail) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	-0.874	0.920	-0.858	0.680	-0.877	1.096	1.369	1.685	2.061	0.817	2.238	0.871	2.219	2.644	2.666	2.790	19.447
Wt. TDV	-0.002	0.053	-0.111	0.032	-0.012	0.073	0.098	0.157	0.236	0.069	0.057	0.153	0.161	0.059	0.050	0.016	1.088
Δ kWh	-0.013	0.026	-0.019	0.021	-0.021	0.031	0.050	0.067	0.084	0.033	0.075	0.029	0.094	0.092	0.128	0.052	0.729
Wt. kWh	0.000	0.001	-0.002	0.001	0.000	0.002	0.004	0.006	0.010	0.003	0.002	0.005	0.007	0.002	0.002	0.000	0.042
Δ therm	-0.006	0.003	-0.005	0.003	-0.005	0.005	0.004	0.005	0.006	0.002	0.007	0.003	0.005	0.007	0.003	0.013	0.051
Wt. therm	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.003

Table 29 – Wood-framed and Other Roof (24-hour) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	2.894	7.255	2.617	4.382	2.668	5.459	5.158	7.394	7.895	6.069	6.631	6.588	6.181	7.472	6.490	8.551	93.704
Wt. TDV	0.014	0.829	0.389	0.256	0.058	0.375	0.567	0.726	0.847	0.283	0.086	0.667	0.398	0.143	0.127	0.038	5.802
Δ kWh	0.030	0.160	0.047	0.113	0.050	0.122	0.167	0.241	0.271	0.203	0.190	0.181	0.229	0.224	0.293	0.136	2.659
Wt. kWh	0.000	0.018	0.007	0.007	0.001	0.008	0.018	0.024	0.029	0.009	0.002	0.018	0.015	0.004	0.006	0.001	0.168
Δ therm	0.017	0.032	0.015	0.020	0.015	0.026	0.022	0.030	0.031	0.021	0.027	0.028	0.022	0.027	0.013	0.044	0.390
Wt. therm	0.000	0.004	0.002	0.001	0.000	0.002	0.002	0.003	0.003	0.001	0.000	0.003	0.001	0.001	0.000	0.000	0.024

Table 30 – Metal Building Wall (Daytime) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	0.000	7.575	0.799	6.528	5.395	0.695	0.755	6.467	7.386	7.994	8.594	7.719	8.317	9.516	11.263	9.193	98.195
Wt. TDV	0.000	0.508	0.132	0.508	0.104	0.040	0.053	0.551	0.745	0.711	0.102	1.114	0.470	0.237	0.225	0.051	5.554
Δ kWh	0.000	0.314	0.032	0.284	0.239	0.037	0.042	0.337	0.393	0.401	0.360	0.335	0.427	0.412	0.583	0.251	4.446
Wt. kWh	0.000	0.021	0.005	0.022	0.005	0.002	0.003	0.029	0.040	0.036	0.004	0.048	0.024	0.010	0.012	0.001	0.262
Δ therm	0.000	0.022	0.003	0.021	0.021	0.002	0.002	0.012	0.013	0.012	0.021	0.020	0.015	0.019	0.008	0.038	0.230
Wt. therm	0.000	0.001	0.001	0.002	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.003	0.001	0.000	0.000	0.000	0.013

Table 31 – Metal Building Wall (Retail) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	0.000	8.923	0.768	7.291	5.592	0.000	0.000	6.967	8.983	9.648	10.781	9.318	10.620	11.982	14.222	11.361	116.458
Wt. TDV	0.000	0.515	0.099	0.340	0.079	0.000	0.000	0.649	1.029	0.812	0.273	1.632	0.768	0.269	0.269	0.065	6.800
Δ kWh	0.000	0.441	0.042	0.384	0.307	0.000	0.000	0.437	0.555	0.554	0.508	0.467	0.613	0.580	0.803	0.353	6.044
Wt. kWh	0.000	0.025	0.005	0.018	0.004	0.000	0.000	0.041	0.064	0.047	0.013	0.082	0.044	0.013	0.015	0.002	0.373
Δ therm	0.000	0.024	0.004	0.022	0.022	0.000	0.000	0.012	0.014	0.013	0.024	0.023	0.018	0.022	0.008	0.047	0.253
Wt. therm	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.002	0.001	0.001	0.004	0.001	0.001	0.000	0.000	0.014

Table 32 – Metal Building Wall (24-hour) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	9.549	12.095	10.605	12.032	10.711	7.774	8.064	10.290	11.347	12.177	14.180	12.752	12.996	15.076	15.931	16.848	192.426
Wt. TDV	0.045	1.382	1.576	0.702	0.231	0.535	0.886	1.010	1.218	0.569	0.184	1.291	0.836	0.288	0.312	0.074	11.138
Δ kWh	0.319	0.585	0.429	0.579	0.471	0.425	0.490	0.615	0.726	0.707	0.658	0.613	0.768	0.742	0.993	0.484	9.603
Wt. kWh	0.002	0.067	0.064	0.034	0.010	0.029	0.054	0.060	0.078	0.033	0.009	0.062	0.049	0.014	0.019	0.002	0.586
Δ therm	0.056	0.045	0.056	0.049	0.054	0.033	0.030	0.032	0.031	0.028	0.046	0.046	0.034	0.042	0.018	0.081	0.679
Wt. therm	0.000	0.005	0.008	0.003	0.001	0.002	0.003	0.003	0.003	0.001	0.001	0.005	0.002	0.001	0.000	0.000	0.040

Table 33 – Metal-framed Wall (Daytime) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	8.626	20.966	11.344	17.057	12.356	8.756	9.516	16.897	19.300	22.125	23.786	21.365	23.021	26.340	31.175	25.444	298.074
Wt. TDV	0.026	1.407	1.881	1.328	0.238	0.507	0.673	1.439	1.948	1.969	0.282	3.085	1.300	0.656	0.624	0.142	17.505
Δ kWh	0.303	0.870	0.454	0.742	0.547	0.467	0.526	0.882	1.028	1.109	0.997	0.926	1.181	1.140	1.613	0.695	13.478
Wt. kWh	0.001	0.058	0.075	0.058	0.011	0.027	0.037	0.075	0.104	0.099	0.012	0.134	0.067	0.028	0.032	0.004	0.821
Δ therm	0.049	0.061	0.050	0.054	0.049	0.026	0.023	0.032	0.035	0.034	0.057	0.056	0.043	0.053	0.023	0.104	0.748
Wt. therm	0.000	0.004	0.008	0.004	0.001	0.002	0.002	0.003	0.004	0.003	0.001	0.008	0.002	0.001	0.000	0.001	0.044

Table 34 – Metal-framed Wall (Retail) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	8.759	24.698	9.676	19.051	14.613	7.662	7.613	18.205	22.050	26.705	29.841	25.791	29.396	33.165	39.364	31.445	348.032
Wt. TDV	0.022	1.425	1.247	0.888	0.208	0.509	0.547	1.697	2.527	2.247	0.757	4.516	2.127	0.745	0.745	0.181	20.385
Δ kWh	0.409	1.221	0.526	1.004	0.801	0.571	0.594	1.143	1.363	1.533	1.406	1.293	1.696	1.606	2.223	0.977	18.365
Wt. kWh	0.001	0.070	0.068	0.047	0.011	0.038	0.043	0.107	0.156	0.129	0.036	0.226	0.123	0.036	0.042	0.006	1.138
Δ therm	0.056	0.068	0.046	0.058	0.057	0.025	0.021	0.031	0.035	0.036	0.066	0.062	0.049	0.062	0.023	0.130	0.824
Wt. therm	0.000	0.004	0.006	0.003	0.001	0.002	0.002	0.003	0.004	0.003	0.002	0.011	0.004	0.001	0.000	0.001	0.045

Table 35 – Metal-framed Wall (24-hour) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	26.430	33.477	26.030	29.533	26.292	20.312	19.793	25.258	27.851	33.704	39.248	35.296	35.972	41.727	44.094	46.633	511.649
Wt. TDV	0.125	3.826	3.869	1.723	0.567	1.397	2.175	2.479	2.989	1.574	0.508	3.574	2.314	0.796	0.862	0.205	28.985
Δ kWh	0.882	1.618	1.053	1.420	1.157	1.112	1.202	1.509	1.781	1.957	1.821	1.697	2.127	2.054	2.747	1.339	25.476
Wt. kWh	0.004	0.185	0.156	0.083	0.025	0.076	0.132	0.148	0.191	0.091	0.024	0.172	0.137	0.039	0.054	0.006	1.524
Δ therm	0.155	0.124	0.137	0.120	0.132	0.086	0.074	0.079	0.075	0.078	0.127	0.126	0.094	0.116	0.051	0.224	1.796
Wt. therm	0.001	0.014	0.020	0.007	0.003	0.006	0.008	0.008	0.008	0.004	0.002	0.013	0.006	0.002	0.001	0.001	0.103

Table 36 – Mass (7.0≤HC<15.0) Wall (Daytime) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	7.808	23.825	5.335	5.337	-8.827	-3.889	-5.743	-12.024	-13.922	9.003	23.941	19.461	21.111	-12.405	-13.374	19.533	65.171
Wt. TDV	0.023	1.599	0.885	0.416	-0.170	-0.225	-0.406	-1.024	-1.405	0.801	0.284	2.810	1.192	-0.309	-0.268	0.109	4.311
Δ kWh	-0.070	0.195	-0.094	-0.022	0.417	0.307	0.045	-0.198	-0.187	0.228	0.397	0.252	0.578	-0.262	-0.528	0.018	1.074
Wt. kWh	0.000	0.013	-0.016	-0.002	0.008	0.018	0.003	-0.017	-0.019	0.020	0.005	0.036	0.033	-0.007	-0.011	0.000	0.066
Δ therm	0.056	0.119	0.044	0.036	-0.114	-0.070	-0.053	-0.060	-0.061	0.027	0.094	0.086	0.064	-0.037	-0.011	0.114	0.234
Wt. therm	0.000	0.008	0.007	0.003	-0.002	-0.004	-0.004	-0.005	-0.006	0.002	0.001	0.012	0.004	-0.001	0.000	0.001	0.016

Table 37 – Mass (7.0≤HC<15.0) Wall (Retail) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	7.955	22.424	5.951	11.154	-10.899	-7.894	-10.446	9.174	13.213	21.254	34.297	27.213	31.797	-18.370	-21.271	26.814	142.366
Wt. TDV	0.020	1.294	0.767	0.520	-0.155	-0.524	-0.750	0.855	1.514	1.788	0.870	4.765	2.300	-0.413	-0.402	0.154	12.603
Δ kWh	0.062	0.821	0.092	0.349	-0.124	-0.325	-0.651	0.497	0.756	1.096	1.199	1.002	1.456	-0.686	-1.152	0.331	4.724
Wt. kWh	0.000	0.047	0.012	0.016	-0.002	-0.022	-0.047	0.046	0.087	0.092	0.030	0.175	0.105	-0.015	-0.022	0.002	0.507
Δ therm	0.064	0.094	0.050	0.061	-0.136	-0.080	-0.063	0.031	0.038	0.048	0.114	0.102	0.080	-0.050	-0.015	0.148	0.486
Wt. therm	0.000	0.005	0.006	0.003	-0.002	-0.005	-0.005	0.003	0.004	0.004	0.003	0.018	0.006	-0.001	0.000	0.001	0.040

Table 38 – Mass (7.0≤HC<15.0) Wall (24-hour) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	25.371	29.026	28.225	23.368	20.552	11.321	9.106	11.126	14.949	23.597	42.749	34.722	38.048	43.097	42.547	35.270	433.075
Wt. TDV	0.120	3.317	4.195	1.363	0.444	0.779	1.001	1.092	1.605	1.102	0.553	3.516	2.448	0.823	0.832	0.155	23.344
Δ kWh	-0.011	0.522	0.143	0.213	-0.024	0.110	0.239	0.354	0.452	0.866	1.114	0.799	1.365	1.200	2.179	0.328	9.847
Wt. kWh	0.000	0.060	0.021	0.012	-0.001	0.008	0.026	0.035	0.048	0.040	0.014	0.081	0.088	0.023	0.043	0.001	0.500
Δ therm	0.153	0.153	0.178	0.142	0.145	0.075	0.059	0.057	0.071	0.078	0.181	0.172	0.132	0.151	0.046	0.205	1.999
Wt. therm	0.001	0.018	0.026	0.008	0.003	0.005	0.006	0.006	0.008	0.004	0.002	0.017	0.008	0.003	0.001	0.001	0.118

Table 39 – Mass (15.0≤HC) Wall (Daytime) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	4.951	-1.322	-0.744	-0.603	0.123	0.000	0.000	0.000	0.000	-0.737	32.102	20.284	25.766	15.068	17.209	19.686	131.783
Wt. TDV	0.015	-0.089	-0.123	-0.047	0.002	0.000	0.000	0.000	0.000	-0.066	0.380	2.929	1.454	0.375	0.344	0.110	5.286
Δ kWh	-0.115	0.014	0.053	0.038	0.066	0.000	0.000	0.000	0.000	-0.002	0.299	0.005	0.486	0.220	0.604	-0.126	1.542
Wt. kWh	0.000	0.001	0.009	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.004	0.001	0.027	0.005	0.012	-0.001	0.062
Δ therm	0.038	-0.008	-0.009	-0.007	-0.006	0.000	0.000	0.000	0.000	-0.003	0.146	0.110	0.088	0.051	0.012	0.126	0.537
Wt. therm	0.000	-0.001	-0.002	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.016	0.005	0.001	0.000	0.001	0.022

Table 40 – Mass (15.0≤HC) Wall (Retail) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	5.587	-2.327	-0.991	-1.313	-0.165	0.000	0.000	0.000	0.000	-1.987	49.348	31.297	41.038	24.300	30.961	29.011	204.757
Wt. TDV	0.014	-0.134	-0.128	-0.061	-0.002	0.000	0.000	0.000	0.000	-0.167	1.251	5.480	2.969	0.546	0.586	0.167	10.520
Δ kWh	-0.022	-0.071	0.011	-0.023	0.028	0.000	0.000	0.000	0.000	-0.107	1.456	0.947	1.713	0.822	1.657	0.183	6.596
Wt. kWh	0.000	-0.004	0.001	-0.001	0.000	0.000	0.000	0.000	0.000	-0.009	0.037	0.166	0.124	0.018	0.031	0.001	0.365
Δ therm	0.046	-0.011	-0.011	-0.010	-0.008	0.000	0.000	0.000	0.000	-0.005	0.189	0.140	0.116	0.074	0.018	0.173	0.709
Wt. therm	0.000	-0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.024	0.008	0.002	0.000	0.001	0.038

Table 41 – Mass (15.0≤HC) Wall (24-hour) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	15.447	-3.429	0.000	0.000	0.000	-1.627	-1.718	-1.287	-1.501	-2.329	64.460	40.719	51.853	29.758	31.082	39.218	260.646
Wt. TDV	0.073	-0.392	0.000	0.000	0.000	-0.112	-0.189	-0.126	-0.161	-0.109	0.834	4.123	3.336	0.568	0.608	0.172	8.626
Δ kWh	-0.113	-0.014	0.000	0.000	0.000	0.024	-0.012	-0.011	-0.011	-0.057	1.274	0.563	1.399	0.628	1.468	0.114	5.250
Wt. kWh	-0.001	-0.002	0.000	0.000	0.000	0.002	-0.001	-0.001	-0.001	-0.003	0.016	0.057	0.090	0.012	0.029	0.001	0.198
Δ therm	0.093	-0.020	0.000	0.000	0.000	-0.012	-0.009	-0.009	-0.009	-0.009	0.300	0.227	0.200	0.115	0.030	0.237	1.134
Wt. therm	0.000	-0.002	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	0.000	0.004	0.023	0.013	0.002	0.001	0.001	0.038

Table 42 – Wood-framed and Other Wall (Daytime) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	0.507	5.816	1.198	1.579	1.305	1.042	1.133	1.564	1.787	6.138	6.599	5.927	6.386	7.307	8.648	7.059	63.998
Wt. TDV	0.002	0.390	0.199	0.123	0.025	0.060	0.080	0.133	0.180	0.546	0.078	0.856	0.361	0.182	0.173	0.039	3.428
Δ kWh	0.018	0.241	0.048	0.069	0.058	0.056	0.063	0.082	0.095	0.308	0.277	0.257	0.328	0.316	0.447	0.193	2.854
Wt. kWh	0.000	0.016	0.008	0.005	0.001	0.003	0.004	0.007	0.010	0.027	0.003	0.037	0.018	0.008	0.009	0.001	0.159
Δ therm	0.003	0.017	0.005	0.005	0.005	0.003	0.003	0.003	0.003	0.010	0.016	0.015	0.012	0.015	0.006	0.029	0.150
Wt. therm	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002	0.001	0.000	0.000	0.000	0.008

Table 43 – Wood-framed and Other Wall (Retail) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	0.515	6.852	1.152	1.764	1.353	0.000	0.000	1.686	6.942	7.408	8.279	7.155	8.155	9.201	15.491	8.723	84.675
Wt. TDV	0.001	0.395	0.148	0.082	0.019	0.000	0.000	0.157	0.795	0.623	0.210	1.253	0.590	0.207	0.293	0.050	4.825
Δ kWh	0.024	0.339	0.063	0.093	0.074	0.000	0.000	0.106	0.429	0.425	0.390	0.359	0.470	0.445	0.875	0.271	4.363
Wt. kWh	0.000	0.020	0.008	0.004	0.001	0.000	0.000	0.010	0.049	0.036	0.010	0.063	0.034	0.010	0.017	0.002	0.263
Δ therm	0.003	0.019	0.005	0.005	0.005	0.000	0.000	0.003	0.011	0.010	0.018	0.017	0.013	0.017	0.009	0.036	0.174
Wt. therm	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.003	0.001	0.000	0.000	0.000	0.010

Table 44 – Mass (15.0≤HC) Wall (24-hour) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	7.332	9.287	8.195	9.298	8.277	0.878	0.855	6.704	7.392	9.350	15.446	9.792	9.979	16.422	17.353	18.352	154.912
Wt. TDV	0.035	1.061	1.218	0.542	0.179	0.060	0.094	0.658	0.793	0.437	0.200	0.992	0.642	0.313	0.339	0.081	7.644

Δ kWh	0.245	0.449	0.331	0.447	0.364	0.048	0.052	0.401	0.473	0.543	0.717	0.471	0.590	0.808	1.081	0.527	7.547
Wt. kWh	0.001	0.051	0.049	0.026	0.008	0.003	0.006	0.039	0.051	0.025	0.009	0.048	0.038	0.015	0.021	0.002	0.394
Δ therm	0.043	0.035	0.043	0.038	0.041	0.004	0.003	0.021	0.020	0.022	0.050	0.035	0.026	0.046	0.020	0.088	0.534
Wt. therm	0.000	0.004	0.006	0.002	0.001	0.000	0.000	0.002	0.002	0.001	0.001	0.004	0.002	0.001	0.000	0.000	0.027

Table 45 – Mass Floor (Daytime) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	0.000	0.000	-1.880	-1.919	0.711	5.572	2.397	3.245	2.305	-1.816	0.000	-0.768	-0.850	3.385	3.225	4.402	18.010
Wt. TDV	0.000	0.000	-0.312	-0.149	0.014	0.323	0.170	0.276	0.233	-0.162	0.000	-0.111	-0.048	0.084	0.065	0.025	0.407
Δ kWh	0.000	0.000	0.410	0.422	0.495	0.487	0.417	0.367	0.319	0.262	0.000	0.023	0.004	-0.008	0.111	-0.052	3.257
Wt. kWh	0.000	0.000	0.068	0.033	0.010	0.028	0.030	0.031	0.032	0.023	0.000	0.003	0.000	0.000	0.002	0.000	0.260
Δ therm	0.000	0.000	-0.057	-0.061	-0.054	-0.028	-0.022	-0.029	-0.029	-0.049	0.000	-0.008	-0.006	0.022	0.006	0.034	-0.282
Wt. therm	0.000	0.000	-0.010	-0.005	-0.001	-0.002	-0.002	-0.002	-0.003	-0.004	0.000	-0.001	0.000	0.001	0.000	0.000	-0.029

Table 46 – Mass Floor (Retail) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	3.424	0.061	8.639	7.539	10.831	15.772	12.269	11.736	10.291	7.162	-5.389	0.262	-3.065	1.315	2.533	0.000	83.379
Wt. TDV	0.009	0.004	1.113	0.351	0.154	1.047	0.881	1.094	1.179	0.603	-0.137	0.046	-0.222	0.030	0.048	0.000	6.200
Δ kWh	0.645	0.448	0.580	0.639	0.751	0.762	0.745	0.598	0.508	0.386	0.082	0.387	0.088	0.001	0.142	0.000	6.761
Wt. kWh	0.002	0.026	0.075	0.030	0.011	0.051	0.053	0.056	0.058	0.032	0.002	0.068	0.006	0.000	0.003	0.000	0.472
Δ therm	-0.051	-0.059	-0.022	-0.030	-0.019	-0.005	-0.004	-0.008	-0.008	-0.019	-0.061	-0.056	-0.044	0.010	0.002	0.000	-0.374
Wt. therm	0.000	-0.003	-0.003	-0.001	0.000	0.000	0.000	-0.001	-0.001	-0.002	-0.002	-0.010	-0.003	0.000	0.000	0.000	-0.026

Table 47 – Mass Floor (24-hour) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	12.481	8.939	14.818	10.976	13.601	6.930	3.545	3.790	3.790	2.639	6.438	5.645	5.518	19.498	11.038	16.304	145.949
Wt. TDV	0.059	1.022	2.202	0.640	0.294	0.477	0.390	0.372	0.407	0.123	0.083	0.572	0.355	0.372	0.216	0.072	7.655
Δ kWh	-0.050	0.004	-0.062	-0.107	-0.079	-0.079	-0.041	-0.030	-0.012	0.015	0.073	0.007	0.075	0.235	0.495	-0.031	0.413
Wt. kWh	0.000	0.000	-0.009	-0.006	-0.002	-0.005	-0.004	-0.003	-0.001	0.001	0.001	0.001	0.005	0.004	0.010	0.000	-0.010
Δ therm	0.076	0.054	0.095	0.082	0.090	0.050	0.028	0.030	0.028	0.016	0.037	0.037	0.030	0.101	0.029	0.105	0.889
Wt. therm	0.000	0.006	0.014	0.005	0.002	0.003	0.003	0.003	0.003	0.001	0.000	0.004	0.002	0.002	0.001	0.000	0.050

Table 48 – Mass Floor (Daytime) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	-1.688	3.144	0.000	0.000	0.000	-0.742	-2.319	0.000	0.000	0.000	3.351	0.000	0.000	3.852	3.777	1.455	10.829
Wt. TDV	-0.005	0.211	0.000	0.000	0.000	-0.043	-0.164	0.000	0.000	0.000	0.040	0.000	0.000	0.096	0.076	0.008	0.218
Δ kWh	0.030	0.012	0.000	0.000	0.000	0.257	0.225	0.000	0.000	0.000	0.043	0.000	0.000	0.044	0.133	0.001	0.745
Wt. kWh	0.000	0.001	0.000	0.000	0.000	0.015	0.016	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.003	0.000	0.036
Δ therm	-0.014	0.018	0.000	0.000	0.000	-0.041	-0.035	0.000	0.000	0.000	0.016	0.000	0.000	0.017	0.006	0.009	-0.023
Wt. therm	0.000	0.001	0.000	0.000	0.000	-0.002	-0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.003

Table 49 – Other Floor (Retail) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	-2.243	0.000	2.378	-1.799	3.260	10.537	9.529	4.454	0.008	0.000	0.000	0.000	0.000	3.560	3.539	1.277	34.501
Wt. TDV	-0.006	0.000	0.306	-0.084	0.046	0.699	0.685	0.415	0.001	0.000	0.000	0.000	0.000	0.080	0.067	0.007	2.218
Δ kWh	0.392	0.000	0.283	0.158	0.345	0.493	0.558	0.228	0.022	0.000	0.000	0.000	0.000	0.065	0.172	0.002	2.718
Wt. kWh	0.001	0.000	0.036	0.007	0.005	0.033	0.040	0.021	0.002	0.000	0.000	0.000	0.000	0.001	0.003	0.000	0.151
Δ therm	-0.063	0.000	-0.035	-0.047	-0.037	-0.012	-0.012	-0.018	-0.020	0.000	0.000	0.000	0.000	0.015	0.003	0.008	-0.215
Wt. therm	0.000	0.000	-0.004	-0.002	-0.001	-0.001	-0.001	-0.002	-0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.012

Table 50 – Mass Floor (24-hour) Energy Impacts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Δ TDV	3.806	8.971	6.255	5.605	6.144	3.564	0.000	3.582	3.975	4.919	7.221	6.810	6.251	9.170	6.189	4.855	87.316
Wt. TDV	0.018	1.025	0.930	0.327	0.133	0.245	0.000	0.352	0.427	0.230	0.093	0.690	0.402	0.175	0.121	0.021	5.188
Δ kWh	-0.011	0.070	0.024	0.046	0.036	-0.007	0.000	0.047	0.065	0.091	0.123	0.088	0.138	0.156	0.271	0.023	1.159
Wt. kWh	0.000	0.008	0.004	0.003	0.001	0.000	0.000	0.005	0.007	0.004	0.002	0.009	0.009	0.003	0.005	0.000	0.058
Δ therm	0.023	0.048	0.039	0.035	0.038	0.024	0.000	0.022	0.022	0.024	0.036	0.037	0.030	0.042	0.014	0.029	0.460
Wt. therm	0.000	0.005	0.006	0.002	0.001	0.002	0.000	0.002	0.002	0.001	0.000	0.004	0.002	0.001	0.000	0.000	0.029

Energy Coefficients

TDV energy per square foot of opaque surface area is calculated through regression analysis, using the coefficients in Table 52. The coefficients are calculated for all 16 climate zones and all three occupancy types (daytime, 24-hour, and retail). Details of the models used for the three occupancy types are provided earlier in the report. Coefficients are calculated separately for floors, roofs and walls and for each of these

As described earlier the form of the regression equation is as follows:

TDV kBtu/sf = Constant + Coefficient * Wall U-factor (Btu/hr·sf·°F)

The U-factors used for each construction assembly come from the Joint Appendices for the 2005 Building Efficiency Standards. The section in the joint appendices where each category of construction can be found is given in Table 51 below.

Table 51 – Application of Energy Coefficients to Construction Categories

Type	Coefficient Type	Category of Construction
Floors	Floor Light	Table IV.20 – Standard U-factors for Wood Framed Floors with a Crawl Space Table IV.21 – Standard U-factor for Wood Framed Floors without a Crawl Space Table IV.23 – Standard U-factor for Metal Framed Floors with a Crawl Space Table IV.24 – Standard U-factor for Metal Framed Floors without a Crawl Space
	Floor Mass	Table IV.25 – Standard U-factors for Concrete Raised Floors
Roofs	Roof Attic	Table IV.1 – U-factors of Wood Framed Attic Roofs Table IV.4 – U-factors of Metal Framed Attic Roofs
	Roof Light	Table IV.2 – U-factors of Wood Framed Rafter Roofs Table IV.5 – U-factors of Metal Framed Rafter Roofs Table IV.7 – U-factors for Metal Building Roofs
	Roof Mass	Table IV.6 – U-factors for Span Deck and Concrete Roofs
Walls	Wall Light	Table IV.9 – U-factors of Wood Framed Walls Table IV.11 – U-factors of Metal Framed Walls Table IV.16 – U-factors for Metal Building Walls
	Wall Mass 15	Table IV.19 – Effective R-values for Interior or Exterior Insulation Layers (in combination with mass construction specified in N2-1 of the nonresidential ACM manual)
	Wall Mass 7	Table IV.19 – Effective R-values for Interior or Exterior Insulation Layers (in combination with mass construction specified in N2-1 of the nonresidential ACM manual)

Table 52 contains the constant and the coefficient with corresponding R^2 by construction type, occupancy schedule and climate zone. The R^2 indicates how the regression equation fits to three points of data as described in the

Energy Model and Assumptions section of this report. The closer R^2 is to 1.0 the better the linear regression model fits the data.

Table 52 – TDV DOE-2 Coefficients

Type	Occupancy	CZ	Constant	Coefficient	R^2
Wall Light	1	Daytime	126.32	72.49	0.9997
Wall Medium	1	Daytime	122.84	58.27	0.9940
Wall Heavy	1	Daytime	122.66	46.27	0.9925
Roof Light	1	Daytime	25.23	100.03	0.9996
Roof Mass	1	Daytime	23.34	82.85	0.9998
Roof Attic	1	Daytime	22.92	116.49	0.9998
Floor Light	1	Daytime	18.92	73.39	0.9973
Floor Mass	1	Daytime	17.13	54.09	0.9668
Wall Light	2	Daytime	297.31	135.26	0.9997
Wall Medium	2	Daytime	292.90	58.05	0.9899
Wall Heavy	2	Daytime	293.31	33.04	0.9811
Roof Light	2	Daytime	61.99	172.08	0.9998
Roof Mass	2	Daytime	59.94	82.19	0.9998
Roof Attic	2	Daytime	58.95	181.54	0.9998
Floor Light	2	Daytime	55.23	98.24	0.9995
Floor Mass	2	Daytime	52.81	50.23	0.9929
Wall Light	3	Daytime	181.44	79.89	1.0000
Wall Medium	3	Daytime	178.60	35.10	0.9832
Wall Heavy	3	Daytime	178.61	18.60	0.9522
Roof Light	3	Daytime	38.01	101.52	1.0000
Roof Mass	3	Daytime	36.05	56.84	0.9996
Roof Attic	3	Daytime	36.28	115.85	0.9996
Floor Light	3	Daytime	36.07	43.41	0.9908
Floor Mass	3	Daytime	34.59	10.68	0.6550
Wall Light	4	Daytime	292.62	105.29	0.9999
Wall Medium	4	Daytime	289.58	35.11	0.9827
Wall Heavy	4	Daytime	289.86	15.06	0.9328
Roof Light	4	Daytime	62.28	134.55	1.0000
Roof Mass	4	Daytime	60.23	58.34	0.9997
Roof Attic	4	Daytime	60.27	140.76	0.9997
Floor Light	4	Daytime	60.01	55.58	0.9977
Floor Mass	4	Daytime	58.15	10.90	0.7143
Wall Light	5	Daytime	209.46	87.01	0.9998
Wall Medium	5	Daytime	205.15	18.39	0.9557
Wall Heavy	5	Daytime	206.60	-3.06	0.1598
Roof Light	5	Daytime	44.24	105.40	0.9998
Roof Mass	5	Daytime	41.21	45.13	0.9996
Roof Attic	5	Daytime	42.35	114.81	0.9996
Floor Light	5	Daytime	42.00	47.25	0.9852
Floor Mass	5	Daytime	40.48	-4.04	0.0944
Wall Light	6	Daytime	244.43	69.49	1.0000

Type	Occupancy	CZ	Constant	Coefficient	R^2
Wall Medium	6	Daytime	242.83	8.10	0.7726
Wall Heavy	6	Daytime	243.38	-7.58	0.9108
Roof Light	6	Daytime	53.07	83.90	1.0000
Roof Mass	6	Daytime	51.38	24.18	0.9993
Roof Attic	6	Daytime	51.87	90.71	0.9993
Floor Light	6	Daytime	56.08	4.44	0.3242
Floor Mass	6	Daytime	55.25	-31.66	0.9141
Wall Light	7	Daytime	269.20	75.52	1.0000
Wall Medium	7	Daytime	267.58	11.96	0.9427
Wall Heavy	7	Daytime	266.28	12.06	0.8292
Roof Light	7	Daytime	58.32	94.40	1.0000
Roof Mass	7	Daytime	57.09	32.67	0.9994
Roof Attic	7	Daytime	57.24	94.64	0.9994
Floor Light	7	Daytime	60.42	13.89	0.9009
Floor Mass	7	Daytime	59.82	-13.62	0.9540
Wall Light	8	Daytime	334.75	104.30	1.0000
Wall Medium	8	Daytime	333.22	25.05	0.9780
Wall Heavy	8	Daytime	333.35	5.54	0.9101
Roof Light	8	Daytime	72.91	113.67	1.0000
Roof Mass	8	Daytime	70.91	40.21	0.9996
Roof Attic	8	Daytime	71.25	117.99	0.9996
Floor Light	8	Daytime	74.05	25.69	0.9622
Floor Mass	8	Daytime	72.75	-18.44	0.8312
Wall Light	9	Daytime	368.32	119.13	0.9999
Wall Medium	9	Daytime	365.49	29.00	0.9744
Wall Heavy	9	Daytime	366.28	4.30	0.6126
Roof Light	9	Daytime	80.03	127.80	1.0000
Roof Mass	9	Daytime	78.04	37.33	0.9997
Roof Attic	9	Daytime	78.08	130.99	0.9997
Floor Light	9	Daytime	79.01	45.16	0.9812
Floor Mass	9	Daytime	78.15	-13.09	0.7372
Wall Light	10	Daytime	396.77	142.74	0.9999
Wall Medium	10	Daytime	393.60	44.35	0.9886
Wall Heavy	10	Daytime	394.24	18.44	0.9613
Roof Light	10	Daytime	85.52	155.30	0.9998
Roof Mass	10	Daytime	83.41	56.14	0.9998
Roof Attic	10	Daytime	83.14	156.42	0.9998
Floor Light	10	Daytime	82.83	65.72	0.9960
Floor Mass	10	Daytime	81.51	8.07	0.5084
Wall Light	11	Daytime	375.05	153.46	0.9999
Wall Medium	11	Daytime	370.68	92.08	0.9951
Wall Heavy	11	Daytime	371.15	68.89	0.9950
Roof Light	11	Daytime	80.47	163.51	0.9999
Roof Mass	11	Daytime	78.40	100.03	0.9998
Roof Attic	11	Daytime	77.34	180.36	0.9998

Type	Occupancy	CZ	Constant	Coefficient	R^2
Floor Light	11	Daytime	72.20	104.71	0.9996
Floor Mass	11	Daytime	70.82	57.42	0.9957
Wall Light	12	Daytime	350.81	137.84	0.9999
Wall Medium	12	Daytime	346.49	74.85	0.9918
Wall Heavy	12	Daytime	346.96	51.09	0.9899
Roof Light	12	Daytime	74.90	159.38	0.9999
Roof Mass	12	Daytime	72.64	89.76	0.9998
Roof Attic	12	Daytime	72.12	173.69	0.9998
Floor Light	12	Daytime	68.53	90.65	0.9994
Floor Mass	12	Daytime	66.88	40.41	0.9814
Wall Light	13	Daytime	398.79	148.52	0.9999
Wall Medium	13	Daytime	394.98	81.20	0.9955
Wall Heavy	13	Daytime	395.64	58.69	0.9955
Roof Light	13	Daytime	85.94	158.48	0.9999
Roof Mass	13	Daytime	84.05	91.75	0.9999
Roof Attic	13	Daytime	82.96	171.47	0.9999
Floor Light	13	Daytime	79.84	89.40	0.9997
Floor Mass	13	Daytime	78.89	44.73	0.9952
Wall Light	14	Daytime	424.72	169.93	0.9999
Wall Medium	14	Daytime	418.76	97.68	0.9934
Wall Heavy	14	Daytime	419.48	66.67	0.9919
Roof Light	14	Daytime	90.62	191.36	0.9998
Roof Mass	14	Daytime	88.19	113.76	0.9999
Roof Attic	14	Daytime	86.72	207.36	0.9999
Floor Light	14	Daytime	81.49	120.37	1.0000
Floor Mass	14	Daytime	79.52	69.08	0.9995
Wall Light	15	Daytime	623.48	201.13	1.0000
Wall Medium	15	Daytime	619.67	105.31	0.9964
Wall Heavy	15	Daytime	620.80	76.15	0.9972
Roof Light	15	Daytime	136.81	187.17	1.0000
Roof Mass	15	Daytime	134.77	96.06	0.9998
Roof Attic	15	Daytime	133.49	191.53	0.9998
Floor Light	15	Daytime	127.63	118.03	0.9975
Floor Mass	15	Daytime	126.26	65.81	0.9898
Wall Light	16	Daytime	335.02	164.16	0.9999
Wall Medium	16	Daytime	329.34	122.08	0.9970
Wall Heavy	16	Daytime	329.74	98.43	0.9974
Roof Light	16	Daytime	69.82	198.47	0.9998
Roof Mass	16	Daytime	67.96	142.00	0.9999
Roof Attic	16	Daytime	65.49	224.18	0.9999
Floor Light	16	Daytime	54.73	161.72	1.0000
Floor Mass	16	Daytime	51.55	125.78	0.9991
Wall Light	1	Retail	76.29	73.60	1.0000
Wall Medium	1	Retail	74.19	59.37	0.9936
Wall Heavy	1	Retail	73.56	52.21	0.9904

Type	Occupancy	CZ	Constant	Coefficient	R^2
Roof Light	1	Retail	19.77	97.08	0.9999
Roof Mass	1	Retail	17.39	79.98	0.9831
Roof Attic	1	Retail	18.91	107.40	0.9988
Floor Light	1	Retail	22.07	11.80	0.6847
Floor Mass	1	Retail	22.40	-15.22	0.6074
Wall Light	2	Retail	255.04	159.34	0.9999
Wall Medium	2	Retail	251.31	86.25	0.9911
Wall Heavy	2	Retail	251.83	58.17	0.9904
Roof Light	2	Retail	70.07	183.93	1.0000
Roof Mass	2	Retail	67.63	88.20	0.9880
Roof Attic	2	Retail	67.73	194.26	0.9994
Floor Light	2	Retail	69.22	59.12	0.9814
Floor Mass	2	Retail	68.28	-0.27	0.0005
Wall Light	3	Retail	145.96	76.79	1.0000
Wall Medium	3	Retail	143.69	39.15	0.9780
Wall Heavy	3	Retail	143.37	24.77	0.9467
Roof Light	3	Retail	40.42	95.29	0.9995
Roof Mass	3	Retail	38.10	51.61	0.9486
Roof Attic	3	Retail	39.59	108.65	0.9984
Floor Light	3	Retail	46.43	-14.24	0.8180
Floor Mass	3	Retail	46.38	-49.09	0.9669
Wall Light	4	Retail	275.42	117.60	1.0000
Wall Medium	4	Retail	272.44	54.95	0.9893
Wall Heavy	4	Retail	272.60	32.82	0.9766
Roof Light	4	Retail	77.28	136.06	0.9999
Roof Mass	4	Retail	75.06	55.17	0.9704
Roof Attic	4	Retail	75.90	145.19	0.9993
Floor Light	4	Retail	81.49	10.77	0.6624
Floor Mass	4	Retail	80.96	-42.84	0.9376
Wall Light	5	Retail	163.42	90.20	0.9998
Wall Medium	5	Retail	162.09	22.71	0.9480
Wall Heavy	5	Retail	162.48	4.13	0.4894
Roof Light	5	Retail	45.74	97.49	0.9993
Roof Mass	5	Retail	43.38	34.46	0.8647
Roof Attic	5	Retail	45.95	99.99	0.9979
Floor Light	5	Retail	52.58	-19.52	0.8943
Floor Mass	5	Retail	52.49	-61.54	0.9807
Wall Light	6	Retail	223.05	60.81	0.9992
Wall Medium	6	Retail	221.58	16.45	0.8922
Wall Heavy	6	Retail	221.83	1.85	0.1426
Roof Light	6	Retail	64.09	68.50	0.9957
Roof Mass	6	Retail	62.99	11.42	0.5778
Roof Attic	6	Retail	64.08	70.90	0.9955
Floor Light	6	Retail	75.95	-63.10	0.9948
Floor Mass	6	Retail	77.24	-89.61	0.9939

Type	Occupancy	CZ	Constant	Coefficient	R^2
Wall Light	7	Retail	249.95	60.42	0.9058
Wall Medium	7	Retail	251.53	21.76	0.9575
Wall Heavy	7	Retail	251.79	5.26	0.6500
Roof Light	7	Retail	69.80	85.56	0.9988
Roof Mass	7	Retail	68.81	25.96	0.9807
Roof Attic	7	Retail	69.41	87.23	0.9980
Floor Light	7	Retail	81.79	-57.06	0.9998
Floor Mass	7	Retail	81.13	-69.71	0.9941
Wall Light	8	Retail	317.76	112.38	1.0000
Wall Medium	8	Retail	315.78	45.19	0.9984
Wall Heavy	8	Retail	315.92	20.84	0.9543
Roof Light	8	Retail	91.06	105.29	0.9995
Roof Mass	8	Retail	89.67	34.02	0.9528
Roof Attic	8	Retail	90.25	116.13	0.9984
Floor Light	8	Retail	99.38	-26.67	0.9562
Floor Mass	8	Retail	98.82	-66.68	0.9864
Wall Light	9	Retail	360.00	136.11	1.0000
Wall Medium	9	Retail	356.70	56.46	0.9872
Wall Heavy	9	Retail	357.22	28.92	0.9682
Roof Light	9	Retail	102.87	128.79	0.9998
Roof Mass	9	Retail	100.68	34.52	0.9085
Roof Attic	9	Retail	101.38	137.90	0.9988
Floor Light	9	Retail	108.29	-0.05	0.0001
Floor Mass	9	Retail	107.90	-58.47	0.9887
Wall Light	10	Retail	385.27	172.29	0.9999
Wall Medium	10	Retail	381.59	81.75	0.9949
Wall Heavy	10	Retail	382.32	49.67	0.9909
Roof Light	10	Retail	109.31	163.37	1.0000
Roof Mass	10	Retail	106.78	62.04	0.9698
Roof Attic	10	Retail	107.04	167.33	0.9992
Floor Light	10	Retail	111.84	31.07	0.9534
Floor Mass	10	Retail	111.22	-31.83	0.9244
Wall Light	11	Retail	343.65	192.52	1.0000
Wall Medium	11	Retail	338.77	131.91	0.9956
Wall Heavy	11	Retail	338.96	105.90	0.9953
Roof Light	11	Retail	96.42	186.48	1.0000
Roof Mass	11	Retail	93.63	118.96	0.9929
Roof Attic	11	Retail	93.65	201.41	0.9997
Floor Light	11	Retail	92.06	84.21	0.9916
Floor Mass	11	Retail	91.45	23.95	0.8212
Wall Light	12	Retail	319.58	166.39	0.9999
Wall Medium	12	Retail	315.03	104.67	0.9941
Wall Heavy	12	Retail	315.20	78.83	0.9938
Roof Light	12	Retail	89.37	174.28	1.0000
Roof Mass	12	Retail	86.54	100.45	0.9891

Type	Occupancy	CZ	Constant	Coefficient	R^2
Roof Attic	12	Retail	87.06	186.53	0.9996
Floor Light	12	Retail	87.51	63.89	0.9828
Floor Mass	12	Retail	86.81	-1.17	0.0097
Wall Light	13	Retail	380.71	189.65	0.9999
Wall Medium	13	Retail	376.56	122.30	0.9973
Wall Heavy	13	Retail	377.16	93.48	0.9973
Roof Light	13	Retail	107.28	184.93	1.0000
Roof Mass	13	Retail	104.94	108.39	0.9944
Roof Attic	13	Retail	104.59	192.12	0.9998
Floor Light	13	Retail	104.96	70.65	0.9911
Floor Mass	13	Retail	104.65	13.62	0.6380
Wall Light	14	Retail	389.05	213.97	0.9998
Wall Medium	14	Retail	383.10	144.65	0.9963
Wall Heavy	14	Retail	383.82	107.52	0.9963
Roof Light	14	Retail	108.49	220.37	0.9999
Roof Mass	14	Retail	105.41	135.66	0.9959
Roof Attic	14	Retail	104.81	235.28	0.9998
Floor Light	14	Retail	101.84	111.25	0.9953
Floor Mass	14	Retail	100.81	43.83	0.9296
Wall Light	15	Retail	615.39	253.96	1.0000
Wall Medium	15	Retail	606.80	167.49	0.9987
Wall Heavy	15	Retail	607.38	137.00	0.9986
Roof Light	15	Retail	175.14	222.20	0.9997
Roof Mass	15	Retail	173.61	114.01	0.9900
Roof Attic	15	Retail	172.38	219.81	0.9997
Floor Light	15	Retail	169.01	110.58	0.9987
Floor Mass	15	Retail	166.76	51.70	0.9975
Wall Light	16	Retail	255.06	202.87	0.9999
Wall Medium	16	Retail	249.03	167.59	0.9972
Wall Heavy	16	Retail	248.77	145.05	0.9972
Roof Light	16	Retail	68.64	232.47	1.0000
Roof Mass	16	Retail	65.25	179.76	0.9971
Roof Attic	16	Retail	65.26	250.01	0.9998
Floor Light	16	Retail	57.68	141.89	0.9951
Floor Mass	16	Retail	55.65	86.00	0.9501
Wall Light	1	24-hour	285.47	170.51	0.9998
Wall Medium	1	24-hour	285.61	158.57	0.9999
Wall Heavy	1	24-hour	286.23	144.37	0.9998
Roof Light	1	24-hour	56.69	241.17	0.9998
Roof Mass	1	24-hour	56.97	213.10	0.9994
Roof Attic	1	24-hour	56.09	218.71	0.9999
Floor Light	1	24-hour	26.98	271.87	1.0000
Floor Mass	1	24-hour	26.36	265.55	0.9997
Wall Light	2	24-hour	349.64	215.98	0.9998
Wall Medium	2	24-hour	348.81	111.64	1.0000

Type	Occupancy	CZ	Constant	Coefficient	R^2
Wall Heavy	2	24-hour	349.20	85.71	0.9999
Roof Light	2	24-hour	68.70	315.45	0.9999
Roof Mass	2	24-hour	67.47	190.51	1.0000
Roof Attic	2	24-hour	69.33	267.29	0.9999
Floor Light	2	24-hour	46.81	242.47	1.0000
Floor Mass	2	24-hour	45.14	190.18	1.0000
Wall Light	3	24-hour	213.35	160.68	1.0000
Wall Medium	3	24-hour	213.35	108.56	1.0000
Wall Heavy	3	24-hour	213.82	89.78	1.0000
Roof Light	3	24-hour	41.39	218.06	1.0000
Roof Mass	3	24-hour	40.78	167.97	1.0000
Roof Attic	3	24-hour	41.93	191.99	1.0000
Floor Light	3	24-hour	21.82	195.46	0.9998
Floor Mass	3	24-hour	20.62	176.41	0.9997
Wall Light	4	24-hour	275.06	182.30	0.9999
Wall Medium	4	24-hour	274.57	89.88	0.9995
Wall Heavy	4	24-hour	275.01	66.34	0.9994
Roof Light	4	24-hour	54.02	257.77	1.0000
Roof Mass	4	24-hour	52.72	153.93	0.9995
Roof Attic	4	24-hour	55.03	215.08	1.0000
Floor Light	4	24-hour	39.32	175.15	0.9997
Floor Mass	4	24-hour	37.81	130.67	0.9996
Wall Light	5	24-hour	210.14	162.30	0.9999
Wall Medium	5	24-hour	209.88	79.05	0.9999
Wall Heavy	5	24-hour	210.00	60.49	0.9992
Roof Light	5	24-hour	40.43	222.35	0.9999
Roof Mass	5	24-hour	39.28	148.23	0.9998
Roof Attic	5	24-hour	41.50	181.95	0.9999
Floor Light	5	24-hour	21.67	192.00	0.9998
Floor Mass	5	24-hour	20.06	161.91	0.9997
Wall Light	6	24-hour	149.25	125.38	1.0000
Wall Medium	6	24-hour	149.11	55.77	0.9972
Wall Heavy	6	24-hour	149.51	40.67	0.9987
Roof Light	6	24-hour	28.05	181.96	1.0000
Roof Mass	6	24-hour	27.37	113.99	0.9991
Roof Attic	6	24-hour	29.23	140.70	1.0000
Floor Light	6	24-hour	19.26	111.38	0.9985
Floor Mass	6	24-hour	17.53	94.94	0.9944
Wall Light	7	24-hour	157.78	122.18	1.0000
Wall Medium	7	24-hour	157.26	44.86	0.9974
Wall Heavy	7	24-hour	156.11	42.95	0.9880
Roof Light	7	24-hour	30.41	171.95	1.0000
Roof Mass	7	24-hour	29.92	96.47	1.0000
Roof Attic	7	24-hour	31.47	132.27	1.0000
Floor Light	7	24-hour	24.39	90.07	0.9985

Type	Occupancy	CZ	Constant	Coefficient	R^2
Floor Mass	7	24-hour	23.02	72.35	0.9999
Wall Light	8	24-hour	216.27	155.91	1.0000
Wall Medium	8	24-hour	214.95	54.81	0.9895
Wall Heavy	8	24-hour	215.91	32.17	0.9936
Roof Light	8	24-hour	42.97	199.83	1.0000
Roof Mass	8	24-hour	41.87	109.89	0.9998
Roof Attic	8	24-hour	43.37	163.28	1.0000
Floor Light	8	24-hour	34.98	111.94	0.9987
Floor Mass	8	24-hour	32.91	77.34	0.9940
Wall Light	9	24-hour	257.53	171.92	1.0000
Wall Medium	9	24-hour	255.91	63.88	0.9956
Wall Heavy	9	24-hour	256.21	37.51	0.9914
Roof Light	9	24-hour	51.98	213.39	1.0000
Roof Mass	9	24-hour	50.37	107.07	0.9977
Roof Attic	9	24-hour	52.41	175.64	1.0000
Floor Light	9	24-hour	42.80	124.22	0.9991
Floor Mass	9	24-hour	40.59	77.35	0.9957
Wall Light	10	24-hour	320.24	217.44	1.0000
Wall Medium	10	24-hour	318.16	90.76	0.9969
Wall Heavy	10	24-hour	318.87	58.24	0.9952
Roof Light	10	24-hour	64.77	263.87	1.0000
Roof Mass	10	24-hour	63.87	134.27	0.9992
Roof Attic	10	24-hour	65.13	217.56	1.0000
Floor Light	10	24-hour	53.43	153.72	0.9999
Floor Mass	10	24-hour	50.48	109.94	0.9984
Wall Light	11	24-hour	416.09	253.22	1.0000
Wall Medium	11	24-hour	414.95	164.42	0.9999
Wall Heavy	11	24-hour	415.25	138.33	0.9997
Roof Light	11	24-hour	85.98	288.29	1.0000
Roof Mass	11	24-hour	84.98	205.92	0.9998
Roof Attic	11	24-hour	84.84	270.93	1.0000
Floor Light	11	24-hour	64.99	225.65	0.9999
Floor Mass	11	24-hour	63.04	183.94	1.0000
Wall Light	12	24-hour	371.06	227.71	1.0000
Wall Medium	12	24-hour	370.26	133.55	0.9999
Wall Heavy	12	24-hour	371.17	102.57	0.9999
Roof Light	12	24-hour	75.33	286.43	1.0000
Roof Mass	12	24-hour	73.94	186.46	0.9998
Roof Attic	12	24-hour	75.09	258.22	1.0000
Floor Light	12	24-hour	56.27	212.82	0.9999
Floor Mass	12	24-hour	54.80	161.28	1.0000
Wall Light	13	24-hour	401.07	232.08	0.9999
Wall Medium	13	24-hour	399.52	146.34	0.9998
Wall Heavy	13	24-hour	400.18	118.12	0.9998
Roof Light	13	24-hour	83.06	268.75	1.0000

Type	Occupancy	CZ	Constant	Coefficient	R^2
Roof Mass	13	24-hour	82.20	184.10	0.9999
Roof Attic	13	24-hour	82.04	246.21	1.0000
Floor Light	13	24-hour	65.84	195.34	1.0000
Floor Mass	13	24-hour	63.88	157.65	1.0000
Wall Light	14	24-hour	466.17	269.21	0.9999
Wall Medium	14	24-hour	463.96	165.76	0.9997
Wall Heavy	14	24-hour	464.70	131.67	0.9997
Roof Light	14	24-hour	95.70	324.85	0.9999
Roof Mass	14	24-hour	95.05	229.38	1.0000
Roof Attic	14	24-hour	94.58	300.35	1.0000
Floor Light	14	24-hour	73.40	247.84	1.0000
Floor Mass	14	24-hour	70.92	203.10	1.0000
Wall Light	15	24-hour	526.27	284.47	1.0000
Wall Medium	15	24-hour	516.46	163.64	0.9990
Wall Heavy	15	24-hour	516.48	137.53	0.9982
Roof Light	15	24-hour	111.18	282.17	0.9996
Roof Mass	15	24-hour	110.14	175.33	0.9987
Roof Attic	15	24-hour	108.96	256.90	1.0000
Floor Light	15	24-hour	95.51	193.39	0.9999
Floor Mass	15	24-hour	92.39	131.40	0.9932
Wall Light	16	24-hour	512.69	300.86	0.9999
Wall Medium	16	24-hour	512.55	220.44	1.0000
Wall Heavy	16	24-hour	513.34	196.09	1.0000
Roof Light	16	24-hour	104.79	371.78	0.9999
Roof Mass	16	24-hour	104.08	287.74	1.0000
Roof Attic	16	24-hour	103.58	345.32	1.0000
Floor Light	16	24-hour	69.58	346.76	1.0000
Floor Mass	16	24-hour	68.52	296.44	1.0000