ORNL-6907

Supporting Documentation for the 1997 Revision to the DOE Insulation Fact Sheet

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August 22, 1997

Building Thermal Envelope Systems and Materials Program

Prepared for the
U.S. Department of Energy
Office of Energy Efficiency and Renewable Resources

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For the U.S. Department of Energy
under contract No. DE-AC05-960R22464.

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Acknowledgments

This revision to the DOE Insulation Fact Sheet relies heavily on the text and methodology of the original fact sheet, generated by David McElroy and Thomas Kollie of Oak Ridge National Laboratory, and Stephen Petersen of the National Institute of Standards and Technology. The program has been ably directed at the Department of Energy by Peter Scofield, John Talbot, and Arun Vohra. Donald Clem, Peter Stratton, and Adrian Tuluca of Steven Winter Associates, Inc. directed the insulation cost survey, contacting over 3000 contractors. Kenneth Wilkes, David Yarbrough, and Jeffrey Christian have provided invaluable guidance during the revision process. Elena Koontz and Kara Kruse developed the Internet version of the ZIP-Code computer program and Ken Childs is responsible for the Fact Sheet's Internet site, both helpful sources of information for insulation consumers. Many reviewers, from trade associations, academia, and assorted governmental agencies, took the time to examine early drafts of the document and offered useful suggestions for improvements.

Abstract

The Department of Energy (DOE) Insulation Fact Sheet has been revised to reflect developments in energy conservation technology and the insulation market. A nation-wide insulation cost survey was made by polling insulation contractors and builders and the results are reported here. These costs, along with regional weather data, regional fuel costs, and fuel-specific system efficiencies were used to produce recommended insulation levels for new and existing houses. This report contains all of the methodology, algorithms, assumptions, references, and data resources that were used to produce the 1997 DOE Insulation Fact Sheet.

1. Introduction

The Department of Energy (DOE) first published an insulation fact sheet in 1978.[1] The publication's aim was to inform consumers about the advantages offered by insulation and to provide guidance that would lead to reasonable insulation purchases. This guidance took the form of recommended insulation R-values for each part of a home, the recommendation varying with climate and heating fuel type. (An insulation R-value defines the thermal resistance of the material, in units of $h \cdot ft^2 \cdot {}^\circ F/Btu$). The fact sheet was revised in 1982 and again in 1988 and is distributed upon request to over 40,000 readers/year.

The 1997 revision to the DOE Insulation Fact Sheet again recommends varying levels of insulation for different parts of the country.[2] This supporting document has been prepared to describe the basis for these insulation level recommendations. As with the previous version of the fact sheet, these recommendations were based on a life-cycle cost optimization strategy found in the ZIP-Code computer program, written by Stephen Petersen of the National Institute of Standards and Technology.[3] The program's methodology is summarized here along with other assumptions and reference material used to prepare the Fact Sheet. The cost optimization relies on regional weather data, regional fuel costs, regional insulation costs, and fuel-specific system efficiencies. Differences are recognized for new and existing houses, primarily in the economic lifetime of insulation installations and in heating and cooling system efficiencies.

2. Energy Savings

Several performance assumptions were necessary to assess the optimal insulation investment level. Heating and cooling system assumptions are shown in Table 1. Heat pump efficiency was adjusted for the climate as shown in Eq. 1.[3] Air conditioner use was assumed wherever there were more than 2000 cooling degree hours (CDH) or if the heating system was a heat pump. The cooling degree hours were based on a 74°F balance point and the heating degree days (HDD) were based on a 65°F balance point, as provided in Ref. 4 and shown in Appendix A.

$$0_h = 1.06 \times (2.3 - 0.1 \times \frac{HDD}{1000}) \times \frac{HSPF}{6.7} \qquad (1)$$

where: η_h = adjusted heat pump heating efficiency,
HDD = heating degree days (65°F balance point), and
HSPF = heat pump heating seasonal performance factor.

Table 1. Heating and cooling system performance assumptions

New gas, propane, or oil furnace seasonal efficiency	0.80
Existing gas, propane, or oil furnace seasonal efficiency	0.675
New electric air conditioner seasonal energy efficiency ratio (SEER), Btu/W•h	11
Existing electric air conditioner SEER, Btu/W•h	9
New heat pump heating seasonal performance factor(HSPF) used in Eq. 1, Btu/W•h	7.5
Existing heat pump HSPF (used in Eq. 1), Btu/W•h	6.7
New heat pump SEER, Btu/W•h	10.25
Existing heat pump SEER, Btu/W•h	9
Electric resistance heat efficiency	1.0
Duct efficiency for electric baseboard heating systems (applied to both heating and cooling energy use)	1.0
Duct efficiency for all other heating systems (applied to both heating and cooling energy use)	0.75

Ducts were assumed to be located in unconditioned spaces and to have losses of about 25%.[5] This assumption is most appropriate for homes with ducts located in the attic and will overpredict energy savings associated with insulation if the ducts are located in the conditioned space. This is discussed later in this report. For baseboard electric heating systems, there were assumed to be no duct losses.

Changes were made to the ZIP-Code computer program where necessary to reflect changes in the scope of the data used by the program. The two models used to calculate energy savings were unaltered. One of these models was used for insulation measures above-ground and another for measures associated with basements or building foundations. As described in Ref. 3, "Reductions in annual heating requirements and annual cooling requirements due to insulation in attics and in wood-frame and masonry walls are estimated using equations derived from the Lawrence Berkeley Laboratory PEAR[6] program in support of the proposed ASHRAE 90.2P Standard for the Energy Efficient Design of New Low-Rise Residential Buildings.[4]". This same approach was used for metal-framed walls and attics, although the thermal conductance (or U-values) were calculated more rigorously, as described later in this section, to account for thermal bridging. Equations 2 and 3 and Table 2 show the PEAR-based calculation.

$$\Delta Q_h = M_h \times HDD \times \frac{\Delta U}{1,000,000} \tag{2}$$

$$\Delta Q_c = M_c \times CDH \times \frac{\Delta U}{1,000,000} \tag{3}$$

where:
- ΔQ_h = change in annual heating energy requirement (million Btu/ft^2·year),
- M_h = constant found in Table 2,
- HDD = heating degree days, base 65°F,
- ΔU = change in U-value (Btu/°F·ft^2·hour),
- ΔQ_c = annual cooling energy reduction (million Btu/ft^2·year),
- M_c = constant found in Table 2, and
- CDH = cooling degree hours, base 74°F.

Table 2. Constants used to calculate annual energy savings for attics and above-ground walls

Application	**M_h**	**M_c**
Attic or cathedral ceiling	25.91	1.978
Frame wall and band joist	21.19	1.005
Masonry wall	20.02	0.739

The model used to estimate savings associated with basement and building foundation insulation was also described in Ref. 3. "The reduction in annual heating requirements and annual cooling requirements for floors over unheated spaces, slab floors, and crawlspace and basement walls are estimated using equations and parameters derived from J. Christian and W. Strzepek, ‘Procedure for Determining the Optimum Foundation Levels for New, Low-Rise Residential Buildings’.[7] Reductions in space heating and cooling requirements per heating degree day and cooling degree hour were estimated in that report at several insulation R-values for floors over unheated areas (Btu/ft^2) and for slab floors, crawlspace walls, and exterior and interior insulation of both shallow and deep basement walls (all in Btu/linear foot). Values for other insulation R-values are computed in the ZIP-Code computer program by interpolation (assuming that reductions in thermal loss or gain are proportional to the inverse of the overall thermal resistance of the component).” For each of the components, equations 4 and 5 are used to estimate incremental reductions in annual heating and cooling requirements. The β coefficients for these equations are found in Appendix B.

$$\Delta Q_h = \beta_h \times \frac{HDD}{1{,}000{,}000} \qquad (4)$$

$$\Delta Q_c = \beta_c \times \frac{CDH}{1{,}000{,}000} \qquad (5)$$

Where: ΔQ_h = change in annual heating energy requirement (million Btu/ft^2·year for floor insulation and million Btu/linear foot·year for other measures),

β_h = the reduction in annual heating energy requirement per heating degree day for a designated increase in component R-value,

ΔQ_c = annual cooling energy reduction (million Btu/ft^2·year for floor insulation and million Btu/linear foot·year for other measures), and

β_c = the corresponding reduction in annual cooling requirement per cooling degree hour.

The PEAR-based model used for walls and attics requires the overall U-value associated with each insulation level. Typical wall and attic constructions were assumed to assign values for the base level U-values and the improved U-values. These typical constructions were based on ASHRAE guidelines and include internal and external film coefficients.[8] For these calculations, no pre-existing insulation was assumed and an R-value of 0.9 h•ft^2•°F/Btu was used for the air space in any wall cavity without insulation. For wood-framed attics and walls, a parallel path heat transfer model was used to include the heat transfer through the framing members in the estimate of the overall U-values.

Heat transfer through studs and joists in metal-framed buildings is of major concern when estimating energy savings associated with insulation applications. The thermal short circuits associated with the more highly conductive metal framing members make cavity insulation options less effective than with wood-framed construction. For metal-framed walls, a modified zone method, similar to that found in the ASHRAE guidelines, was used to account for the heat transfer that occurs through more highly conductive metal frame members. Ghost marks, or dark vertical marks that appear over the framing on the interior surfaces of exterior walls, are likely to occur in moderate and cold climates when metal frames are used without proper attention to the heat transfer that occurs in the framing members.[9] Because of this concern for metal walls, they were evaluated with a minimum insulation sheathing requirement of 0.5 in., or R2.5, of extruded polystyrene. For both wood- and metal-framed walls, sheathing and cavity insulation were evaluated together as an integrated wall assembly. Sheathing of extruded polystyrene was considered at thicknesses of 0, ½, and 1 inch, corresponding to R-values of 0, 2.5, and 5. An alternate sheathing material, foil-faced polyisocyanurate board was also considered at the same thicknesses, corresponding to R-values of 0, 3.5, and 7. (Note that these higher R-values for foil-faced products only apply if the foil-facing is perfectly adhered to the foam and if the foil facing is not damaged before or during the installation process.) For both insulative sheathing materials, it was assumed that the insulation was placed on top of a structural wood sheathing with an R-value of 1.32. This arrangement is used by many builders to avoid the use of bracing and to facilitate exterior siding installation. The wall studs were assigned a thickness of 3.5 inches for cavity insulation of R-15 and below and 5.5 inches for R-21. A short computer program was written to explore these sheathing and cavity insulation options for both wood- and metal-framed walls, as shown in Appendix C. The resulting composite U-values are included later in this report with the cost data for each measure.

The U-values used for metal-framed ceilings in this evaluation were calculated based on experimental work described in Ref. 10. The correlations used are a strong function of the number of interior and edge vertical framing elements that protrude through the insulation. Because there is no “standard” attic truss system, the attic was modeled as a space 30x40 ft, with joists every 24 in. and with a vertical truss connection every 6 ft. This produces 84 interior vertical members and 42 edge vertical members over an area of 1200 ft^2. For this arrangement, the correlations in Ref. 10 show an increase in the overall U-value (compared to a ceiling with no frame at all) of 0.0133 Btu/h·ft^2·°F. (The difference between the base, or uninsulated, U-values for the wood- and metal-framed attics shown later in this report appears to be attributable to different assumptions about the air-film resistance. This difference is negligible for insulation levels greater than R-19, which encompass more than 90% of the cases.) The model also considers the performance of a layer of foam insulation placed between the frame and the ceiling drywall. For cases with foam insulation, the metal-frame increase in the overall U-value is multiplied by a "ceiling foam board adjustment" producing the overall U-values shown later in this report with the cost data. The author of Ref. 10 points out that these correlations neglect heat loss associated with the extension of the attic joists into the eaves, which provides a direct path for heat transfer from the ceiling to the outdoor air.

A metal-framed floor conducts more heat than a wood-framed floor, as is shown by the equivalent metal-floor R-values given in Ref. 10. Corresponding β coefficients used to calculate the savings for a metal-framed floor (see Eqs. 4 and 5) were interpolated from those provided in Ref. 7 by assuming that reductions in thermal loss or gain are proportional to the inverse of the overall thermal resistance. For this interpolation, the overall R-values of the floors were used, as shown in Table 3. The base level resistance (without any insulation in place) was assumed to be the same for both wood and metal floors, because there was no experimental data on the uninsulated metal floor.

Table 3. Interpolation of heating season savings factors for metal-framed floors

Cavity insulation R-value	System R-value		System U-value		Saving factor (β)	
	Wood	Metal	Wood	Metal	Wood	Metal
0	4	4	.249	.249		
11	13.9	7.3	.072	.14	1.7	1.05
19	21	8.9	.047	.11	1.96	1.33
30	30	11.0	.033	.091	2.22	1.52

3. Insulation Costs

Insulation measures were considered for each type of house, new or existing, based on current market practices. For new construction, these included insulation in the attic, on the interior surface of masonry walls, underneath floors over crawl spaces, along the perimeter of the slab edge, on the interior wall of an unvented crawlspace, on the interior or exterior of a basement wall, within a cathedral ceiling, along the band joists between floors, and a combination of insulative sheathing and cavity insulation for wood- and metal-frame walls. For existing houses, fewer insulation measures were considered, because several measures are difficult to install after construction is complete. Insulative sheathing was considered for existing houses under renovation. Some possible insulation applications were not considered for the DOE Insulation Fact Sheet because alternative treatments proved to be less costly. For example, crawl space walls can be insulated on the inside or outside surface. The inside treatment cost estimates were lower than the outside costs, so the inside application was included in the fact sheet and the outside one was not. For attics, the installed cost of loose fill insulation was less than that of batt insulation products, so loose fill costs were used to derive the recommended levels. For new construction, batt products were the least expensive method for wall insulation, whereas blown-in products were less costly for existing walls.

A survey was made to determine appropriate costs for the analysis. The aim of the survey was to obtain costs from 60 insulation contractors for both new construction and retrofit applications, and from at least 60 building contractors able to provide cost information representative of new construction. Over 2000 insulation contractors and over 1000 builders were selected at random across the United States and were contacted by phone. Approximately 18% of the contractors agreed to return the survey, but only 9% of these (or less than 2% of the original 2000 who were polled) actually returned the survey, despite a series of follow-up contacts by phone, fax, and mail. Out of the all the builders contacted, only 18 responded to the survey.

The survey participants were asked to provide installed costs, including materials, labor, overhead, and profit for a variety of insulation applications. They were asked to provide estimates separately for new construction and existing houses. Appendix D shows the survey forms used to collect data from the participants. A large number of contractors provided prices for common attic, wall, and floor insulation jobs. However, they provided very few estimates for other applications, such as masonry wall insulation.

Builders were asked to provide incremental framing costs associated with higher levels of insulation in cathedral ceilings and wood-frame walls. These forms are also shown in Appendix D. Tables 4 and 5 summarize the survey, showing the number of responses, and the mean and standard deviation for the values reported. The mean values were used to represent national average costs for the ZIP-Code computer program. When the 1988 cost files were updated, it was noted that most insulation costs had remained very nearly the same. Some costs were even slightly lower than those quoted in 1988, despite the modest inflation that has occurred during the last eight years. Therefore, for those insulation applications where the new data were insufficient, the 1988 cost figures were retained for this analysis. Additional cost survey data compilations are included in Appendix D.

Table 4. Insulation contractor survey results (cont.)

Material	R-value	Mean installed cost ($/ft^2)	Number of responses	Standard Deviation ($/ft^2)
New construction: attic floor				
Fiberglass blanket	11	.33	25	.10
Blown fiberglass	11	.24	20	.06
Blown cellulose	11	.27	14	.12
Blown rockwool	11	.21	7	.04
Average blown material	11	.24	41	.09
Fiberglass blanket	19	.44	25	.10
Blown fiberglass	19	.33	24	.07
Blown cellulose	19	.34	16	.12
Blown rockwool	19	.29	7	.06
Average blown material	19	.33	47	.09
Fiberglass blanket	22	.58	15	.18
Blown fiberglass	22	.35	15	.06
Blown cellulose	22	.41	15	.15
Blown rockwool	22	.32	7	.06
Average blown material	22	.37	37	.11
Fiberglass blanket	25	.66	9	.24
Fiberglass blanket	30	.62	24	.13

Table 4. Insulation contractor survey results (cont.)

Material	**R-value**	**Mean installed cost ($/ft^2)**	**Number of responses**	**Standard Deviation ($/ft^2)**
Blown fiberglass	30	.44	23	.08
Blown cellulose	30	.47	17	.13
Blown rockwool	30	.42	7	.08
Average blown material	30	.45	47	.10
Fiberglass blanket	38	.74	23	.15
Blown fiberglass	38	.55	21	.10
Blown cellulose	38	.57	20	.13
Blown rockwool	38	.52	7	.11
Average blown material	38	.56	48	.11
Fiberglass blanket	49	1.17	6	.28
Blown fiberglass	49	.68	10	.16
Blown cellulose	49	.70	13	.15
Blown rockwool	49	.66	6	.16
Average blown material	49	.68	29	.15
Fiberglass blanket	60	1.41	6	.34
Blown fiberglass	60	.84	10	.19
Blown cellulose	60	.81	12	.19
Blown rockwool	60	.82	6	.21
Average blown material	60	.82	28	.19
Existing house: attic floor				
Fiberglass blanket	11	.35	24	.08
Blown fiberglass	11	.26	24	.08
Blown cellulose	11	.31	16	.12
Blown rockwool	11	.22	9	.05
Average blown material	11	.27	49	.10
Fiberglass blanket	19	.49	27	.11
Blown fiberglass	19	.35	27	.08
Blown cellulose	19	.41	22	.13
Blown rockwool	19	.31	49	.07

Table 4. Insulation contractor survey results (cont.)

Material	R-value	Mean installed cost ($/ft^2)	Number of responses	Standard Deviation ($/ft^2)
Average blown material	19	.37	58	.11
Fiberglass blanket	22	.65	15	.16
Fiberglass blanket	25	.71	15	.23
Fiberglass blanket	30	.67	23	.13
Blown fiberglass	30	.48	27	.10
Blown cellulose	30	.52	21	.10
Blown rockwool	30	.45	9	.10
Average blown material	30	.49	57	.10
Fiberglass blanket	38	.84	20	.22
Blown fiberglass	38	.60	24	.11
Blown cellulose	38	.62	23	.10
Blown rockwool	38	.59	8	.11
Average blown material	38	.60	55	.10
Fiberglass blanket	49	1.07	9	.32
Blown fiberglass	49	.77	14	.14
Blown cellulose	49	.78	18	.13
Blown rockwool	49	.75	7	.16
Average blown material	49	.77	39	.14
New construction: cathedral ceiling				
Fiberglass blanket	11	.34	19	.10
Fiberglass blanket	13	.46	21	.22
Fiberglass blanket	15	.63	17	.11
Fiberglass blanket	19	.53	24	.25
Fiberglass blanket	21	.62	14	.12
Fiberglass blanket	22	.59	11	.20
Fiberglass blanket	30	.73	25	.36
Fiberglass blanket	38	.87	24	.43
Fiberglass blanket	49	1.10	6	.35
Fiberglass blanket	60	1.24	6	.47

Table 4. Insulation contractor survey results (cont.)

Material	R-value	Mean installed cost ($/ft^2)	Number of responses	Standard Deviation ($/ft^2)
New construction: exterior walls				
Fiberglass blanket	11	.31	22	.09
Fiberglass blanket	13	.37	23	.09
Fiberglass blanket	15	.56	21	.11
Fiberglass blanket	19	.44	23	.11
Fiberglass blanket	21	.55	14	.11
Insulative sheathing	3	.40	1	0
Insulative sheathing	4	.52	2	.12
Insulative sheathing	5	.64	1	0
Insulative sheathing	7	.67	2	.15
Insulative sheathing	8	.80	1	0
Insulative sheathing	10	.77	2	.18
Sprayed cellulose	12	.67	8	.22
Sprayed cellulose	19	.80	8	.25
Existing house: exterior walls				
Cellulose (3 lb/ft^3)	11	.76	18	.28
Cellulose (4/lb/ft^3)	11	.86	14	.30
Blown fiberglass	11	.80	14	.32
New construction: floor				
Fiberglass blanket	11	.37	20	.12
Fiberglass blanket	13	.41	19	.09
Fiberglass blanket	15	.61	17	.08
Fiberglass blanket	19	.53	24	.16
Fiberglass blanket	25	.62	7	.12
Existing house: floor				
Fiberglass blanket	11	.38	25	.11
Fiberglass blanket	13	.46	24	.15
Fiberglass blanket	15	.61	19	.11
Fiberglass blanket	19	.58	32	.20

Table 4. Insulation contractor survey results (cont.)

Material	R-value	Mean installed cost ($/ft^2)	Number of responses	Standard Deviation ($/ft^2)
Fiberglass blanket	25	.76	13	.36
New construction: concrete/block walls - exterior and below grade				
Fiberglass blanket	5	.42	1	0
Fiberglass blanket	10	.45	3	.02
Fiberglass blanket	15	.56	8	.11
Fiberglass blanket	20	.66	1	0
New construction: crawl space wall - interior application				
Fiberglass blanket	11	.37	21	.13
Fiberglass blanket	13	.41	20	.11
Fiberglass blanket	15	.59	19	.11
Fiberglass blanket	19	.52	22	.15
Extruded polystyrene	10	.98	1	0
Existing house: crawl space wall - interior application				
Fiberglass blanket	11	.37	25	.12
Fiberglass blanket	13	.44	23	.16
Fiberglass blanket	15	.59	20	.13
Fiberglass blanket	19	.55	26	.19
Extruded polystyrene	7	.72	1	0
Extruded polystyrene	10	.90	1	0
Extruded polystyrene	15	1.05	1	0
Extruded polystyrene	19	1.15	1	0
Band Joist				
Fiberglass blanket	11	.31	22	.09
Fiberglass blanket	13	.36	21	.08
Fiberglass blanket	19	.45	24	.10
Fiberglass blanket	30	.60	18	.09
New construction: masonry walls				
Insulating stucco over fiberglass	11	.31	2	.01
Insulating stucco over fiberglass	13	.38	2	.03

Table 4. Insulation contractor survey results (cont.)

Material	R-value	Mean installed cost ($/ft^2)	Number of responses	Standard Deviation ($/ft^2)
Insulating stucco over fiberglass	19	.43	2	.04
Isocyanurate foam in block cavity	14	1.92	1	0
Isocyanurate foam in block cavity	25	2.81	1	0
New construction: concrete/block walls - interior application above- or below-grade				
Fiberglass blanket	11	.34	16	.14
Fiberglass blanket	13	.40	13	.11
Fiberglass blanket	15	.56	10	.14
Fiberglass blanket	19	.47	15	.15
Fiberglass batts with flame-resistant facing	11	.52	10	.20
Expanded polystyrene	5	.80	1	0
Expanded polystyrene	7	.70	1	0

Framing costs from Table 5 were included in the costs used in this analysis for wood- and metal-framed walls at higher insulation levels. The total framing costs shown in Table 5 have been calculated from the incremental costs requested from the builders (see the forms in Appendix D). Data were not collected for metal-framed walls. Additional framing costs for all wall thicknesses greater than 3.5 inches were estimated to be $0.83/ft^2 for both wood and metal, based on the builder estimates for wood frame construction. No data were collected for Optimum Value Engineered (OVE) framing costs. The evaluation of insulation options for OVE construction was based on the assumption that a 2x6 wall could be built for the same cost as a conventional 2x4 wall, i.e., no framing costs were associated with the higher levels of insulation. Note that this assumption indicates that the cost of extension jambs for windows and doors has also been offset during the OVE design process.

Framing costs from Table 5 were originally used for cathedral ceiling insulation levels greater than R-19. However, many reviewers argued that additional framing costs for cathedral ceilings were inappropriate. A series of phone consultations with major builders supported these comments. The builders reported typically using an engineered truss system with more than six inches of space for insulation. Therefore, the cathedral ceiling analysis assumed that no additional framing costs were associated with insulation values up to R-38.

Table 5. Builder survey results

R-value	Mean cost ($/ft^2)	Number of responses	Standard deviation ($/ft^2)
Raised heel attic framing			
22	.08	6	.04
30	.18	9	.09
38	.28	11	.18
49	.42	9	.25
60	.62	9	.41
Cathedral ceiling framing			
19	.14	4	.11
22	.20	5	.15
30	.41	9	.30
38	.60	7	.42
49	.92	6	.68
60	1.04	5	.84
Wood frame walls, increased costs for changing from 2×4 to 2×6 construction			
>15	.83	15	.72
Concrete-block wall, interior framing for insulation			
7.5	.97	12	.71
10	1.19	12	.66
15	1.56	12	.91
19	1.78	12	1.04

When builder-reported costs for raised heel framing were used to estimate savings for attics in new construction, the recommended insulation levels were much lower than for existing houses. In existing houses, the average savings coefficients based on the PEAR analysis are used, even though it is assumed that the higher insulation levels will be installed only over those parts of the attic floor with adequate clearance. Comparing these two conflicting results, it was deemed more conservative to neglect the raised heel framing costs for new construction, thereby using the retrofit assumption that the additional insulation will only be placed over those parts of the attic floor with adequate clearance.

For insulative sheathing, the builders were asked to report the incremental cost incurred when insulative sheathing is used to replace fiberboard on a 900 ft^2 wall for R-values ranging from 3.6 to 10. The responses ranged from $0 to $550. Examination of the answers revealed three sets of answers that appeared to correspond to estimates for: (1)the whole 900 ft^2, (2)each 4×8 sheet of sheathing, and (3) each square foot. Scatter within these groups probably reflects differences in building practices, because some builders routinely place foam sheathing on top of wood sheathing while other use it to replace the sheathing and add necessary bracing to the frame. Yet another technique is to use the foam sheathing for portions of the walls where strength is not important and to use wood sheathing near corners where the bracing is needed. Follow-up phone calls to these builders were not returned and these quoted prices were therefore not used. An additional effort was made to collect retail costs for 1 and 2-in. (R-5 and R-10) sheets of extruded polystyrene. This small survey, where home supply stores in 14 states were polled, is summarized in Table 6. The cost of insulative wall sheathing was estimated using this survey to represent material costs, which were then combined with labor, overhead, and profit from 1996 R.S. Means.[11] These costs showed reasonable agreement to the few insulation contractor-reported costs for insulative sheathing gathered during the 1996 cost survey, and were therefore used in the wall insulation analysis. Foil-faced polyisocyanurate is another potential wall sheathing material and has a nominal R-value of R7 per inch. (Note that the higher R-values for foil-faced products only apply if the foil-facing is perfectly adhered to the foam and if the foil facing is not damaged before or during the installation process.) Installed costs for this sheathing were taken from a Polyisocyanurate Insulation Manufacturers' Association (PIMA) case study and are $.65/$ft^2$ for ½ inch and $.87/$ft^2$ for one inch.[22]

Table 6. Retail prices for extruded polystyrene from 14 states

R-value	Number of responses	Mean ($/$ft^2$)	Standard deviation ($/$ft^2$)	Minimum ($/$ft^2$)	Maximum ($/$ft^2$)
5	14	0.25	0.09	0.14	0.40
10	15	0.45	0.14	0.24	0.66

The ZIP-Code computer program used regional cost multipliers to adjust insulation costs for differences in material and labor costs. These factors were updated using RS Means city factors (~300 cities) for "thermal and moisture protection", averaged into state factors.[11] These state cost correction factors, normalized to 100 for the national average, have been included in Appendix E.

The results of the cost survey, combined with the composite U-values described previously, are summarized in Table 7.

Table 7. Insulation costs and thermal resistances used in the ZIP-Code computer program(cont.)

Added insulation R-value (h-ft²-F/Btu)		**Overall component U-value (Btu/°F·ft²·h)**	**Cost ($/ft² or $/linear ft)**	
			New construction	**Existing**
Wood-framed attic ($/ft²)				
0		0.2540		
11		0.0688	0.24	.27
19		0.0455	0.33	.37
22		0.0400	0.37	
30		0.0333	0.45	.49
38		0.0241	0.56	.60
49		0.0199	0.68	.77
60		0.0193	0.82	
Metal-framed attic ($/ft²)				
Sheathing	Cavity			
none	0	0.592		
none	11	0.092	0.24	
none	19	0.062	0.33	
none	30	0.045	0.45	
none	38	0.039	0.56	
none	49	0.033	0.68	
5	38	0.028	1.14	
5	49	0.023	1.26	
10	49	0.020	1.53	
Cathedral ceiling ($/ft²)				
0		0.2616		
11		0.0742	.34	

Table 7. Insulation costs and thermal resistances used in the ZIP-Code computer program(cont.)

Added insulation R-value (h-ft^2-F/Btu)	Overall component U-value (Btu/°F·ft^2·h)	Cost ($/ft^2 or $/linear ft)	
		New construction	Existing
13	0.0666	.46	
15	0.0607	.63	
19	0.0493	.53	
21	0.0460	.62	
22	0.0434	.59	
30	0.0332	.73	
38	0.0270	.87	
49	0.0216	2.02	
60	0.0178	2.29	
Masonry Walls ($/ft^2)			
0	0.263		
3.8	0.164	0.22	
5.7	0.130	0.36	
7.6	0.108	0.52	
9.5	0.092	0.67	
11.4	0.080	0.82	
15.0	0.068	1.78	
21.6	0.056	2.20	
Wood- or metal-framed floor ($/ft^2)			
11	not used	0.37	.38
13	not used	0.41	.46
19	not used	0.53	.58
25	not used	0.62	.76
Slab edge ($/linear foot)			
4	not used	1.40	
8	not used	1.82	
Crawl space walls ($/linear foot)			
11	not used	1.47	1.49

Table 7. Insulation costs and thermal resistances used in the ZIP-Code computer program(cont.)

Added insulation R-value (h-ft^2-F/Btu)	Overall component U-value (Btu/°F·ft^2·h)	Cost ($/ft^2 or $/linear ft)	
		New construction	Existing
13	not used	1.63	1.75
19	not used	2.08	2.19
Basement walls - exterior application ($/linear foot)			
4	not used	6.20	
5	not used	7.01	
8	not used	9.30	
10	not used	10.87	
12	not used	12.30	
15	not used	14.55	
Basement walls - interior application ($/linear foot)			
11[a]	not used	4.24	4.24
11	not used	6.48	6.48
13	not used	7.20	7.20
19	not used	9.30	9.30
Band joist ($/linear foot)			
0	0.197		
11	0.065	0.31	
13	0.059	0.36	
19	0.044	0.45	
30	0.031	0.60	
Add insulative sheathing to uninsulated exterior wall[b] ($/ft^2)			
0	0.204		
2.5	.134		.47
5.	.1		.58
Add insulative sheathing to wall with R-11 cavity insulation[b] ($/ft^2)			
0	0.084		
2.5	0.068		.47
5.	0.058		.58

Table 7. Insulation costs and thermal resistances used in the ZIP-Code computer program(cont.)

Added insulation R-value (h-ft²-F/Btu)		**Overall component U-value (Btu/°F·ft²·h)**	**Cost ($/ft² or $/linear ft)**	
			New construction	**Existing**
Wood-framed wall - combined insulative sheathing and cavity insulation ($/ft²)				
Sheathing	Cavity			
0	none	0.2052		
2.5	11	.0686	.77	
3.5	11	0.0639	.95	
2.5	13	.0639	.83	
3.5	13	.0597	1.01	
2.5	15	.0601	1.03	
3.5	15	.0563	1.21	
2.5	19	.0496	1.74	
3.5	19	.0470	1.92	
2.5	21	.0474	1.85	
3.5	21	.0450	2.03	
5	11	.0581	.88	
7	11	.0519	1.17	
5	13	.0545	.94	
7	13	.0489	1.23	
5	15	.0515	1.14	
7	15	.0464	1.43	
5	19	.0437	1.85	
7	19	.0399	2.14	
5	21	.0418	1.96	
7	21	.0383	2.25	
none	11	.0840	.30	.80
none	13	.0777	.36	
none	15	.0727	.56	
none	19	.0577	1.27	
none	21	.0550	1.38	

Table 7. Insulation costs and thermal resistances used in the ZIP-Code computer program(cont.)

Added insulation R-value (h-ft²-F/Btu)		Overall component U-value (Btu/°F·ft²·h)	Cost ($/ft² or $/linear ft)	
			New construction	Existing
Sheathing	Cavity			
2.5	none	.1341	.47	
3.5	none	.1179	.65	
5	none	.0999	.58	
7	none	.0831	.87	
Metal-framed wall - combined insulative sheathing and cavity insulation ($/ft²)				
Sheathing	Cavity			
none	none	.2362		
2.5	none	.1486	.47	
3.5	none	.1293	.65	
5	none	.1084	.58	
7	none	.0891	.87	
none	11	.1049	not used	
none	13	.0988	not used	
none	15	.0942	not used	
none	19	.0864	not used	
none	21	.0841	not used	
2.5	11	.0808	.77	
3.5	11	.0731	.95	
2.5	13	.0766	.83	
3.5	13	.0693	1.01	
2.5	15	.0733	1.03	
3.5	15	.0662	1.21	
2.5	19	.0685	1.74	
3.5	19	.0619	1.92	
2.5	21	.0668	1.85	
3.5	21	.0603	2.03	
5	11	.0672	.88	

Table 7. Insulation costs and thermal resistances used in the ZIP-Code computer program(cont.)

Added insulation R-value (h-ft²-F/Btu)		Overall component U-value (Btu/°F·ft²·h)	Cost ($/ft² or $/linear ft)	
			New construction	Existing
Sheathing	Cavity			
7	11	.0580	1.17	
5	13	.0642	.94	
7	13	.0554	1.23	
5	15	.0618	1.14	
7	15	.0533	1.43	
5	19	.0586	1.85	
7	19	.0505	2.14	
5	21	.0573	1.96	
7	21	.0493	2.25	
Wood-framed OVE (assumed that 2x6 wall costs the same as a 2x4 wall) wall - combined insulative sheathing and cavity insulation ($/ft²)				
Sheathing	Cavity			
0	none	0.2052		
2.5	19	.0496	.91	
5	19	.0437	1.02	
5	21	.0418	1.13	
7	19	.0399	1.31	
7	21	.0383	1.42	
none	11	.0840	.30	
none	13	.0777	.36	
none	19	.0577	.44	
none	21	.0550	.55	

a Fiberglass batts with flame resistant facing and minimal framing for unused basement areas.

b Costs do not include removing and replacing exterior wall material, therefore, only appropriate when exterior sheathing is under renovation.

4. Economic Calculations

The ZIP-Code program is based on a life-cycle cost optimization calculation. A discount rate of 3.4% is defined for government-sponsored energy related investment evaluations by the Department of Energy.[12] The effective lifetime of investments in existing houses was set at 20 years and at 30 years for new houses. A present worth factor, used to calculate the current value of future energy savings, is then calculated as shown in Eq. 6 for each region and for each fuel type. This calculation uses energy price escalation factors for 1997-2026 for 4 regions from Ref. 12. These energy price escalation factors are shown in Appendix F. For years beyond 2026, the last factor in the file is repeated.

$$PW = \sum_{n=1}^{n=lifetime} \frac{EF_n / EF_{baseyear}}{(1 + discount\ rate)^n} \tag{6}$$

where:	PW	=	present worth factor,
	EF	=	price escalation factor (see Appendix F), and
	lifetime	=	effective lifetime of investment, and
	discount rate	=	energy related discount rate, 0.034 used.

All energy prices shown in Appendix E reflect those paid by residential consumers in each state in October 1996, consistent with the escalations factors described above. The prices do not include any taxes paid by consumers. Electricity prices were taken from DOE-reported average utility revenues for each state.[13] These revenues do not represent last kWh cost for customers with pyramid rate structures or demand charges. Natural gas prices are reported for each state in Ref. 14. Propane prices are reported for each of 7 Petroleum Administration for Defense (PAD) districts in Ref. 15. Distillate oil prices for 24 states, including all of the states located in the Northeast, as well as average prices for each PAD district, are also taken from Ref. 15. The energy content of fuel oil, propane, and natural gas were taken from Ref. 16.

After the changes in annual heating and cooling energy requirements are estimated for an insulation level, the present value of the savings are calculated as shown in Eq. 7. The insulation level producing the greatest savings is then chosen. Examination of this equation shows the importance of the performance assumptions and insulation costs described in this report. The savings are inversely proportional to the HVAC system efficiencies and the assumed duct efficiency. The differences in the assumed HVAC efficiency for new and existing houses are responsible for much of the differences in the recommendations for these two groups. The role played by the insulation cost is also significant, as was demonstrated by the effect of omitting the cost of raised heel frames in new construction attics.

$$SAVINGS = [\frac{\Delta Q_h}{\eta_h \times \eta_{duct}} \times P_h \times PW_h] + [\frac{\Delta Q_c}{\eta_c \times \eta_{duct}} \times P_c \times PW_c] - COST \qquad (7)$$

where:	SAVINGS	=	present value of net savings associated with insulation measure, $/ft^2 or $/linear foot,
	ΔQ_h	=	annual heating energy reduction (million Btu/ft^2·year or million Btu/linear foot·year),
	P_h	=	heating energy price for base year, $/million Btu,
	PW_h	=	present worth factor for heating fuel,
	η_h	=	heating system efficiency,
	η_{duct}	=	duct system efficiency,
	ΔQ_c	=	annual cooling energy reduction (million Btu/ft^2·year or million Btu/linear foot·year),
	P_c	=	cooling energy price for base year, $/million Btu,
	PW_c	=	present worth factor for cooling fuel,
	η_c	=	cooling system efficiency, = SEER/3.412, and
	COST	=	cost of the insulation, $/ft^2 or $/linear foot.

5. Insulation Groups

The detailed results of the ZIP-Code cost/benefit analysis will be available to anyone accessing the electronic version of the DOE Insulation Fact Sheet on the Internet.[2] However, it was necessary to group these recommendations into some more usable format for the printed version. An analysis of the results showed the expected high correlation between the various insulation levels. For example, an area that calls for a higher level of attic insulation is also likely to call for a higher level of floor insulation. Using this trend, six insulation groups were defined for existing houses and seven groups were defined for new houses, as shown in Tables 8 and 9. Each 3-digit zip code area was assigned to one of these groups based on the optimal attic, floor, and cathedral ceiling insulation levels for each type of heating system and for new or existing houses. Presenting this information directly would have required 12 tables (two house types times six heating system types). Therefore, the assignment was further simplified for the DOE Insulation Fact Sheet presentation by defining nine insulation zones and assigning the most representative insulation zone to each zip code, as shown in Tables 10 and 11. When making this assignment, the overall distribution of homes by fuel type, shown in Table 12, was considered.

Table 8. Recommended insulation levels for existing houses from the 1997 DOE Insulation Fact Sheet(a)

Insulation Group	Attic	Floor over unconditioned space	Wall cavity	Crawl space wall(b)	Basement wall	Add insulative sheathing to an uninsulated wall(c)	Add insulative sheathing to an insulated wall(c)
E1	19	11	0	11	11	5	0
E2	30	11	11	11	11	5	0
E3	38	11	11	19	11	5	0
E4	38	19	11	19	11	5	0
E5	38	25	11	19	11	5	5
E6	49	25	11	25	11-13	5	5

(a) R-values have units of $^\circ F \bullet ft^2 \bullet h/Btu$. This table, when used with Tables 10 and 11, provides recommended total R-values for existing houses and was produced using the ZIP-Code computer program. The recommendations are based on an analysis of cost-effectiveness, using average local energy prices, regional average insulation costs, equipment efficiencies, climate factors, and energy savings for both the heating and cooling seasons.

(b) Use only if floor is uninsulated and the crawlspace is unventilated - see the discussion about unventilated crawlspaces.

(c) Recommendation assumes that the exterior siding was removed for other purposes, i.e., does not include any consideration of the cost of removing and replacing the exterior siding. The R-values shown here represent 1 inch of foam sheathing. Foam sheathing with R-values up to R-7 could be used.

Table 9. Recommended insulation levels for residential new construction from the 1997 DOE Insulation Fact Sheet (a)

Attics and Floors

Insulation Group	Attic(b)	Floors	Cathedral ceilings(c)		Metal-framed building(**d**)	
					Attic(b)	Floors
N1	22	11	22		30	11
N2	38	11	30		30	25
N3	38	13	38		49	25
N4	38	25	38		49	25
N5	49	25	38		49	25
N6	49	25	38		49	25
N7	49	25	60		49	25

Walls

Insulation Group	Wood frame wall assembly (c,e)		Optimum-Value Engineered (OVE) wall cavities(f)	Above-grade masonry wall interior (g)	Band joist	Metal frame wall assembly(c,**d**,e)	
	Insulative Sheathing	Cavity				Insulative Sheathing	Cavity
N1	0	11 to 13	19	5.7	19	2.5 to 5	11 to 13
N2	0	11 to 13	19	9.5	19	2.5 to 5	11 to 13
N3	0	11 to 15	19	11.4	30	2.5 to 5	11 to 13
N4	0 to 5	11 to 15	19	11.4	30	2.5 to 7	11 to 15
N5	0 to 7	11 to 15	19	11.4	30	5 to 7	11 to 15
N6	2.5 to 7	13 to 21	21	15	30	5 to 7	11 to 21
N7	5 to 7	19 to 21	21	15	30	5 to 7	13 to 21

Basements and Foundations

Insulation Group	Crawl space walls(h)	Slab edge	Basement wall exterior (below grade)	Basement wall interior (below grade) (g)
N1	11	0	4	11
N2	13	4	4	11
N3	19	4	4	11
N4	19	4	5	11
N5	19	8	10	11
N6	19	8	15	19
N7	19	8	15	19

(a) R-values have units of $^\circ F \cdot ft^2 \cdot h/Btu$. This table, when used with Tables 10 and 11 provides recommended R-values for new houses and was produced using the ZIP-Code computer program. The recommendations are based on an analysis of cost-effectiveness, using average local energy prices, regional average insulation costs, equipment efficiencies, climate factors, and energy savings for both the heating and cooling seasons.

(b) Does not include the cost of raised heel framing necessary to install the higher levels of insulation in the portions of the attic near the eaves.

(c) Includes the cost of thicker framing where necessary.

(d) *The recommended insulation levels for metal frames will not necessarily give you performance as good as the recommended levels for a wood-framed building.* Please see the discussion about heat loss paths associated with metal frames.

(e) For new construction, it is important to use both the insulative sheathing and cavity insulation recommended, especially for metal walls. Assumes insulative sheathing placed outside of wood sheathing product. For a full discussion of the ranges shown here, see new homes discussion.

(f) These recommendations assume that a 2x6 wall can be built for the same cost as a 2x4 wall, using a careful design procedure called Optimum Value Engineering. Discuss this option with your builder.

(g) Evaluation included cost of necessary framing but did not include cost of finishing drywall and paint.

(h) Crawl space walls are only insulated if the crawl space is unventilated. Please see the *Builders Foundation Handbook* listed at the back of the fact sheet.

Please see the separate pdf file for Table 10, the Zip Code assignments from the 1997 DOE Insulation Fact Sheet.

Table 11. Insulation group assignment for each Insulation Zone from the 1997 DOE Insulation Fact Sheet (a)

Insulation Zone	Existing Houses						New Houses					
	Gas heat	Electric furnace	Electric baseboard (b)	Heat Pump	LPG	Fuel Oil	Gas heat	Electric furnace	Electric baseboard (b)	Heat Pump	LPG	Fuel Oil
1	E1	E4	E3	E3	E2	E2	N1	N5	N4	N2	N2	N2
2	E2	E4	E4	E3	E2	E3	N2	N5	N5	N3	N4	N3
3	E3	E4	E3	E3	E2	E3	N3	N5	N5	N3	N5	N3
4	E3	E6	E4	E3	E4	E3	N5	N5	N5	N5	N5	N5
5	E4	E6	E5	E4	E6	E5	N5	N5	N5	N5	N5	N5
6	E4	E6	E6	E6	E6	E5	N5	N6	N5	N5	N5	N5
7	E5	E6	E6	E5	E6	E5	N5	N5	N5	N5	N5	N5
8	E5	E6	E6	E6	E6	E5	N5	N6	N5	N5	N5	N5
9	E6	E6	E6	E6	E6	E6	N5	N7	N6	N5	N5	N5

(a)Electric air conditioning is assumed for all homes.
(b)Use for any electric resistance heating system without ducts, and for a central electric furnace if the ducts are totally within the conditioned part of the house.

Table 12. Distribution (%) of heating system fuels for new construction and existing houses (from Ref. 17)

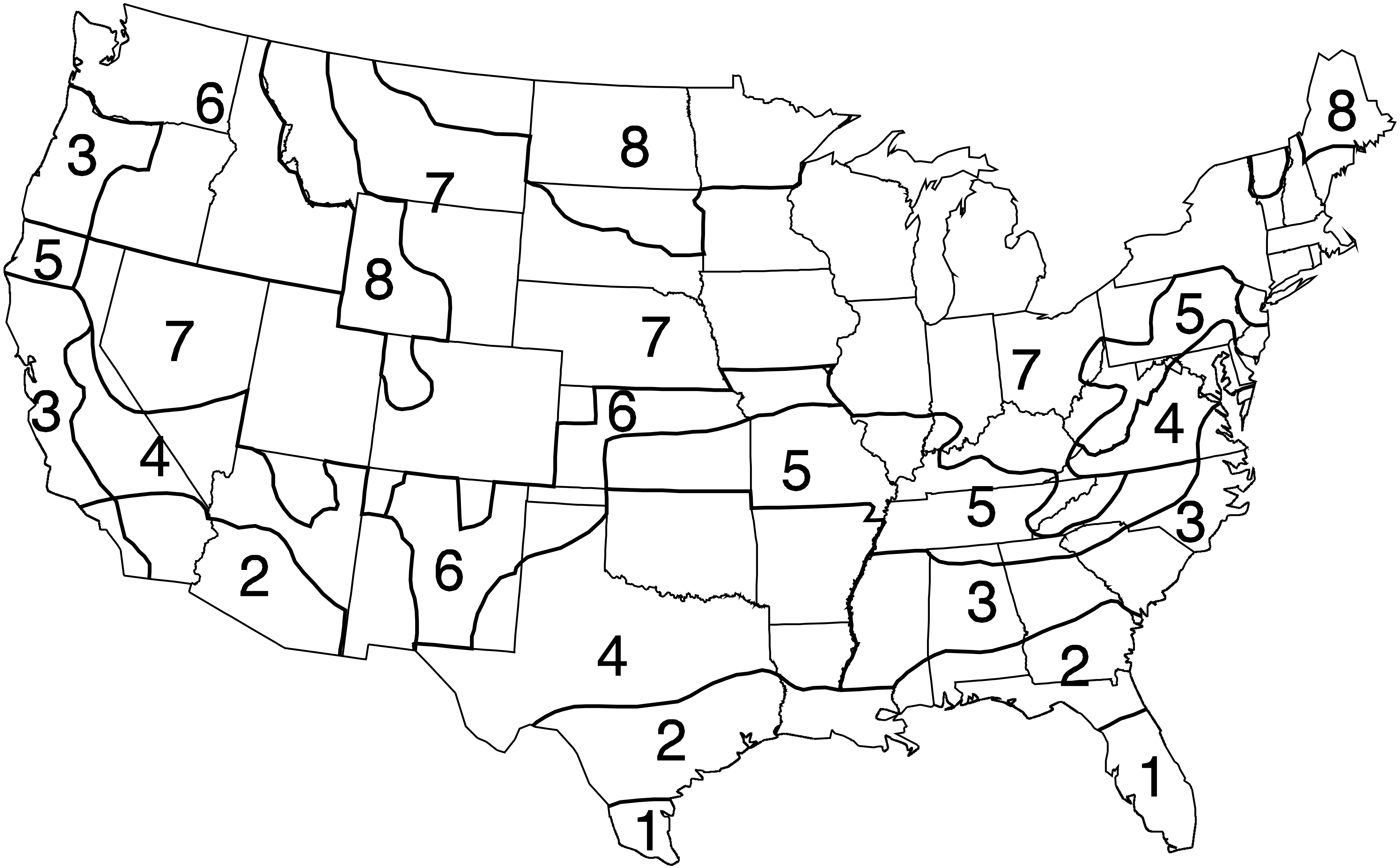
Heating system	**Built 1991-1993 (new construction)**	**All homes (existing)**
Natural gas	46	53
Electric resistance furnace	19	10
Electric heat pump	19	8
Electric (ductless)	0	9
LPG (propane)	8	5
Fuel oil	3	11

6. Discussion

As shown in Appendix C, U-values for framed walls were carefully evaluated. Wood frame walls were evaluated using a parallel-path heat transfer model which evaluated sheathing and cavity insulation together as a system. Metal-frame walls were evaluated using the modified zone heat transfer model with a minimum insulative sheathing requirement of ½ inch. This combination of insulative sheathing and cavity insulation is more complex than the other insulation applications considered and was therefore examined more closely. For other insulation measures, an optimal insulation level is calculated and reported. For the walls however, several combinations of insulative sheathing and cavity insulation are possible. Appendix G shows the net savings for each possible wall treatment (calculated using Eq. 7) for each insulation group. To generate these summaries, the ZIP-Code computer program was run for each zipcode/heating system combination. After examining these results, a range of wall insulation options was selected, as shown in Table 9. The effective wall R-values for these combinations are shown in Table 13.

Walls were evaluated differently for existing houses. Three options were considered: (1) blowing insulation into an empty wall cavity, (2) placing insulative sheathing over a wall without any cavity insulation, and (3) placing insulative sheathing over a wall with pre-existing cavity insulation. The second and third options are only applicable when existing siding is being replaced for some other reason, i.e, the costs of removing and replacing existing exterior siding were not considered.

It is interesting to compare the 1997 Fact Sheet's recommendations to those presented in the 1988 Fact Sheet, the Model Energy Code, and ASHRAE Standard 90.2.[1,18,4] Figures 1 and 2 and Tables 14 and 15 facilitate this comparison. One of the most important changes between the previous edition of the Fact Sheet and this latest revision is the separation of recommendations for new and existing houses. Two factors, heating/cooling system efficiencies and economic lifetimes, are most responsible for the differences between the recommendations for these two groups. There are also differences in the installed cost of insulation measures in new and existing houses, most especially for wall insulation. The maps also reflect differences caused by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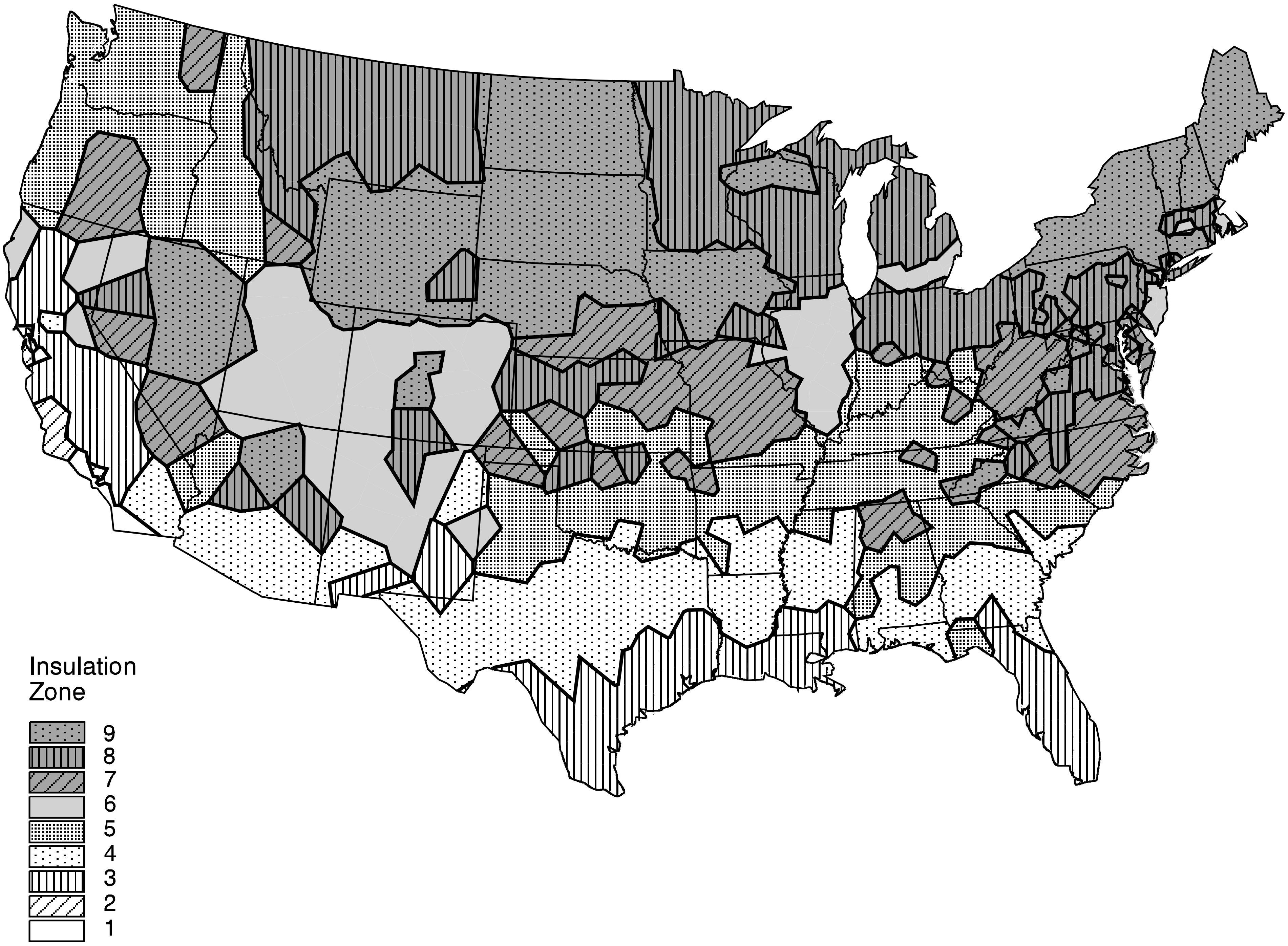
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Zone
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Table 13. Total effective R-values for the recommended wall insulation combinations, including surface heat transfer coefficients, exterior siding, ½ in. wood sheathing, joists, and drywall

Insulation Group	Minimum recommended R-value		Maximum recommended R-value		Total U-value		Effective wall R-value	
	Insulative Sheathing	Cavity	Insulative Sheathing	Cavity	Minimum	Maximum	Minimum	Maximum
Wood-frame wall assembly (without insulation, U-value=.2052, effective R-value=4.9)								
N1	0	11	0	13	.084	.078	11.9	12.9
N2	0	11	0	13	.084	.078	11.9	12.9
N3	0	11	0	15	.084	.073	11.9	13.8
N4	0	11	5	15	.084	.052	11.9	19.4
N5	0	11	7	15	.084	.046	11.9	21.6
N6	2.5	13	7	21	.064	.038	15.6	26.1
N7	5	19	7	21	.044	.038	22.7	26.1
Metal frame wall assembly (without insulation, U-value = .2362, effective R-value = 4.2)								
N1	2.5	11	5	13	.081	.064	12.4	15.6
N2	2.5	11	5	13	.081	.064	12.4	15.6
N3	2.5	11	5	13	.081	.064	12.4	15.6
N4	2.5	11	7	15	.081	.053	12.4	18.8
N5	5	11	7	15	.067	.053	14.9	18.8
N6	5	11	7	21	.067	.049	14.9	20.4
N7	5	13	7	21	.064	.049	15.6	20.4

using energy costs for each state rather than average costs for four regions, and adjusting the insulation cost for each state as well. The revision also provides a separate consideration of heat pump systems, because their fuel cost and efficiency are markedly different from oil- and gas-fired furnaces. Neither the Model Energy Code (MEC) nor ASHRAE Standard 90.2 offer separate recommendations for different heating system types. The DOE Insulation Fact Sheet therefore agrees with these two documents to varying degrees, depending on the selected fuel and local fuel costs.

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Figure 1. Map showing eight Insulation Zones identified in the 1988 DOE Insulation Fact Sheet (Alaska was Zone 8 and Hawaii, Puerto Rico, and the Virgin Islands were Zone 1).

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Figure 2. Map showing 9 Insulation Zones identified in the 1997 DOE Insulation Fact Sheet

Table 14. Comparison of recommended attic insulation R-values from the MEC, ASHRAE90.2, and the DOE Insulation Fact Sheet

City	MEC (1992) (all fuels)	ASHRAE 90.2 (1993)[a] (all fuels)	1988 Fact Sheet (heat pump or gas)	1997 Fact Sheet[a] (gas heat)		1997 Fact Sheet[a] (heat pump)	
				Existing	New construction	Existing	New construction
St. Paul	38	49	38	38	49	49	49
Salt Lake City	38	30	38	38	49	49	49
Seattle	32	30	38	38	49	38	49
St. Louis	32	30	38	38	49	38	49
Washington, D.C.	32	30	30	38	49	38	49
San Francisco	25	30	30	38	38	38	38
Houston	23	30	30	38	38	38	38
Miami	20	30	19	38	38	38	38

a - assumes ducts outside conditioned space

Some recommendations in the DOE Fact Sheet differ from those found in ASHRAE 90.2, or from the Builder's Foundation Handbook.[4,19] The differences between these recommendations can largely be attributed to two factors. First, the fuel price escalation forecasts used in this most recent analysis are much lower than those used five to nine years ago. Using an average fuel price escalation rate of 5% and a mortgage rate of 11%, as was done for the *Builder's Foundation Handbook* in 1991, produces a present worth ratio (defined in Ref. 19) of 18.16. Using an average fuel price escalation rate of 1%, more appropriate for 1997, produces a present worth ratio of 11.91 (see Table 5.7 in Ref. 19). In other words, the projected value of the energy saved with the present set of economic factors is about 35% less than with the economic factors used in 1991. However, a second factor serves to counteract this effect. A discount rate is used to define the present value of future savings, as was shown in Eq. 6 (and was included in Ref. 19 via the selected mortgage rate). Earlier analyses, including the 1988 DOE Insulation fact sheet and early versions of the MEC, were based on a 7% discount rate. A lower discount rate, 3.4%,

Table 15. Recommended insulation levels from the 1988 DOE Insulation Fact Sheet (Insulation Zones shown in this table refer to Fig. 1.)
"Recommended Total R-Values for Existing Houses in Eight Insulation Zones[a]"

Component	Ceilings Below Ventilated Attics		Floors over Unheated Crawlspaces, Basements		Exterior Walls[b] (Wood Frame)		Crawlspace Walls[c]	
Insulation Zone	Oil, Gas, Heat Pump	Electric Resistance	Oil, Gas, Heat Pump	Electric Resistance	Oil, Gas, Heat Pump	Electric Resistance	Oil, Gas, Heat Pump	Electric Resistance
1	19	30	0	0	0	11	11	11
2	30	30	0	0	11	11	19	19
3	30	38	0	19	11	11	19	19
4	30	38	19	19	11	11	19	19
5	38	38	19	19	11	11	19	19
6	38	38	19	19	11	11	19	19
7	38	49	19	19	11	11	19	19
8	49	49	19	19	11	11	19	19

a. These recommendations are based on the assumption that no structural modification are needed to accommodate the added insulation.
b. R-value of full wall insulation, which is 3 ½ inches thick, will depend on material used. Range is R-11 to R-13. For new construction R-19 is recommended for exterior walls. Jamming an R-19 batt in a 3 ½ inch cavity will not yield R-19.
c. Insulate crawl space walls only if the crawl space is dry all year, the floor above is not insulated, and all ventilation to the crawl space is blocked. A vapor barrier (e.g. 4- or 6-mil polyethylene film) should be installed on the ground to reduce moisture migration into the crawl space.

is now recommended by DOE for use in evaluating energy-saving investments. The lower rate reflects benefits associated with energy conservation that are not explicitly calculated, such as reductions in air and water pollution and a reduction in oil imports. The lower discount factor increases the perceived value of future savings, thus offsetting the effect of the lower fuel price escalation projections.

The procedure for mapping the data from Table 10 to produce Fig. 2 involved several steps because mapping coordinates for the boundaries of the 3-digit zip code areas were unavailable. First, a mapping program was chosen that included the coordinates for all state and county boundaries and many city locations. Second, a city was assigned for each of the 3-digit zip codes, thus associating that city with an insulation zone. Third, the city assignments were mapped onto their corresponding counties, using the higher level recommendation whenever two or more cities with different recommendations were located in the same county. The resulting map contained blank areas, or areas with no assigned insulation group, because they were outside the selected county/city boundaries. Therefore, a fourth step used an algorithm that compared values within adjoining polygons to assign insulation levels to these blank areas. Again, the choice was made to use the higher insulation level whenever an unassigned area touched areas of differing levels.

The fact sheet includes a short discussion about the effectiveness of placing new insulation on top of existing insulation in attics. This discussion recognizes that the older insulation is likely to be somewhat compressed, thus losing some part of its effective insulating value. The fact sheet's recommendation that additional insulation be used to compensate for insulation compression is based on experimental work described in Reference 20.

The duct insulation level recommendation of R4 or R6 found in the text of the Fact Sheet was based on ASHRAE 90.2.[4]

Changing the duct efficiency from 0.75 to 1.0, i.e., assuming that the ducts are located in conditioned space or that a ductless heating system is used, would reduce savings associated with any insulation installation. The savings reduction could in turn change the selection of the recommended insulation levels. To examine this issue, a second ZIP-Code calculation for attic insulation was made for both new and existing homes with gas furnaces, but assuming that there were no duct losses. These results were then compared to the original values (which were based on a duct efficiency of 75%) to see what portion of the assigned R-values would be changed. Table 16 shows that 98% of the R-38 attic recommendations for existing gas-heated homes would be unchanged if there were no duct losses. All of the R-30 recommendations would be reduced to R-19, but this affects less than 2% of the existing houses (because 53% of existing houses have gas heat and only about 4% of the 3-digit Zip Codes are in group E2). For new homes, the impact is greater because about half of the R-49 attic recommendations would be reduced to R-38. This would affect about 40% of the new homes built (because 46% of new homes have gas heat and about 87% of the 3-digit Zip Codes are in groups N5, N6, or N7).

Table 16. Effect of duct efficiency on recommended attic insulation levels

Optimal attic insulation level for η_{duct}=0.75 [R-value (°F•ft^2•h/Btu)]	Effect on selected optimal attic insulation level if η_{duct}=1.0	
	Lower	Same
Existing gas-heated homes		
19		100%
30	100%	
38	2%	98%
49	2%	98%
New construction gas-heated homes		
22	46%	54%
38	15%	85%
49	50%	50%

The breakdown in residential end-use consumption discussed in the fact sheet's introduction is based on data summarized in Ref. 21. Ranges are shown to reflect the variations due to climate and household differences.

The DOE Insulation Fact Sheet was sent in draft form to 41 persons or institutions for review. Many helpful comments were received. In some cases, the suggestions from one reviewer were in opposition to those received from another. The most substantive comments are summarized in Appendix H.

7. Conclusions

Insulation differs from many other homeowner purchases - it is seldom bought because of changes in fashion, it doesn't wear out or break, it offers no additional convenience to the homeowner. Few people buy insulation out of an altruistic desire to increase their nation's energy independence or to improve the earth's environment. Consumers purchase insulation because of its perceived value as either a wise investment or a comfort enhancer. Insulation's investment value should be assessed on a life-cycle cost basis, but many homeowners lack the resources to make this evaluation. It is therefore important that the DOE provide clear and reasonable guidance in the field of home insulation. It would obviously be best if each consumer had access to a specific survey and calculation for their own home, accounting for their own utility costs, heating and cooling system efficiency, et cetera. The DOE is facilitating such an evaluation by making a user-friendly version of the ZIP-Code computer program available on the Internet.[2] For consumers without computer resources however, the printed DOE Insulation Fact Sheet offers a useful tool to help them select the appropriate level of insulation for their home.

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Appendix A: Climate and Cost Information Used in The Zip Computer Program.

The data values shown in this table include the 3-digit zip code (i.e., the first three digits of a five digit postal zip code), the fuel escalation region, and the state number, which is used to reference energy prices and insulation cost adjustment factors. Climate values for heating (HDDk = heating degree days divided by 1000, base 65°F) and cooling (CDHk= cooling degree hours divided by 1000, base 74°F) are also shown.

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
001	Not used	00	0.0	0.0	0	0
002	Not used	00	0.0	0.0	0	0
003	Not used	00	0.0	0.0	0	0
004	Not used	00	0.0	0.0	0	0
005	Not used	00	0.0	0.0	0	0
006	Not used	00	0.0	0.0	0	0
007	Not used	00	0.0	0.0	0	0
008	Not used	00	0.0	0.0	0	0
009	Not used	00	0.0	0.0	0	0
010	Springfield	MA	6.0	5.2	1	22
011	Springfield	MA	6.0	5.2	1	22
012	Pittsfield	MA	7.3	1.2	1	22
013	Greenfield	MA	6.6	2.9	1	22
014	Worcester	MA	7.0	1.5	1	22
015	Worcester	MA	7.0	1.5	1	22
016	Worcester	MA	7.0	1.5	1	22
017	Framing-ham	MA	6.2	4.2	1	22
018	Woburn	MA	6.2	3.6	1	22
019	Lynn	MA	6.1	2.8	1	22
020	Boston	MA	5.6	5.4	1	22
021	Boston	MA	5.6	5.4	1	22
022	Boston	MA	5.6	5.4	1	22
023	Brockton	MA	6.0	3.4	1	22
024	Brockton	MA	6.0	3.4	1	22
025	Buzzards Bay	MA	6.3	2.4	1	22
026	Hyannis	MA	6.0	2.0	1	22
027	New Bedford	MA	5.3	6.4	1	22
028	Providence	RI	5.9	3.6	1	40
029	Providence	RI	5.9	3.6	1	40
030	Manchester	NH	7.1	1.6	1	30
031	Manchester	NH	7.1	1.6	1	30
032	Pittsfield	NH	7.4	2.0	1	30
033	Concord	NH	7.4	2.0	1	30
034	Keene	NH	7.0	2.2	1	30
035	Littleton	NH	8.6	1.2	1	30
036	Acworth	NH	7.0	2.2	1	30
037	Claremont	NH	7.9	1.7	1	30
038	Portsmouth	NH	6.9	2.2	1	30
039	Kittery	ME	6.9	2.2	1	20
040	Portland	ME	7.5	1.1	1	20
041	Portland	ME	7.5	1.1	1	20
042	Auburn	ME	7.4	2.3	1	20
043	Augusta	ME	7.6	2.2	1	20
044	Bangor	ME	8.0	1.2	1	20
045	Bath	ME	7.5	1.1	1	20
046	Ellsworth	ME	7.2	1.0	1	20
047	Caribou	ME	9.6	0.9	1	20
048	Rockland	ME	7.3	1.0	1	20
049	Waterville	ME	7.5	1.8	1	20

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
050	White River Junct.	VT	8.3	1.1	1	46
051	Bellows Falls	VT	7.4	2.2	1	46
052	Bennington	VT	7.6	0.8	1	46
053	Brattleboro	VT	7.2	2.2	1	46
054	Burlington	VT	8.0	2.6	1	46
055	Not used	00	0.0	0.0	0	0
056	Montpelier	VT	8.5	1.4	1	46
057	Rutland	VT	7.2	1.8	1	46
058	St. Johnsbury	VT	7.9	1.9	1	46
059	Canaan	VT	8.7	1.5	1	46
060	Hartford	CT	6.2	4.8	1	7
061	Hartford	CT	6.2	4.8	1	7
062	Willimantic	CT	6.5	1.3	1	7
063	New London	CT	6.0	5.0	1	7
064	New Haven	CT	6.0	5.0	1	7
065	New Haven	CT	6.0	5.0	1	7
066	Bridgeport	CT	5.5	5.0	1	7
067	Waterbury	CT	6.5	2.0	1	7
068	Stamford	CT	5.9	3.6	1	7
069	Stamford	CT	5.9	3.6	1	7
070	Newark	NJ	5.0	9.1	1	31
071	Newark	NJ	5.0	9.1	1	31
072	Elizabeth	NJ	5.0	9.1	1	31
073	Jersey City	NJ	5.3	7.0	1	31
074	Paterson	NJ	5.4	6.1	1	31
075	Paterson	NJ	5.4	6.1	1	31
076	Hackensack	NJ	5.4	6.1	1	31
077	Red Bank	NJ	5.3	5.4	1	31
078	Dover	NJ	6.3	3.1	1	31
079	Summit	NJ	5.9	4.0	1	31
080	Cherry Hill	NJ	5.2	7.9	1	31
081	Camden	NJ	5.0	8.9	1	31
082	South Jersey	NJ	4.9	7.4	1	31
083	South Jersey	NJ	4.9	7.4	1	31
084	Atlantic City	NJ	4.9	6.0	1	31
085	Trenton	NJ	5.0	7.4	1	31
086	Trenton	NJ	5.0	7.4	1	31
087	Lakewood	NJ	5.3	5.4	1	31
088	New Brunswick	NJ	5.2	5.4	1	31
089	New Brunswick	NJ	5.2	5.4	1	31
090	Not used	00	0.0	0.0	0	0
091	Not used	00	0.0	0.0	0	0
092	Not used	00	0.0	0.0	0	0
093	Not used	00	0.0	0.0	0	0
094	Not used	00	0.0	0.0	0	0
095	Not used	00	0.0	0.0	0	0
096	Not used	00	0.0	0.0	0	0
097	Not used	00	0.0	0.0	0	0
098	Not used	00	0.0	0.0	0	0
099	Not used	00	0.0	0.0	0	0
100	New York	NY	4.9	9.5	1	33
101	New York	NY	4.9	9.5	1	33
102	New York	NY	4.9	9.5	1	33
103	Staten Island	NY	5.0	7.0	1	33
104	Bronx	NY	4.9	9.2	1	33
105	Westchester	NY	5.4	5.4	1	33
106	White Plains	NY	5.4	5.4	1	33
107	Yonkers	NY	5.4	5.4	1	33

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
108	New Rochelle	NY	5.4	5.4	1	33
109	Suffern	NY	5.7	6.1	1	33
110	Great Neck	NY	5.0	9.2	1	33
111	Queens	NY	5.0	9.2	1	33
112	Brooklyn	NY	5.0	7.6	1	33
113	Flushing	NY	5.0	7.6	1	33
114	Jamaica	NY	5.2	7.6	1	33
115	Minneola	NY	5.2	7.4	1	33
116	Far Rockaway	NY	5.0	7.6	1	33
117	Hicksville	NY	5.2	7.4	1	33
118	Hicksville	NY	5.2	7.4	1	33
119	Riverhead	NY	5.3	4.7	1	33
120	Albany	NY	6.9	3.0	1	33
121	Albany	NY	6.9	3.0	1	33
122	Albany	NY	6.9	3.0	1	33
123	Schenectady	NY	7.0	3.0	1	33
124	Kingston	NY	6.4	4.3	1	33
125	Poughkeep-sie	NY	6.4	4.3	1	33
126	Poughkeep-sie	NY	6.4	4.3	1	33
127	Monticello	NY	7.5	0.8	1	33
128	Glens Falls	NY	7.5	2.0	1	33
129	Plattsburgh	NY	7.8	1.9	1	33
130	Syracuse	NY	6.8	3.5	1	33
131	Syracuse	NY	6.8	3.5	1	33
132	Syracuse	NY	6.8	3.5	1	33
133	Utica	NY	7.4	2.7	1	33
134	Utica	NY	7.4	2.7	1	33
135	Utica	NY	7.4	2.7	1	33
136	Watertown	NY	7.5	2.7	1	33
137	Binghamton	NY	7.3	1.6	1	33
138	Binghamton	NY	7.3	1.6	1	33
139	Binghamton	NY	7.3	1.6	1	33
140	Buffalo	NY	6.8	3.0	1	33
141	Buffalo	NY	6.8	3.0	1	33
142	Buffalo	NY	6.8	3.0	1	33
143	Niagara Falls	NY	6.8	3.0	1	33
144	Rochester	NY	6.7	3.8	1	33
145	Rochester	NY	6.7	3.8	1	33
146	Rochester	NY	6.7	3.8	1	33
147	Jamestown	NY	7.4	3.7	1	33
148	Ithaca	NY	7.1	1.6	1	33
149	Elmira	NY	6.9	2.5	1	33
150	Pittsburgh	PA	6.0	5.0	1	39
151	Pittsburgh	PA	6.0	5.0	1	39
152	Pittsburgh	PA	6.0	5.0	1	39
153	Washington	PA	5.9	3.9	1	39
154	Uniontown	PA	5.4	6.2	1	39
155	Somerset	PA	6.0	6.1	1	39
156	Greensburg	PA	7.0	2.4	1	39
157	Indiana	PA	6.2	2.6	1	39
158	Du Bois	PA	7.2	1.8	1	39
159	Johnstown	PA	5.8	5.7	1	39
160	Butler	PA	6.5	4.7	1	39
161	New Castle	PA	5.9	4.8	1	39
162	Kittanning	PA	6.8	2.5	1	39
163	Oil City	PA	6.6	2.8	1	39
164	Erie	PA	6.8	2.2	1	39
165	Erie	PA	6.8	2.2	1	39
166	Altoona	PA	7.4	1.5	1	39
167	Bradford	PA	8.0	0.8	1	39

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
168	State College	PA	6.3	3.5	1	39
169	Wellsboro	PA	7.7	1.4	1	39
170	Harrisburg	PA	5.3	9.1	1	39
171	Harrisburg	PA	5.3	9.1	1	39
172	Chambers-burg	PA	5.6	5.4	1	39
173	York	PA	5.2	6.6	1	39
174	York	PA	5.2	6.6	1	39
175	Lancaster	PA	5.4	6.0	1	39
176	Lancaster	PA	5.4	6.0	1	39
177	Williams-port	PA	6.1	5.0	1	39
178	Sunbury	PA	5.8	5.3	1	39
179	Pottsville	PA	6.4	3.0	1	39
180	Lehigh Valley	PA	6.0	5.5	1	39
181	Allentown	PA	5.8	5.8	1	39
182	Hazleton	PA	6.9	1.7	1	39
183	Stroudsburg	PA	6.2	5.3	1	39
184	Scranton	PA	6.3	3.8	1	39
185	Scranton	PA	6.3	3.8	1	39
186	Wilkes-Barre	PA	6.3	3.8	1	39
187	Wilkes-Barre	PA	6.3	3.8	1	39
188	Montrose	PA	7.7	1.6	1	39
189	Doylestown	PA	5.4	6.5	1	39
190	Philadelphia	PA	5.0	8.9	1	39
191	Philadelphia	PA	5.0	8.9	1	39
192	Not used	00	0.0	0.0	1	0
193	South-eastern PA	PA	5.0	8.9	1	39
194	South-eastern PA	PA	5.0	8.9	1	39
195	Reading	PA	5.8	4.0	1	39
196	Reading	PA	5.8	4.0	1	39
197	Wilmington	DE	5.0	8.2	3	8
198	Wilmington	DE	5.0	8.2	3	8
199	Dover	DE	4.4	9.3	3	8
200	Washington	DC	4.2	12.4	3	9
201	Washington	DC	4.2	12.4	3	9
202	Washington	DC	4.2	12.4	3	9
203	Washington	DC	4.2	12.4	3	9
204	Washington	DC	4.2	12.4	3	9
205	Washington	DC	4.2	12.4	3	9
206	Waldorf	MD	4.4	8.2	3	21
207	Laurel	MD	4.5	10.5	3	21
208	Rockville	MD	4.7	9.8	3	21
209	Silver Spring	MD	4.7	9.8	3	21
210	Baltimore	MD	4.7	9.5	3	21
211	Baltimore	MD	4.7	9.5	3	21
212	Baltimore	MD	4.7	9.5	3	21
213	Baltimore	MD	4.7	9.5	3	21
214	Annapolis	MD	4.7	9.0	3	21
215	Cumberland	MD	5.1	7.1	3	21
216	Easton	MD	4.2	11.0	3	21
217	Frederick	MD	5.1	7.3	3	21
218	Salisbury	MD	4.0	9.2	3	21
219	Elkton	MD	5.2	6.6	3	21
220	Northern VA	VA	4.2	12.4	3	47
221	Northern VA	VA	4.2	12.4	3	47
222	Arlington	VA	4.2	12.4	3	47
223	Alexandria	VA	4.2	12.4	3	47
224	Frederick-sburg	VA	4.4	10.2	3	47

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
225	Fredericks-burg	VA	4.4	10.2	3	47
226	Winchester	VA	4.8	8.1	3	47
227	Culpeper	VA	4.4	8.9	3	47
228	Harrison-burg	VA	5.1	6.5	3	47
229	Charlottes-ville	VA	4.2	10.3	3	47
230	Richmond	VA	4.0	12.3	3	47
231	Richmond	VA	4.0	12.3	3	47
232	Richmond	VA	4.0	12.3	3	47
233	Norfolk	VA	3.5	13.7	3	47
234	Norfolk	VA	3.5	13.7	3	47
235	Norfolk	VA	3.5	13.7	3	47
236	Norfolk	VA	3.5	13.7	3	47
237	Portsmouth	VA	3.5	13.7	3	47
238	Petersburg	VA	3.4	14.6	3	47
239	Farmville	VA	4.0	9.4	3	47
240	Roanoke	VA	4.3	9.3	3	47
241	Roanoke	VA	4.3	9.3	3	47
242	Bristol	VA	3.9	8.8	3	47
243	Pulaski	VA	5.1	3.3	3	47
244	Staunton	VA	5.1	6.5	3	47
245	Lynchburg	VA	4.3	8.4	3	47
246	Tazewell	VA	6.0	0.8	3	47
247	Bluefield	WV	5.2	2.6	3	49
248	Welch	WV	5.1	7.9	3	49
249	Lewisburg	WV	5.3	3.7	3	49
250	Charleston	WV	4.7	8.8	3	49
251	Charleston	WV	4.7	8.8	3	49
252	Charleston	WV	4.7	8.8	3	49
253	Charleston	WV	4.7	8.8	3	49
254	Martinsburg	WV	5.2	8.2	3	49
255	Huntington	WV	4.7	11.2	3	49
256	Logan	WV	5.1	7.5	3	49
257	Huntington	WV	4.7	11.2	3	49
258	Beckley	WV	5.6	2.1	3	49
259	Beckley	WV	5.6	2.1	3	49
260	Wheeling	WV	5.5	6.8	3	49
261	Parkersburg	WV	5.0	9.1	3	49
262	Buckhannon	WV	5.4	4.0	3	49
263	Clarksburg	WV	5.5	6.4	3	49
264	Clarksburg	WV	5.5	6.4	3	49
265	Morgan-town	WV	5.4	6.9	3	49
266	Gassaway	WV	4.8	6.3	3	49
267	Keyser	WV	5.1	7.1	3	49
268	Petersburg	WV	5.5	3.8	3	49
269	Not used	00	0.0	0.0	0	0
270	Winston-Salem	NC	3.4	11.8	3	34
271	Winston-Salem	NC	3.4	11.8	3	34
272	Greensboro	NC	3.9	11.0	3	34
273	Greensboro	NC	3.9	11.0	3	34
274	Greensboro	NC	3.9	11.0	3	34
275	Raleigh	NC	3.5	11.8	3	34
276	Raleigh	NC	3.5	11.8	3	34
277	Durham	NC	3.5	11.8	3	34
278	Rocky Mount	NC	3.4	13.8	3	34
279	Elizabeth City	NC	3.2	14.0	3	34
280	Charlotte	NC	3.3	15.2	3	34
281	Charlotte	NC	3.3	15.2	3	34

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
282	Charlotte	NC	3.3	15.2	3	34
283	Fayetteville	NC	3.2	15.6	3	34
284	Wilmington	NC	2.5	17.6	3	34
285	Kinston	NC	3.1	15.7	3	34
286	Hickory	NC	3.8	11.1	3	34
287	Asheville	NC	4.1	6.2	3	34
288	Asheville	NC	4.1	6.2	3	34
289	Andrews	NC	4.5	5.2	3	34
290	Columbia	SC	2.6	22.0	3	41
291	Columbia	SC	2.6	22.0	3	41
292	Columbia	SC	2.6	22.0	3	41
293	Spartanburg	SC	3.4	14.1	3	41
294	Charleston	SC	2.1	23.3	3	41
295	Florence	SC	2.6	17.9	3	41
296	Greenville	SC	3.2	14.1	3	41
297	Rock Hill	SC	3.0	15.8	3	41
298	Aiken	SC	2.4	20.3	3	41
299	Beaufort	SC	1.9	21.5	3	41
300	Atlanta	GA	3.0	16.8	3	11
301	Atlanta	GA	3.0	16.8	3	11
302	Atlanta	GA	3.0	16.8	3	11
303	Atlanta	GA	3.0	16.8	3	11
304	Swainsboro	GA	2.1	23.0	3	11
305	Gainesville	GA	3.4	14.8	3	11
306	Athens	GA	3.0	16.1	3	11
307	Dalton	GA	3.5	14.7	3	11
308	Augusta	GA	2.6	19.5	3	11
309	Augusta	GA	2.6	19.5	3	11
310	Macon	GA	2.3	24.4	3	11
311	Macon	GA	2.3	24.4	3	11
312	Macon	GA	2.3	24.4	3	11
313	Savannah	GA	1.9	22.8	3	11
314	Savannah	GA	1.9	22.8	3	11
315	Waycross	GA	1.9	23.6	3	11
316	Valdosta	GA	1.7	24.6	3	11
317	Albany	GA	2.1	26.5	3	11
318	Columbus	GA	2.4	22.1	3	11
319	Columbus	GA	2.4	22.1	3	11
320	Jacksonville	FL	1.4	24.2	3	10
321	Jacksonville	FL	1.4	24.2	3	10
322	Jacksonville	FL	1.4	24.2	3	10
323	Tallahassee	FL	1.7	25.2	3	10
324	Panama City	FL	1.6	29.0	3	10
325	Pensacola	FL	1.6	29.0	3	10
326	Gainesville	FL	1.1	27.7	3	10
327	Titusville	FL	0.7	29.9	3	10
328	Orlando	FL	0.7	34.0	3	10
329	Melbourne	FL	0.6	29.7	3	10
330	Miami	FL	0.2	39.0	3	10
331	Miami	FL	0.2	39.0	3	10
332	Miami	FL	0.2	39.0	3	10
333	Fort Lauderdale	FL	0.3	37.1	3	10
334	West Palm Beach	FL	0.3	35.2	3	10
335	Tampa	FL	0.7	33.7	3	10
336	Tampa	FL	0.7	33.7	3	10
337	Saint Petersburg	FL	0.5	38.6	3	10
338	Lakeland	FL	0.6	34.9	3	10
339	Fort Myers	FL	0.4	37.4	3	10
340	Not used	00	0.0	0.0	0	0
341	Not used	00	0.0	0.0	0	0

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
342	Bradenton	FL	0.6	29.2	3	10
343	Not used	00	0.0	0.0	0	0
344	Ocala	FL	0.9	32.2	3	10
345	Not used	00	0.0	0.0	0	0
346	Clearwater	FL	0.7	33.7	3	10
347	Orlando	FL	0.7	34.0	3	10
348	Not used	00	0.0	0.0	0	0
349	Fort Pierce	FL	0.5	30.4	3	10
350	Birmingham	AL	2.9	21.0	3	1
351	Birmingham	AL	2.9	21.0	3	1
352	Birmingham	AL	2.9	21.0	3	1
353	Not used	00	0.0	0.0	0	0
354	Tuscaloosa	AL	2.7	24.0	3	1
355	Jasper	AL	3.3	18.0	3	1
356	Decatur/ Florence	AL	3.3	20.7	3	1
357	Huntsville	AL	3.3	18.6	3	1
358	Huntsville	AL	3.3	18.6	3	1
359	Gadsden	AL	3.2	17.1	3	1
360	Montgom-ery	AL	2.3	24.6	3	1
361	Montgom-ery	AL	2.3	24.6	3	1
362	Anniston	AL	2.9	18.2	3	1
363	Dothan	AL	2.0	23.0	3	1
364	Evergreen	AL	2.2	22.2	3	1
365	Mobile	AL	1.7	28.2	3	1
366	Mobile	AL	1.7	28.2	3	1
367	Selma	AL	2.0	26.5	3	1
368	Opelika	AL	2.6	19.2	3	1
369	Butler	AL	2.5	23.8	3	1
370	Nashville	TN	3.8	18.5	3	43
371	Nashville	TN	3.8	18.5	3	43
372	Nashville	TN	3.8	18.5	3	43
373	Chattanooga	TN	3.6	17.0	3	43
374	Chattanooga	TN	3.6	17.0	3	43
375	Not used	00	0.0	0.0	0	0
376	Johnson City	TN	3.9	8.8	3	43
377	Knoxville	TN	3.7	15.0	3	43
378	Knoxville	TN	3.7	15.0	3	43
379	Knoxville	TN	3.7	15.0	3	43
380	Memphis	TN	3.2	24.5	3	43
381	Memphis	TN	3.2	24.5	3	43
382	Mc Kenzie	TN	4.1	15.6	3	43
383	Jackson	TN	3.6	18.0	3	43
384	Columbia	TN	3.8	16.0	3	43
385	Cookeville	TN	4.5	7.0	3	43
386	Oxford	MS	3.6	19.2	3	25
387	Greenville	MS	2.6	25.5	3	25
388	Tupelo	MS	3.1	23.0	3	25
389	Grenada	MS	2.7	26.0	3	25
390	Jackson	MS	2.4	25.2	3	25
391	Jackson	MS	2.4	25.2	3	25
392	Jackson	MS	2.4	25.2	3	25
393	Meridian	MS	2.5	23.8	3	25
394	Hattiesburg	MS	2.0	24.3	3	25
395	Gulfport	MS	1.5	27.5	3	25
396	McComb	MS	2.1	22.8	3	25
397	Columbus	MS	2.9	21.8	3	25
398	Not used	00	0.0	0.0	0	0
399	Not used	00	0.0	0.0	0	0
400	Louisville	KY	4.5	13.3	3	18
401	Louisville	KY	4.5	13.3	3	18

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
402	Louisville	KY	4.5	13.3	3	18
403	Lexington	KY	4.8	11.2	3	18
404	Lexington	KY	4.8	11.2	3	18
405	Lexington	KY	4.8	11.2	3	18
406	Frankfort	KY	5.0	9.7	3	18
407	Corbin	KY	4.3	11.4	3	18
408	Baxter	KY	4.7	7.8	3	18
409	Middlesboro	KY	4.4	9.5	3	18
410	Newport	KY	5.3	9.3	3	18
411	Ashland	KY	4.9	11.4	3	18
412	Ashland	KY	4.9	11.4	3	18
413	Campton	KY	5.1	8.1	3	18
414	Campton	KY	5.1	8.1	3	18
415	Pikeville	KY	4.7	9.0	3	18
416	Pikeville	KY	4.7	9.0	3	18
417	Hazard	KY	4.7	9.0	3	18
418	Hazard	KY	4.7	9.0	3	18
419	Not used	00	0.0	0.0	0	0
420	Paducah	KY	4.1	16.7	3	18
421	Bowling Green	KY	4.3	14.7	3	18
422	Russellville	KY	4.3	14.4	3	18
423	Owensboro	KY	4.3	14.5	3	18
424	Henderson	KY	4.3	14.2	3	18
425	Somerset	KY	4.4	9.2	3	18
426	Somerset	KY	4.4	9.2	3	18
427	Elizabeth-town	KY	4.2	11.8	3	18
428	Not used	00	0.0	0.0	0	0
429	Not used	00	0.0	0.0	0	0
430	Columbus	OH	5.7	7.5	2	36
431	Columbus	OH	5.7	7.5	2	36
432	Columbus	OH	5.7	7.5	2	36
433	Marion	OH	5.9	6.5	2	36
434	Bowling Green	OH	6.0	6.6	2	36
435	Napoleon	OH	6.0	7.1	2	36
436	Toledo	OH	6.6	5.1	2	36
437	Zanesville	OH	5.8	5.4	2	36
438	Zanesville	OH	5.8	5.4	2	36
439	Stuebenville	OH	5.6	5.7	2	36
440	Cleveland	OH	6.2	4.8	2	36
441	Cleveland	OH	6.2	4.8	2	36
442	Akron	OH	6.2	4.8	2	36
443	Akron	OH	6.2	4.8	2	36
444	Youngstown	OH	6.6	3.0	2	36
445	Youngstown	OH	6.6	3.0	2	36
446	Canton	OH	6.2	4.8	2	36
447	Canton	OH	6.2	4.8	2	36
448	Mansfield	OH	6.3	4.9	2	36
449	Mansfield	OH	6.3	4.9	2	36
450	Cincinnati	OH	5.0	10.7	2	36
451	Cincinnati	OH	5.0	10.7	2	36
452	Cincinnati	OH	5.0	10.7	2	36
453	Dayton	OH	5.7	8.3	2	36
454	Dayton	OH	5.7	8.3	2	36
455	Springfield	OH	5.7	8.3	2	36
456	Chillicothe	OH	5.2	8.0	2	36
457	Athens	OH	5.5	5.6	2	36
458	Lima	OH	5.9	7.5	2	36
459	Not used	00	0.0	0.0	0	0
460	Indianapolis	IN	5.7	9.1	2	15
461	Indianapolis	IN	5.7	9.1	2	15

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
462	Indianapolis	IN	5.7	9.1	2	15
463	Gary	IN	6.3	9.1	2	15
464	Gary	IN	6.3	9.1	2	15
465	South Bend	IN	6.4	6.6	2	15
466	South Bend	IN	6.4	6.6	2	15
467	Fort Wayne	IN	6.3	6.8	2	15
468	Fort Wayne	IN	6.3	6.8	2	15
469	Kokomo	IN	6.0	11.1	2	15
470	Lawrence-burg	IN	5.3	10.7	2	15
471	New Albany	IN	4.5	13.3	2	15
472	Columbus	IN	5.5	8.8	2	15
473	Muncie	IN	6.1	7.1	2	15
474	Blooming-ton	IN	5.3	10.7	2	15
475	Washington	IN	4.7	13.3	2	15
476	Evansville	IN	4.7	15.0	2	15
477	Evansville	IN	4.7	15.0	2	15
478	Terre Haute	IN	5.5	9.5	2	15
479	Lafayette	IN	6.2	7.7	2	15
480	Royal Oak	MI	6.6	5.3	2	23
481	Ann Arbor	MI	6.3	6.1	2	23
482	Detroit	MI	6.6	4.9	2	23
483	Detroit	MI	6.6	4.9	2	23
484	Flint	MI	7.1	2.9	2	23
485	Flint	MI	7.1	2.9	2	23
486	Saginaw	MI	7.1	3.3	2	23
487	Saginaw	MI	7.1	3.3	2	23
488	Lansing	MI	7.0	4.1	2	23
489	Lansing	MI	7.0	4.1	2	23
490	Kalamazoo	MI	6.3	6.3	2	23
491	Kalamazoo	MI	6.3	6.3	2	23
492	Jackson	MI	6.8	4.8	2	23
493	Grand Rapids	MI	6.9	4.6	2	23
494	Muskegon	MI	6.9	2.9	2	23
495	Grand Rapids	MI	6.9	4.6	2	23
496	Traverse City	MI	7.8	3.0	2	23
497	Mackinaw City	MI	8.0	2.0	2	23
498	Iron Mountain	MI	8.7	1.4	2	23
499	Houghton	MI	9.4	1.0	2	23
500	Des Moines	IA	6.6	10.5	2	16
501	Des Moines	IA	6.6	10.5	2	16
502	Des Moines	IA	6.6	10.5	2	16
503	Des Moines	IA	6.6	10.5	2	16
504	Mason City	IA	7.9	6.0	2	16
505	Fort Dodge	IA	7.2	8.0	2	16
506	Waterloo	IA	7.5	6.6	2	16
507	Waterloo	IA	7.5	6.6	2	16
508	Creston	IA	6.5	9.5	2	16
509	Not used	00	0.0	0.0	0	0
510	Sioux City	IA	7.0	10.1	2	16
511	Sioux City	IA	7.0	10.1	2	16
512	Sheldon	IA	7.7	6.6	2	16
513	Spencer	IA	7.8	6.1	2	16
514	Carroll	IA	7.1	8.2	2	16
515	Council Bluffs	IA	6.2	12.0	2	16
516	Shenandoah	IA	5.9	12.7	2	16
517	Not used	00	0.0	0.0	0	0
518	Not used	00	0.0	0.0	0	0
519	not used	00	0.0	0.0	0	0

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
520	Dubuque	IA	7.4	4.7	2	16
521	Decorah	IA	7.6	5.3	2	16
522	Cedar Rapids	IA	6.7	7.9	2	16
523	Cedar Rapids	IA	6.7	7.9	2	16
524	Cedar Rapids	IA	6.7	7.9	2	16
525	Ottumwa	IA	6.3	10.0	2	16
526	Burlington	IA	6.2	10.0	2	16
527	Davenport	IA	6.3	10.0	2	16
528	Davenport	IA	6.3	10.0	2	16
529	Not used	00	0.0	0.0	0	0
530	Milwaukee	WI	7.3	3.3	2	50
531	Milwaukee	WI	7.3	3.3	2	50
532	Milwaukee	WI	7.3	3.3	2	50
533	Milwaukee	WI	7.3	3.3	2	50
534	Racine	WI	6.9	5.2	2	50
535	Madison	WI	7.6	3.3	2	50
536	Madison	WI	7.6	3.3	2	50
537	Madison	WI	7.6	3.3	2	50
538	Platteville	WI	7.2	5.6	2	50
539	Portage	WI	7.4	5.5	2	50
540	River Falls	WI	8.1	4.6	2	50
541	Green Bay	WI	8.1	2.5	2	50
542	Green Bay	WI	8.1	2.5	2	50
543	Green Bay	WI	8.1	2.5	2	50
544	Wausau	WI	8.6	2.5	2	50
545	Rhinelander	WI	8.9	2.3	2	50
546	La Crosse	WI	7.5	6.8	2	50
547	Eau Claire	WI	8.5	3.9	2	50
548	Spooner	WI	8.8	2.5	2	50
549	Oshkosh	WI	7.7	3.7	2	50
550	Saint Paul	MN	8.0	6.8	2	24
551	Saint Paul	MN	8.0	6.8	2	24
552	Not used	00	0.0	0.0	0	0
553	Minneapolis	MN	8.0	6.8	2	24
554	Minneapolis	MN	8.0	6.8	2	24
555	Not used	00	0.0	0.0	0	0
556	Duluth	MN	9.9	0.8	2	24
557	Duluth	MN	9.9	0.8	2	24
558	Duluth	MN	9.9	0.8	2	24
559	Rochester	MN	8.3	3.9	2	24
560	Mankato	MN	8.3	5.0	2	24
561	Windom	MN	7.8	7.2	2	24
562	Willmar	MN	8.3	4.7	2	24
563	Saint Cloud	MN	9.0	3.0	2	24
564	Brainerd	MN	9.0	3.5	2	24
565	Detroit Lakes	MN	9.9	2.3	2	24
566	Bemidji	MN	10.2	2.2	2	24
567	Thief River Falls	MN	9.7	3.0	2	24
568	Not used	00	0.0	0.0	0	0
569	Not used	00	0.0	0.0	0	0
570	Sioux Falls	SD	7.9	8.6	2	42
571	Sioux Falls	SD	7.9	8.6	2	42
572	Watertown	SD	8.8	4.9	2	42
573	Mitchell	SD	7.4	10.3	2	42
574	Aberdeen	SD	8.6	6.5	2	42
575	Pierre	SD	7.6	10.4	2	42
576	Mobridge	SD	8.2	7.8	2	42
577	Rapid City	SD	7.3	8.2	2	42
578	Not used	00	0.0	0.0	0	0

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
579	Not used	00	0.0	0.0	0	0
580	Fargo	ND	9.3	4.3	2	35
581	Fargo	ND	9.3	4.3	2	35
582	Grand Forks	ND	9.9	4.1	2	35
583	Devils Lake	ND	9.9	3.1	2	35
584	Jamestown	ND	9.4	4.0	2	35
585	Bismarck	ND	9.1	4.6	2	35
586	Dickinson	ND	8.9	4.0	2	35
587	Minot	ND	9.4	4.0	2	35
588	Williston	ND	9.3	4.0	2	35
589	Not used	00	0.0	0.0	0	0
590	Billings	MT	7.2	6.0	4	27
591	Billings	MT	7.2	6.0	4	27
592	Wolf Point	MT	9.0	4.8	4	27
593	Miles City	MT	7.9	10.0	4	27
594	Great Falls	MT	7.8	3.6	4	27
595	Havre	MT	8.7	4.0	4	27
596	Helena	MT	8.2	2.5	4	27
597	Butte	MT	9.6	0.9	4	27
598	Missoula	MT	7.8	1.1	4	27
599	Kalispell	MT	8.4	1.7	4	27
600	North Chicago Sub.	IL	6.9	5.2	2	14
601	North Chicago Sub.	IL	6.9	5.2	2	14
602	Evanston	IL	6.5	6.6	2	14
603	Oak Park	IL	6.5	6.6	2	14
604	South Chicago Sub.	IL	6.5	7.4	2	14
605	South Chicago Sub.	IL	6.2	7.4	2	14
606	Chicago	IL	6.2	9.7	2	14
607	Chicago	IL	6.2	9.7	2	14
608	Not used	00	0.0	0.0	0	0
609	Kankakee	IL	6.1	8.8	2	14
610	Rockford	IL	7.0	6.5	2	14
611	Rockford	IL	7.0	6.5	2	14
612	Rock Island	IL	6.3	10.0	2	14
613	La Salle	IL	6.2	11.1	2	14
614	Galesburg	IL	6.3	8.9	2	14
615	Peoria	IL	6.2	9.5	2	14
616	Peoria	IL	6.2	9.5	2	14
617	Blooming-ton	IL	5.9	9.4	2	14
618	Champaign/ Urbana	IL	5.8	9.9	2	14
619	Champaign/ Urbana	IL	5.8	9.9	2	14
620	East Saint Louis	IL	4.8	14.7	2	14
621	Not used	00	0.0	0.0	0	0
622	East Saint Louis	IL	4.8	14.7	2	14
623	Quincy	IL	5.8	12.2	2	14
624	Effingham	IL	5.3	13.2	2	14
625	Springfield	IL	5.7	12.4	2	14
626	Springfield	IL	5.7	12.4	2	14
627	Springfield	IL	5.7	12.4	2	14
628	Centralia	IL	4.8	13.5	2	14
629	Carbondale	IL	4.6	14.1	2	14
630	Saint Louis	MO	4.9	17.8	2	26
631	Saint Louis	MO	4.9	17.8	2	26
632	Not used	00	0.0	0.0	0	0
633	Saint Charles	MO	5.0	17.1	2	26

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
634	Hannibal	MO	5.6	11.8	2	26
635	Kirksville	MO	5.9	9.9	2	26
636	Flat River	MO	4.8	12.2	2	26
637	Cape Girardeau	MO	4.3	16.8	2	26
638	Sikeston	MO	4.2	16.9	2	26
639	Poplar Bluff	MO	4.1	17.2	2	26
640	Kansas City	MO	5.3	17.5	2	26
641	Kansas City	MO	5.3	17.5	2	26
642	Not used	00	0.0	0.0	0	0
643	not used	00	0.0	0.0	0	0
644	Saint Joseph	MO	5.5	16.1	2	26
645	Saint Joseph	MO	5.5	16.1	2	26
646	Chillicothe	MO	5.4	14.4	2	26
647	Harrison-ville	MO	4.9	17.4	2	26
648	Joplin	MO	4.3	20.8	2	26
649	Not used	00	0.0	0.0	0	0
650	Jefferson City	MO	4.9	15.0	2	26
651	Jefferson City	MO	4.9	15.0	2	26
652	Columbia	MO	5.2	14.5	2	26
653	Sedalia	MO	5.0	17.2	2	26
654	Rolla	MO	4.8	12.8	2	26
655	Rolla	MO	4.8	12.8	2	26
656	Springfield	MO	4.7	16.3	2	26
657	Springfield	MO	4.7	16.3	2	26
658	Springfield	MO	4.7	16.3	2	26
659	Not used	00	0.0	0.0	0	0
660	Kansas City	KS	5.3	17.5	2	17
661	Kansas City	KS	5.3	17.5	2	17
662	Shawnee/ Mission	KS	5.3	17.5	2	17
663	Not used	00	0.0	0.0	0	0
664	Topeka	KS	5.3	16.6	2	17
665	Topeka	KS	5.3	16.6	2	17
666	Topeka	KS	5.3	16.6	2	17
667	Fort Scott	KS	4.3	24.1	2	17
668	Emporia	KS	5.1	17.4	2	17
669	Concordia	KS	5.6	16.7	2	17
670	Wichita	KS	4.8	21.2	2	17
671	Wichita	KS	4.8	21.2	2	17
672	Wichita	KS	4.8	21.2	2	17
673	Indepen-dence	KS	4.3	20.3	2	17
674	Salina	KS	5.2	19.8	2	17
675	Hutchinson	KS	4.6	21.9	2	17
676	Hays	KS	5.7	16.3	2	17
677	Colby	KS	6.2	11.9	2	17
678	Dodge City	KS	5.1	18.5	2	17
679	Liberal	KS	4.3	18.5	2	17
680	Omaha	NE	6.2	12.0	2	28
681	Omaha	NE	6.2	12.0	2	28
682	Not used	00	0.0	0.0	0	0
683	Lincoln	NE	6.4	13.6	2	28
684	Lincoln	NE	6.4	13.6	2	28
685	Lincoln	NE	6.4	13.6	2	28
686	Columbus	NE	6.5	12.7	2	28
687	Norfolk	NE	7.0	10.6	2	28
688	Grand Island	NE	6.5	12.0	2	28
689	Hastings	NE	6.1	12.6	2	28
690	McCook	NE	5.8	13.6	2	28
691	North Platte	NE	6.9	8.5	2	28

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
692	Valentine	NE	7.4	8.2	2	28
693	Alliance	NE	7.1	6.4	2	28
694	Not used	00	0.0	0.0	0	0
695	Not used	00	0.0	0.0	0	0
696	Not used	00	0.0	0.0	0	0
697	Not used	00	0.0	0.0	0	0
698	Not used	00	0.0	0.0	0	0
699	Not used	00	0.0	0.0	0	0
700	New Orleans	LA	1.5	28.6	3	19
701	New Orleans	LA	1.5	28.6	3	19
702	Not used	00	0.0	0.0	0	0
703	Thibodaux	LA	1.3	27.9	3	19
704	Hammond	LA	1.7	24.7	3	19
705	Lafayette	LA	1.6	28.5	3	19
706	Lake Charles	LA	1.6	28.6	3	19
707	Baton Rouge	LA	1.7	26.9	3	19
708	Baton Rouge	LA	1.7	26.9	3	19
709	Not used	00	0.0	0.0	0	0
710	Shreveport	LA	2.3	28.3	3	19
711	Shreveport	LA	2.3	28.3	3	19
712	Monroe	LA	2.4	26.6	3	19
713	Alexandria	LA	2.0	27.3	3	19
714	Alexandria	LA	2.0	27.3	3	19
715	Not used	00	0.0	0.0	0	0
716	Pine Bluff	AR	2.7	26.7	3	4
717	Camden	AR	2.8	23.7	3	4
718	Hope	AR	3.0	22.5	3	4
719	Hot Springs Nat Pk	AR	2.9	26.6	3	4
720	Little Rock	AR	3.2	23.8	3	4
721	Little Rock	AR	3.2	23.8	3	4
722	Little Rock	AR	3.2	23.8	3	4
723	West Memphis	AR	3.2	24.5	3	4
724	Jonesboro	AR	3.6	23.2	3	4
725	Batesville	AR	3.7	19.0	3	4
726	Harrison	AR	3.9	18.5	3	4
727	Fayetteville	AR	4.2	16.0	3	4
728	Russellville	AR	3.4	22.7	3	4
729	Fort Smith	AR	3.5	23.5	3	4
730	Oklahoma City	OK	3.7	23.0	3	37
731	Oklahoma City	OK	3.7	23.0	3	37
732	Not used	00	0.0	0.0	0	0
733	Not used	00	0.0	0.0	0	0
734	Ardmore	OK	2.6	31.7	3	37
735	Lawton	OK	3.2	27.1	3	37
736	Clinton	OK	3.7	26.4	3	37
737	Enid	OK	3.8	26.1	3	37
738	Woodward	OK	4.4	23.2	3	37
739	Guymon	OK	4.5	17.5	3	37
740	Tulsa	OK	3.7	26.5	3	37
741	Tulsa	OK	3.7	26.5	3	37
742	Not used	00	0.0	0.0	0	0
743	Vinita	OK	3.9	23.2	3	37
744	Muskogee	OK	3.4	25.7	3	37
745	McAlester	OK	3.4	26.3	3	37
746	Ponca City	OK	4.3	24.3	3	37
747	Durant	OK	2.7	26.1	3	37
748	Shawnee	OK	3.1	27.4	3	37
749	Poteau	OK	3.1	25.3	3	37
750	Dallas	TX	2.3	36.7	3	44

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
751	Dallas	TX	2.3	36.7	3	44
752	Dallas	TX	2.3	36.7	3	44
753	Dallas	TX	2.5	36.7	3	44
754	Greenville	TX	2.3	27.7	3	44
755	Texarkana	TX	2.6	23.0	3	44
756	Longview	TX	2.5	28.7	3	44
757	Tyler	TX	2.3	24.9	3	44
758	Palestine	TX	2.3	28.5	3	44
759	Lufkin	TX	1.9	30.4	3	44
760	Fort Worth	TX	2.4	36.3	3	44
761	Fort Worth	TX	2.4	36.3	3	44
762	Denton	TX	2.5	31.5	3	44
763	Wichita Falls	TX	3.0	34.5	3	44
764	Stephenville	TX	2.7	27.4	3	44
765	Temple	TX	2.1	33.1	3	44
766	Waco	TX	2.1	36.7	3	44
767	Waco	TX	2.1	36.7	3	44
768	Brownwood	TX	2.5	32.4	3	44
769	San Angelo	TX	2.3	32.7	3	44
770	Houston	TX	1.5	30.5	3	44
771	Houston	TX	1.5	30.5	3	44
772	Houston	TX	1.5	30.5	3	44
773	Conroe	TX	1.8	30.5	3	44
774	Houston	TX	1.5	30.5	3	44
775	Galveston	TX	1.3	31.9	3	44
776	Beaumont	TX	1.5	31.7	3	44
777	Beaumont	TX	1.5	31.7	3	44
778	Bryan	TX	1.7	34.2	3	44
779	Victoria	TX	1.3	37.3	3	44
780	Laredo/ Pearsall	TX	1.3	52.6	3	44
781	San Antonio	TX	1.6	36.2	3	44
782	San Antonio	TX	1.6	36.2	3	44
783	Corpus Christi	TX	1.0	42.0	3	44
784	Corpus Christi	TX	1.0	42.0	3	44
785	Brownsville	TX	0.6	42.5	3	44
786	Austin	TX	1.8	35.2	3	44
787	Austin	TX	1.8	35.2	3	44
788	Uvalde	TX	1.6	37.1	3	44
789	Giddings	TX	1.7	34.2	3	44
790	Amarillo	TX	4.2	15.7	3	44
791	Amarillo	TX	4.2	15.7	3	44
792	Childress	TX	3.3	27.1	3	44
793	Lubbock	TX	3.5	18.2	3	44
794	Lubbock	TX	3.5	18.2	3	44
795	Abilene	TX	2.6	31.9	3	44
796	Abilene	TX	2.6	31.9	3	44
797	Midland	TX	2.6	25.0	3	44
798	El Paso	TX	2.7	23.0	3	44
799	El Paso	TX	2.7	23.0	3	44
800	Denver	CO	6.0	5.9	4	6
801	Denver	CO	6.0	5.9	4	6
802	Denver	CO	6.0	5.9	4	6
803	Boulder	CO	5.5	7.7	4	6
804	Golden/ Dillon	CO	10.0	0.0	4	6
805	Longmont	CO	6.4	3.8	4	6
806	Greeley	CO	6.5	5.1	4	6
807	Fort Morgan	CO	6.5	7.2	4	6
808	Colorado Springs	CO	6.4	3.7	4	6

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
809	Colorado Springs	CO	6.4	3.7	4	6
810	Pueblo	CO	5.5	11.0	4	6
811	Alamosa	CO	8.7	0.0	4	6
812	Salida	CO	9.0	0.0	4	6
813	Durango	CO	6.8	0.4	4	6
814	Montrose	CO	6.4	3.6	4	6
815	Grand Junction	CO	5.7	12.1	4	6
816	Glenwood Springs	CO	7.0	2.1	4	6
817	Not used	00	0.0	0.0	0	0
818	Not used	00	0.0	0.0	0	0
819	Not used	00	0.0	0.0	0	0
820	Cheyenne	WY	7.3	2.1	4	51
821	Yellowstone Nat Pk	WY	9.1	0.5	4	51
822	Wheatland	WY	6.5	5.4	4	51
823	Rawlins	WY	8.6	0.3	4	51
824	Worland	WY	8.0	4.8	4	51
825	Riverton	WY	8.4	2.6	4	51
826	Casper	WY	6.9	4.5	4	51
827	Gillette	WY	7.8	4.3	4	51
828	Sheridan	WY	7.9	4.5	4	51
829	Rock Springs	WY	8.4	1.0	4	51
830	Jackson	WY	9.8	0.1	4	51
831	Kemmerer	WY	9.6	0.3	4	51
832	Pocatello	ID	7.1	3.3	4	13
833	Twin Falls	ID	6.7	2.8	4	13
834	Idaho Falls	ID	8.6	1.4	4	13
835	Lewiston	ID	5.4	7.9	4	13
836	Boise	ID	5.8	8.0	4	13
837	Boise	ID	5.8	8.0	4	13
838	Coeur D Alene	ID	6.5	2.8	4	13
839	Not used	00	0.0	0.0	0	0
840	Salt Lake City/ Heber City	UT	7.6	0.5	4	45
841	Salt Lake City	UT	5.8	9.9	4	45
842	Not used	00	0.0	0.0	0	0
843	Ogden/ Logan	UT	6.8	5.0	4	45
844	Ogden	UT	5.9	9.0	4	45
845	Southeast Utah/ Green River	UT	6.0	9.0	4	45
846	Provo	UT	6.0	9.0	4	45
847	Southwest Utah/ Cedar City	UT	6.0	5.0	4	45
848	Not used	00	0.0	0.0	0	0
849	Not used	00	0.0	0.0	0	0
850	Phoenix	AZ	1.4	55.0	4	3
851	Phoenix	AZ	1.4	55.0	4	3
852	Casa Grande	AZ	1.6	49.0	4	3
853	Buckeye/ Yuma	AZ	1.3	55.0	4	3
854	Not used	00	0.0	0.0	0	0
855	Globe	AZ	2.8	24.6	4	3
856	Sierra Vista/ Nogales	AZ	2.9	10.0	4	3
857	Tucson	AZ	1.7	36.0	4	3
858	Not used	00	0.0	0.0	0	0
859	Show Low	AZ	5.0	4.6	4	3
860	Flagstaff	AZ	7.3	0.4	4	3
861	Not used	00	0.0	0.0	0	0
862	Not used	00	0.0	0.0	0	0

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
863	Prescott	AZ	5.0	3.8	4	3
864	Kingman	AZ	3.1	21.6	4	3
865	Window Rock	AZ	6.7	1.9	4	3
866	Not used	00	0.0	0.0	0	0
867	Not used	00	0.0	0.0	0	0
868	Not used	00	0.0	0.0	0	0
869	Not used	00	0.0	0.0	0	0
870	Bernalillo	NM	4.7	7.6	4	32
871	Albuquer-que	NM	4.4	11.0	4	32
872	Albuquer-que	NM	4.4	11.0	4	32
873	Gallup	NM	6.2	1.9	4	32
874	Farmington	NM	5.7	5.0	4	32
875	Santa Fe	NM	6.4	1.2	4	32
876	Not used	00	0.0	0.0	0	0
877	Las Vegas	NM	6.1	1.1	4	32
878	Socorro	NM	4.1	11.0	4	32
879	Truth or Conseq.	NM	3.4	14.6	4	32
880	Las Cruces	NM	3.1	14.5	4	32
881	Clovis	NM	4.1	10.0	4	32
882	Roswell	NM	3.1	20.0	4	32
883	Carrizozo	NM	4.3	7.2	4	32
884	Tucumcari	NM	3.9	15.0	4	32
885	Not used	00	0.0	0.0	0	0
886	Not used	00	0.0	0.0	0	0
887	Not used	00	0.0	0.0	0	0
888	Not used	00	0.0	0.0	0	0
889	not used	00	0.0	0.0	0	0
890	Las Vegas/ Tonopah	NV	5.8	5.9	4	28
891	Las Vegas	NV	2.5	43.0	4	28
892	Not used	00	0.0	0.0	0	0
893	Ely	NV	7.7	0.7	4	28
894	Reno	NV	6.0	2.2	4	28
895	Reno	NV	6.0	2.2	4	28
896	Reno	NV	6.0	2.2	4	28
897	Carson City	NV	5.8	2.0	4	28
898	Elko	NV	7.3	3.8	4	28
899	Not used	00	0.0	0.0	0	0
900	Los Angeles	CA	1.2	10.6	4	5
901	Los Angeles	CA	1.2	10.6	4	5
902	Los Angeles	CA	1.2	10.6	4	5
903	Inglewood	CA	1.6	4.3	4	5
904	Santa Monica	CA	1.9	1.9	4	5
905	Torrance	CA	1.7	3.9	4	5
906	Whittier	CA	2.0	10.2	4	5
907	San Pedro	CA	1.5	7.8	4	5
908	Long Beach	CA	1.5	7.8	4	5
909	Not used	00	0.0	0.0	0	0
910	Pasadena	CA	1.6	11.0	4	5
911	Pasadena	CA	1.6	11.0	4	5
912	Glendale	CA	1.7	11.4	4	5
913	Van Nuys	CA	1.7	11.4	4	5
914	Van Nuys	CA	1.7	11.4	4	5
915	Burbank	CA	1.7	11.4	4	5
916	North Hollywood	CA	1.7	11.4	4	5
917	Covina	CA	2.0	10.2	4	5
918	Alhambra	CA	1.6	11.0	4	5
919	San Diego	CA	1.3	4.6	4	5
920	San Diego	CA	1.3	4.6	4	5

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
921	San Diego	CA	1.3	4.6	4	5
922	Palm Springs	CA	1.1	54.0	4	5
923	San Bern./ Victorville/ Redlands	CA	2.5	16.0	4	5
924	San Bernardino	CA	1.8	17.8	4	5
925	Riverside	CA	1.8	14.0	4	5
926	Santa Ana	CA	1.4	6.9	4	5
927	Santa Ana	CA	1.4	6.9	4	5
928	Anaheim	CA	1.4	6.9	4	5
929	Not used	00	0.0	0.0	0	0
930	Ventura/ Oxnard	CA	2.1	1.2	4	5
931	Santa Barbara	CA	2.5	0.9	4	5
932	Bakersfield/ Visalia	CA	2.5	19.0	4	5
933	Bakersfield	CA	2.1	30.0	4	5
934	San Luis Obispo	CA	2.5	1.1	4	5
935	Lancaster	CA	2.9	21.0	4	5
936	Fresno	CA	2.6	19.4	4	5
937	Fresno	CA	2.6	19.4	4	5
938	Not used	00	0.0	0.0	0	0
939	Monterey	CA	3.2	0.1	4	5
940	So. San Francisco	CA	3.1	0.3	4	5
941	San Francisco	CA	3.1	0.2	4	5
942	Sacramento/ Placerville	CA	4.1	7.8	4	5
943	Palo Alto	CA	2.9	0.7	4	5
944	San Mateo	CA	2.6	1.2	4	5
945	Concord	CA	3.0	3.0	4	5
946	Oakland	CA	2.9	0.4	4	5
947	Berkeley	CA	3.0	0.3	4	5
948	Richmond	CA	2.7	0.4	4	5
949	San Rafael	CA	2.5	1.9	4	5
950	Gilroy	CA	3.4	0.1	4	5
951	San Jose	CA	2.4	1.4	4	5
952	Stockton	CA	2.7	13.0	4	5
953	Merced	CA	2.7	14.0	4	5
954	Santa Rosa	CA	3.0	1.2	4	5
955	Eureka	CA	4.7	0.0	4	5
956	Sacramento/ Placerville	CA	4.1	7.8	4	5
957	Pollock Pines	CA	6.0	1.0	4	5
958	Sacramento	CA	2.5	12.0	4	5
959	Marysville	CA	2.6	15.0	4	5
960	Redding	CA	2.5	28.0	4	5
961	Susanville	CA	6.2	2.2	4	5
962	Not used	00	0.0	0.0	0	0
963	Not used	00	0.0	0.0	0	0
964	Not used	00	0.0	0.0	0	0
965	Not used	00	0.0	0.0	0	0
966	Not used	00	0.0	0.0	0	0
967	Honolulu	HI	0.0	20.0	4	12
968	Honolulu	HI	0.0	30.0	4	12
969	Not used	00	0.0	0.0	0	0
970	Hood River	OR	5.0	1.5	4	38
971	Portland	OR	4.7	1.9	4	38
972	Portland	OR	4.7	1.9	4	38
973	Salem	OR	5.0	1.0	4	38
974	Eugene	OR	4.8	1.3	4	38
975	Medford	OR	4.8	6.2	4	38

Zip Code	City	State	HDDk	CDHk	Fuel escalation region	State No.
976	Klamath Falls	OR	6.6	2.4	4	38
977	Bend	OR	7.1	0.6	4	38
978	Pendleton	OR	5.3	8.1	4	38
979	Ontario	OR	5.7	10.0	4	38
980	Seattle	WA	5.1	1.0	4	48
981	Seattle	WA	5.1	1.0	4	48
982	Everett	WA	5.4	0.2	4	48
983	Tacoma	WA	5.1	1.0	4	48
984	Tacoma	WA	4.8	0.5	4	48
985	Olympia	WA	5.7	0.3	4	48
986	Vancouver	WA	5.0	1.7	4	48
987	Not used	00	0.0	0.0	0	0
988	Wenatchee	WA	5.7	7.6	4	48
989	Yakima	WA	6.0	4.1	4	48
990	Spokane	WA	6.9	3.5	4	48
991	Spokane	WA	6.9	3.5	4	48
992	Spokane	WA	6.9	3.5	4	48
993	Richland	WA	4.7	9.8	4	48
994	Clarkston	WA	5.4	8.0	4	48
995	Anchorage	AK	11.0	0.0	4	2
996	Anchorage	AK	11.0	0.0	4	2
997	Fairbanks	AK	14.0	0.0	4	2
998	Juneau	AK	9.0	0.0	4	2
999	Ketchikan	AK	7.0	0.0	4	2

Appendix B. Coefficients Used to Calculate Savings for Floor* and Building Foundation** Insulation.

R-value	β_h	β_c
Plastic foam on upper half of deep basement, base R-value is 2.5**		
4	20.69	0.34
5	21.70	0.37
8	23.62	0.44
10	24.48	0.47
12	25.18	0.50
15	26.07	0.54
Plastic foam on full height of deep basement, base R-value is 2.5**		
4	28.57	0.45
5	30.00	0.47
8	32.75	0.50
10	34.00	0.51
12	35.03	0.52
15	35.35	0.54
Plastic foam on full height of shallow basement, base R-value is 2.5**		
4	44.35	0.95
5	46.38	0.99
8	50.04	1.06
10	51.56	1.08
12	52.75	1.10
15	54.17	1.12

* per ft^2
** per linear foot

R-value	β_h	β_c
Batt insulation on inside of deep basement wall, base R-value is 2.5**		
11	34.24	0.51
19	35.20	0.52
30	37.55	0.53
Batt insulation on inside of shallow basement wall, base R-value is 2.5**		
11	51.36	1.08
19	52.48	1.10
30	54.98	1.13
Slab on grade - Vertical 2 feet, base R-value is 1.0**		
4	2.79	0.23
5	2.94	0.24
8	3.25	0.25
10	3.40	0.25
12	3.53	0.25
15	3.70	0.25
Slab on grade - vertical 4 feet, base R-value is 1.0*		
4	3.56	0.23
5	3.78	0.24
8	4.25	0.25
10	4.50	0.25
12	4.72	0.25
15	5.03	0.25

R-value	β_h	β_c
Wood-framed floor insulation, base R-value is 4.0*		
11	1.7	.12
19	1.96	.12
30	2.22	.12
Metal-framed floor insulation, base R-value is 4.0*		
11	1.05	.07
19	1.33	.09
30	1.52	.11
Concrete-masonry crawl space walls - plastic foam, base R-value is 2.5**		
5	19.51	.83
7	20.59	.86
10	21.56	.88
14	22.37	.90
Concrete-masonry crawl space walls - batts, base R-value is 2.5**		
11	21.80	.93
13	22.20	.94

Appendix C: The Modified Zone Heat Transfer Model

The modified zone heat transfer model provides a more accurate estimate of total heat transfer through a wall with highly conductive framing members. The following Fortran listing was used to calculate representative U-values for metal frame walls using this method. It also includes a parallel-path heat transfer calculation for wood frame walls. This program varies the sheathing thickness from 0 to 2 inches, the wall cavity insulation from an R-value of 0.9 (an empty air space) to R-22, and varies the thickness of the cavity corresponding to the thickness of the batt insulation product. The output files contain the U-value and cost for every combination of these factors. Before using this data in the Zip computer program, any combination of sheathing and cavity insulation that offered less insulation (i.e. a higher U-value) for a higher cost than an alternative combination was deleted.

```
C    METWALL2.FOR
c    THIS VERSION not MODIFIED FOR OVE, THAT IS: ADDED COST FOR THICKER WALLS
c    s= distance between joists, inches
c    zf=zone factor, use curve fit equations provided by Jan Kosny
c    rsheath=thermal resistance of sheathing, h-ft2-F/Btu
c    ds=thickness between plywood and drywall
c    rins=r value of insulation per inch, h-ft2-F/Btu-in.
c    tmetal=thickness of metal joist, in.
c    xl=width of metal flange, in.
c    rmet=resistance of metal, h-ft2-F/Btu-in.
c    sumda=thickness of sidewall materials outside of cavity for thickest
c         of two sides), in.
c    sumra=total R value of sidewall materials outside of cavity for thickest
c         of two sides, h-ft2-F/Btu , uses 0.17 for exterior surface h,
c         0.81 for 0.5 in. siding, and 1.32 for 0.5 in plywood
c    sumdb=thickness of sidewall materials outside of cavity for thinnest
c         of two sides, in.
c    sumrb=total R value of sidewall materials outside of cavity for thinnest
c         of two sides), h-ft2-F/Btu, uses 0.68 for interior surface h,
c         0.45 for 0.5 in. drywall
c    use R value of 0.9 for air space in base case wall without any cavity insulation
c    ASSUMPTION -- add-on cost for thicker metal wall sections taken from wood walls
      real rsheath(5), tsheath(5), ds(6), rnom(6), rins(6)
      real costsh(5), costins(6)
      data rsheath/2.5,3.5,5.,7.,0./
      data tsheath/.5,.5,1.0,1.0,0./
      data costsh/0.47,0.65,0.58,0.87,0./
      data ds/3*3.5,5.5,3.5,5.5/
      data rnom/11.,13.,15.,21.,0.9,19./
      data costins/.30,.36,.56,.55,0.,.44/
      s=16.0
      tmetal=0.05
      rmet=0.003
      xL=1.5
      sumdb=0.5
```

```
      sumrb=0.45 + 0.68
      open(6,file="xmetwal.out", status='UNKNOWN')
      open(7,file="xametwal.out",status='unknown')
      open(8,file="xawoodwl.out",status='unknown')
      write(6,*)" rsheath  rinsul   rtotal   utotal      zf  cost"
      do 200 isheath=1,5
      sumda=.5 + tsheath(isheath) + .5
      sumra=.17 + .81 + rsheath(isheath) + 1.32
      avgra=sumra/sumda
      do 100 iins=1,6
      rlabel=rsheath(isheath)*1000. + rnom(iins)
      rins(iins)=rnom(iins)/ds(iins)
      rratio=rins(iins)/avgra
      if(ds(iins).ge.5.)zf=2.11065*rratio**0.2932
      if((ds(iins).lt.5.).and.(ds(iins).gt.3.5))zf=1.7032*
     c                              rratio**0.29663
      if(ds(iins).le.3.5)zf=1.55303*rratio**0.28665
      dl=ds(iins)-2*tmetal
      w=xl + zf*sumda
      R1ins=rins(iins)*dl
      R2ins=Rins(iins)*tmetal
      R1met=Rmet*dl
      R2met=Rmet*tmetal
      R1=(R1met*R1ins*w)/(tmetal*(R1ins-R1met) + w*R1met)
      R2=R2met*R2ins*w/(xl*(R2ins-R2met) + w*R2met)
      sumrcav=sumra + sumrb + R1ins + 2.*R2ins
      sumrw=sumra + sumrb + R1 + 2.*R2
      Rtot=sumrw*sumrcav*s/(w*(sumrcav - sumrw) + s*sumrw)
      Utot=1./Rtot
      rstud=1.25*ds(iins)
c     Use parallel path resistance for wood with a 25% framing factor,
c     outside surface=0.17, wood siding=0.81, plywood sheathing=1.32
c     wallboard=0.45, inside surface=0.68
      UWOOD=.75/(.17+.81+1.32+.45+.68 + RNOM(iins) + rsheath(isheath)) +
     c      .25/(.17+.81+1.32+.45+ .68 +rsheath(isheath) + rstud)
      costtot=costsh(isheath) + costins(iins)
      if (rnom(iins).gt.15)costtot=costtot+.83
      write(6,90)rsheath(isheath),rnom(iins),Rtot, Utot,zf, costtot
      write(7,91)rlabel,utot,costtot
      write(8,91)rlabel,uwood,costtot
   90 format(3f8.2,f10.5,2f8.2)
   91 format(f6.0,',',f6.4,',',f4.2)
  100 continue
  200 continue
      stop
      end
```

Appendix D: Insulation Cost Survey Forms and Selected Results

Company Name:
Address:
Contact:
Phone/Fax:

☐ withhold company name from database

From: Steven Winter Associates, Inc.
Phone: (203) 857-0200
Fax: (203) 852-0741
Attention: Peter Stratton

Residential Retrofit Costs

National Survey

Oak Ridge National Laboratory

	Material	Cost per ft² (including labor, materials, OH, profit)						
		R-11	R-19	R-30	R-38	R-49	R-22	R-25
Attic 1200ft² floor pull down stair access	Fiberglass batt	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²
	Blown fiberglass	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²		
	Blown cellulose	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²		
	Blown rock wool	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²		
Interior/Exterior Wall 200ft² one side unfinished with open access	Fiberglass batt	R-11	R-13	R-19	R-22	R-38	R-49	
		$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	
Exterior Walls 900ft² 2x4s @ 16″ o.c. inlcuding wall surface repair	Blown cellulose	3lb/ft³	4lb/ft³	Blown fiberglass	Blown fiberglass	R-11		
		$ /ft²	$ /ft²			$ /ft²		
Crawl Space Wall 560ft² - 4′ high x 140′ long - 3′x4′ access	Extruded Polystyrene	R-4	R-5	R-7.5	R-10	R-15	R-19	
		$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	
	Fiberglass batts	R-11	R-13	R-15	R-19			
		$ /ft²	$ /ft²	$ /ft²	$ /ft²			
Floor 1200ft² 4′ high crawl space 3′x4′ access	Fiberglass batts	R-11	R-13	R-15	R-19	R-25		
		$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²		
Basement Wall 900ft² 140′ long with 2x2 at top, center, and bottom of wall	Fiberglass batts with flame resistant polypropylene face	R-11						
		$ /ft²						

Company Name:
Address:

Contact:
Phone/Fax:

☐ withhold company name from database

From: Steven Winter Associates, Inc.
Phone: (203) 857-0200
Fax: (203) 852-0741
Attention: Peter Stratton

Residential New Construction Costs

National Survey
Oak Ridge National Laboratory

	Material	Cost per ft² (including material, labor, OH, profit)								
		R-11	R-19	R-22	R-25	R-30	R-38	R-49	R-60	
Attic 1200ft² floor 30′x40′	Fiberglass Batt	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	
	Blown fiberglass	$ /ft²	$ /ft²	$ /ft²		$ /ft²	$ /ft²	$ /ft²	$ /ft²	
	Blown rock wool	$ /ft²	$ /ft²	$ /ft²		$ /ft²	$ /ft²	$ /ft²	$ /ft²	
	Blown cellulose	$ /ft²	$ /ft²	$ /ft²		$ /ft²	$ /ft²	$ /ft²	$ /ft²	
Cathedral Ceiling 500ft²	R-11	R-13	R-15	R-19	R-21	R-22	R-30	R-38	R-49	R-60
	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²
Interior/Exterior Walls 200ft² 8′x25′	Fiberglass batt	R-11	R-13	R-15	R-19	R-21	R-22	R-30	R-38	R-49
		$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²
Exterior Wall 900ft² - 8′x112.5′	Foam sheathing board	R-1.3	R-3.6	R-4	R-4.5	R-5	R-5.4	R-7.2	R-9	R-10
		$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²
	Fiberglass batts	R-11	R-13	R-15	R-19	R-21	Cellulose Wall Spray 3lb/ft³		2x4	2x6
		$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²			$ /ft²	$ /ft²
Band Joist 140ft² 2x10	Fiberglass batts	R-11	R-13	R-19	R-30					
		$ /ft²	$ /ft²	$ /ft²	$ /ft²					
Crawl Space Wall Interior 560ft² - 4′ high x 140′ long with 3′x4′ access	Extruded polystyrene	R-4	R-5	R-7.5	R-10	R-15	R-19			
		$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²			
	Fiberglass batts	R-11	R-13	R-15	R-19					
		$ /ft²	$ /ft²	$ /ft²	$ /ft²					
Exterior	Fiberglass batts	R-5	R-10	R-15	R-20					
		$ /ft²	$ /ft²	$ /ft²	$ /ft²					
Floor 1200ft² 4′ crawl space w/ 3′x4′ door	Fiberglass batts	R-11	R-13	R-15	R-19	R-25				
		$ /ft²	$ /ft²	$ /ft²	$ /ft²	$ /ft²				

Company Name:
Phone/Fax:
Address:
Contact:

☐ withhold company name from database

From: Steven Winter Associates, Inc.
Phone: (203) 857-0200
Fax: (203) 852-0741
Attention: Peter Stratton

Residential New Construction Costs

National Survey
Oak Ridge National Laboratory

Item	Material	Cost per ft^2 (including material, labor, OH, profit)					
Concrete/Block Walls 900ft^2 40′ long	Expanded polystyrene 1lb ft^3	R-4	R-5	R-7.5	R-10	R-15	R-19
		\$ /ft^2	\$ /ft^2	\$ /ft^2	\$ /ft^2	\$ /ft^2	\$ /ft^2
	fiberglass batts	R-11	R-13	R-15	R-19	R-11 w/flame resistant poly-face	
Interior		\$ /ft^2	\$ /ft^2	\$ /ft^2	\$ /ft^2	\$ /ft^2	
Exterior & Below grade	fiberglass	R-5	R-10	R-15	R-20		
		\$ /ft^2	\$ /ft^2	\$ /ft^2	\$ /ft^2		
Concrete Slab Edge 2ft deep 140′ long	polystyrene	R-5	R-10				
		\$ /ft^2	\$ /ft^2				
Masonry Walls Above grade 900ft^2 8′x122.5′	in block insulation	vermiculite		perlite		korfil - 1lb ft^3	
		\$ /ft^2		\$ /ft^2		\$ /ft^2	
In Block/Brick Cavity	EPS foam	R-4	R-5	R-8	R-10		
		\$ /ft^2	\$ /ft^2	\$ /ft^2	\$ /ft^2		
	isocyanurate foam	R-14	R-25				
		\$ /ft^2	\$ /ft^2				
Interior	foil backed gypsum	\$ /ft^2	\$ /ft^2				
Exterior	insulating stucco	\$ /ft^2	\$ /ft^2				
	insulating stucco over foam (R-value foam only)	R-4	R-5	R-8	R-10	R-14	
		\$ /ft^2	\$ /ft^2	\$ /ft^2	\$ /ft^2	\$ /ft^2	
	insulating stucco over fiberglass	R-11	R-13	R-19			
		\$ /ft^2	\$ /ft^2	\$ /ft^2			

Company Name:
Address:
Contact:
Phone/Fax:
☐ withhold company name from database

From: Steven Winter Associates, Inc.
Phone: (203) 857-0200
Fax: (203) 852-0741
Attention: Peter Stratton

1. Assume: - 1200 sq.ft. single-story house (30ft x 40ft)
- 6/12 roof pitch, flat ceiling
- 19 trusses at 24" oc and 2 frame gables

What are the **increased framing costs** associated with increasing the thickness of attic insulation from (note: assume raised heel):

	Increased Framing Cost
5.5" (R-19,21) to a thickness of 6.75" (R-22):	+ $___________
6.75" (R-22) to a thickness of 9.5" (R-30):	+ $___________
9.5" (R-30) to a thickness of 12" (R-38):	+ $___________
12" (R-38) to a thickness of 15" (R-49):	+ $___________
15" (R-49) to a thickness of 19" (R-60):	+ $___________

2. Assume: - Exterior walls 900 sq.ft. (8ft high x 112.5 linear feet)
- 12 windows at 3' x 4' (168 linear feet)
- 2 doors at 3'0" x 6'8" (34 linear feet)

Assume easy access before the drywall is applied. What are the **increased costs** associated with going from 2x4 to 2x6 framing, including added costs for extension jambs on all windows and doors.

+$ ____________

3. Assume: - 1/2" fiberboard is being replaced by insulative sheathing.

What are the costs of insulative sheathing with the following R values:

R-3.6 $__________
Such as 1/2 in. Thermax Polyisocyanurate

R-4 $__________
Such as 1/2 in. TUFF-R

R-4.5 $__________
Such as 5/8 in. Thermax Polyisocyanurate

R-5 $__________
Such as 5/8 in. TUFF-R

R-5.4 $__________
Such as 3/4 in. Thermax Polyisocyanurate

R-7.2 $__________
Such as 1 in. Thermax Polyisocyanurate

R-8 $__________ Such as 1 in. TUFF-R

R-10 $__________ Such as 1 1/4 in. TUFF-R

4. **Assume:** **- 500 SF cathedral ceiling (20' x 25')**
- 11 trusses at 24" oc
- Ceiling slope of 3/12 scissor truss within 6/12 pitch roof

Indicate **increased framing costs** associated with installing higher levels of insulation from a thickness of:

	Increased Framing Cost
3.5 " (R-11,13,15) to a thickness of 5.5" (R-19,21):	+ $____________
5.5" (R-19,21) to a thickness of 6.75" (R-22):	+ $____________
6.75" (R-22) to a thickness of 9.5" (R-30):	+ $____________
9.5" (R-30) to a thickness of 12" (R-38):	+ $____________
12" (R-38) to a thickness of 15" (R-49):	+ $____________
15" (R-49) to a thickness of 19" (R-60):	+ $____________

5. **Assume:** **- 8ft high of above-grade concrete block walls**
- 900 SF of wall (112.5 x 8ft H)
- 12 windows: 3' x 4' (168 LF)
- 2 doors at 3'0" x 6'8" (34 LF)

Assuming easy access before the drywall is applied, what are the framing costs associated with increasing insulation, including added costs for extension jambs on all windows and doors.

Above grade concrete block walls, interior application: expanded or extruded polystyrene:

	Increased Cost		Increased Cost
R-7.5	$_____________	R-10	$_____________
R-15	$_____________	R-19	$_____________

Appendix E: Insulation Cost Multipliers and Energy Prices for Electricity, Natural Gas, and Fuel Oil [13,14,15]

State No.	State name	Electricity (¢/kWh)	Distillate oil (¢/gal)	Propane (¢/gal)	Natural gas ($/$10^3$ ft^3)	Insulation cost multiplier*
1	Alabama	7	87.1	97.8	9.68	79
2	Alaska	11.6	96.4	112.3	3.46	161
3	Arizona	9.3	106.4	112.3	9.25	96
4	Arkansas	8.1	87.1	97.8	7.03	77
5	California	11.4	106.4	112.3	6.66	117
6	Colorado	7.9	97.8	88.8	5.1	92
7	Connecticut	12.3	103	127	10.58	107
8	Delaware	9.1	103.1	116	9.02	101
9	District of Columbia	7.2	120.9	116	9.86	91
10	Florida	8.3	103.5	107.8	13.8	83
11	Georgia	7.5	103.5	107.8	8.49	79
12	Hawaii	14.6	106.4	112.3	21.05	121
13	Idaho	5.3	97.8	88.8	5.59	99
14	Illinois	11.8	92.4	83.7	5.93	103
15	Indiana	7.8	96.7	83.7	6.33	94
16	Iowa	8	96.8	83.7	6.74	86
17	Kansas	7.9	96.8	83.7	6.52	86
18	Kentucky	6	96.8	83.7	6.65	88
19	Louisiana	8	87.1	97.8	8.3	81
20	Maine	12.6	101	127	7.04	83
21	Maryland	8.2	108.3	116	10.63	86
22	Massachusetts	11.1	103	127	7.49	114
23	Michigan	8.3	103	83.7	5.5	99
24	Minnesota	7.2	97.6	83.7	5.47	108
25	Mississippi	7.4	87.1	97.8	6.19	75
26	Missouri	6.8	96.8	83.7	7.58	90

State No.	State name	Electricity (¢/kWh)	Distillate oil (¢/gal)	Propane (¢/gal)	Natural gas ($/$10^3$ ft^3)	Insulation cost multiplier*
27	Montana	6.3	97.8	88.8	5.56	96
28	Nebraska	6	96.8	83.7	6.31	83
29	Nevada	7.1	106.4	112.3	7.4	102
30	New Hampshire	13.6	99.1	127	6.99	104
31	New Jersey	12	105.5	116	8.05	109
32	New Mexico	9.3	87.1	97.8	5.58	89
33	New York	14	108.2	116	10.86	110
34	North Carolina	8.7	103.5	107.8	9.9	74
35	North Dakota	6.5	96.8	83.7	5.42	82
36	Ohio	9.2	98.2	83.7	7.26	103
37	Oklahoma	7.3	96.8	83.7	8.02	79
38	Oregon	5.9	108.5	112.3	6.95	105
39	Pennsylvania	10	99.5	116	8.59	102
40	Rhode Island	11	104	127	9.9	106
41	South Carolina	7.6	103.5	107.8	8.44	76
42	South Dakota	7.5	96.8	83.7	5.94	80
43	Tennessee	6.1	96.8	83.7	7.17	80
44	Texas	8.1	87.1	97.8	6.97	79
45	Utah	6.7	97.8	88.8	3.79	90
46	Vermont	10.5	100.7	127	7.21	84
47	Virginia	7.9	98.6	107.8	9.78	80
48	Washington	5	116.3	112.3	6.86	110
49	West Virginia	6.7	101.1	107.8	7.58	90
50	Wisconsin	7.1	95.6	83.7	5.76	93
51	Wyoming	6.6	97.8	88.8	7.07	86

* normalized to 100 for the national average

Appendix F. Residential Energy Price Escalation Factors.

Four regional energy price escalation tables are shown in this appendix. (The regional assignments for each zip code are shown in Appendix A.) These factors were taken from Ref. 12.

Table F.1 Relative energy prices for DOE region 1

	Electricity (¢/kWh)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.02	1.01	1.01	1.02	1.03	1.03
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.03	1.03	1.04	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
	Distillate oil (¢/gal)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.02	1.05	1.06	1.09	1.11	1.12	1.12	1.13	1.14	1.16	1.16	1.17	1.18	1.18	1.18
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.19	1.19	1.20	1.21	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.31
	Propane (¢/gal)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.01	1.03	1.04	1.05	1.07	1.08	1.08	1.08	1.09	1.11	1.11	1.11	1.13	1.14	1.13
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.13	1.14	1.15	1.14	1.15	1.15	1.16	1.16	1.17	1.17	1.18	1.18	1.19	1.20	1.20
	Natural gas ($/1000 ft^3)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	0.99	1.00	0.99	0.99	0.99	0.98	0.98	0.97	0.96	0.95	0.94	0.94	0.94	0.94	0.95
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	0.96	0.98	1.01	1.03	1.03	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.05

Table F.2 Relative energy prices for DOE region 2

	Electricity (¢/kWh)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	0.99	0.99	0.99	0.98	0.97	0.97	0.97	0.96	0.96	0.96	0.97	0.97	0.97	0.96	0.95
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	0.93	0.93	.094	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Distillate oil (¢/gal)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.03	1.06	1.08	1.10	1.12	1.14	1.14	1.16	1.17	1.18	1.19	1.20	1.21	1.21	1.22
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.22	1.23	1.24	1.24	1.25	1.26	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.36	1.37
	Propane (¢/gal)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.02	1.05	1.07	1.10	1.13	1.14	1.15	1.15	1.16	1.19	1.18	1.18	1.20	1.20	1.20
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.20	1.20	1.22	1.22	1.22	1.23	1.24	1.25	1.25	1.26	1.27	1.28	1.28	1.29	1.30
	Natural gas ($/1000 ft^3)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.00	1.01	1.01	1.02	1.02	1.02	1.02	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.01
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.03	1.05	1.08	1.10	1.10	1.10	1.11	1.11	1.12	1.12	1.13	1.13	1.14	1.14	1.15

Table F.3 Relative energy prices for DOE region 3

	Electricity (¢/kWh)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	0.96	0.95	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	Distillate oil (¢/gal)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.02	1.04	1.06	1.09	1.10	1.11	1.12	1.13	1.14	1.16	1.16	1.17	1.18	1.18	1.18
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.19	1.19	1.20	1.21	1.21	1.22	1.23	1.24	1.25	1.27	1.28	1.29	1.30	1.31	1.32
	Propane (¢/gal)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.02	1.04	1.06	1.08	1.10	1.12	1.12	1.12	1.13	1.15	1.15	1.14	1.16	1.16	1.16
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.16	1.16	1.18	1.17	1.18	1.18	1.19	1.19	1.20	1.21	1.21	1.22	1.22	1.23	1.24
	Natural gas ($/1000 ft^3)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.00	1.00	1.00	1.01	1.01	1.03
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.04	1.05	1.08	1.11	1.11	1.11	1.11	1.12	1.12	1.12	1.13	1.13	1.13	1.14	1.14

Table F.4 Relative energy prices for DOE region 4

	Electricity (¢/kWh)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.00	1.00	1.02	1.03	1.04	1.05	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.07
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.07	1.07	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
	Distillate oil (¢/gal)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.04	1.06	1.08	1.11	1.13	1.15	1.16	1.16	1.18	1.20	1.20	1.21	1.24	1.25	1.23
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.24	1.27	1.28	1.26	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.39
	Propane (¢/gal)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.02	1.03	1.05	1.04	1.06	1.06	1.07	1.07	1.09	1.10	1.10	1.11	1.12	1.13	1.14
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	1.15	1.16	1.16	1.17	1.18	1.18	1.19	1.20	1.20	1.21	1.22	1.22	1.23	1.23	1.24
	Natural gas ($/1000 ft^3)														
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Factor	1.01	1.02	1.01	1.02	1.01	1.01	1.01	0.99	0.98	0.97	0.97	0.96	0.97	0.97	0.98
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Factor	0.98	0.99	1.00	1.00	1.01	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.04	1.05

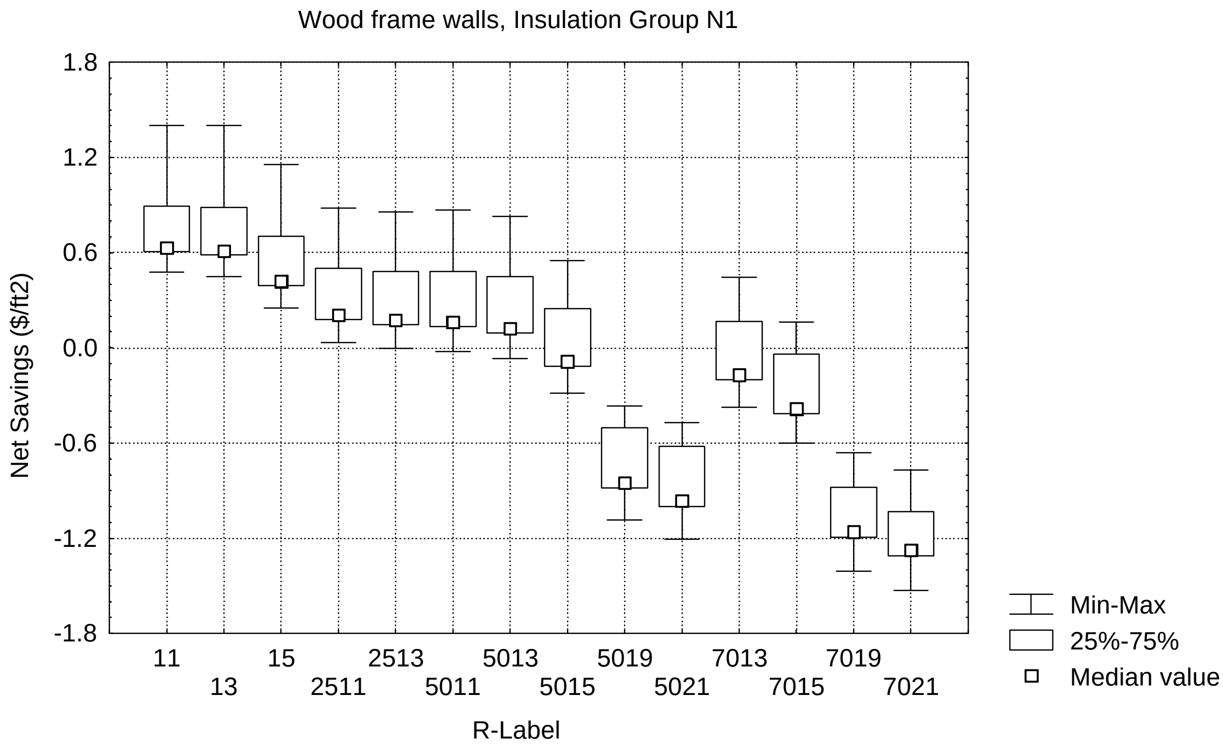
Appendix G. Net Savings for Wall Insulation Options.

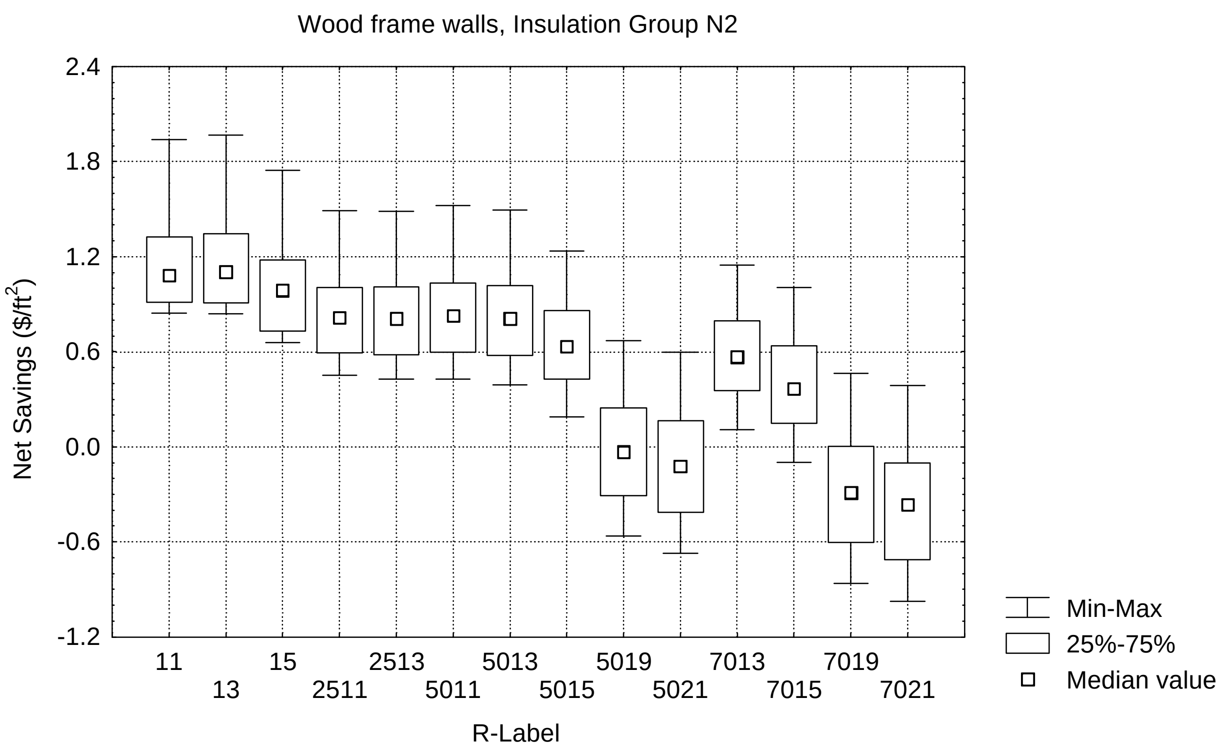
The figures in this appendix show the range of savings calculated for several possible combinations of wall sheathing and wall cavity insulation for new homes with wood or metal frames. A separate data value was calculated using the ZIP-Code computer program for each zip code and for each heating system type. The results were then summarized according to the new construction Insulation Group assignment. For this analysis, the insulative sheathing was assumed to be placed on top of a wooden sheathing.

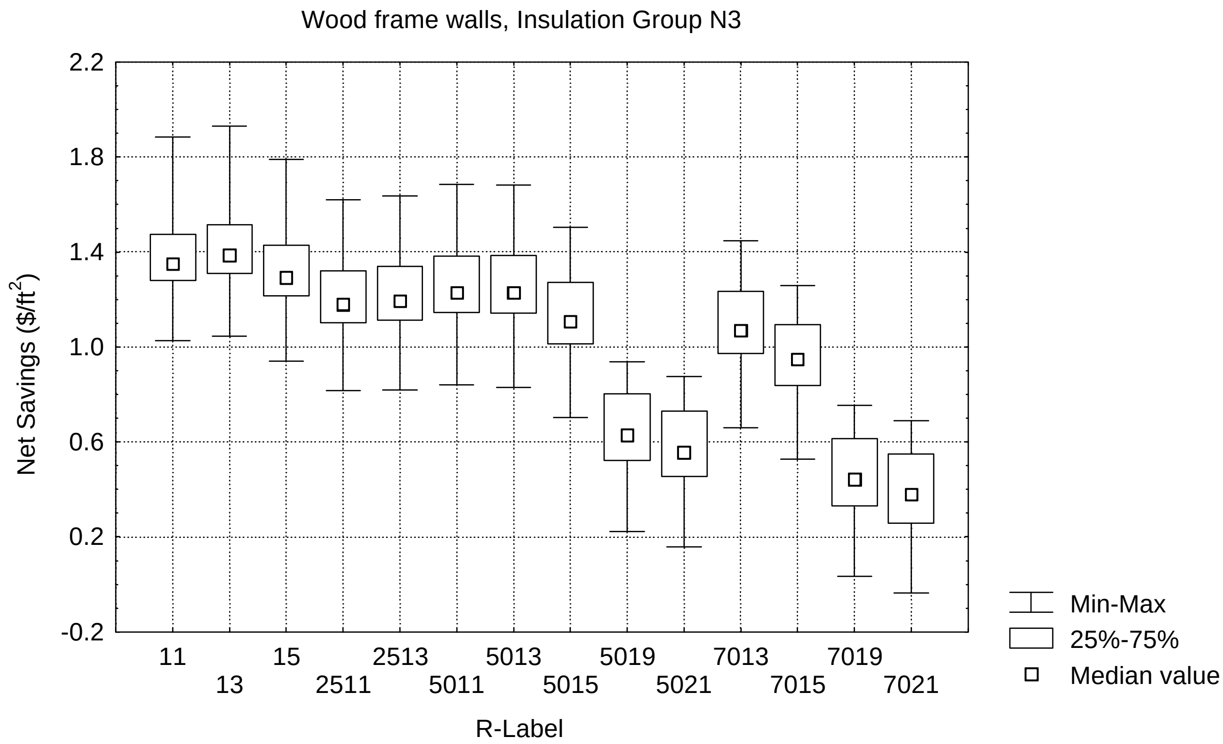
The R-Labels shown on each figure can be understood using the following translation table. The R-values shown in this table are for the insulation products only. They do not reflect the remainder of the wall assembly, which was however considered in the overall U-values used by the ZIP-Code computer analysis (see Appendix C for the details of the U-value calculations). Combinations of sheathing and cavity insulation other than those shown in this table are available. However, the combinations shown in this table offered more thermal resistance for less expense when compared to some of these other possible choices.

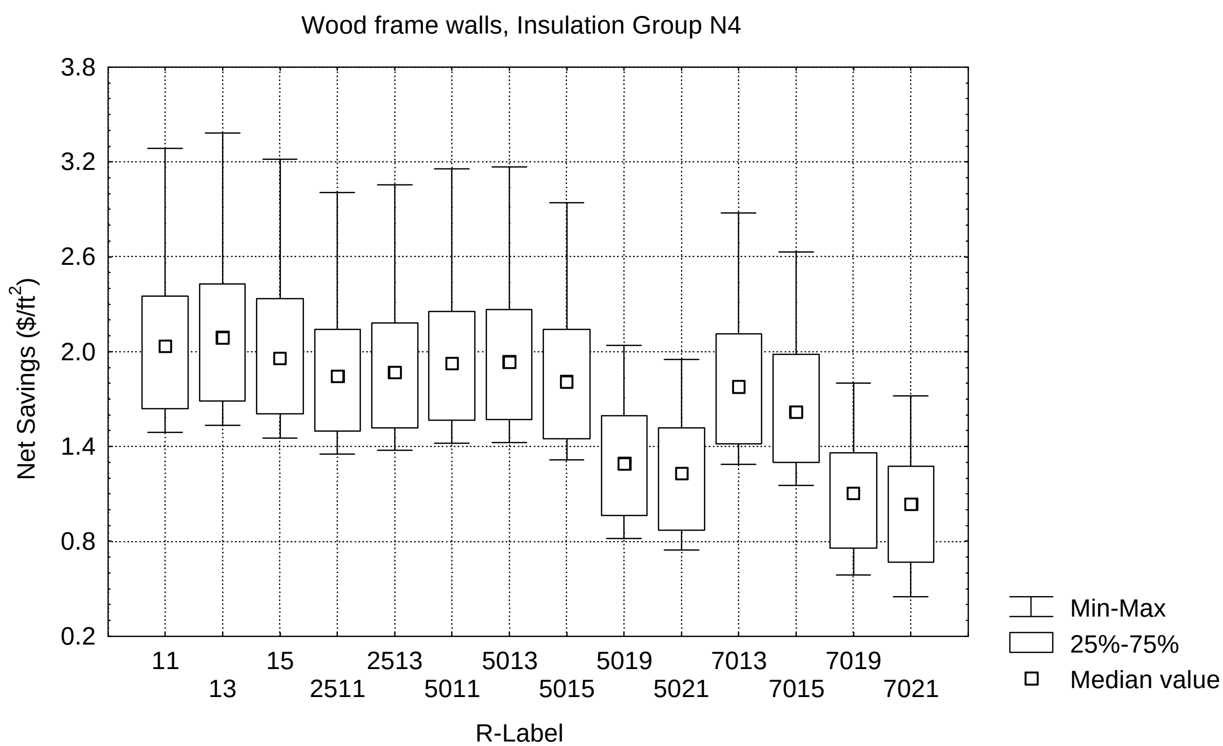
Table I.1. Definitions of "R-Label" shown on Figures in this appendix

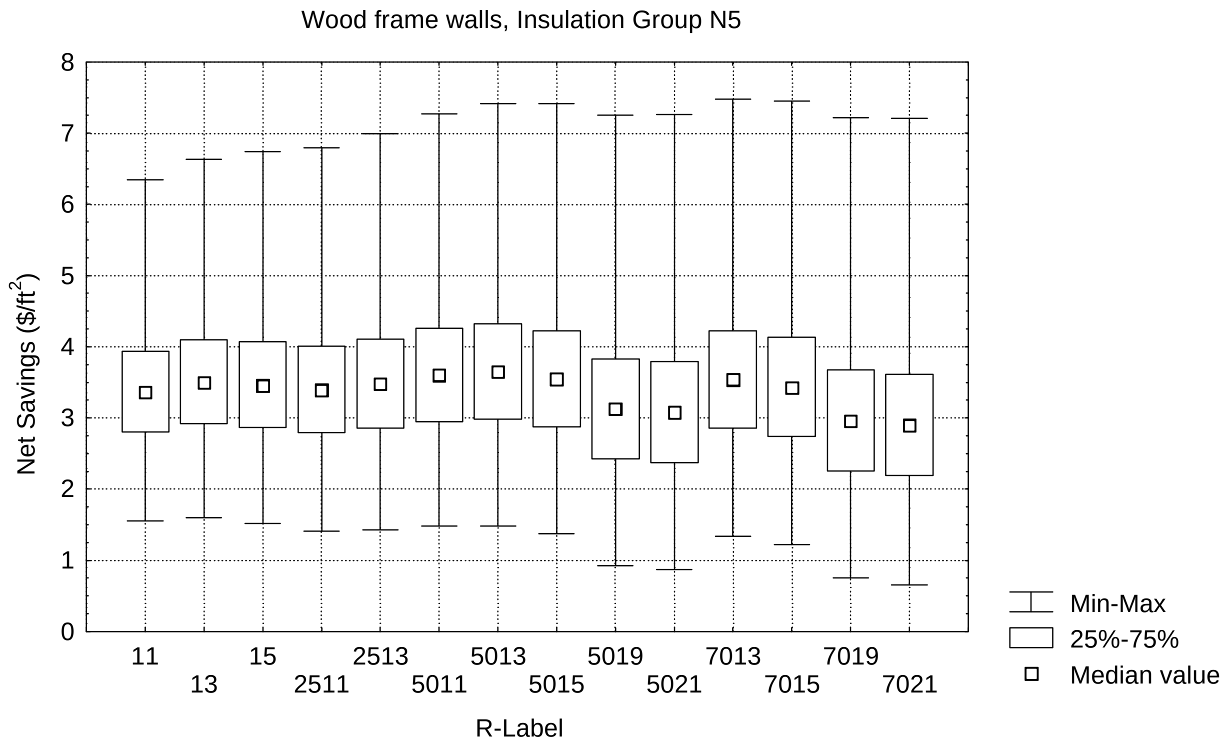
R-Label	Insulative sheathing R-value	Cavity insulation R-value
11	0	11
13	0	13
15	0	15
2501	2.5 (or ½ in. of R-5 per inch sheathing)	0
2511	2.5 (or ½ in. of R-5 per inch sheathing)	11
2513	2.5 (or ½ in. of R-5 per inch sheathing)	13
5001	5 (or 1 in. of R-5 per inch sheathing)	0
5011	5 (or 1 in. of R-5 per inch sheathing)	11
5013	5 (or 1 in. of R-5 per inch sheathing)	13
5015	5 (or 1 in. of R-5 per inch sheathing)	15
5019	5 (or 1 in. of R-5 per inch sheathing)	19
5021	5 (or 1 in. of R-5 per inch sheathing)	21
7011	7 (or 1 in. of R-7 per inch sheathing)	11
7013	7 (or 1 in. of R-7 per inch sheathing)	13
7015	7 (or 1 in. of R-7 per inch sheathing)	15
7019	7 (or 1 in. of R-7 per inch sheathing)	19
7021	7 (or 1 in. of R-7 per inch sheathing)	21

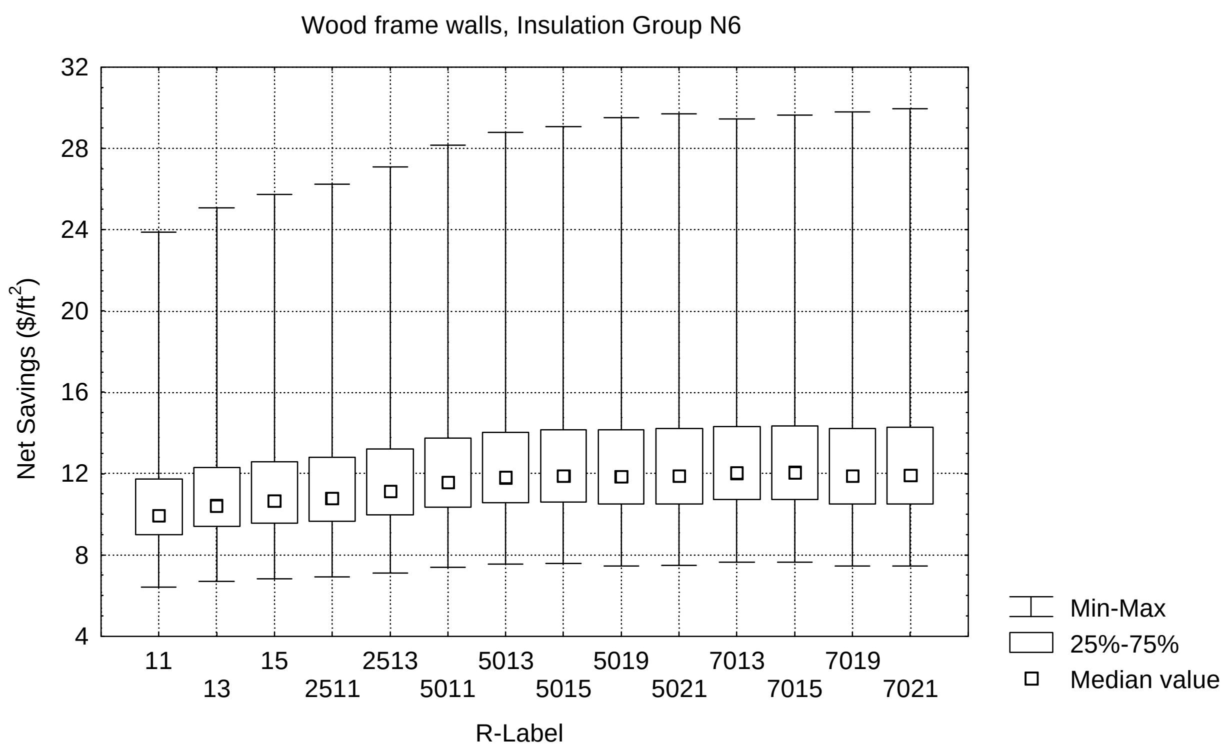

Wood frame walls, Insulation Group N1
1.8
1.2
0.6
0.0
-0.6
-1.2
-1.8
Net Savings ($/ft2)
11
13
15
2511
2513
5011
5013
5015
5019
5021
7013
7015
7019
7021
R-Label
Min-Max
25%-75%
Median value

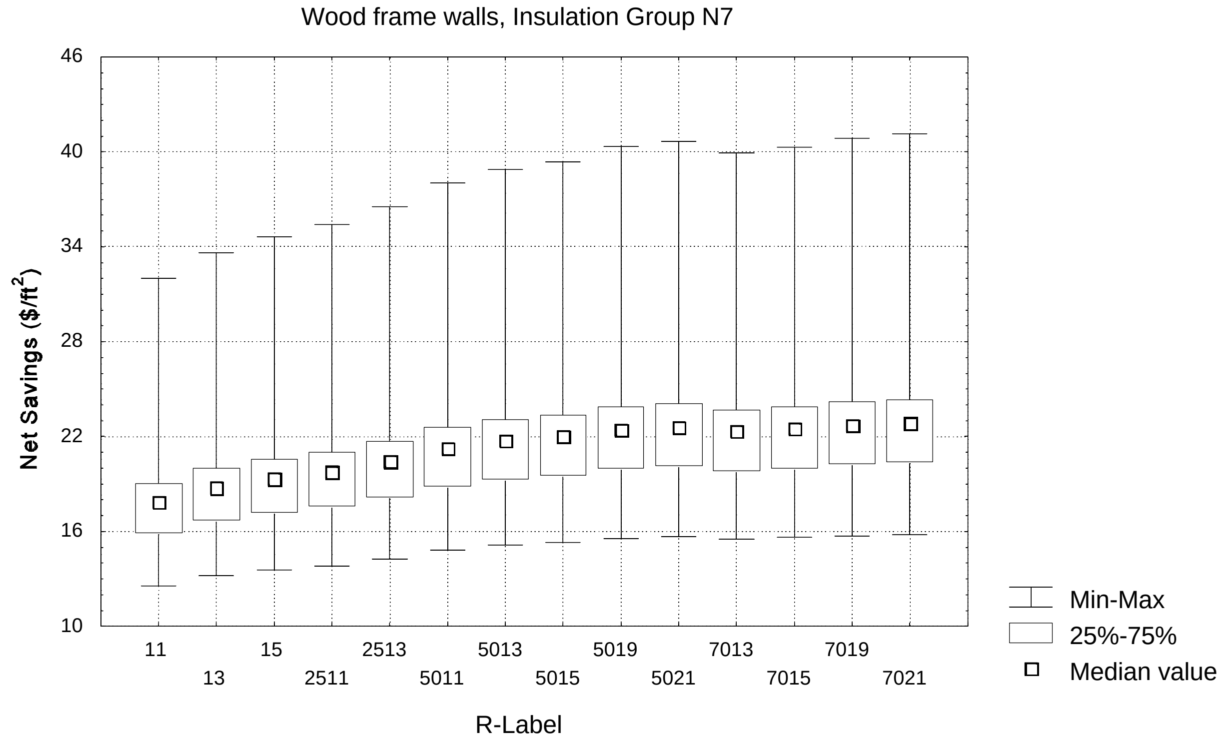

Wood frame walls, Insulation Group N2
2.4
1.8
1.2
0.6
0.0
-0.6
-1.2
Net Savings ($/ft^2)
11
13
15
2511
2513
5011
5013
5015
5019
5021
7013
7015
7019
7021
R-Label
Min-Max
25%-75%
Median value

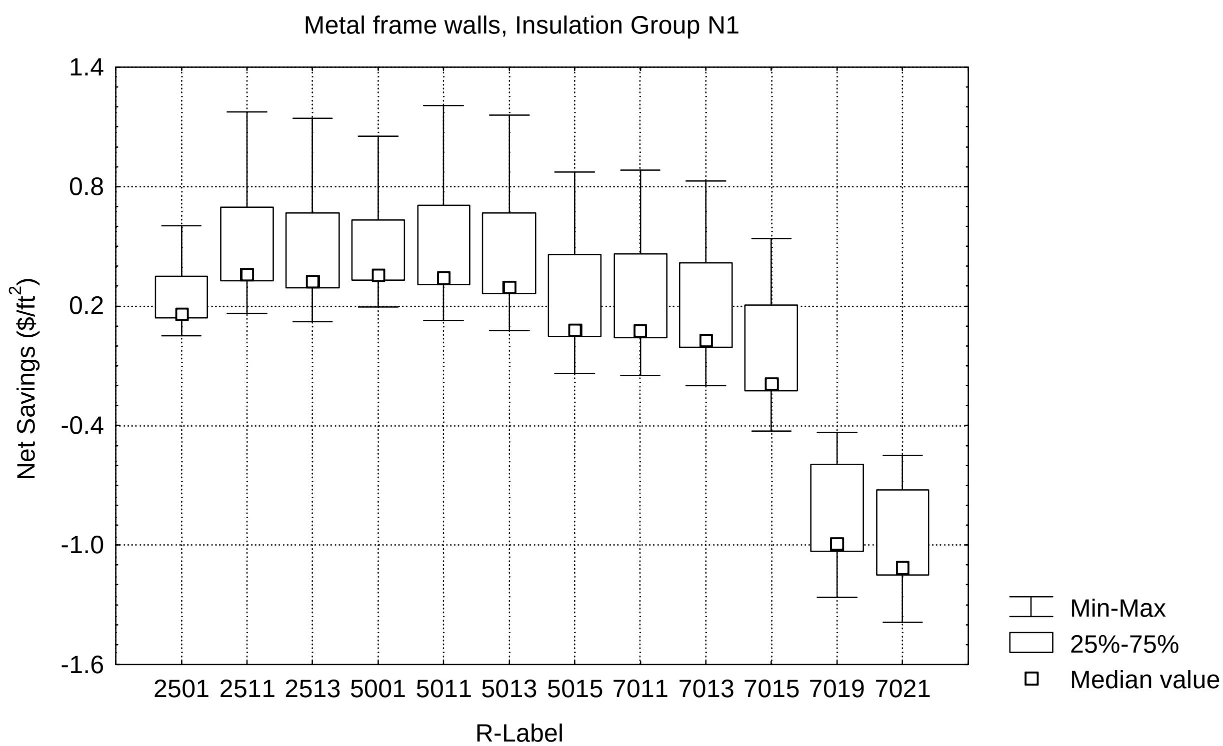

Wood frame walls, Insulation Group N3
Net Savings ($/ft^2)
2.2
1.8
1.4
1.0
0.6
0.2
-0.2
11
13
15
2511
2513
5011
5013
5015
5019
5021
7013
7015
7019
7021
R-Label
Min-Max
25%-75%
Median value

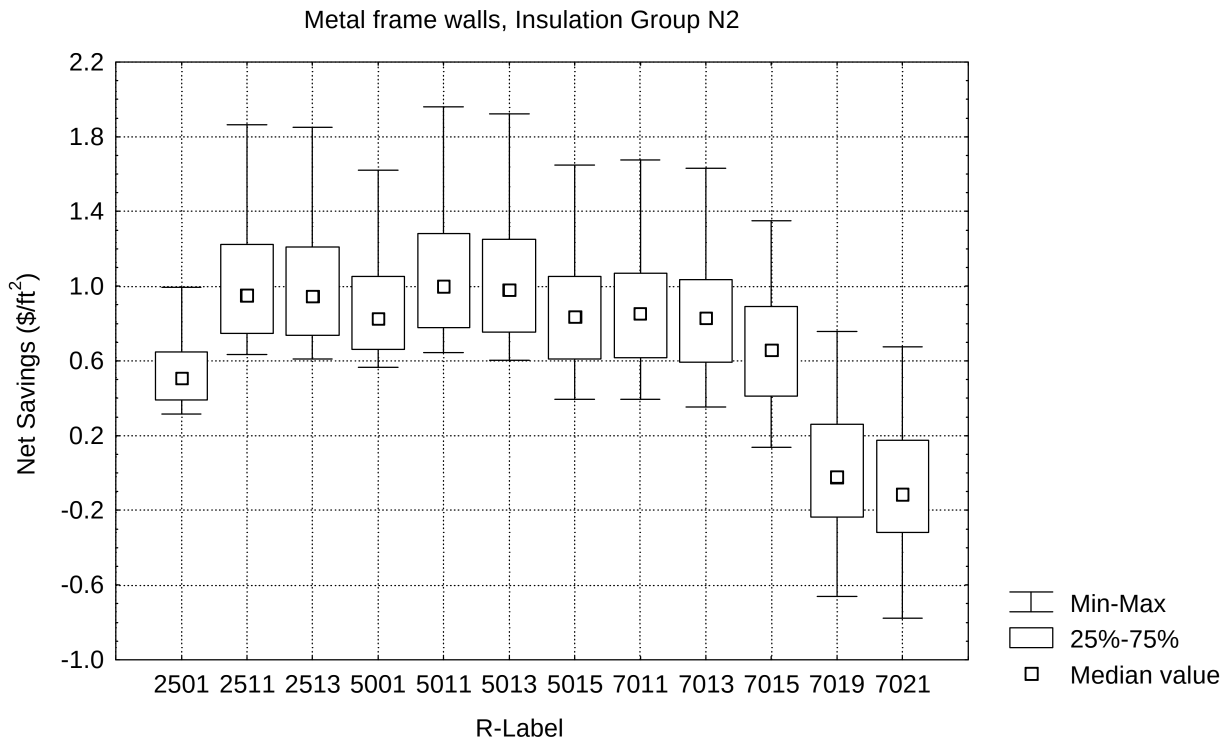

Wood frame walls, Insulation Group N4
Net Savings ($/ft^2)
3.8
3.2
2.6
2.0
1.4
0.8
0.2
11
13
15
2511
2513
5011
5013
5015
5019
5021
7013
7015
7019
7021
R-Label
Min-Max
25%-75%
Median value

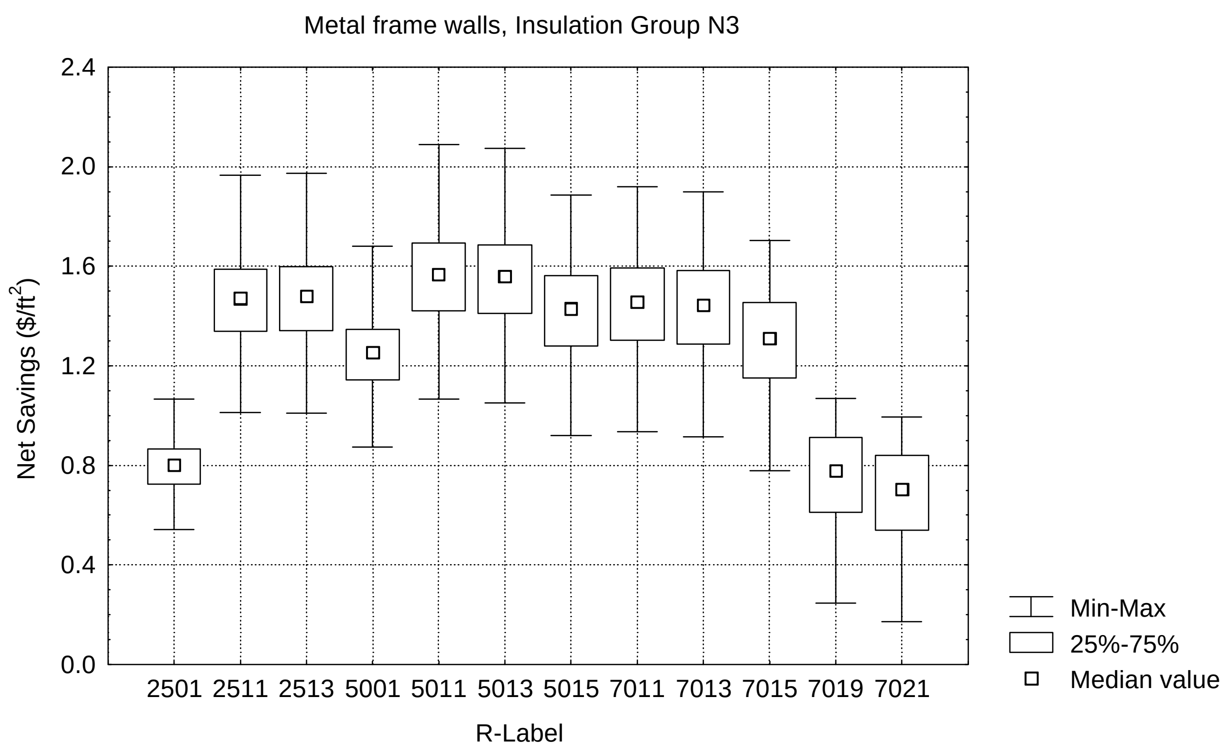

Wood frame walls, Insulation Group N5
Net Savings ($/ft^2)
8
7
6
5
4
3
2
1
0
11
13
15
2511
2513
5011
5013
5015
5019
5021
7013
7015
7019
7021
R-Label
Min-Max
25%-75%
Median value

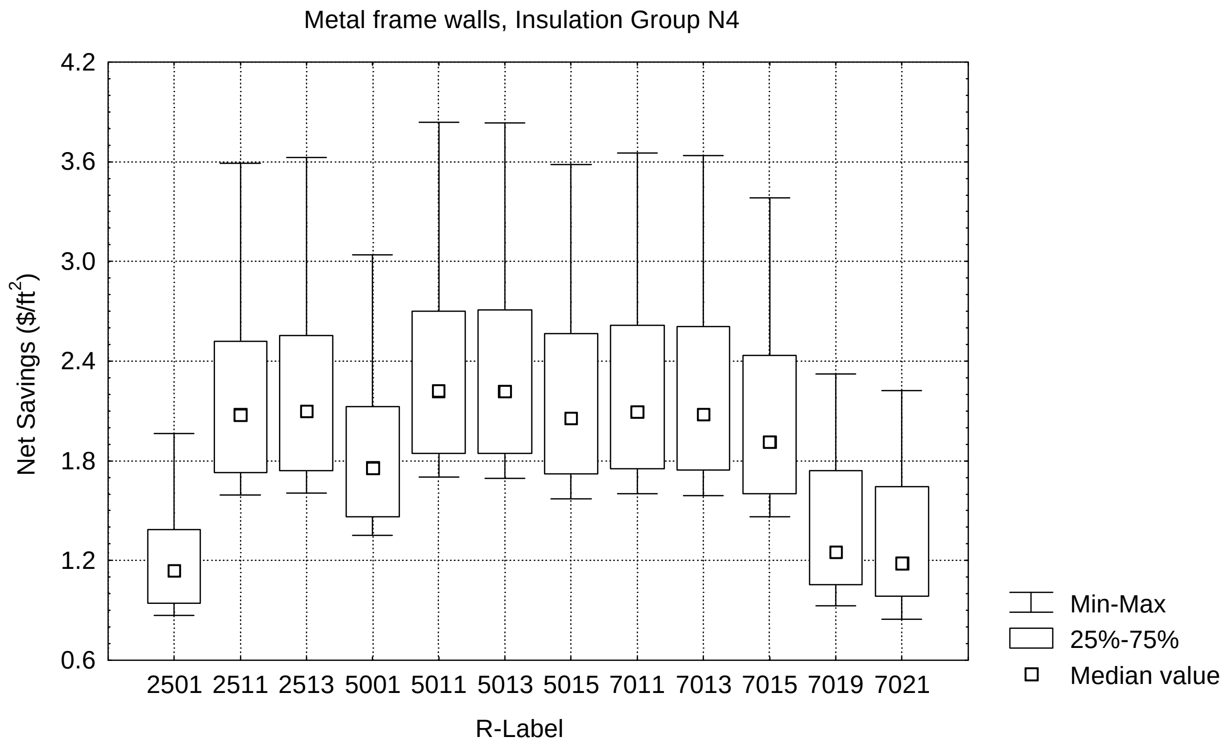

Wood frame walls, Insulation Group N6
Net Savings ($/ft^2)
32
28
24
20
16
12
8
4
11
13
15
2511
2513
5011
5013
5015
5019
5021
7013
7015
7019
7021
R-Label
Min-Max
25%-75%
Median value

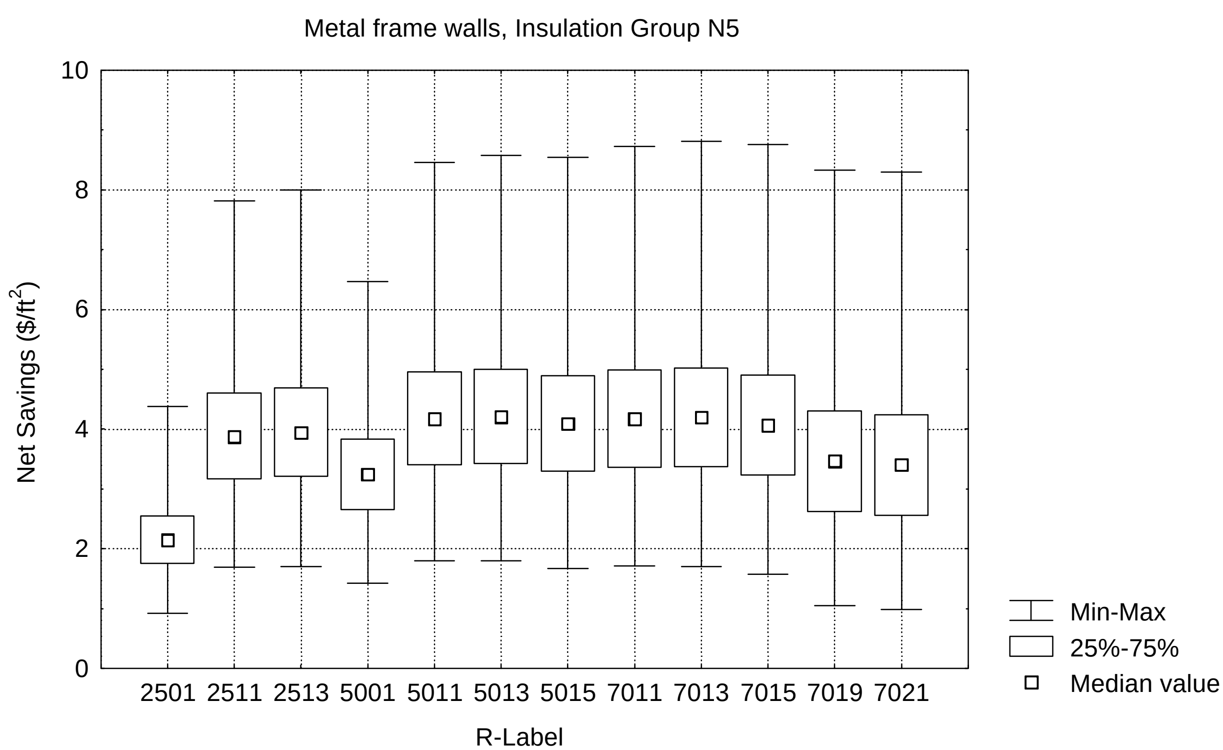

Wood frame walls, Insulation Group N7
46
40
34
28
22
16
10
Net Savings ($/ft^2)
11
13
15
2511
2513
5011
5013
5015
5019
5021
7013
7015
7019
7021
R-Label
Min-Max
25%-75%
Median value

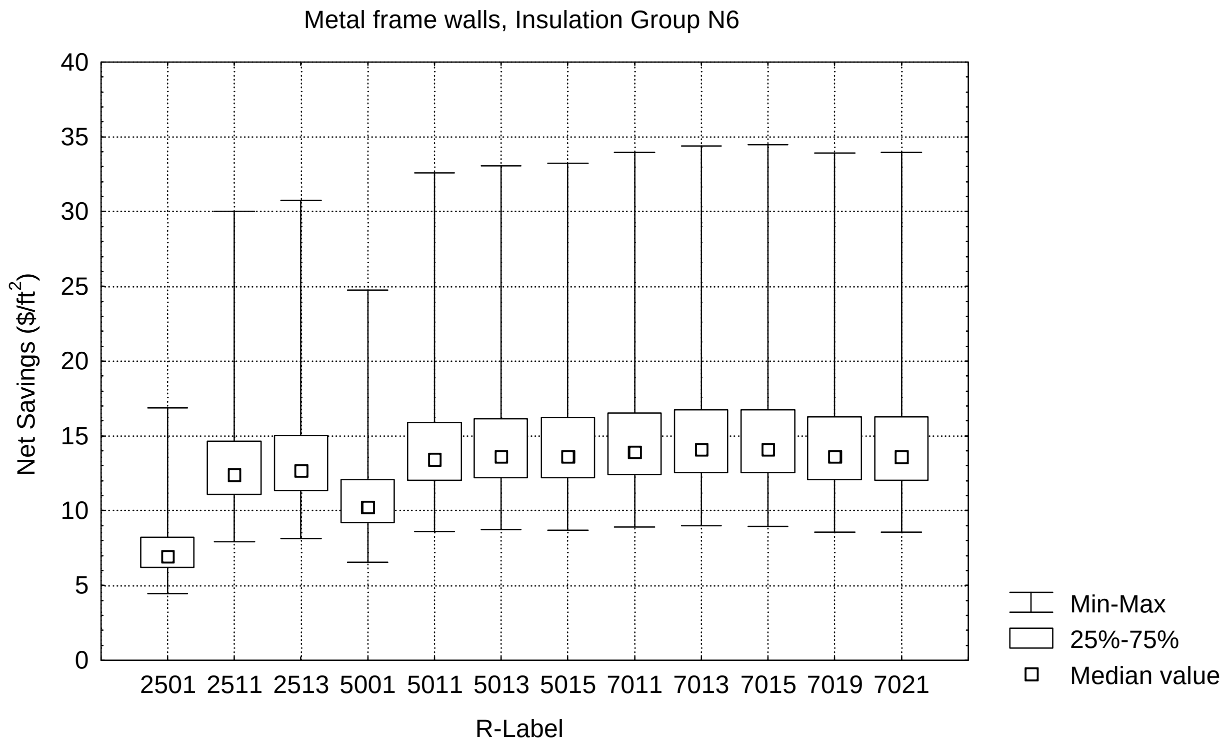

Metal frame walls, Insulation Group N1
1.4
0.8
0.2
-0.4
-1.0
-1.6
Net Savings ($/ft^2)
2501
2511
2513
5001
5011
5013
5015
7011
7013
7015
7019
7021
R-Label
Min-Max
25%-75%
Median value

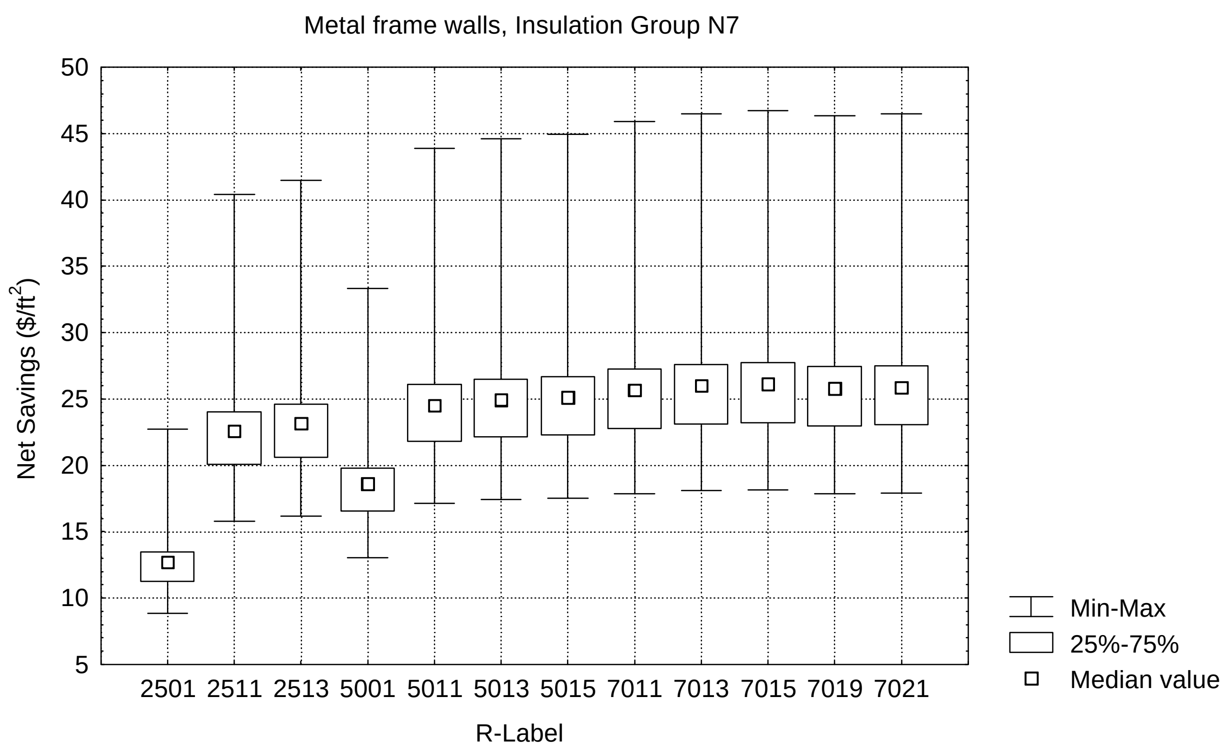

Metal frame walls, Insulation Group N2
Net Savings ($/ft2)
2.2
1.8
1.4
1.0
0.6
0.2
-0.2
-0.6
-1.0
2501 2511 2513 5001 5011 5013 5015 7011 7013 7015 7019 7021
R-Label
Min-Max
25%-75%
Median value


Metal frame walls, Insulation Group N3
Net Savings ($/ft2)
2.4
2.0
1.6
1.2
0.8
0.4
0.0
2501 2511 2513 5001 5011 5013 5015 7011 7013 7015 7019 7021
R-Label
Min-Max
25%-75%
Median value


Metal frame walls, Insulation Group N4
Net Savings ($/ft^2)
4.2
3.6
3.0
2.4
1.8
1.2
0.6
2501 2511 2513 5001 5011 5013 5015 7011 7013 7015 7019 7021
R-Label
Min-Max
25%-75%
Median value


Metal frame walls, Insulation Group N5
Net Savings ($/ft^2)
10
8
6
4
2
0
2501 2511 2513 5001 5011 5013 5015 7011 7013 7015 7019 7021
R-Label
Min-Max
25%-75%
Median value


Metal frame walls, Insulation Group N6
Net Savings ($/ft2)
40
35
30
25
20
15
10
5
0
2501 2511 2513 5001 5011 5013 5015 7011 7013 7015 7019 7021
R-Label
Min-Max
25%-75%
Median value


Metal frame walls, Insulation Group N7
Net Savings ($/ft2)
50
45
40
35
30
25
20
15
10
5
2501 2511 2513 5001 5011 5013 5015 7011 7013 7015 7019 7021
R-Label
Min-Max
25%-75%
Median value

Appendix H: Summary of Comments Received During the Review Period for the Draft Version of the Doe Insulation Fact Sheet

The DOE Insulation Fact Sheet was sent in draft form to 41 persons or institutions for review and many helpful comments were received. The most substantive comments are summarized here.

Comments received during the first external review of the DOE Insulation Fact Sheet:

Energy Efficiency and Renewable Energy Clearinghouse (EREC): reviewed by Paul Hesse (Senior Technical Specialist), Michael Lamb (Technical Specialist - Residential Energy Efficiency), and Cameron Duncan (Technical Specialist - Residential and Commercial Building Design).

> "Overall the text of the Fact Sheet (FS) is well written and informative, and seems to be directed to the "average" homeowner (which is a primary customer of our service)." However, the recommendations are viewed by EREC as too complex - they suggest separate inserts for new construction and existing construction as a simplification. EREC prefers the old list of zip codes and fewer categories of fuel and building types to the new maps and tables. It would be helpful to include an additional table that presents information on nominal R-values per inch for different insulations. "Is, can, or will the ZipCode program be made available on the Web? Does it cost anything to get it from ORNL?"
>
> Recommended R-values appear too low and don't appear to be consistent with ORNL's "Building Foundation Design Handbook" values that were based on 1987 costs.
>
> The recommended R-values for metal framed, exterior walls are too low. "Maybe even a separate section on steel-wall framing insulation is necessary to address or clarify these issues." "I keep seeing the steel-framing industry making a marketing hayday out of the fact (sheet) that 'the US DOE says steel structures do not need as much thermal insulation as do other framing systems!' (...insinuating they are MORE thermally efficient than other framing- or building systems.) I think we want to expose the conductivity problems, not reward the system for the frightful inefficiency of current system assemblies. We definitely don't want people to think 'steel-framed assemblies are so efficient they require LESS (life-cycle or otherwise) insulation than other building systems.'"
>
> If the fact sheet is photocopied, some of the printing will be too small to see and the figures will not be legible.

Energy Star Program: reviewed by Sarah Bretz, Principal Research Associate, Energy Analysis Program, Lawrence Berkeley National Laboratory,

> Was 'optimal value engineering', which reduces the amount of framing and thereby increases the R-value of the envelope, considered?
>
> Make the fact sheet less technical, easier for a consumer to understand.
>
> Remove bias toward batt products where possible.

North American Insulation Manufacturers Association (NAIMA): reviewed by many members, comments presented by Stephen G. Braun, Director, Technical Services

"The R-value recommendations for new construction are not in concert with the code change proposals that DOE has made in the past to the Model Energy Code process. NAIMA has concerns about the potential for conflicting positions from DOE. More recently, DOE has partnered with EPA in sponsoring the Energy Star Programs. In particular, the Energy Star Homes Program sets energy efficiency levels at 30 percent greater than the 1992 CABO Model Energy Code. Maybe DOE should direct home buyers to the EPA/DOE Energy Star Program or local utility energy efficiency programs rather than attempt specific R-values."

Materials issues: NAIMA objects to every mention of insulation being used to reduce air flows. NAIMA objects to the discussion of insulation compression. NAIMA objects to the discussion of convection within loose-fill insulation.

Fact Sheet scope: Ventilation and moisture control sections questioned. Add recommendations for insulating ducts in attic and crawl spaces.

Framing issues: Consider optimum value engineer framing strategies for wood frame wall assemblies. Add metal framed roof/ceilings and metal framed floors as there is an increasing trend to use metal in residential construction.

Insulation Contractors Association of America: reviewed by Michael Kwart, Executive Director

Suggested additional consumer protection text regarding unscrupulous installation practices.

National Association of Home Builders Research Center (NAHB): reviewed by David Dacquisto, Vice President of Technology, Tom Kenney, and Dan Cautley

Economic analysis issues: NAHB questions the use of a 7% discount rate. They suggest that a higher rate would more appropriately reflect consumers' debt at much higher interest rates. NAHB also believes that the fact sheet should caution people that they won't get their money's worth on insulation unless they live in the house a long time.

Recommended insulation levels: R-11 is too high for basements in mild climates.

Scope: Delete all references to insulation compression as too confusing for consumers. Infiltration discussions questioned.

Consumer protection: Refer readers to NAHB product and installer certification programs.

National Institute of Standards and Technology: reviewed by Douglas M. Burch, NIST Building and Fire Research Laboratory

Would like to see the guidelines and practices for controlling moisture in hot and humid climates be considerable strengthened. Recommends telling consumers in such climates that the combined permeance of the interior construction layers be greater than 2.9E-10 kg/s-m^2-Pa.

U. S. Department of Housing and Urban Development: reviewed by William Freeborne, Office of the Assistant Secretary for Policy Development and Research

"From my perspective you have included and covered everything I would have suggested in the Fact Sheet, so I have no comments."

University of Illinois at Urbana-Champaign: reviewed by William Rose, School of Architecture-Building Research Council

Crawl space issues handled well. Consider discussing design option of building unventilated attics in warm, humid climates. Limit discussion of moisture control to wintertime because of uncertainties associated with ventilation and air conditioning.

Management Resource Associates: reviewed by George Sievert, Spray Polyurethane Foam Industry Facilitator

Add discussion of spray polyurethane's ability to control air and moisture infiltration.

Seattle Department of Construction and Land Use: reviewed by John Hogan, Senior Energy Analyst

Recommended insulation levels are too low. They are lower than the Model Energy Code and should be revised upward. Emphasize necessity of meeting local building codes.

Discuss thermal short circuits, especially in metal-framed buildings.

Doesn't believe reflective insulation should be called insulation.

Home Energy Magazine: reviewed by Jeanne Byrne, Managing Editor

Improve description of batt installation procedures.

Oak Ridge National Laboratory: reviewed by Ken Wilkes, Dave Yarbrough, David McElroy

Based on the comments received during the first external review, the fact sheet was revised and recirculated for further comments. Shown here is a summary of all comments received on that March 1997 revision to the DOE Insulation Fact Sheet:

North American Insulation Manufacturers Association: reviewed by members, comments collected by Steve Braun

Editorial changes suggested. Substantive - questions discussion of insulation compression, questions description of structural insulated panel systems, corrects R/in. values for fiberglass products, questions framing cost add-ons for cathedral ceiling calculations, requests that cavity insulation be reconsidered for metal walls in mild climates.

Response: Agreed with many of their comments. However, experimental data support compression discussion. Conflicting experimental data available for structural insulated panel systems, so that statement was retained but made less strong. A small survey of builders supported their cathedral ceiling observation, so those recommendations were recalculated with no additional framing costs for insulation levels up to R-38. The wall insulation issue was revisited upon request from several reviewers and the new values now show ranges of acceptable insulation levels.

Polyisocyanurate Insulation Manufacturers Association: reviewed by Lorraine Aulisio

Request recognition of R7/in. foil-faced product. Also thinks that insulative sheathing should be more widely recommended.

Response: Foil-faced product added to table, new wall calculations completed, still show sheathing not necessary for mild climates with wood-wall construction.

Reflective Insulation Manufacturer's Association: reviewed by Bill Lippy and David Yarbrough, ORNL

The description of their product should not be longer than others, thinks that it leads people to see it as something that requires more warnings.

Response: Agreed

National Association of Home Builders : reviewed by David Dacquisto, Vice President of Technology, NAHB Research Center

"... am writing to express displeasure, for the record, regarding the 'significant changes' made to the recommended insulation levels for new and existing homes. ..., I am concerned that the recommended levels of thermal protection in the latest version are misleading to the point of being a disservice to the public. ..., I can only conclude that ORNL is ignorant of or indifferent to the economic theory that should properly be applied to the subject." He refers to his earlier economic analysis preferences: NAHB suggests that a higher discount rate would more appropriately reflect consumers' debt at much higher credit card interest rates. NAHB also believes that the fact sheet should caution people that they won't get their money's worth on insulation unless they live in the house a long time.

Response: I cannot agree with their proposals. Using an 18% discount rate would assume that all purchasers are carrying substantial long term credit card debt, and would ignore the societal benefits attributable to energy conservation. I also think that it's inappropriate to consider only the first owner of a home when evaluating the benefits due to insulation. The energy savings provide a benefit to all future homeowners as well and their economic value will be reflected in the resale price of the home.

Department of Energy, Office of Codes and Standards: reviewed by Stephen Turchen

Editorial suggestions and questions about reflective insulation drawing.

Response: The drawing is being revised.

Department of Energy: reviewed by Arun Vohra

Many editorial suggestions and substantive comments that include: a request that the discount rate be specified and further information about the life cycle cost analysis be placed on the Web or made available from OSTI, a request to consider wall insulation for solid-walled homes, a request to put all the additional reference sources listed at the back of the Fact Sheet on the Web, and suggested additional caveats about fire hazards associated with overheated wires surrounded by insulation, especially for knob and tube wiring.

Response: Agreed with most comments. The detailed economic discussion will be included in the Supporting Documentation, and Fact Sheet readers are referred to that resource for more information. The interior insulation recommendations for above-grade masonry walls is considered sufficient for the fact sheet.

Pacific Northwest Laboratories: reviewed by Jeff Johnson and Dave Conover

Expressed concerns about DOE publishing differing values from their proposed numbers and the current MEC. Questions about preempting Office of Codes and Standards positions, consistency with Federal Trade Commission labeling issues, and recognition of Housing and Urban Development Department financing requirements.

Response: Some verbiage changed to recognize codes and HUD requirements. A more detailed examination of the MEC/Fact Sheet comparison was completed and submitted for DOE review.

Energy Efficiency and Renewable Energy Clearinghouse (EREC): reviewed by Michael Lamb (Technical Specialist - Residential Energy Efficiency)

"The text is fairly informative with the latest information on housing energy conservation. However, we still feel that Tables 5 and 6 understate what we have come to know as 'good' insulation practices. ...the new fact sheet should have it's economics projected out in excess of 10 years from now." They recommend that the evaluation be adjusted to account for savings due to down-sized cooling HVAC equipment. He doesn't understand why the wall cavity R-values are lower that those for crawl spaces. He explains that some terms require clarification, for example, not all basement walls are below-grade. He wants to add basement floor insulation as a recommended measure and offers a detailed installation description. He questions whether R-10 sheathing can be added to an existing wall and points out the door stoop must be removed to avoid a thermal short. The sheathing recommendations for insulated walls in regions E-2 to E-4 have to be wrong based on his instincts. "The entire column 'Cathedral Ceiling' should have the same R-values as the column labeled 'Attic'. After all, a ceiling is a ceiling. They all do the same thing so they all should be treated the same way." Similar questions about why OVE wall cavities, band joist, wall cavities, and crawlspace wall columns don't all have the same R-values. "...concern is with the section 'Basement and Foundations' columns labeled 'crawlspace walls' and 'slab edge' insulation. I know from experience that slab insulation is of great value in my region (VA) yet there is no recommendation for it in this table. This makes me think that this omission is probably carried over into other regions as well."

Response: We have paid a great deal of attention to EREC comments, because their staff deals directly with the Fact Sheet's users. For example, the zip code table (to supplement the simplified zone map) and the R-value per inch table were added at their request. However, many of these requests cannot be supported by the economic analysis (which uses an insulation life of 30 years for new homes, not 10). There are costs associated with wall and ceiling framing, unrecognized by the EREC reviewer, that introduce differences into the table of recommendations from one application to the next. Basement floor insulation could be added at a future date, after appropriate savings estimates are prepared and verified for this measure. Estimating the savings due to downsizing the HVAC equipment is complex, because equipment sizing is based on maximum loads and because much of the equipment is already oversized. I don't *feel we have an adequate basis to include these savings at this time. We agree that it would be difficult to add two inches of insulative sheathing and have redone all the wall calculations to limit the sheathing thickness to one inch.*

<u>Cellulose Insulation Manufacturers Association (CIMA)</u>: reviewed by Daniel Lea, Executive Director

Suggested that we expand the fire protection warning for hot flue pipes to include faced batts and plastic foams.
Response: Agreed

<u>Department of Housing and Urban Development</u>: reviewed by William Freebourne of the Office of Policy Development and research

Provides several formatting suggestions.

<u>Seattle Department of construction and Land Use</u>: reviewed by John Hogan

Expressed concern about numbers that are not in agreement with the MEC, "...the basic flaw of the low insulation levels and undermining local code enforcement is unremedied. ...these draft recommendations work against jurisdictions trying to enforce the MEC in accordance with the EPA Act." His numerical comparisons between the draft values and the Washington State Energy Code for new construction show agreement for attic insulation levels. However, he requests that all floor and wall levels (except for metal walls) be increased significantly.
Response: We have prepared a detailed comparison of MEC/Fact Sheet recommendations for DOE's consideration. We recognize that new home construction must still meet local building codes and have underlined that statement in the fact sheet to meet his request for a stronger focus on this issue. However, we cannot accomodate his request to change the fact sheet's recommendations to match every local code, especially without a sound economic basis.

<u>Energy Star Program, LBL</u>: reviewed by Sarah Bretz

editorial suggestions

<u>Environmental Building News</u>: reviewed by Alex Wilson

Offers several editorial corrections and points out errors in the R-value per inch table. Expresses regret that the map was replaced by a Zip-code table and that the insulation thickness table has been replaced. Believed that there were errors in the zip code table because of the low levels recommended for Alaska and because of the differences between geographical neighbors such as Washington D.C and Montgomery County, MD. "Overall, I am very excited about this new insulation fact sheet, particularly the high insulation levels recommended and the fact that rigid foam is always recommended, even in warmer climates."
Response: I discussed the perceived errors with him, they were all due to local low fuel costs.

<u>Oak Ridge National Laboratory (ORNL)</u>: reviewed by Kenneth Wilkes and David Yarbrough

K.W. suggested adding a criss-cross batt installation recommendation, corrected error in Table 2 values for fiberglass, and questioned whether separate advice needs to be given for homes with ducts located with conditioned space. DY suggests that we use the exact wording as the FTC 'Rule', delete reference to cotton, not make recommendations for vapor retarder placement, delete references to pouring loose-fill insulation, and delete the discussion of price variations among contractors. DY questions whether we should discuss metal-framed buildings or recommend different insulation for them than for wood-framed walls. DY questions whether R-10 sheathing could be added to the exterior of an existing wall.

Response: Agree with most comments. However, discussion of duct losses will be reserved for the supporting documentation, because this issue cannot be reduced to any simple rule of thumb for fact sheet readers. Vapor retarder placement and metal wall discussions were retained, many other reviewers had requested this information in earlier reviews. Agreed that two inches of insulative sheathing would be difficult to install, all wall calculations were redone with a maximum thickness of one inch.