CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

2008 California Energy Commission Title 24 Building Energy Efficiency Standards
October 25, 2005

Draft Report
Insulation Requirements

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Table of Contents

Overview ... **3**

Description ... 3
Energy Benefits ... 3
Non-energy Benefits ... 3
Environmental Impact ... 3
Type of Change ... 4
Technology Measures ... 4
Analysis Tools ... 4
Relationship to Other Measures ... 4

Methodology ... **5**

Approach ... 5
Categories of Construction ... 5
Cost Data ... 6
Energy Use for Each Construction Assembly ... 11
Life Cycle Cost Model ... 14

Results ... **15**

2005 versus 2008 Insulation Level Comparisons ... 15
Cost-effectiveness ... 23

Recommendations ... **23**

Proposed Standards Language ... 25
Alternate Calculation Manual ... 25

Bibliography and Other Research ... **25**

Acknowledgments ... **26**

Appendices ... **27**

Energy Coefficients ... 27
Construction Categories and How They Relate to the Proposed Criteria ... 37

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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 to achieve equivalent U-factor performance for this construction type compared to other roof types.

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; to 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 CEC approved life-cycle cost methodology.

Description

The proposed change is a modification to the prescriptive insulation requirements for nonresidential 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 taken from construction data listed in Joint Appendix IV are used in the analysis.

Non-energy Benefits

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

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]

[1] The reduction in emissions due to redueed 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.

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 that 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 used 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.

Relationship to Other Measures

Heating and cooling loads will be impacted by improved insulation levels and heating and cooling systems may possibly be downsized.

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. The initial cost of each construction assembly was estimated from nationally published data[2] but cross checked against regional data for California[3].

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., highrise 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

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 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

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[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.

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. Thesc 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. 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 costs 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. The multiplier and markup is not represented below.

Insulation Costs

Table 1 – Cavity Insulation Costs

R-value	Material Cost	16" Labor Cost	24" Labor Cost	Total 16" Cost	Total 24" Cost	DEER Cost
11	0.24	0.20	0.17	0.44	0.41	
13	***0.32***	***0.20***	***0.17***	***0.52***	***0.49***	
15	***0.35***	***0.20***	***0.17***	***0.55***	***0.52***	0.61
19	0.48	0.24	0.20	0.72	0.68	0.65
21	***0.45***	***0.24***	***0.20***	***0.69***	***0.65***	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						

Table 2 – Rigid Insulation Costs

R-value	Material Cost	Labor Cost	Total Cost
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 3 – Rigid Insulation Costs from Regression Only

R-value	Material Cost	Labor Cost	Total Cost
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 4 – Attic Insulation Costs

R-value	Material Cost	Labor Cost	Total Cost
None	0	0	0
R-11	***0.12***	***0.11***	***0.23***
R-13	0.13	0.13	0.26
R-19	0.21	0.17	0.38
R-22	0.26	0.22	0.48
R-25	***0.28***	***0.23***	***0.51***
R-30	0.34	0.25	0.59
R-38	0.43	0.36	0.79
R-49	***0.57***	***0.44***	***1.01***
R-60	***0.7***	***0.54***	***1.24***
Attic insulation is assumed to be blown in insulation as the least cost to the contractor.			
CostWorks description: blown-in insulation, ceilings, with open access, cellulose			

Table 5 – Cement Insulation Costs

Inches	Material Cost	Labor Cost	Total Cost
2	0.51	0.17	0.68
3	0.76	0.22	0.98
4	***1.01***	***0.27***	***1.28***
6	***1.51***	***0.37***	***1.88***
CostWorks description: insulating roof fill, perlite/vermiculite, 1:6 ready mix			

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 6 – Wood Framing Costs

	Frame Size	Material Cost	Labor Cost	Total Cost	Square Foot Cost	Incremental Cost
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 7 – Metal Framing Costs

	Frame Size	Material Cost	Labor Cost	Total Cost	Square Foot Cost	Incremental Cost
16 in. O.C.	2x4	13.25	8.45	21.7	2.17	0
	2x6	16.65	8.55	25.2	2.52	0.35
	2x8	20.5	8.7	29.2	2.92	0.75
	2x10	***24.04***	***8.96***	***33.00***	***3.30***	***1.13***
	2x12	***27.66***	***9.17***	***36.83***	***3.68***	***1.51***
24 in. O.C.	2x4	9.6	6.1	15.7	1.57	0
	2x6	12.1	6.25	18.35	1.835	0.265
	2x8	14.95	6.35	21.3	2.13	0.56
	2x10	***17.52***	***6.57***	***24.10***	***2.41***	***0.84***
	2x12	***20.17***	***6.75***	***26.92***	***2.69***	***1.12***

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

Attic roof framing costs were excluded from the calculation because additional insulation may be added to the attic without altering the framing. 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 16 in. O.C. framing as the basis.

Table 8 – Wood Rafters Roof Costs

Framing Size	Material Cost	Labor Cost	Total Cost	16" Total Cost	24" Total Cost	16" Incremental Cost	24" Incremental Cost
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 9 – Metal Rafter Roof Costs

Framing Size	Material Cost	Labor Cost	Total Cost	16" Total Cost	24" Total Cost	16" Incremental Cost	24" Incremental Cost
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***	***4.48***	***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

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 10 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 10 – 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 12 through Table 14 below. From these runs, a simple equation was developed to give TDV energy use per square foot of surfacc 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.

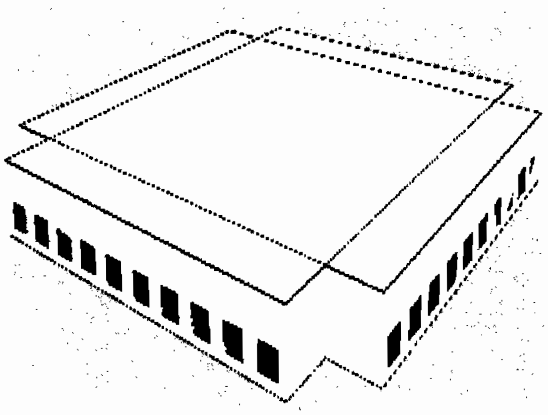
The constants and coefficients, along with the R^2 for the coefficient can be found in Table 22 – TDV DOE-2 Coefficients of the Appendix. Separate coefficients are calculated for each of three occupancy types and sixteen climate zones. For each of these cases, light and heavy mass constructions were considered. For roofs, constructions with and without attics were considered. In all, six different conditions were considered. The six models were put through a DOE-2 simulation and hourly TDV factors were applied. Then a regression was performed on the results determining the wall constant and coefficient for each climate zone and each occupancy in TDV. After the constant and coefficient were determined, the U-factor was applied to the TDV equation above to determine TDV energy use.

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 C coefficients is developed for each class of construction and fenestration, climate zone and occupancy type. These 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 is set to 30% for daytime and 24-hour occupancy and 10% 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
- Plan View & 3D View



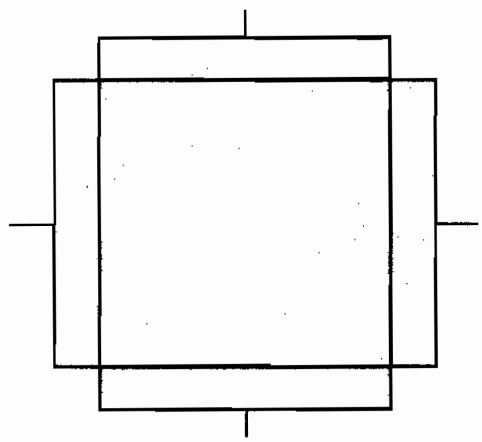


Figure 1 – Five-Zone DOE-2 Model

- Internal loads

Table 11 – 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
    - 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 12 – 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, IN76, GP01)	0.095
Mass	Medium	(RG01, BR01, CC14, IN71, GP01)	0.281
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 13 – 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, WWF19, GP01)	0.053
Light	High	(SC01, BP01, WMF00, GP01)	0.417
Mass7	Low	(SC01, IN36, CB49)	0.065
Mass7	Medium	(SC01, IN33, CB49)	0.143
Mass7	High	(SC01, CB49)	0.351
Mass15	Low	(SC01, IN36, CB32)	0.066
Mass15	Medium	(SC01, IN33, CB32)	0.147
Mass15	High	(SC01, CB32)	0.381

Table 14 – 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:

$$\mathbf{LCC = Initial\_Cost + PV_{TDV} \times TDV}$$

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 which is determined to be 0.129 for 30-year nonresidential measures

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

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

Results

2005 versus 2008 Insulation Level Comparisons

The tables below provide a comparison between the current standard and the proposed standard for certain representative 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.

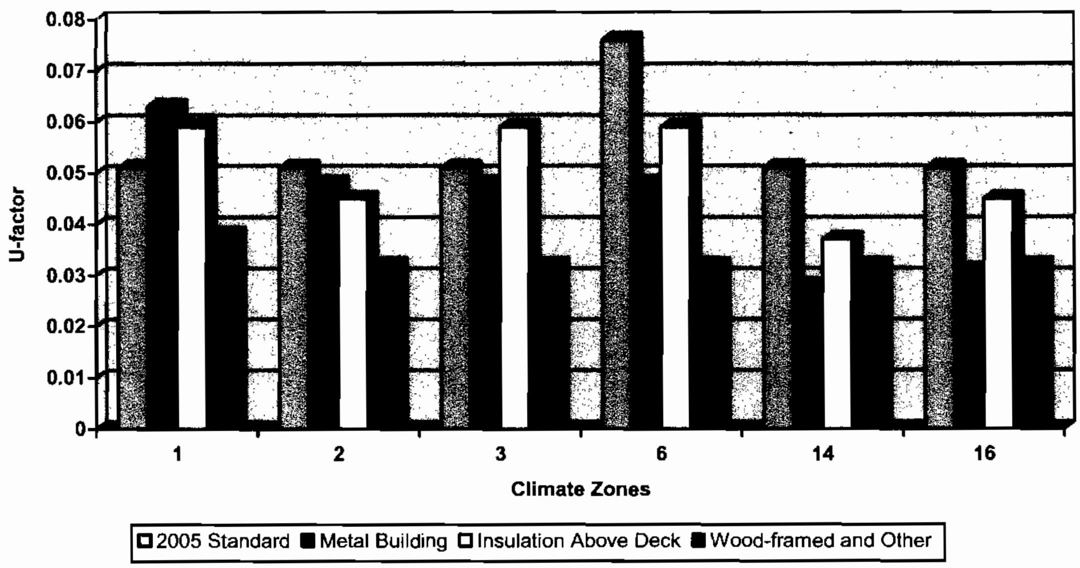


Figure 2 – Daytime Roof Insulation Level Comparison

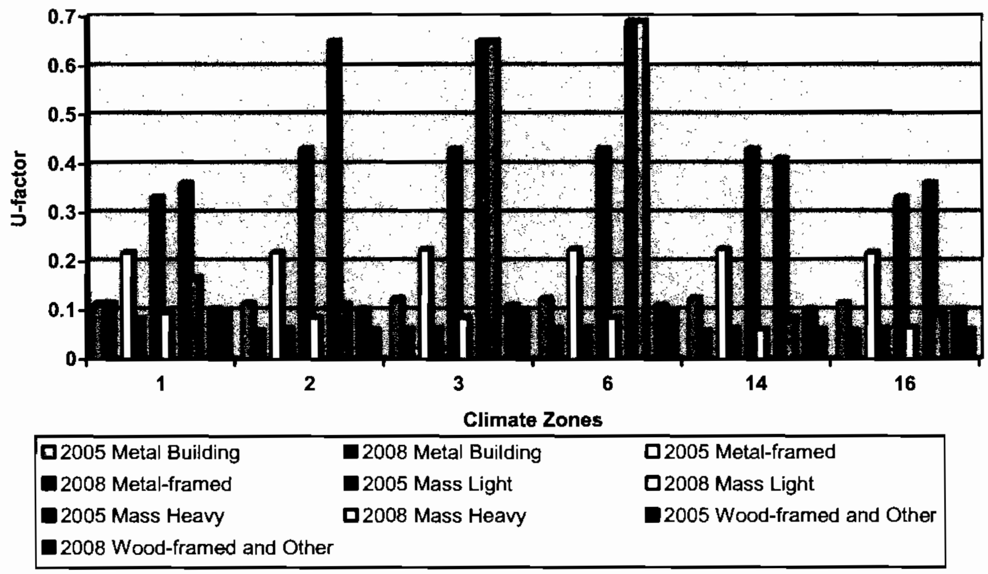


Figure 3 – Daytime Wall Insulation Level Comparison

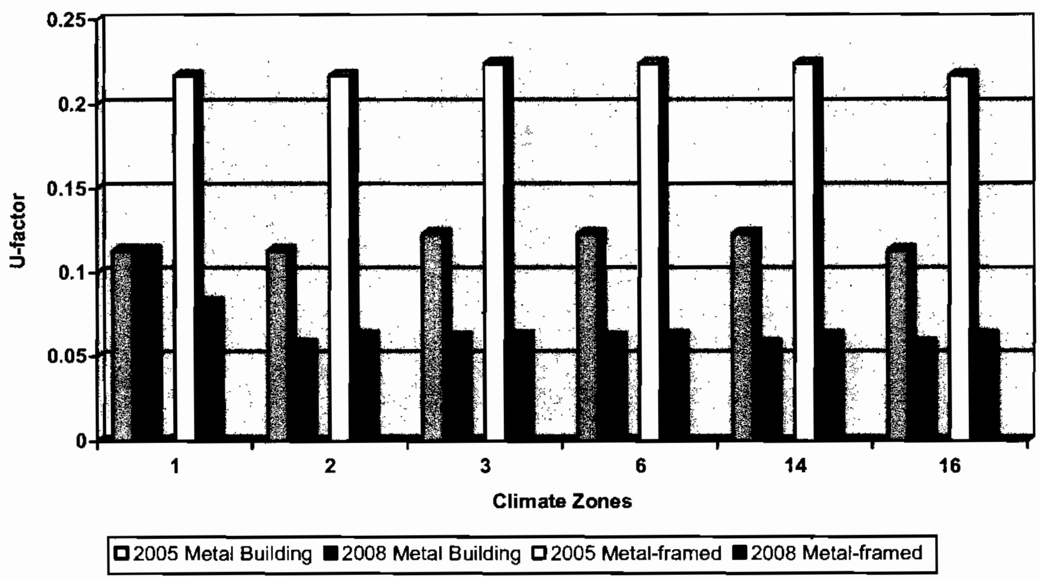


Figure 4 – Daytime (Metal) Wall Insulation Level Comparison

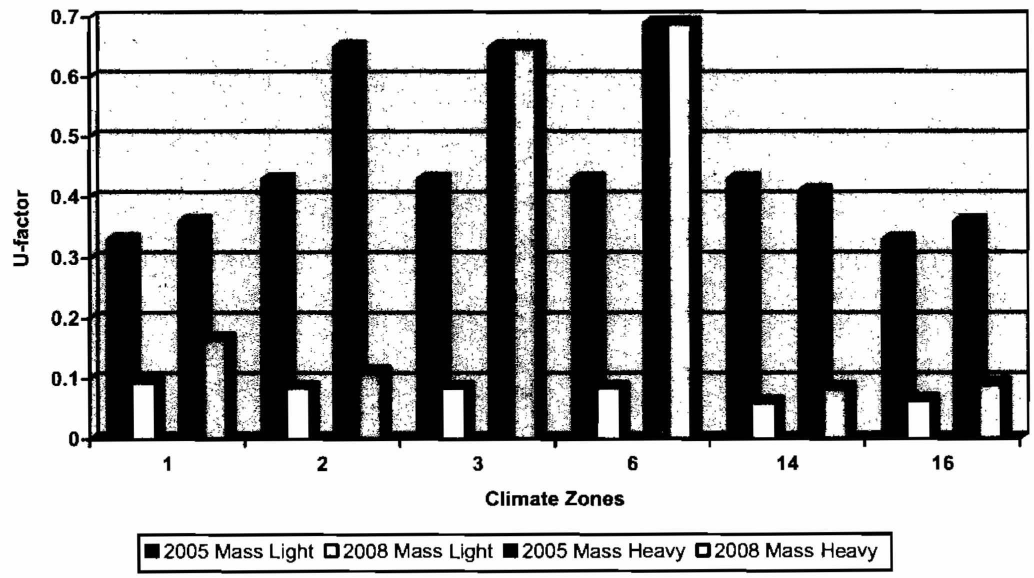


Figure 5 – Daytime (Mass) Wall Insulation Level Comparison

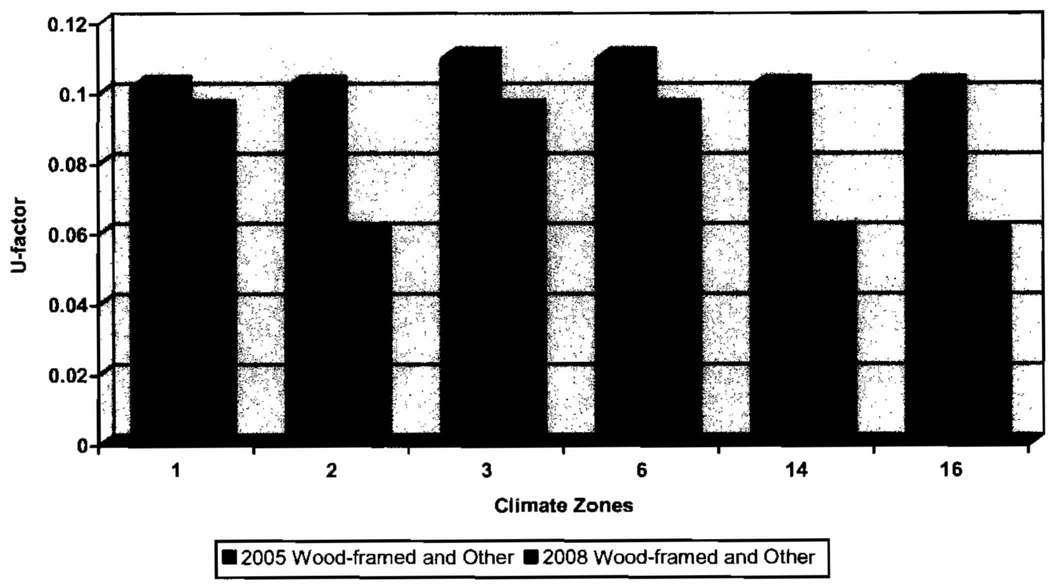


Figure 6 – Daytime (Wood and Other) Wall Insulation Level Comparison

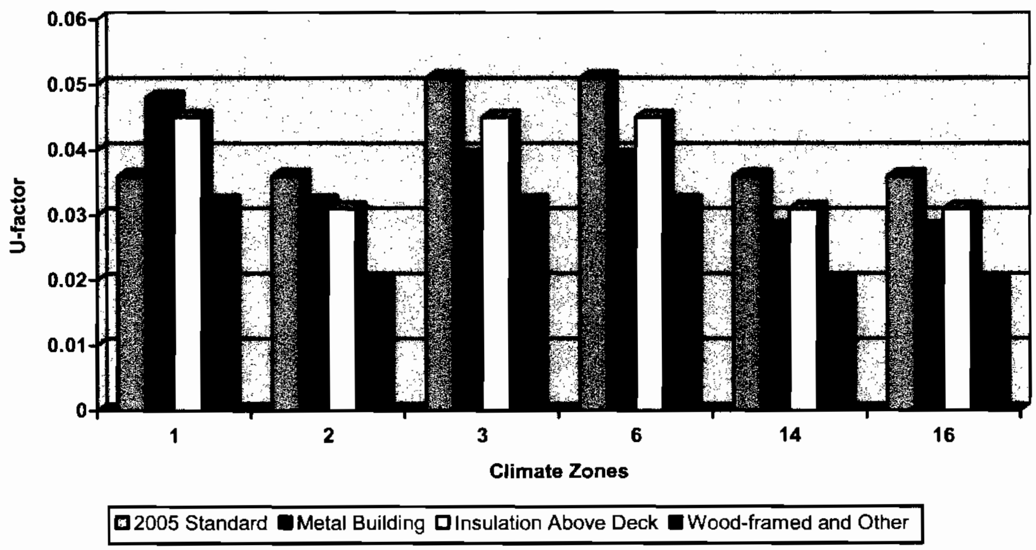


Figure 7 – 24-hour Roof Insulation Level Comparison

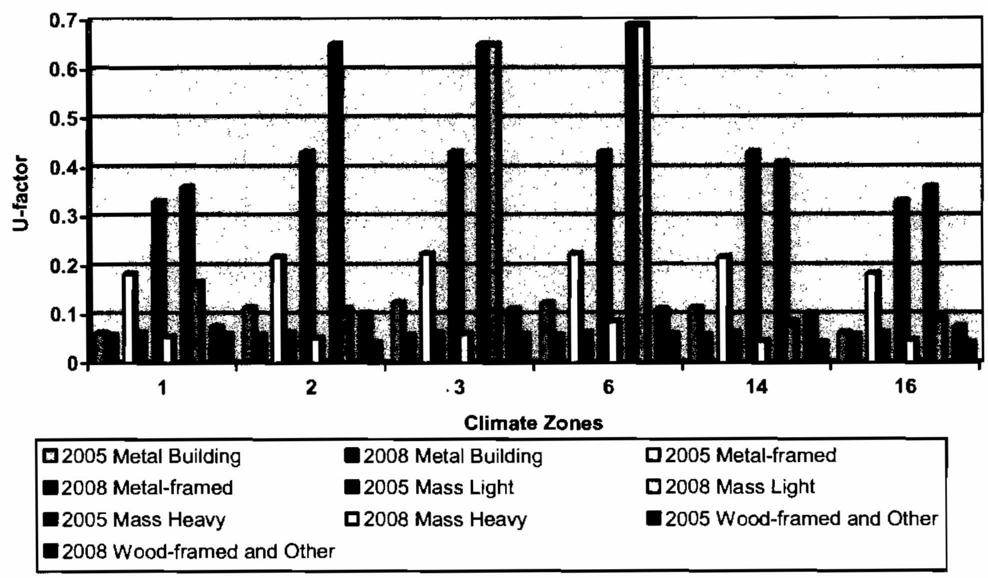


Figure 8 – 24-hour Wall Insulation Level Comparison

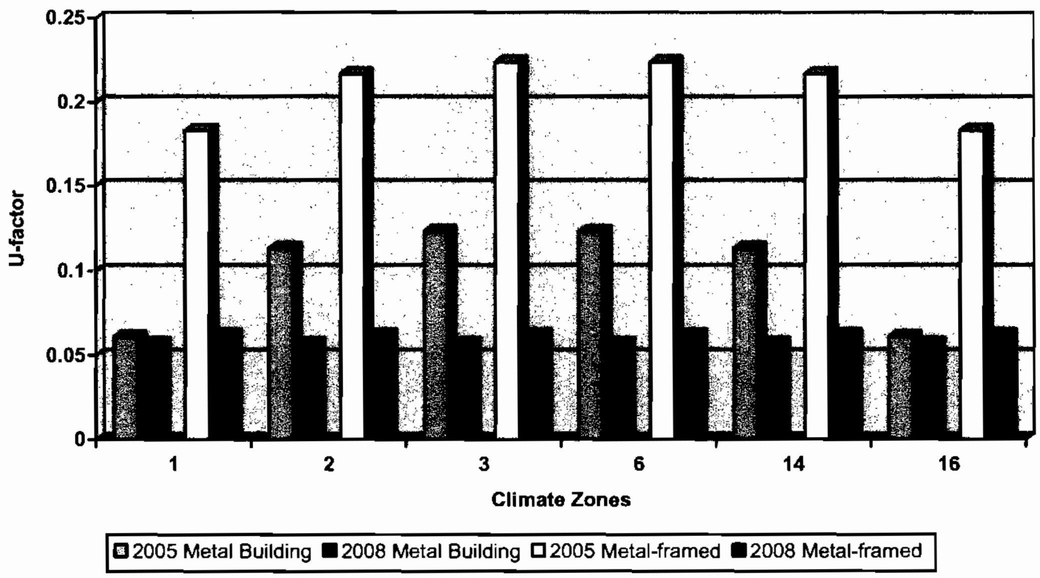


Figure 9 – 24-hour (Metal) Wall Insulation Level Comparison

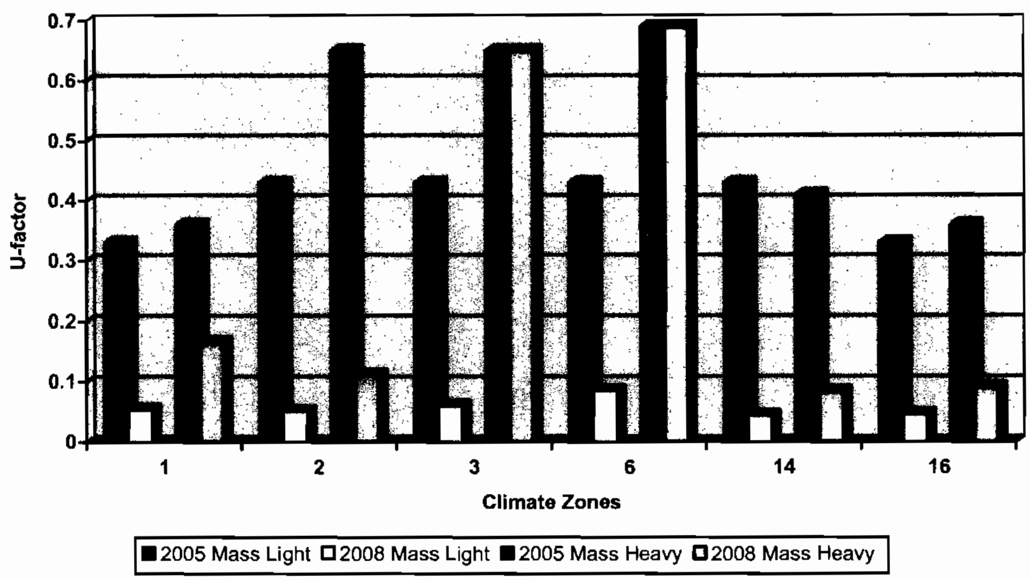


Figure 10 – 24-hour (Mass) Wall Insulation Level Comparison

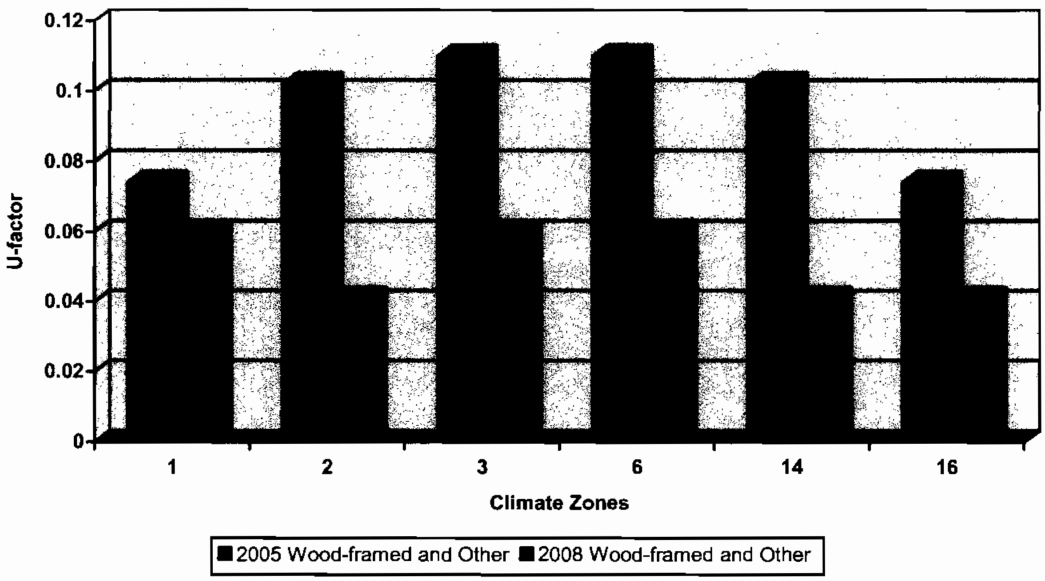


Figure 11 – 24-hour (Wood and Other) Wall Insulation Level Comparison

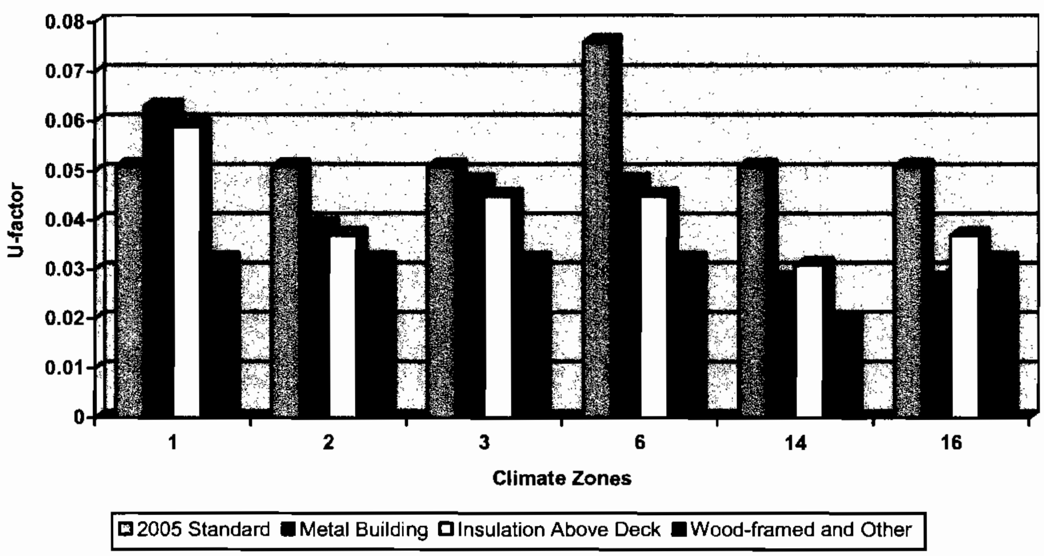


Figure 12 – Retail Roof Insulation Level Comparison

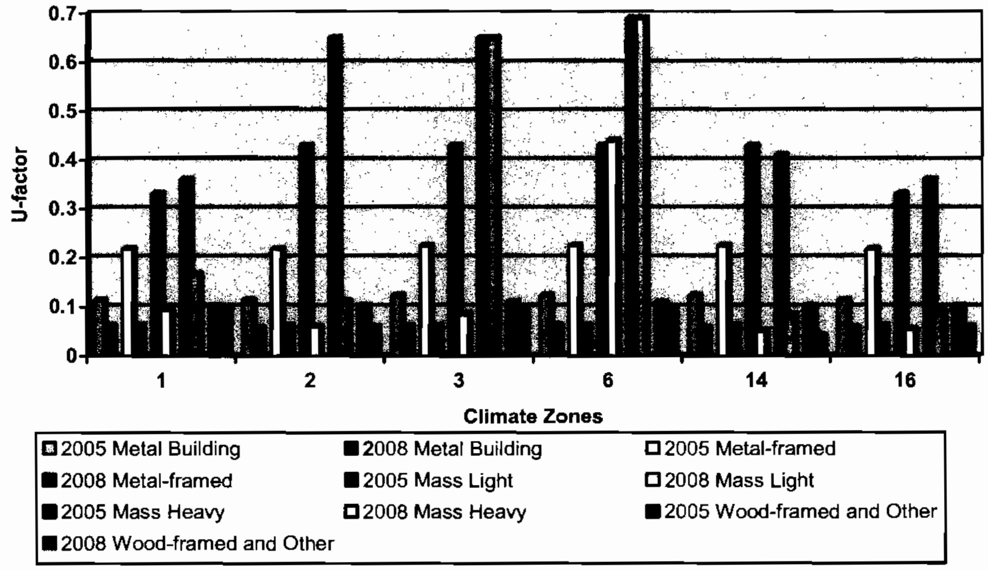


Figure 13 – Retail Wall Insulation Level Comparison

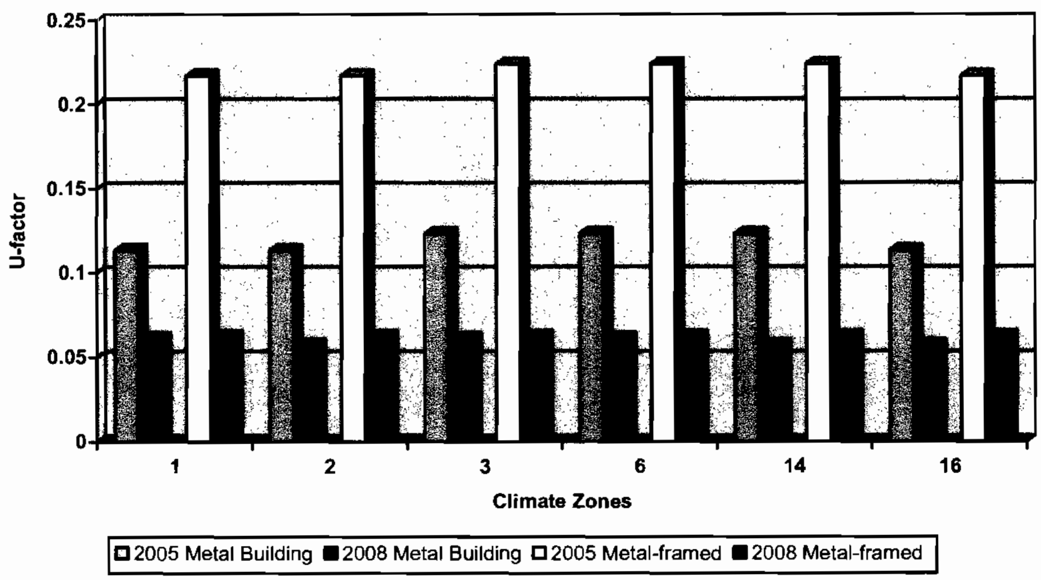


Figure 14 – Retail (Metal) Wall Insulation Level Comparison

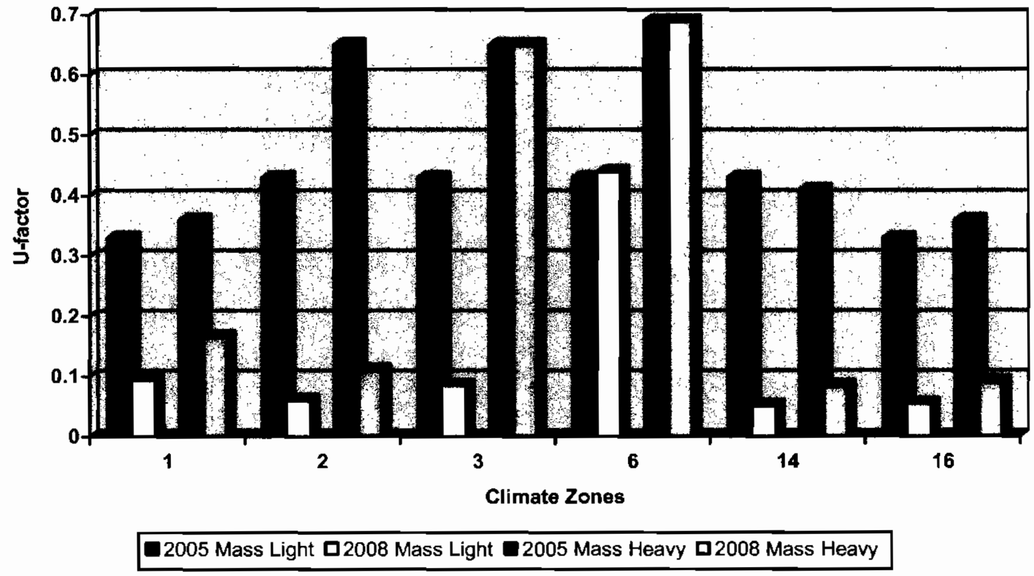


Figure 15 – Retail (Mass) Wall Insulation Level Comparison

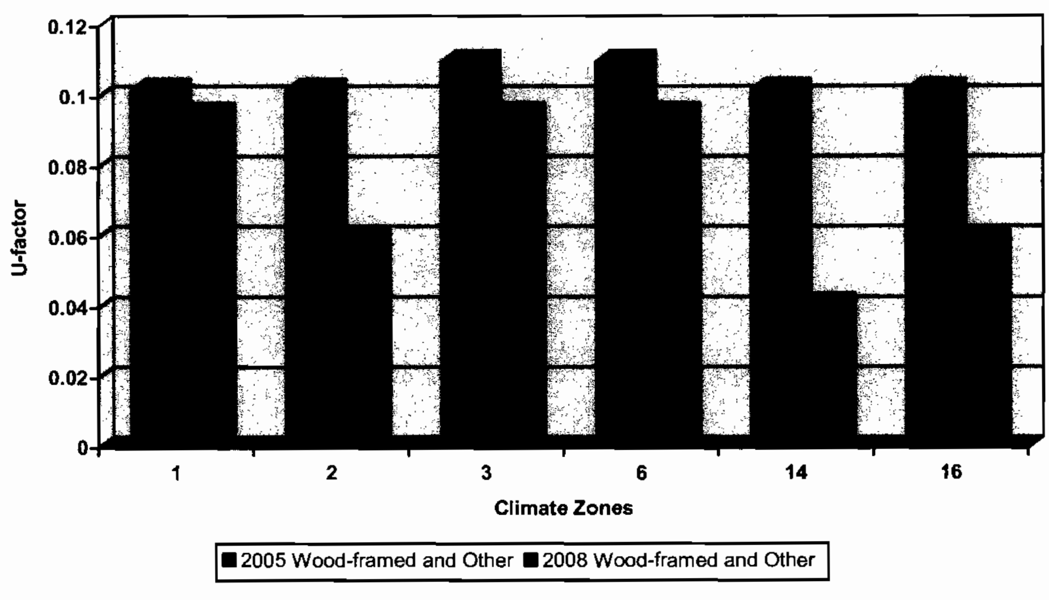


Figure 16 – Retail (Wood and Other) Wall Insulation Level Comparison

Cost-effectiveness

A spreadsheet listing the life-cycle cost values for all evaluated construction assemblies can be found at the http link below. The spreadsheet is split by class of construction and can be sorted by the following descriptions:

http://www.archenergy.com/downloads/pub/sf/lcc_envelope_results.xls

Table 15 – 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)
Class and Category	Class and category of construction combined

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, Insulation Above Deck, and Wood-framed and Others
- Walls: Metal Building, Metal-framed, Mass Light, Mass Heavy, and Wood-framed and Other
- Floors: Mass and Other

The ACM Requirements for mass walls specify different types of mass walls as the base case for each climate zone. During the life cycle cost analysis, the mass wall that was specified in the ACM was used.

Table 16 – 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	0.048	0.048	0.048	0.048	0.048	0.048	0.031	0.028	0.031	0.031	0.028	0.028	0.028	0.031
Insulation Above Deck	0.059	0.045	0.059	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Word-framed and other	0.038	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.026	0.032
Wall																
Metal Building	0.113	0.057	0.061	0.061	0.061	0.061	0.061	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
Metal-framed	0.082	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	0.094	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.068	0.085	0.060	0.060	0.056	0.064
Mass Heavy	0.166	0.111	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.111	0.091	0.111	0.091	0.084	0.084	0.091
Wood-framed and Other	0.095	0.059	0.095	0.095	0.095	0.095	0.095	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Floor/Soffit																
Mass	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Other	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Table 17 – 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	0.048	0.032	0.039	0.032	0.039	0.039	0.039	0.032	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Insulation Above Deck	0.045	0.031	0.045	0.037	0.045	0.045	0.045	0.037	0.037	0.031	0.031	0.031	0.031	0.031	0.031	0.031
Word-framed and other	0.032	0.020	0.032	0.026	0.032	0.032	0.032	0.026	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Wall																
Metal Building	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.045	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	0.054	0.051	0.060	0.060	0.060	0.085	0.068	0.060	0.060	0.051	0.048	0.051	0.044	0.044	0.044	0.046
Mass Heavy	0.166	0.111	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.111	0.091	0.111	0.091	0.084	0.084	0.091
Wood-framed and Other	0.059	0.041	0.059	0.059	0.059	0.059	0.059	0.059	0.041	0.041	0.041	0.041	0.041	0.041	0.038	0.041
Floor/Soffit																
Mass	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Other	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Table 18 – Retail Occupancy Recommended Standard (new Table)

	Climate Zones															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Roof/Ceiling																
Metal Building	0.063	0.039	0.048	0.048	0.048	0.048	0.048	0.039	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Insulation Above Deck	0.059	0.037	0.045	0.045	0.045	0.045	0.045	0.045	0.037	0.037	0.037	0.037	0.037	0.031	0.031	0.037
Word-framed and other	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.026	0.032	0.032	0.026	0.020	0.020	0.032
Wall																
Metal Building	0.061	0.057	0.061	0.057	0.061	0.061	0.061	0.057	0.057	0.057	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	0.094	0.060	0.085	0.085	0.085	0.440	0.085	0.085	0.060	0.056	0.051	0.060	0.051	0.051	0.044	0.054
Mass Heavy	0.166	0.111	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.111	0.091	0.111	0.091	0.084	0.084	0.091
Wood-framed and Other	0.095	0.059	0.095	0.059	0.095	0.095	0.095	0.059	0.059	0.059	0.059	0.059	0.059	0.041	0.041	0.059
Floor/Soffit																
Mass	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Other	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Proposed Standards Language

The proposed changes to the Standards are the substitution of the tables shown above for Tables 143-A and 143-B and the addition of a new Table 143 for retail occupancies. 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

California Energy Commission by Eley Associates. *Life Cycle Cost Methodology, 2005 California Building Energy Efficiency Standards*, 2002. Available at http://www.energy.ca.gov/title24/2005standards/archive/documents/2002-04-02_workshop/2002-03-20_LIFE_CYCLE.PDF

Pacific Gas & Electric Company by Heschong Mahone Group. *Time Dependent Valuation (TDV) Economics Methodology, 2005 Title 24 Building Standards Energy Efficiency Update*, 2002. Available at http://www.energy.ca.gov/title24/2005standards/archive/documents/2002-04-02_workshop/2002-03-20_TDV_ECON.PDF

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

California Public Utilities Commission and California Energy Commission, *2004-05 Database for Energy Efficient Resources (DEER) Version 2.0*, 2005. Available at http://eega.cpuc.ca.gov/deer/.

California Energy Commission by Eley Associates. Impact Analysis, 2005 Update to the California Energy Efficiency Standards, 2003. Available at http://www.energy.ca.gov/title24/2005standards/archive/rulemaking/documents/2003-07-11_400-03-014.PDF.

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Appendices

Energy Coefficients

TDV energy per square foot of opaque surface area is calculated through regression analysis, using the coefficients in the following table. 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

Table 19 – 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 20 – TDV DOE-2 Coefficients

Type	Occupancy	CZ	Constant	Coefficient	R^2
Floor Light	24-hour	1	46.88	179.27	1.0000
Floor Light	24-hour	2	74.19	231.19	0.9999
Floor Light	24-hour	3	47.84	159.28	0.9993
Floor Light	24-hour	4	66.08	190.52	0.9995
Floor Light	24-hour	5	48.92	163.95	0.9991
Floor Light	24-hour	6	53.61	106.62	0.9980
Floor Light	24-hour	7	55.96	118.13	0.9993
Floor Light	24-hour	8	72.77	149.36	0.9998
Floor Light	24-hour	9	83.91	183.39	0.9997
Floor Light	24-hour	10	93.64	223.43	0.9999
Floor Light	24-hour	11	88.83	261.11	1.0000
Floor Light	24-hour	12	83.32	239.07	0.9999
Floor Light	24-hour	13	98.03	262.72	1.0000
Floor Light	24-hour	14	104.70	288.62	1.0000
Floor Light	24-hour	15	135.97	333.82	1.0000
Floor Light	24-hour	16	82.72	298.75	0.9999
Floor Light	Daytime	1	44.12	56.44	0.9966
Floor Light	Daytime	2	80.40	119.67	0.9998
Floor Light	Daytime	3	63.21	56.59	0.9958
Floor Light	Daytime	4	84.55	89.53	0.9989
Floor Light	Daytime	5	69.81	62.04	0.9930
Floor Light	Daytime	6	85.24	52.67	0.9801
Floor Light	Daytime	7	87.65	43.69	0.9910
Floor Light	Daytime	8	106.28	76.57	0.9975
Floor Light	Daytime	9	112.71	99.63	0.9981
Floor Light	Daytime	10	116.92	124.53	0.9993
Floor Light	Daytime	11	92.12	135.92	0.9997
Floor Light	Daytime	12	91.38	124.48	0.9998
Floor Light	Daytime	13	107.75	144.67	0.9999
Floor Light	Daytime	14	112.58	164.80	1.0000
Floor Light	Daytime	15	161.09	200.24	0.9999
Floor Light	Daytime	16	72.40	150.35	1.0000
Floor Light	Retail	1	50.88	21.02	0.9229
Floor Light	Retail	2	97.37	119.14	0.9977
Floor Light	Retail	3	76.94	27.08	0.9626
Floor Light	Retail	4	108.26	74.95	0.9936
Floor Light	Retail	5	83.60	24.56	0.7968
Floor Light	Retail	6	112.12	0.86	0.0440
Floor Light	Retail	7	113.26	16.15	0.9384
Floor Light	Retail	8	134.95	61.87	0.9953
Floor Light	Retail	9	143.47	96.38	0.9979
Floor Light	Retail	10	147.79	134.60	0.9990
Floor Light	Retail	11	114.55	148.71	0.9982
Floor Light	Retail	12	113.15	128.98	0.9976

Type	Occupancy	CZ	Constant	Coefficient	R^2
Floor Light	Retail	13	135.28	162.76	0.9992
Floor Light	Retail	14	137.52	197.99	0.9995
Floor Light	Retail	15	202.06	237.80	0.9999
Floor Light	Retail	16	81.23	157.96	0.9981
Floor Mass	24-hour	1	44.62	134.06	0.9998
Floor Mass	24-hour	2	70.28	129.89	0.9981
Floor Mass	24-hour	3	45.26	84.40	0.9926
Floor Mass	24-hour	4	63.25	81.96	0.9960
Floor Mass	24-hour	5	46.70	72.38	0.9922
Floor Mass	24-hour	6	51.66	32.10	0.9718
Floor Mass	24-hour	7	52.96	40.14	0.9775
Floor Mass	24-hour	8	69.24	54.98	0.9872
Floor Mass	24-hour	9	79.99	56.69	0.9828
Floor Mass	24-hour	10	89.29	94.82	0.9980
Floor Mass	24-hour	11	85.45	171.48	0.9996
Floor Mass	24-hour	12	80.04	136.94	0.9992
Floor Mass	24-hour	13	94.68	161.19	0.9996
Floor Mass	24-hour	14	100.61	170.96	0.9998
Floor Mass	24-hour	15	131.86	205.37	1.0000
Floor Mass	24-hour	16	79.68	206.64	0.9997
Floor Mass	Daytime	1	41.82	12.31	0.7284
Floor Mass	Daytime	2	77.05	39.35	0.9799
Floor Mass	Daytime	3	60.77	-5.89	0.4479
Floor Mass	Daytime	4	82.15	8.21	0.6738
Floor Mass	Daytime	5	67.48	-16.18	0.7231
Floor Mass	Daytime	6	86.35	-29.49	0.9502
Floor Mass	Daytime	7	85.84	-19.19	0.8824
Floor Mass	Daytime	8	103.55	5.08	0.2762
Floor Mass	Daytime	9	110.39	0.20	0.0009
Floor Mass	Daytime	10	114.45	27.79	0.9638
Floor Mass	Daytime	11	89.70	64.86	0.9966
Floor Mass	Daytime	12	88.88	43.31	0.9846
Floor Mass	Daytime	13	106.04	63.33	0.9984
Floor Mass	Daytime	14	109.92	73.94	0.9989
Floor Mass	Daytime	15	159.59	96.66	0.9999
Floor Mass	Daytime	16	68.89	83.58	0.9986
Floor Mass	Retail	1	49.88	-27.25	0.8938
Floor Mass	Retail	2	94.82	21.09	0.8457
Floor Mass	Retail	3	75.40	-41.72	0.9345
Floor Mass	Retail	4	106.54	-20.29	0.8503
Floor Mass	Retail	5	82.70	-51.98	0.9760
Floor Mass	Retail	6	110.70	-60.02	0.9892
Floor Mass	Retail	7	111.85	-47.54	0.9820
Floor Mass	Retail	8	133.02	-19.51	0.8874
Floor Mass	Retail	9	141.33	-17.03	0.8756

Type	Occupancy	CZ	Constant	Coefficient	R^2
Floor Mass	Retail	10	145.45	24.23	0.8924
Floor Mass	Retail	11	112.73	56.43	0.9777
Floor Mass	Retail	12	111.03	30.22	0.8935
Floor Mass	Retail	13	133.65	60.44	0.9912
Floor Mass	Retail	14	135.16	83.08	0.9921
Floor Mass	Retail	15	198.15	135.92	0.9996
Floor Mass	Retail	16	78.52	69.85	0.9564
Roof Attic	24-hour	1	61.28	194.51	0.9999
Roof Attic	24-hour	2	88.53	277.33	0.9999
Roof Attic	24-hour	3	58.28	212.68	0.9998
Roof Attic	24-hour	4	76.64	259.31	0.9999
Roof Attic	24-hour	5	60.55	207.02	0.9998
Roof Attic	24-hour	6	56.50	188.22	0.9996
Roof Attic	24-hour	7	57.45	196.61	0.9997
Roof Attic	24-hour	8	77.18	242.48	0.9997
Roof Attic	24-hour	9	91.46	255.59	0.9997
Roof Attic	24-hour	10	104.56	286.18	0.9998
Roof Attic	24-hour	11	106.28	299.94	0.9999
Roof Attic	24-hour	12	98.44	291.22	0.9999
Roof Attic	24-hour	13	114.09	305.57	1.0000
Roof Attic	24-hour	14	121.79	326.55	0.9999
Roof Attic	24-hour	15	156.17	358.38	0.9999
Roof Attic	24-hour	16	106.35	314.69	1.0000
Roof Attic	Daytime	1	43.96	126.30	0.9997
Roof Attic	Daytime	2	83.69	192.61	0.9998
Roof Attic	Daytime	3	61.86	148.64	0.9995
Roof Attic	Daytime	4	85.35	181.15	0.9997
Roof Attic	Daytime	5	69.06	148.86	0.9995
Roof Attic	Daytime	6	81.46	140.65	0.9994
Roof Attic	Daytime	7	82.69	144.02	0.9995
Roof Attic	Daytime	8	104.38	180.40	0.9996
Roof Attic	Daytime	9	113.30	193.20	0.9998
Roof Attic	Daytime	10	119.96	211.04	0.9998
Roof Attic	Daytime	11	97.62	206.65	0.9998
Roof Attic	Daytime	12	95.22	203.48	0.9998
Roof Attic	Daytime	13	112.73	223.58	0.9999
Roof Attic	Daytime	14	118.82	241.64	0.9999
Roof Attic	Daytime	15	170.68	271.27	0.9999
Roof Attic	Daytime	16	79.93	208.05	0.9999
Roof Attic	Retail	1	45.83	138.37	0.9991
Roof Attic	Retail	2	98.69	225.99	0.9997
Roof Attic	Retail	3	70.95	165.15	0.9992
Roof Attic	Retail	4	105.45	211.91	0.9996
Roof Attic	Retail	5	77.64	160.62	0.9989
Roof Attic	Retail	6	101.89	155.39	0.9992

Type	Occupancy	CZ	Constant	Coefficient	R^2
Roof Attic	Retail	7	104.56	173.12	0.9994
Roof Attic	Retail	8	128.50	206.29	0.9995
Roof Attic	Retail	9	141.29	226.02	0.9996
Roof Attic	Retail	10	149.48	242.94	0.9998
Roof Attic	Retail	11	119.26	239.78	0.9998
Roof Attic	Retail	12	115.47	234.87	0.9998
Roof Attic	Retail	13	139.85	261.23	0.9999
Roof Attic	Retail	14	144.66	282.68	0.9999
Roof Attic	Retail	15	213.49	316.87	0.9999
Roof Attic	Retail	16	87.88	240.14	0.9998
Roof Light	24-hour	1	62.14	260.98	1.0000
Roof Light	24-hour	2	89.73	424.54	1.0000
Roof Light	24-hour	3	58.74	293.82	1.0000
Roof Light	24-hour	4	77.57	380.66	1.0000
Roof Light	24-hour	5	60.15	305.20	1.0000
Roof Light	24-hour	6	56.63	286.57	1.0000
Roof Light	24-hour	7	59.71	310.67	1.0000
Roof Light	24-hour	8	78.25	379.95	1.0000
Roof Light	24-hour	9	93.02	412.45	1.0000
Roof Light	24-hour	10	106.58	458.05	1.0000
Roof Light	24-hour	11	108.31	439.65	1.0000
Roof Light	24-hour	12	99.93	429.57	1.0000
Roof Light	24-hour	13	115.98	478.11	1.0000
Roof Light	24-hour	14	124.36	522.06	1.0000
Roof Light	24-hour	15	160.03	576.18	1.0000
Roof Light	24-hour	16	107.93	439.56	1.0000
Roof Light	Daytime	1	45.89	145.32	0.9999
Roof Light	Daytime	2	86.26	264.00	0.9999
Roof Light	Daytime	3	63.62	179.79	1.0000
Roof Light	Daytime	4	87.27	236.00	1.0000
Roof Light	Daytime	5	70.57	191.70	1.0000
Roof Light	Daytime	6	84.66	192.18	1.0000
Roof Light	Daytime	7	85.02	203.81	1.0000
Roof Light	Daytime	8	106.12	257.57	1.0000
Roof Light	Daytime	9	115.20	276.11	1.0000
Roof Light	Daytime	10	121.92	302.93	1.0000
Roof Light	Daytime	11	100.17	273.69	1.0000
Roof Light	Daytime	12	97.82	268.44	0.9999
Roof Light	Daytime	13	115.29	309.18	0.9999
Roof Light	Daytime	14	121.94	337.40	1.0000
Roof Light	Daytime	15	173.97	377.28	1.0000
Roof Light	Daytime	16	83.06	260.82	0.9999
Roof Light	Retail	1	46.88	165.63	0.9999
Roof Light	Retail	2	100.85	322.44	1.0000
Roof Light	Retail	3	72.14	201.39	1.0000

Type	Occupancy	CZ	Constant	Coefficient	R^2
Roof Light	Retail	4	107.05	280.08	1.0000
Roof Light	Retail	5	78.42	209.50	0.9999
Roof Light	Retail	6	103.42	203.95	0.9999
Roof Light	Retail	7	105.70	227.47	1.0000
Roof Light	Retail	8	131.25	293.26	1.0000
Roof Light	Retail	9	143.29	328.62	1.0000
Roof Light	Retail	10	151.34	373.05	1.0000
Roof Light	Retail	11	121.55	342.93	1.0000
Roof Light	Retail	12	117.60	330.86	1.0000
Roof Light	Retail	13	142.22	388.70	1.0000
Roof Light	Retail	14	148.04	421.05	0.9999
Roof Light	Retail	15	216.27	489.33	1.0000
Roof Light	Retail	16	90.65	316.48	1.0000
Roof Mass	24-hour	1	57.65	165.52	0.9999
Roof Mass	24-hour	2	83.27	232.74	1.0000
Roof Mass	24-hour	3	53.03	162.17	0.9998
Roof Mass	24-hour	4	69.72	198.92	0.9999
Roof Mass	24-hour	5	52.32	146.53	0.9997
Roof Mass	24-hour	6	51.41	138.05	0.9998
Roof Mass	24-hour	7	51.75	164.98	0.9998
Roof Mass	24-hour	8	69.68	200.44	0.9999
Roof Mass	24-hour	9	83.42	204.70	0.9997
Roof Mass	24-hour	10	96.80	250.95	0.9999
Roof Mass	24-hour	11	102.56	292.27	1.0000
Roof Mass	24-hour	12	92.66	266.52	0.9998
Roof Mass	24-hour	13	109.19	311.13	1.0000
Roof Mass	24-hour	14	115.66	335.21	1.0000
Roof Mass	24-hour	15	150.27	383.66	0.9997
Roof Mass	24-hour	16	102.58	290.12	1.0000
Roof Mass	Daytime	1	40.48	78.86	0.9992
Roof Mass	Daytime	2	79.16	131.35	0.9996
Roof Mass	Daytime	3	57.58	84.93	0.9989
Roof Mass	Daytime	4	79.77	116.51	0.9996
Roof Mass	Daytime	5	63.78	81.59	0.9991
Roof Mass	Daytime	6	78.65	82.60	0.9992
Roof Mass	Daytime	7	78.57	97.96	0.9996
Roof Mass	Daytime	8	99.66	124.02	0.9994
Roof Mass	Daytime	9	107.22	127.32	0.9993
Roof Mass	Daytime	10	113.93	155.26	0.9996
Roof Mass	Daytime	11	93.61	167.38	0.9998
Roof Mass	Daytime	12	90.57	158.41	0.9996
Roof Mass	Daytime	13	108.74	185.80	0.9999
Roof Mass	Daytime	14	113.13	206.24	0.9999
Roof Mass	Daytime	15	165.40	235.97	0.9997
Roof Mass	Daytime	16	76.79	165.64	0.9999

Type	Occupancy	CZ	Constant	Coefficient	R^2
Roof Mass	Retail	1	40.62	100.05	0.9990
Roof Mass	Retail	2	91.79	186.99	0.9997
Roof Mass	Retail	3	65.59	104.20	0.9986
Roof Mass	Retail	4	98.45	151.33	0.9995
Roof Mass	Retail	5	71.48	95.40	0.9983
Roof Mass	Retail	6	95.86	103.00	0.9984
Roof Mass	Retail	7	98.08	124.98	0.9992
Roof Mass	Retail	8	122.40	160.72	0.9995
Roof Mass	Retail	9	132.88	174.90	0.9998
Roof Mass	Retail	10	141.72	214.44	0.9998
Roof Mass	Retail	11	112.57	230.16	0.9998
Roof Mass	Retail	12	108.55	214.23	0.9998
Roof Mass	Retail	13	132.72	256.80	0.9999
Roof Mass	Retail	14	136.50	278.54	0.9999
Roof Mass	Retail	15	206.14	322.89	0.9999
Roof Mass	Retail	16	81.96	219.12	0.9999
Wall Light	24-hour	1	313.98	207.87	1.0000
Wall Light	24-hour	2	464.54	281.92	1.0000
Wall Light	24-hour	3	305.25	208.33	1.0000
Wall Light	24-hour	4	404.38	240.22	1.0000
Wall Light	24-hour	5	312.55	218.15	1.0000
Wall Light	24-hour	6	296.97	183.64	1.0000
Wall Light	24-hour	7	314.81	184.75	1.0000
Wall Light	24-hour	8	406.59	235.19	1.0000
Wall Light	24-hour	9	476.32	273.15	1.0000
Wall Light	24-hour	10	543.77	306.08	1.0000
Wall Light	24-hour	11	547.41	309.91	1.0000
Wall Light	24-hour	12	509.29	296.00	1.0000
Wall Light	24-hour	13	587.99	325.90	1.0000
Wall Light	24-hour	14	633.09	350.30	1.0000
Wall Light	24-hour	15	797.22	416.53	1.0000
Wall Light	24-hour	16	545.05	319.20	1.0000
Wall Light	Daytime	1	226.65	91.38	1.0000
Wall Light	Daytime	2	424.43	158.97	1.0000
Wall Light	Daytime	3	310.20	102.25	1.0000
Wall Light	Daytime	4	424.29	130.30	1.0000
Wall Light	Daytime	5	342.14	116.41	1.0000
Wall Light	Daytime	6	404.49	105.72	1.0000
Wall Light	Daytime	7	408.86	107.11	1.0000
Wall Light	Daytime	8	510.53	143.95	1.0000
Wall Light	Daytime	9	552.70	171.31	1.0000
Wall Light	Daytime	10	586.69	189.72	1.0000
Wall Light	Daytime	11	485.80	177.61	1.0000
Wall Light	Daytime	12	475.54	166.29	1.0000
Wall Light	Daytime	13	559.49	191.09	1.0000

Type	Occupancy	CZ	Constant	Coefficient	R^2
Wall Light	Daytime	14	593.17	207.47	1.0000
Wall Light	Daytime	15	827.47	255.94	1.0000
Wall Light	Daytime	16	409.06	168.73	1.0000
Wall Light	Retail	1	179.33	109.54	1.0000
Wall Light	Retail	2	383.85	201.94	1.0000
Wall Light	Retail	3	271.15	117.04	1.0000
Wall Light	Retail	4	400.53	161.56	1.0000
Wall Light	Retail	5	292.29	130.18	1.0000
Wall Light	Retail	6	377.85	117.25	1.0000
Wall Light	Retail	7	389.32	122.12	1.0000
Wall Light	Retail	8	484.66	166.84	1.0000
Wall Light	Retail	9	529.22	211.80	1.0000
Wall Light	Retail	10	561.59	251.26	1.0000
Wall Light	Retail	11	456.38	230.85	1.0000
Wall Light	Retail	12	442.29	213.47	1.0000
Wall Light	Retail	13	533.17	252.97	1.0000
Wall Light	Retail	14	558.03	270.79	1.0000
Wall Light	Retail	15	795.42	342.52	1.0000
Wall Light	Retail	16	348.02	216.01	1.0000
Wall Mass 15	24-hour	1	294.37	101.41	0.9999
Wall Mass 15	24-hour	2	432.71	97.25	0.9989
Wall Mass 15	24-hour	3	280.39	72.54	0.9986
Wall Mass 15	24-hour	4	376.20	68.10	0.9980
Wall Mass 15	24-hour	5	283.83	52.01	0.9981
Wall Mass 15	24-hour	6	274.08	15.27	0.9929
Wall Mass 15	24-hour	7	289.43	42.44	0.9929
Wall Mass 15	24-hour	8	377.49	51.28	0.9864
Wall Mass 15	24-hour	9	441.41	51.15	0.9846
Wall Mass 15	24-hour	10	505.20	89.60	0.9946
Wall Mass 15	24-hour	11	519.58	143.89	0.9994
Wall Mass 15	24-hour	12	480.11	113.11	0.9994
Wall Mass 15	24-hour	13	559.33	140.16	0.9996
Wall Mass 15	24-hour	14	599.17	138.23	0.9988
Wall Mass 15	24-hour	15	762.28	175.39	0.9992
Wall Mass 15	24-hour	16	520.01	164.82	1.0000
Wall Mass 15	Daytime	1	207.67	34.42	0.9889
Wall Mass 15	Daytime	2	400.41	37.76	0.9916
Wall Mass 15	Daytime	3	289.39	16.46	0.9623
Wall Mass 15	Daytime	4	401.82	22.25	0.9715
Wall Mass 15	Daytime	5	316.87	6.86	0.4150
Wall Mass 15	Daytime	6	383.22	2.79	0.3624
Wall Mass 15	Daytime	7	389.68	8.90	0.9054
Wall Mass 15	Daytime	8	488.24	24.54	1.0000
Wall Mass 15	Daytime	9	528.11	16.59	0.9519
Wall Mass 15	Daytime	10	561.25	36.65	0.9850

Type	Occupancy	CZ	Constant	Coefficient	R^2
Wall Mass 15	Daytime	11	468.62	63.68	0.9995
Wall Mass 15	Daytime	12	455.17	48.44	0.9964
Wall Mass 15	Daytime	13	542.24	63.53	0.9992
Wall Mass 15	Daytime	14	572.00	62.49	0.9980
Wall Mass 15	Daytime	15	809.95	82.55	0.9999
Wall Mass 15	Daytime	16	391.19	72.80	0.9998
Wall Mass 15	Retail	1	163.69	42.42	0.9558
Wall Mass 15	Retail	2	362.32	69.70	0.9879
Wall Mass 15	Retail	3	255.56	16.37	0.8914
Wall Mass 15	Retail	4	380.68	40.57	0.9594
Wall Mass 15	Retail	5	272.46	10.99	0.6438
Wall Mass 15	Retail	6	365.47	-18.50	0.9875
Wall Mass 15	Retail	7	374.89	16.80	0.8338
Wall Mass 15	Retail	8	467.40	36.38	0.9618
Wall Mass 15	Retail	9	508.59	45.88	0.9592
Wall Mass 15	Retail	10	540.95	81.55	0.9968
Wall Mass 15	Retail	11	438.06	111.82	0.9979
Wall Mass 15	Retail	12	422.30	89.15	0.9947
Wall Mass 15	Retail	13	515.60	109.53	0.9991
Wall Mass 15	Retail	14	538.29	111.10	0.9983
Wall Mass 15	Retail	15	780.35	162.88	0.9998
Wall Mass 15	Retail	16	327.49	122.42	0.9989
Wall Mass 7	24-hour	1	293.75	154.04	0.9952
Wall Mass 7	24-hour	2	430.93	191.33	0.9899
Wall Mass 7	24-hour	3	279.25	144.21	0.9897
Wall Mass 7	24-hour	4	375.01	146.04	0.9879
Wall Mass 7	24-hour	5	281.57	133.40	0.9819
Wall Mass 7	24-hour	6	272.11	88.39	0.9806
Wall Mass 7	24-hour	7	287.92	118.01	0.9800
Wall Mass 7	24-hour	8	375.53	144.72	0.9798
Wall Mass 7	24-hour	9	439.45	151.53	0.9795
Wall Mass 7	24-hour	10	503.35	200.55	0.9846
Wall Mass 7	24-hour	11	517.76	232.77	0.9927
Wall Mass 7	24-hour	12	477.72	208.01	0.9906
Wall Mass 7	24-hour	13	556.80	238.22	0.9934
Wall Mass 7	24-hour	14	597.24	243.89	0.9914
Wall Mass 7	24-hour	15	759.60	295.92	0.9935
Wall Mass 7	24-hour	16	518.20	246.73	0.9962
Wall Mass 7	Daytime	1	208.83	72.79	0.9852
Wall Mass 7	Daytime	2	399.52	101.90	0.9775
Wall Mass 7	Daytime	3	289.41	68.63	0.9710
Wall Mass 7	Daytime	4	401.42	79.63	0.9715
Wall Mass 7	Daytime	5	315.38	70.28	0.9625
Wall Mass 7	Daytime	6	382.60	57.85	0.9538
Wall Mass 7	Daytime	7	388.78	62.65	0.9626

Type	Occupancy	CZ	Constant	Coefficient	R^2
Wall Mass 7	Daytime	8	488.48	85.08	0.9719
Wall Mass 7	Daytime	9	526.58	88.91	0.9666
Wall Mass 7	Daytime	10	559.23	113.96	0.9750
Wall Mass 7	Daytime	11	467.00	121.96	0.9910
Wall Mass 7	Daytime	12	453.96	110.95	0.9858
Wall Mass 7	Daytime	13	539.93	126.19	0.9904
Wall Mass 7	Daytime	14	570.01	133.41	0.9893
Wall Mass 7	Daytime	15	805.32	166.07	0.9896
Wall Mass 7	Daytime	16	390.39	125.02	0.9923
Wall Mass 7	Retail	1	163.59	84.73	0.9741
Wall Mass 7	Retail	2	360.95	146.24	0.9864
Wall Mass 7	Retail	3	254.16	74.60	0.9623
Wall Mass 7	Retail	4	379.03	112.50	0.9739
Wall Mass 7	Retail	5	270.18	77.33	0.9424
Wall Mass 7	Retail	6	363.07	43.39	0.9293
Wall Mass 7	Retail	7	372.77	79.17	0.9577
Wall Mass 7	Retail	8	464.60	110.42	0.9681
Wall Mass 7	Retail	9	505.82	134.71	0.9730
Wall Mass 7	Retail	10	537.44	168.74	0.9829
Wall Mass 7	Retail	11	436.35	182.61	0.9919
Wall Mass 7	Retail	12	420.92	163.02	0.9889
Wall Mass 7	Retail	13	513.15	186.83	0.9917
Wall Mass 7	Retail	14	535.66	199.11	0.9925
Wall Mass 7	Retail	15	775.27	267.13	0.9939
Wall Mass 7	Retail	16	327.30	179.76	0.9951

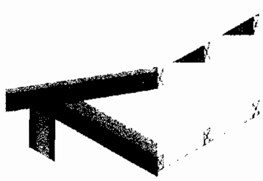
Construction Categories and How They Relate to the Proposed Criteria

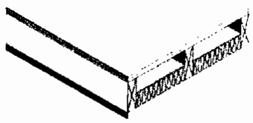
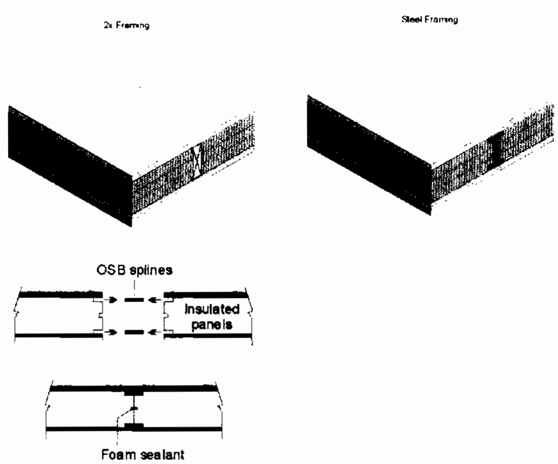
The following tables show the lowest life-cycle cost determined for each construction after professional judgment has been applied. The table lists the climate zone grouping and occupancy type. In each cell, the U-factor is given as well as the joint appendix reference for a particular table. For example, in Table IV.1 Day, 1, you will find the values 0.038 and A6. Day refers to daytime occupancy, 1 refers to the climate zone, 0.038 is the U-factor, and A6 is the column and row of the construction assembly found in Table IV.1. For Table IV.12, the cell contains two Joint Appendix references that are more detailed. For example, 12A9 on the second line represents the construction type and refers to Table 9, Column A, and Row 9. Similarly, 19E1 on the third line represents the insulation value and refers to Table 19, Column E, and Row 1.

Table 21 – Table Abbreviation Definitions and References

Abbreviation	Definiton	Climate Zone(s)
1	1	2
16	16	16
CV	Central Valley	2, 10-13
Dsrt	Desert	14, 15
NC	North Coast	3-5
SC	South Coast	6-9
Day	Daytime Occupancy	
24	24-hour Occupancy	
Rtl	Retail Occupancy	

Table 22 – Life-cycle Cost Results for Each Construction Category

Construction Category from Joint Appendix IV	Comment	Life-Cycle Cost			
		CZ	Day	24	Rtl
Table IV.1 – U-factors of Wood Framed Attic Roofs 	This table is the basis of the "Wood Framed and Other" roof class.	1	0.038 A6	0.032 A7	0.032 A7
		16	0.032 A7	0.032 A7	0.032 A7
		CV	0.032 A7	0.032 A7	0.032 A7
		Dsrt	0.032 A7	0.020 A9	0.020 A9
		NC	0.032 A7	0.032 A7	0.032 A7
		SC	0.032 A7	0.032 A7	0.032 A7

<table>
<tr><th>Construction Category from Joint Appendix IV</th><th>Comment</th><th>Life-Cycle Cost</th></tr>
<tr><td>Table IV.2 – U-factors of Wood Framed Rafter Roofs
</td><td>The constructions in this table have to comply with the criteria developed based on Table IV.1. It would be difficult for a building with this type of construction for the whole building to comply with the prescriptive requirements. Most buildings only have a small area of this category of roof construction and compliance could most likely be achieved with the overall envelope tradeoff method, by increasing the insulation of other roof components or other envelope elements.</td><td>
<table>
<tr><th>CZ</th><th>Day</th><th>24</th><th>Rtl</th></tr>
<tr><td>1</td><td>0.048
A6</td><td>0.048
A6</td><td>0.062
A4</td></tr>
<tr><td>16</td><td>0.036
A9</td><td>0.029
A11</td><td>0.036
A9</td></tr>
<tr><td>CV</td><td>0.036
A9</td><td>0.029
A11</td><td>0.029
A11</td></tr>
<tr><td>Dsrt</td><td>0.036
A9</td><td>0.029
A11</td><td>0.029
A11</td></tr>
<tr><td>NC</td><td>0.048
A6</td><td>0.036
A9</td><td>0.048
A6</td></tr>
<tr><td>SC</td><td>0.048
A6</td><td>0.036
A9</td><td>0.048
A6</td></tr>
</table>
</td></tr>
<tr><td>Table IV.3 – U-factors of Structurally Insulated Panels (SIPS) Roof/Ceilings

</td><td>The constructions in this table have to comply with the criteria developed based on Table IV.1. The constructions in this table generally perform better so compliance will likely not be a problem.</td><td>None</td></tr>
</table>

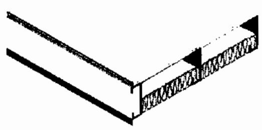
Construction Category from Joint Appendix IV	Comment	Life-Cycle Cost

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

The constructions in this table have to comply with the "Wood Framed and Other" criteria developed based on Table IV.1.

CZ	Day	24	Rtl
1	0.042 A7	0.042 A7	0.042 A7
16	0.032 A8	0.032 A8	0.032 A8
CV	0.032 A8	0.032 A8	0.032 A8
Dsrt	0.024 A9	0.024 A9	0.024 A9
NC	0.042 A7	0.042 A7	0.042 A7
SC	0.042 A7	0.042 A7	0.042 A7

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



The constructions in this table have to comply with the "Wood Framed and Other" criteria developed based on Table IV.1.

CZ	Day	24	Rtl
1	0.059 H1	0.059 H1	0.059 H1
16	0.059 H1	0.045 H2	0.059 H1
CV	0.059 H1	0.045 H2	0.059 H1
Dsrt	0.059 H1	0.045 H2	0.045 H1
NC	0.059 H1	0.059 H1	0.059 H1
SC	0.059 H1	0.059 H1	0.059 H1

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

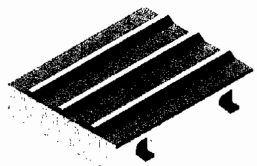
A separate class of construction is recommended for this category of construction. To qualify for this class of construction, the insulation shall be continuous and located entirely above the structural deck. If insulation is pinned below the deck (a case not covered in the table), then the more stringent "Attics and Other" class is triggered.

CZ	Day	24	Rtl
1	0.059 G5	0.045 H5	0.059 G5
16	0.045 H5	0.031 J5	0.037 I5
CV	0.045 H5	0.031 J5	0.037 I5
Dsrt	0.037 I5	0.031 J5	0.031 J5
NC	0.059 G5	0.045 H5	0.045 H5
SC	0.059 G5	0.045 H5	0.045 H5

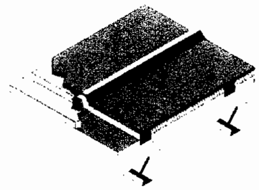
Construction Category from Joint Appendix IV	Comment	Life-Cycle Cost

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

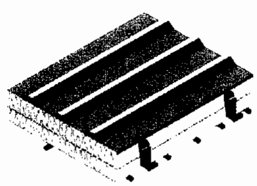
Screw-Down, No Thermal Blocks



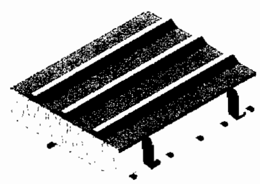
Single Layer, Thermal Blocks



Double Layer, Thermal Blocks



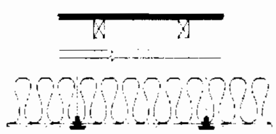
Filled Cavity, Thermal Blocks



A separate class of construction is recommended for this category of construction.

CZ	Day	24	Rtl
1	0.063	0.048	0.063
	G1	H1	G1
16	0.031	0.028	0.028
	I4	I5	I5
CV	0.048	0.028	0.028
	H1	I5	I5
Dsrt	0.028	0.028	0.028
	I5	I5	I5
NC	0.048	0.039	0.048
	H1	I1	H1
SC	0.048	0.039	0.048
	H1	I1	H1

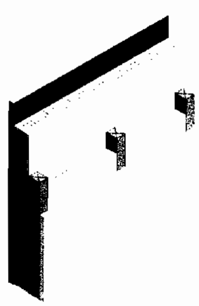
Table IV.8 – U-factors for Insulated Ceiling with Removable Panels



The constructions in this table have to comply with the criteria developed based on Table IV.1.

No life-cycle cost analysis.

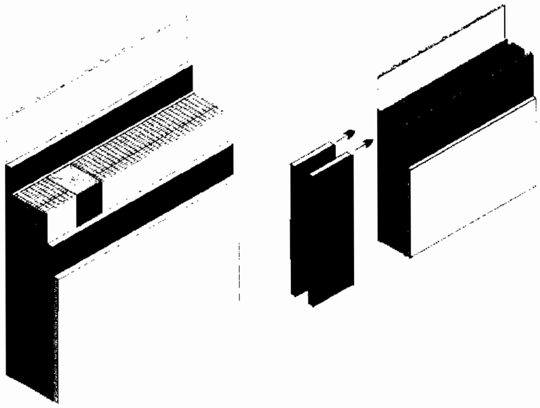
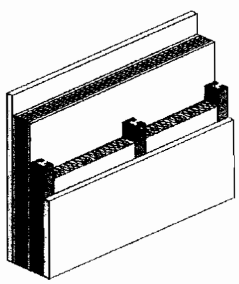
Table IV.9 – U-factors of Wood Framed Walls

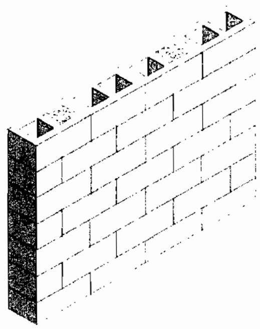


The constructions in this table are the basis of the "Wood Framed and Other" class of construction. Only 16 in. stud spacing are considered in developing the criteria. The better performing 24 in. spacing is not considered, since this spacing is not possible for all situations.

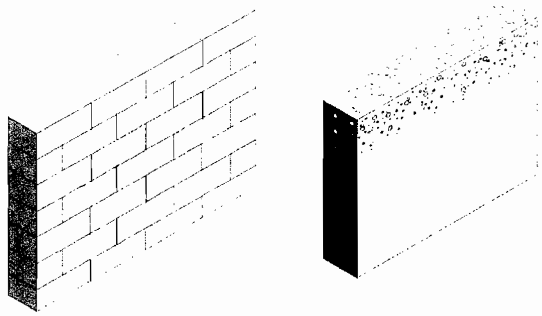
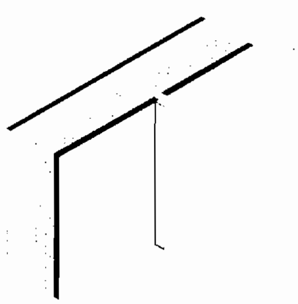
CZ	Day	24	Rtl
1	0.095	0.059	0.095
	A4	H1	A4
16	0.059	0.041	0.059
	H1	H2	H1
CV	0.059	0.059	0.059
	H1	H1	H1
Dsrt	0.059	0.059	0.041
	H1	H1	H2
NC	0.095	0.041	0.095
	A4	H2	A4
SC	0.095	0.041	0.059
	A4	H2	A4

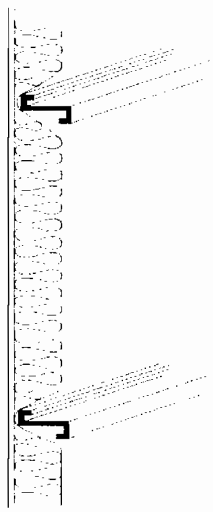
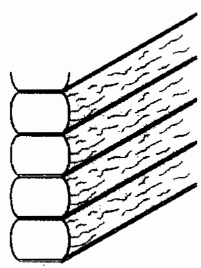
<table>
<tr><th>Construction Category from Joint Appendix IV</th><th>Comment</th><th>Life-Cycle Cost</th></tr>
<tr><td>Table IV.10 – U-factors of Structurally Insulated Wall Panels (SIPS)

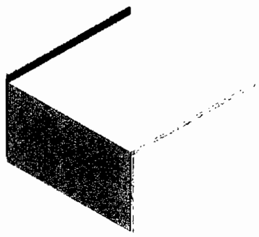
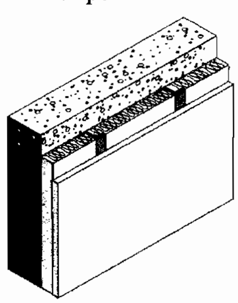
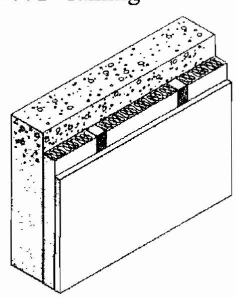
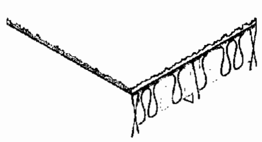
Wood Spacers OSB Spline
</td><td>The “Wood Framed and Other” criteria based on Table IV-9 applies for this category of construction.</td><td>No life-cycle cost analysis.</td></tr>
<tr><td>Table IV.11 – U-factors of Metal Framed Walls
</td><td>A separate class of construction is recommended for this common wall type.</td><td>
<table>
<tr><th>CZ</th><th>Day</th><th>24</th><th>Rtl</th></tr>
<tr><td>1</td><td>0.082
G1</td><td>0.062
H1</td><td>0.062
H1</td></tr>
<tr><td>16</td><td>0.062
H1</td><td>0.062
H1</td><td>0.062
H1</td></tr>
<tr><td>CV</td><td>0.062
H1</td><td>0.062
H1</td><td>0.062
H1</td></tr>
<tr><td>Dsrt</td><td>0.062
H1</td><td>0.062
H1</td><td>0.062
H1</td></tr>
<tr><td>NC</td><td>0.062
H1</td><td>0.062
H1</td><td>0.062
H1</td></tr>
<tr><td>SC</td><td>0.062
H1</td><td>0.062
H1</td><td>0.062
H1</td></tr>
</table>
</td></tr>
</table>

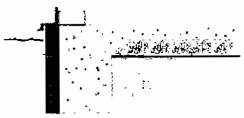
Construction Category from Joint Appendix IV	Comment	Life-Cycle Cost
Table IV.12 – Properties of Hollow Unit Masonry Walls 	Two classes of construction (light mass and heavy mass) are recommended for this category of construction. The "Heavy Mass" class includes walls with an HC greater than 15. The "Light Mass" class includes constructions with an HC greater than 7 (which do not qualify as Heavy Mass). All cells in this table qualify as either Heavy Mass or Light Mass.	

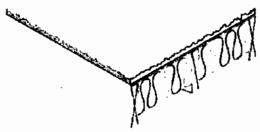
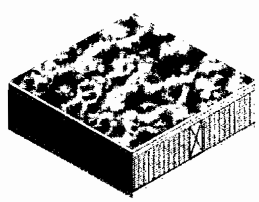
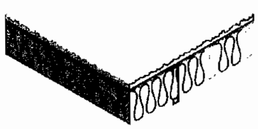
Heavy Mass			
CZ	Day	24	Rtl
1	0.166	0.166	0.166
	12A9	12A9	12A9
	19E1	19E1	19E1
16	0.091	0.091	0.091
	12A9	12A9	12A9
	19J1	19J1	19J1
CV	0.111	0.111	0.111
	12A9	12A9	12A9
	19H1	19H1	19H1
Dsrt	0.084	0.084	0.084
	12C9	12C9	12C9
	19J1	19J1	19J1
NC	0.650	0.650	0.650
	12A9	12A9	12A9
SC	0.690	0.690	0.690
	12A10	12A10	12A10
Light Mass			
CZ	Day	24	Rtl
1	0.094	0.054	0.094
	13B5	13B5	13B5
	19J1	19R1	19J1
16	0.064	0.046	0.054
	13B5	13B5	13B5
	19O1	19U1	19R1
CV	0.085	0.051	0.060
	12C10	12C10	12C10
	19J1	19R1	19O1
Dsrt	0.060	0.044	0.051
	12C10	12C10	12C10
	19O1	19U1	19R1
NC	0.085	0.060	0.085
	12C10	12C10	12C10
	19J1	19O1	19J1
SC	0.085	0.060	0.085
	12C10	12C10	12C10
	19J1	19O1	19J1

Construction Category from Joint Appendix IV	Comment	Life-Cycle Cost
Table IV.13 – Properties of Solid Unit Masonry and Solid Concrete Walls 	The criteria developed for Heavy Mass and Light Mass apply for the constructions in this table. Note that Cells A3 and A4 have a HC less than 7. We should either except these constructions, since they are close (6.25 and 6.30) or delete them from the table.	No life-cycle cost analysis.
Table IV.14 – Properties of Concrete Sandwich Panels 	The criteria for Heavy Mass apply for all the constructions in this table. All have an HC greater than 15.	No life-cycle cost analysis.
Table IV.15 – U-factors for Spandrel Panels and Glass Curtain Walls 	The criteria for "Metal Framed" walls applies for the constructions in this table. No life-cycle cost analysis was performed for this category of constructions.	No life-cycle cost analysis.

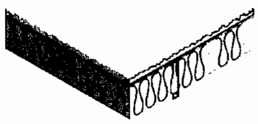
<table>
<tr><th>Construction Category from Joint Appendix IV</th><th>Comment</th><th>Life-Cycle Cost</th></tr>
<tr><td>Table IV.16 – U-factors for Metal Building Walls
</td><td>A separate class of construction is recommended for this category of wall constructions.</td><td>
<table>
<tr><th>CZ</th><th>Day</th><th>24</th><th>Rtl</th></tr>
<tr><td>1</td><td>0.113
A4</td><td>0.057
A6</td><td>0.061
A5</td></tr>
<tr><td>16</td><td>0.057
A6</td><td>0.057
A6</td><td>0.057
A6</td></tr>
<tr><td>CV</td><td>0.057
A6</td><td>0.057
A6</td><td>0.057
A6</td></tr>
<tr><td>Dsrt</td><td>0.057
A6</td><td>0.057
A6</td><td>0.057
A6</td></tr>
<tr><td>NC</td><td>0.061
A5</td><td>0.057
A6</td><td>0.061
A5</td></tr>
<tr><td>SC</td><td>0.061
A5</td><td>0.057
A6</td><td>0.061
A5</td></tr>
</table>
</td></tr>
<tr><td>Table IV.17 – Thermal Properties of Log Home Walls
</td><td>This category of wall construction is not very common for nonresidential buildings, but if it is used, the “Wood Framed and Other” criteria would apply.</td><td>No life-cycle cost analysis.</td></tr>
</table>

<table>
<tr><th>Construction Category from Joint Appendix IV</th><th>Comment</th><th>Life-Cycle Cost</th></tr>
<tr><td>Table IV.18 – Thermal and Mass Properties of Straw Bale Walls
</td><td>This category of wall construction is not very common for nonresidential buildings, but if it is used, the “Wood Framed and Other” criteria would apply.</td><td>No life-cycle cost analysis.</td></tr>
<tr><td>Table IV.19 – Effective R-values for Interior or Exterior Insulation Layers
Metal Clips

Wood Framing
</td><td>This table is used in conjunction with IV.12 and IV.13. This is not a category of construction in and of itself.</td><td>See Concrete Walls.</td></tr>
<tr><td>Table IV.20 – Standard U-factors for Wood-Framed Floors with a Crawl Space
</td><td></td><td><table>
<tr><th>CZ</th><th>Day</th><th>24</th><th>Rtl</th></tr>
<tr><td>1</td><td>0.099
A1</td><td>0.034
A5</td><td>0.099
A1</td></tr>
<tr><td>16</td><td>0.050
A2</td><td>0.031
A6</td><td>0.050
A2</td></tr>
<tr><td>CV</td><td>0.050
A2</td><td>0.031
A6</td><td>0.050
A2</td></tr>
<tr><td>Dsrt</td><td>0.050
A2</td><td>0.031
A6</td><td>0.031
A6</td></tr>
<tr><td>NC</td><td>0.099
A1</td><td>0.050
A2</td><td>0.099
A1</td></tr>
<tr><td>SC</td><td>0.099
A1</td><td>0.050
A2</td><td>0.099
A1</td></tr>
</table></td></tr>
</table>

Construction Category from Joint Appendix IV	Comment	Life-Cycle Cost
Table IV.27 – F-Factors for Heated Slab-on-Grade Floors 		No life-cycle cost analysis.

<table>
<tr><th>Construction Category from Joint Appendix IV</th><th>Comment</th><th>Life-Cycle Cost</th></tr>
<tr><td>Table IV.21 – Standard U-factors for Wood Framed Floors without a Crawl Space
</td><td>This category of construction is the recommended basis of the "Wood Framed and Other" class of floor construction.</td><td>
<table>
<tr><th>CZ</th><th>Day</th><th>24</th><th>Rtl</th></tr>
<tr><td>1</td><td>0.071
A2</td><td>0.039
A6</td><td>0.238
A1</td></tr>
<tr><td>16</td><td>0.039
A6</td><td>0.034
A7</td><td>0.039
A6</td></tr>
<tr><td>CV</td><td>0.039
A6</td><td>0.039
A6</td><td>0.039
A6</td></tr>
<tr><td>Dsrt</td><td>0.039
A6</td><td>0.034
A7</td><td>0.039
A6</td></tr>
<tr><td>NC</td><td>0.071
A2</td><td>0.039
A6</td><td>0.238
A1</td></tr>
<tr><td>SC</td><td>0.071
A2</td><td>0.039
A6</td><td>0.238
A1</td></tr>
</table>
</td></tr>
<tr><td>Table IV.22 – Standard U-factors for Wood Foam Panel (SIP) Floors
</td><td></td><td>No life cycle cost analysis.</td></tr>
<tr><td>Table IV.23 – Standard U-factors for Metal-Framed Floors with a Crawl Space
</td><td></td><td>
<table>
<tr><th>CZ</th><th>Day</th><th>24</th><th>Rtl</th></tr>
<tr><td>1</td><td>0.094
A1</td><td>0.065
A2</td><td>0.094
A1</td></tr>
<tr><td>16</td><td>0.094
A1</td><td>0.041
H1</td><td>0.094
A1</td></tr>
<tr><td>CV</td><td>0.094
A1</td><td>0.065
A2</td><td>0.094
A1</td></tr>
<tr><td>Dsrt</td><td>0.065
A2</td><td>0.041
H1</td><td>0.065
A2</td></tr>
<tr><td>NC</td><td>0.094
A1</td><td>0.094
A1</td><td>0.094
A1</td></tr>
<tr><td>SC</td><td>0.094
A1</td><td>0.094
A1</td><td>0.094
A1</td></tr>
</table>
</td></tr>
</table>

Construction Category from Joint Appendix IV	Comment	Life-Cycle Cost
Table IV.24 – Standard U-factors for Metal-Framed Floors without a Crawl Space		

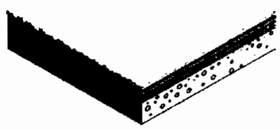


CZ	Day	24	Rtl
1	0.106	0.056	0.253
	A2	H1	A1
16	0.056	0.056	0.056
	H1	H1	H1
CV	0.106	0.056	0.056
	A2	H1	H1
Dsrt	0.056	0.056	0.056
	H1	H1	H1
NC	0.106	0.056	0.253
	A2	H1	A1
SC	0.106	0.106	0.253
	A2	A2	A1

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

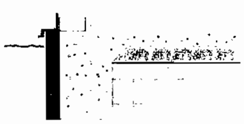
Continuous Insulation Underneath

Continuous Insulation Above Deck



CZ	Day	24	Rtl
1	0.315	0.066	0.315
	A1	A7	A1
16	0.090	0.055	0.090
	A5	A8	A5
CV	0.109	0.066	0.315
	A4	A7	A1
Dsrt	0.090	0.055	0.090
	A5	A8	A5
NC	0.315	0.090	0.315
	A1	A5	A1
SC	0.315	0.090	0.315
	A1	A5	A1

Table IV.26 – F-Factors for Unheated Slab-on-Grade Floors



No life-cycle cost analysis.