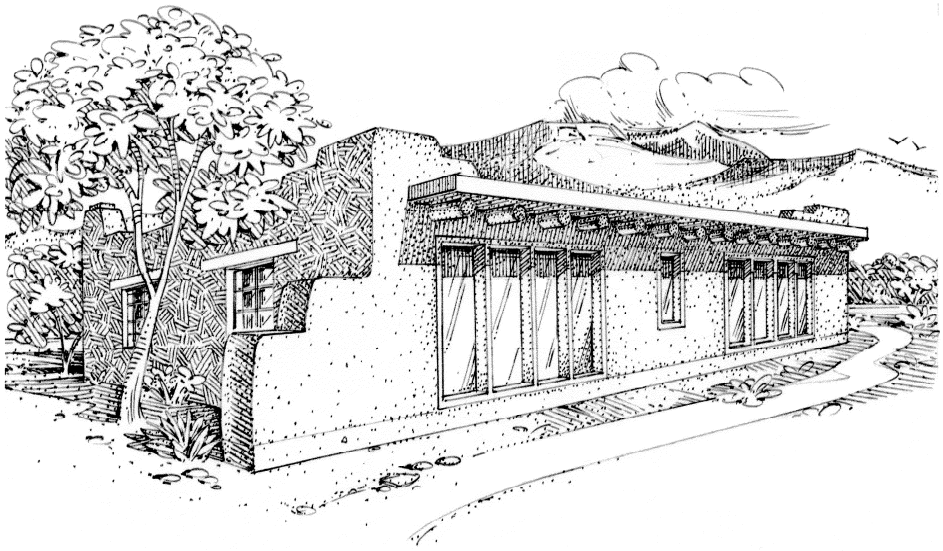
2009 NEW MEXICO ENERGY CONSERVATION CODE Residential Applications Manual



January 2011
v2.0

Energy Conservation and Management Division
Energy, Minerals and Natural Resources Department

RESIDENTIAL APPLICATIONS MANUAL

January 2011
V2.0

This manual was prepared by:

State of New Mexico
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The Department of Energy maintains an energy code website. With prior approval from the building official, electronic tools on the website may be used to demonstrate compliance with the 2009 New Mexico Energy Conservation Code, which is based upon the 2009 International Energy Conservation Code.
http://www.energycodes.gov/rescheck/

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INTRODUCTION

New Mexico has had in force an Energy Code for building construction since the 1970's. The New Mexico Construction Industries Commission most recently adopted the 2009 New Mexico Energy Conservation Code (NMECC 2009) in late 2010, effective January 28, 2011. The New Mexico code references the "International Energy Conservation Code 2009" (IECC 2009).

This publication does not intend to negate any of the standards found in NMECC 2009. The changes are additions to the NMECC 2009 intended to:

1. Allow the use of a worksheet to trade off R-values between various parts of the house, without increasing the energy use of the house.

2. Make it easier to demonstrate code compliance for passive solar heated homes.

This applications manual is to be used in conjunction with the NMECC 2009 book. Call the Construction Industries Division (CID), if you don't have one.

To use the Tradeoff Worksheet, the applicant must first determine the appropriate climate zone for the building site. A list of New Mexico towns and their respective climate zones are found in **Table 301.2** of Chapter 3 of the NMECC 2009. Their elevations, heating-degree-days (HDD), and cooling-degree-days (CDD) are included to assist in selecting a nearby location with similar weather. For truly remote locations, the applicant should select a town with similar north latitude and elevation. The town and climate zone should be entered in the appropriate sections.

The NM Energy Conservation Code should be viewed only as a minimum standard. As such, the Code is not a design tool or rating system. Much better programs for these purposes exist outside of the Energy Conservation Code, and the applicant is strongly encouraged to use them.

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TRADEOFF WORKSHEET

The Tradeoff Worksheet is used to show compliance using the **Total UA alternative** as described in **Section 402.1.4** of the NMECC 2009. It is a compliance demonstration method for the external portions of the building, the building thermal envelope. Interior walls and floors between heated spaces are not part of the building thermal envelope. The worksheet considers all of the parts of the building thermal envelope at once. The overall house, as designed, is compared to the same house using the requirements from Chapter 4 of the NMECC 2009 code book.

The applicant must first obtain the area and R_o of each thermal envelope component for the Proposed House. The R_o is the steady-state R-value, or resistance to heat flow, of the components as assembled; e.g. a frame wall is comprised of insulation, studs, finishes, et cetera. At the ceiling (or roof), the area of the insulated portion and any skylights must be calculated separately. At the wall, the area and R_o of the insulated portion, windows and doors must also be calculated separately.

At the foundation, the areas and R_o needed depend upon the type of construction. For a slab on grade the area is the exposed perimeter of the slab times the depth. For floors over crawl spaces with insulated walls, the area and R_o is the area of the crawl wall. For insulated floors over un-insulated crawl spaces, the area is the area of the floor. For heated basements, the area is the area of the basement wall.

All features of the building having a unique R_o must be entered separately in the Worksheet. For example, some homes have two different kinds of doors, a solid wood unit at the entry, and French doors elsewhere. The same is true for ceilings and walls. If a proposed building has both a cathedral ceiling and a flat ceiling, each with different R_o, the area and R_o for each must be entered. If a proposed building has both log walls and frame gable walls, the area and R_o for each must be entered. Windows and doors must likewise be entered, and their respective areas subtracted from the gross area of the walls.

The R_o for the Proposed House should be obtained from manufacturer's product test data. If that is not available at time of permitting, it may be estimated from the tables in Appendix A. Manufacturer's data will be required at inspection. The areas and R_o for the building thermal envelope of the Proposed House are entered into the left section – Proposed House of the Tradeoff Worksheet. The UA for each component is calculated as the area divided by the R_o. The UA values can be summed for the total UA of the Proposed House.

The total areas of the Proposed House are also entered into the right section – Code House of the Worksheet. Following the instructions in the Introduction, the applicant must then determine the climate zone for the Proposed House. The town and climate zone should be entered in the appropriate sections. Once the appropriate climate zone is determined, the U_{req} can be found in **Table 402.1.3** of Chapter 4 of the NMECC 2009 for windows and doors (fenestration); skylights; ceilings; walls (including mass walls); and floors. U-Factors are the inverse of R_0, or $1/R_0$. These U_{req} values are entered into the right side of the worksheet. The UA of these components is calculated as the area of the component multiplied by the U_{req}. For slab on grade foundations, The UA is the same area as calculated in the Proposed House divided by the R_{req} found in **Table 402.1.1**. Like the Proposed House, all the UA values are summed to determine the total allowed heat loss.

If the total of all of the UA values for the Proposed House is less than the sum of the UA values for the Code House, the design is in compliance with this section.

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TRADEOFF WORKSHEET

Project ID		Building Floor Area	
Builder Name			
Builder Address			
Submitted by			
Building Address			
Town			

Date	
Phone	
Climate zone	

PROPOSED HOUSE (Area and R_o as designed)

Ceiling & Skylights

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
			/		=	
			/		=	
			/		=	
Total		-				

Walls & Openings

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
			/		=	
			/		=	
			/		=	
			/		=	
			/		=	
Total		-				

Heated Slab Edge (when applicable)

Description	Insulation R-Value	Length * Depth, ft		/	R_o	=	UA
		Lentgh	Depth				
Total				/		=	

Unheated Slab Edge (when applicable)

Description	Insulation R-Value	Length * Depth, ft		/	R_o	=	UA
		Lentgh	Depth				
Total				/		=	

Crawlspace Wall (when applicable)

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Total			/		=	

Floor Over Crawlspace (when applicable)

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Total			/		=	

Basement Wall (when applicable)

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Total			/		=	

Totals

Total Roof, Wall, Foundation	

CODE HOUSE

Ceiling & Skylights

Same As Your House — $U_{req.}$ from NMECC

Area, ft²	*	$U_{req.}$	=	UA
-	*		=	-

Walls & Openings

Area, ft²: -

Maximum allowed Fenestration: 18% of total

Area, ft²	*	$U_{req.}$	=	UA
0	*		=	-

Walls: 82% of total

Area, ft²	*	$U_{req.}$	=	Area/$R_{req.}$
	*		=	-

Heated Slab Edge

Length * Depth, ft		/	R_{req}	=	UA
Lentgh	Depth				
		/		=	

UnheatedSlab Edge

Length * Depth, ft		/	R_{req}	=	UA
Lentgh	Depth				
		/		=	

Crawlspace Wall

Area, ft²	*	$U_{req.}$	=	UA
	*		=	-

Floor Over Crawlspace

Area, ft²	*	$U_{req.}$	=	UA
	*		=	-

Basement Wall

Area, ft²	*	$U_{req.}$	=	UA
	*		=	-

Totals

Total Roof, Wall, Found.	

If the total for PROPOSED HOUSE is less than the total for CODE HOUSE, PROPOSED HOUSE is in compliance.

Note: an electronic version of this Worksheet calculates the UA values and can be found at **www.CleanEnergyNM.org**.

PASSIVE SOLAR HEATING WORKSHEET

The Passive Solar Heating Worksheet is a compliance demonstration method for solar heated buildings that cannot demonstrate code compliance solely using the Tradeoff Worksheet. This may be the case for buildings that include passive solar heating features, due to the extra glass that may be incorporated.

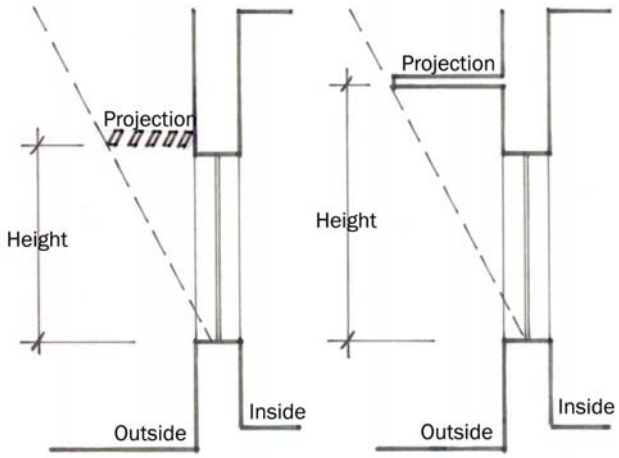
The Passive Solar Heating Worksheet may be used for Direct Gain, Solar Mass Wall (also called Trombe Wall), and Attached Sunspace features. In order to qualify for use of this method, the solar features must meet all of the criteria found on the Passive Solar Heating Worksheet. These criteria have been found to include a very large percentage of passive solar heated buildings. For any passive solar heating feature meeting all of the criteria, the area of each system type is entered in the appropriate box on the Passive Solar Heating Worksheet. The same areas are entered on the Tradeoff Worksheet. However, the “R-value” and “Area/R” are not entered on the Tradeoff Worksheet for these passive solar features.

For buildings using combinations of the three passive solar heating systems, the area of each is entered in the appropriate box on the Passive Solar Heating Worksheet, and in the Tradeoff Worksheet.

For Direct Gain passive solar heating features, all south-facing glass meeting the definition must be included on the sheets.

All solar features require overhangs to shade the south-facing glass during the summer. In the diagram below, the dashed line represents the sun angle on June 21st. The projection factor must be calculated such that the the overhang blocks the sun from the entire height of the south-facing glass.

$$\text{Projection Factor} = \frac{\text{Horizontal Projection}}{\text{Height Above Sill}}$$



Note:
Overhangs located directly above the window head need the least projection.

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PASSIVE SOLAR HEATING WORKSHEET

Project ID		Date	
Builder Name			
Builder Address			
Submitted By		Phone	
Building Address			

Items meeting the listed criteria may be presented for simplified code compliance as solar features. All boxes by the system type definitions must be checked to certify compliance. The area in square feet of such features should be entered here and on the Tradeoff Worksheet with the other wall components. The Ro and A/Ro columns may be left blank on the Tradeoff Worksheet for these solar features.

All Solar Features

Orientation within 25° east and 15° west degrees of true South	
No significant obstructions to sun above 25° elevation, from bottom of feature	
No significant obstructions to sun within 45° horizontal from the east and west edges of the solar feature	
Solar features of all kinds no greater than 20% of heated floor area	
N + E + W windows not greater than 12% of heated floor area	
Overhangs that prevent sun on south-facing glazing on June 21st	

Direct Gain

Double glazed (minimum)		
If South windows greater than 8% of heated floor area, add thermal mass (at least 5x area of South glazing, at least 3" thick)		
TOTAL AREA DIRECT GAIN GLAZING		ft^2

Solar Mass Wall

Solid masonry wall, no vents		
TOTAL AREA MASS WALL GLAZING		ft^2

Attached Sunspace

Double glazed (minimum)		
Mass area at least 3x glazing area		
Operable windows or doors to living space, at least 15% of sunspace glazing area		
TOTAL AREA SUN SPACE GLAZING		ft^2

Note: This applications manual is not a solar heating design guide. The inclusion of solar features meeting the above definitions does not by guarantee correct solar heating performance for a building design. For example, solar features totaling 20% of heated floor area, while allowed by this manual, may be excessive in many applications. Passive solar heating features should be designed using appropriate design tools.

Note: an electronic version of this Worksheet can be found at **www.CleanEnergyNM.org**.

U-Factor Calculations

The NMECC 2009 allows an area-weighted average of fenestration products to satisfy the U-Factor and SHGC requirements. The first worksheet below can be used to determine the average U_o for the Tradeoff Worksheet. The second worksheet is to verify that the SHGC requirements are met, in addition to the UA requirements from the Tradeoff Worksheet.

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U-Factor Area-weighted Average

Window Description	U_o	*	Area (ft^2)	UA
		*		-
		*		-
		*		-
		*		-
	Totals		**-**	**-**
	Average U_o (Total UA/Total SF)			

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SHGC Area-weighted Average

Window Description	SHGC	*	Area (ft^2)	SHGC•A
		*		-
		*		-
		*		-
		*		-
	Totals		**-**	**-**
	Average SHGC (Total SHGC•A/Total SF)			

Note: electronic versions of these Worksheets calculates the U-Factor & SHGC values and can be found at **www.CleanEnergyNM.org**.

BUILDING ASSEMBLY THERMAL DATA

This appendix contains *generic* information on thermal properties for selected building assemblies, for use in the Tradeoff Worksheet. R_o values include the interactive effect of all of the individual components in the total building assembly. For example, R_o for a frame wall considers the studs, insulation and interior and exterior sheathing (if any) and finishes. When available, thermal properties from the actual manufacturer of an assembly should be used instead of these generic values.

To achieve compliance, the inspectors will verify that the actual R_o values are equivalent or better than those proposed.

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WOOD FRAME WALL R_o-VALUES[a,b]

Insulation R-Value[c]	16 inch O.C. Wall Ro-Value	24 inch O.C. Wall Ro-Value
R-0	4.2	4.1
R-7	9.5	9.6
R-8	10.1	10.3
R-9	10.6	10.9
R-10	11.1	11.4
R-11	11.2	11.5
R-12	11.8	12.0
R-13	12.2	12.5
R-14	12.7	13.0
R-15	13.0	13.5
R-16	15.2	15.6
R-17	15.6	16.1
R-18	16.1	16.7
R-19	16.7	16.9
R-20	16.9	17.5
R-21	17.5	17.9
R-22	17.9	18.5
R-23	18.2	18.9
R-24	18.5	19.2
R-25	18.9	19.6
R-26	19.2	20.0
R-27	19.6	20.4
R-28	20.0	20.8

a. R_o are for uncompressed insulation.

b. Ro-values in this table were developed for wood-frame walls, but the 16" O.C. column may be used for above-grade block walls.

c. Insulation R-values are the sum of the cavity insulation plus insulating sheathing, if used.

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NEW MEXICO ALTERNATIVE WALL R_o-VALUE

Wall Type	Added Insulation	Steady State R_o
adobe, 10 inch	R-0	4.1
adobe, 10 inch	R-5	9.1
adobe, 10 inch	R-7	11.1
adobe, 10 inch	R-10	14.1
adobe, 10 inch	R-15	19.1
adobe, 10 inch	R-19	23.1
adobe 14 inch	R-0	5.2
adobe 14 inch	R-5	10.2
adobe 14 inch	R-7	12.2
adobe 14 inch	R-10	15.2
adobe 14 inch	R-15	20.2
adobe 14 inch	R-19	24.2
straw, 18 inch	R-0	27.4
straw 24 inch	R-0	36.1
pumicecrete, 12 inch	R-0	10.6
pumicecrete, 14 inch	R-0	12.1
pumicecrete, 16 inch	R-0	13.6
pumicecrete, 18 inch	R-0	15.2
pumicecrete, 20 inch	R-0	16.7
log, 6 inch	R-0	8.0
log, 8 inch	R-0	9.3
log, 10 inch	R-0	11.8
log,12 inch	R-0	14.3
log, 14 inch	R-0	16.9

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24 inch O.C. STEEL FRAME WALL R_o-Values

Cavity R-Value	Insulated Sheathing R-Value										
	R-0	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8	R-9	R-10
R-0	3.7	3.9	4.9	5.9	6.8	7.9	8.8	9.9	10.9	11.9	12.8
R-11	9.4	9.6	10.5	11.6	12.5	13.5	14.5	15.6	16.7	17.5	18.5
R-13	10.0	10.2	11.1	12.2	13.2	14.1	15.2	16.1	17.2	18.2	19.2
R-15	10.6	10.8	11.8	12.8	13.7	14.7	15.9	16.7	17.9	18.9	19.6
R-19	11.4	11.6	12.5	13.5	14.5	15.6	16.7	17.5	18.5	19.6	20.4
R-21	11.8	11.9	13.0	13.9	14.9	15.9	16.9	17.9	18.9	20.0	20.8
R-25	12.3	12.5	13.5	14.5	15.6	16.7	17.5	18.5	19.6	20.4	21.7

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16 inch O.C. STEEL FRAME WALL R_o-Values

Cavity R-Value	Insulated Sheathing R-Value										
	R-0	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8	R-9	R-10
R-0	3.7	3.9	4.9	5.9	6.8	7.9	8.8	9.9	10.9	11.9	12.8
R-11	8.3	8.5	9.4	10.4	11.5	12.5	13.5	14.5	15.4	16.4	17.5
R-13	8.8	9.0	10.0	11.0	11.9	13.0	13.9	14.9	15.9	16.9	17.9
R-15	9.2	9.3	10.4	11.4	12.3	13.3	14.3	15.4	16.4	17.2	18.5
R-19	9.9	10.1	11.1	12.0	13.0	14.1	15.2	16.1	16.9	18.2	19.2
R-21	10.2	10.4	11.4	12.3	13.3	14.3	15.4	16.4	17.2	18.5	19.2
R-25	10.6	10.8	11.8	12.8	13.7	14.7	15.9	16.7	17.9	18.9	19.6

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TRUSS CEILING Ro-VALUES

16" or 24" OC

Insulation R-Value	Standard Truss R_o-Value	Raised Truss R_o-Value[(a)]
R-0	1.8	1.8
R-11	12.2	12.2
R-13	14.3	14.3
R-19	19.6	20.4
R-24	23.8	25.0
R-30	28.6	31.3
R-38	33.3	40.0
R-43	35.7	43.5
R-49	38.5	50.0
R-54	40.0	55.6
R-59	41.7	58.8

a. To receive credit for a raised truss, the insulation must achieve full thickness over the plate lines of

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FLAT ROOF, CEILING R_o-VALUES

Continuous Insulation R-Value	Ceiling R_o-Value
R-0	2.0
R-5	7.0
R-7	9.0
R-10	12.0
R-14	16.0
R-19	21.0
R-21	23.0
R-25	27.0
R-28	30.0
R-30	32.0
R-35	37.0
R-38	40.0
R-40	42.0
R-45	47.0
R-50	52.0
R-60	62.0

Joist Cavity Insulation R-Value	Joist Ceiling R_o-Value
R-0	3.1
R-11	11.1
R-13	12.8
R-19	17.7
R-24	21.9
R-30	26.8
R-38	33.4
R-43	37.6
R-49	42.5
R-54	46.7
R-59	50.8
R-60	51.6

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WINDOW AND SKYLIGHT R_o-VALUE

Frame Material Product Type	Single Glazed	Double Glazed	Double, with low-e	low-e and inert gas
Metal Without Thermal Break				
Curtain wall	0.82	1.27	----	----
Fixed	0.88	1.45	----	----
Operable (including sliding and swinging glass doors)	0.79	1.15	----	----
Site assembled sloped/overhead	0.74	1.22	----	----
Skylight	0.51	0.76	----	----
Metal With Thermal Break				
Curtain wall	0.90	1.47	----	----
Fixed	0.93	1.59	----	----
Operable (including sliding and swinging glass doors)	0.93	1.54	----	----
Site assembled sloped/overhead	0.80	1.43	----	----
Skylight	0.53	0.90	----	----
Wood/Vinyl/Fiberglass				
Fixed	1.02	1.79	2.56	2.86
Operable (including sliding and swinging glass doors)	1.12	1.82	2.38	2.56
Skylight	0.68	1.19	----	----
Glass Block Assemblies				
With mortar, no reinforcement	1.67	----	----	----

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SOLAR HEAT GAIN COEFFICIENT FOR WINDOWS[(a)]

Product Type	Single Glazed			Double Glazed				Triple Glazed
	Clear	Color	Reflective 20% trans.	Clear + Clear	Clear + Color	Reflective 20% trans.	low-e	Clear+Clear+Clear
Metal Frames								
Fixed	0.78	0.65	0.24	0.68	0.57	0.21	0.64	0.61
Operable	0.75	0.62	0.23	0.66	0.55	0.21	0.61	0.59
Nonmetal Frames								
Fixed	0.75	0.62	0.22	0.66	0.54	0.20	0.61	0.59
Operable	0.63	0.53	0.19	0.55	0.46	0.17	0.52	0.50

a. Manufacturer's data should always be used when available.

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DOOR Ro-VALUE

Door Type		
Steel Door (1.75 inches thick)		
	With Foam Core	Without Foam Core
Flush	2.9	1.7
Wood Door (1.75 inches thick)		
	With Storm Door	Without Storm Door
Hollow core, flush	3.1	2.2
Panel (0.438 inch panel)	2.8	1.9
Panel (1.125 inch panel)	3.6	2.6
Solid core flush	3.8	2.5

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FLOOR R_o-VALUES

16" OC

Insulation R-Value	Floor U-factor
R-0	4.0
R-7	10.4
R-11	13.9
R-13	15.6
R-15	17.5
R-19	21.3
R-21	22.7
R-26	27.0
R-30	30.3

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BASEMENT WALL R_o-VALUE

Insulation R-Value	Basement Ro-Value
R-0	2.8
R-1	4.1
R-2	5.3
R-3	6.5
R-4	7.6
R-5	8.7
R-6	9.8
R-7	10.9
R-8	11.9
R-9	13.0

Insulation R-Value	Basement Ro-Value
R-10	13.9
R-11	14.9
R-12	16.1
R-13	16.9
R-14	18.2
R-15	19.2
R-16	20.0
R-17	21.3
R-18	22.2
R-19	23.3
R-20	24.4

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CRAWL SPACE WALL Ro-VALUE

Insulation R-Value	Crawl Space Wall Ro-Value
R-0	2.1
R-2	4.3
R-4	6.3
R-5	7.4
R-6	8.3
R-7	9.3
R-8	10.4
R-9	11.4
R-10	12.3
R-15	17.5
R-20	22.2

BUILDING MATERIAL THERMAL DATA

This section contains thermal data for selected building materials. This data can often be used to estimate the thermal performance of building assemblies.

New materials are being developed and may also be appropriate. They must be laboratory tested, to determine the actual R-value, and approved by the New Mexico Construction Industries Division (CID). Check with CID before using alternative materials.

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SELECTED BUILDING MATERIALS R-VALUE

Insulation		
Batt/Blanket Mineral Fiber	R- 3.50	per inch
Expanded Polystyrene, Extruded (XPS)	R- 5.00	per inch
Expanded Polystyrene, Molded Beads (EPS)	R- 3.85	per inch
Cellular Polyurethane	R- 6.25	per inch
Cellular Polyisocyanurate	R- 6.25	per inch
Loose Fill Mineral Fiber	R- 2.50*	per inch
Loose Fill Cellulose	R- 3.40	per inch
Wood products		
Hard Wood	R- 0.90	per inch
Soft Woods	R- 1.23	per inch
Plywood	R- 1.25	per inch
Hardboard- Medium density	R- 1.37	per inch
Particle Board- Medium Density	R- 1.06	per inch
Building Board/Siding		
Gypboard	R- 0.90	per inch
Vegetable Board Sheathing	R- 2.64	per inch
Gypsum Plaster	R- 0.32	per inch
Masonry		
Common Brick	R- 0.20	per inch
Face Brick	R- 0.11	per inch
Stone	R- 0.04	per inch
Stucco/Cement Plaster	R- 0.20	per inch
Concrete Block, 8", 36 lb, empty core	R- 1.04	entire item
Cinder Block, 8", 21 lb., empty core	R- 2.55	entire item
Adobe	R- 0.28	per inch
Pumicecrete	R- 0.77	per inch
Straw Bale	R- 1.45	per inch
Surface Air Film Inside		
Heat Flow Up Nonreflective (ceilings)	R- 0.61	entire item
Heat Flow Down Nonreflective (ceilings)	R- 0.92	entire item
Heat Flow Horizontal Nonreflective (walls)	R- 0.68	entire item
Surface Air Film Outside		
Any Surface Position, 15 mph, Winter	R- 0.17	entire item
Any Surface Position, 7-1/2 mph, Summer	R- 0.25	entire item

* R-Value ranges from 2.3 to 4.3 per inch

SLAB EDGE INSULATION DETAILS

The slab edge insulation requirements are found in the **Table 402.1.1** of NMECC 2009 for each climate zone. The table shows both R_{req} and Depth. The R_{req} impedes heat loss through the insulated portion. The Depth determines the distance involved for heat to flow around the insulation.

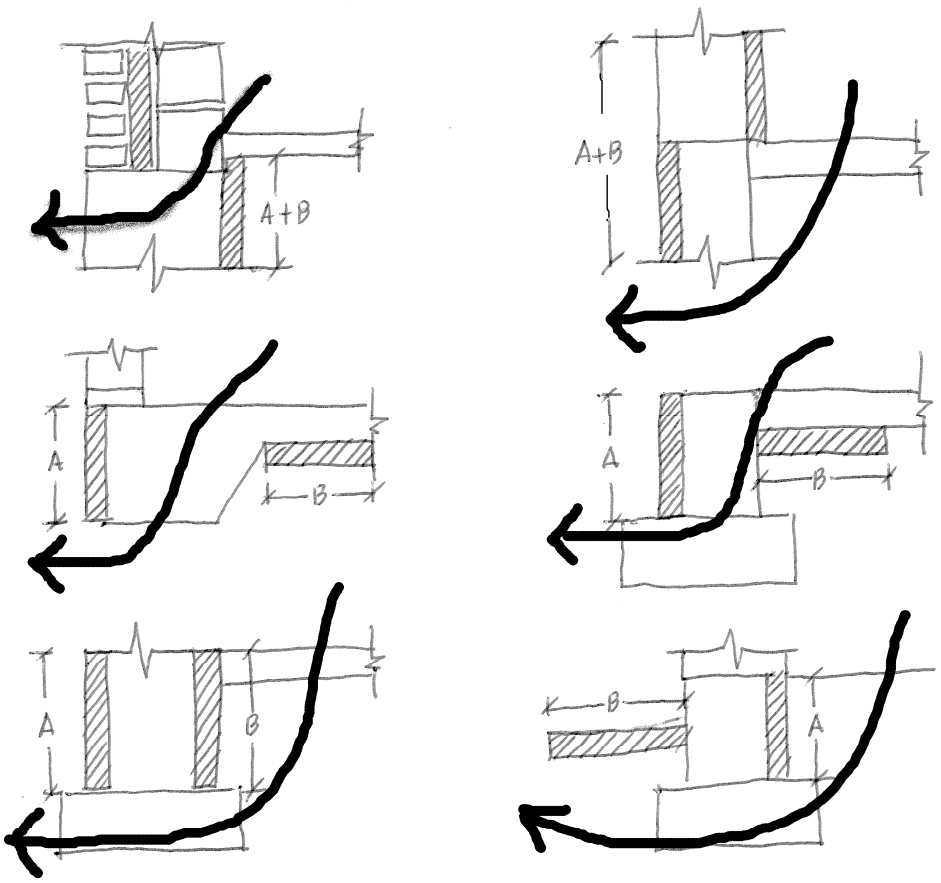
The edge insulation must be installed from the top of the slab, down to the depth indicated in the table. When the foundation design is not deep enough to accommodate the full depth, a portion of the insulation may be installed horizontally, but must be contiguous to the vertical portion and, unless it's under the slab, it must be covered by pavement or 10" of soil.

The insulation installation details must preserve the functionality of both R_{req} and Depth. See footnote d. of **Table 402.1.1** for heated slabs.

Below are drawings of incorrect and correct slab insulation details. The incorrect details allow heat flow to bypass ("short circuit") the insulation, and thus void the intent of the Depth parameter. A + B in the diagrams represent the Depth requirement.

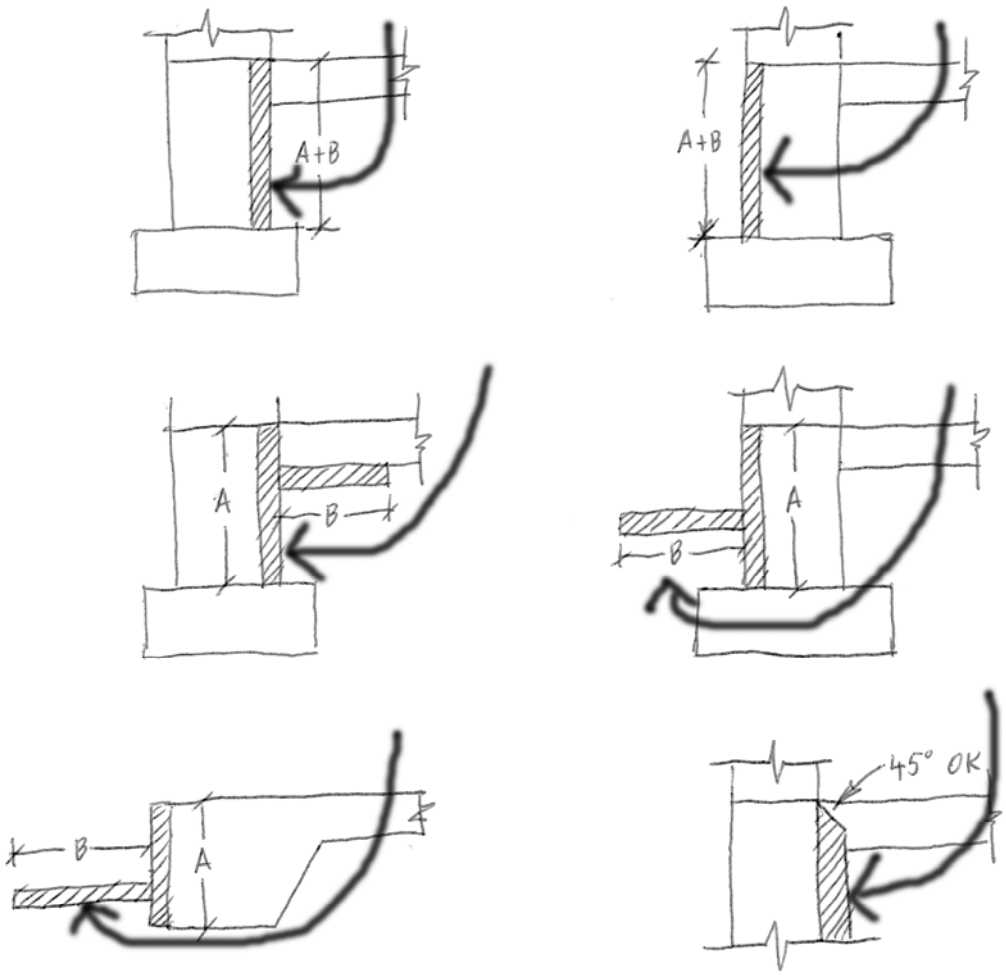
The following installation details for perimeter insulation are <u>incorrect</u>, as all void the intent of the Depth requirement by allowing heat loss around the installed insulation.

INCORRECT



The following slab insulation installation details meet the intent of the code.

CORRECT



Drawings in this manual are intended only to show placement of insulation, and are not to be used for structural design, moisture protection design, or other uses.

TAPERED INSULATION PERFORMANCE

Heat loss through building components is proportional to the U-value, which is equal to 1/(R-value). The result is that the equivalent R-value of tapered insulation is not the average of the minimum and maximum R-values, but rather the inverse of the weighted "average" of the U-values. This can be calculated by an exact equation:

Equivalent Insulation

R-Value = $(R_b-R_a)/(\ln(R_b/R_a))$,

where:

R_b is the R-value at the thickest
R_a is the R-value at the thinnest
ln is natural log.

The following presents the results of this equation in a simple tabular form:

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TAPERED INSULATION

R-VALUE[a] OF UNIFORM INSULATION WITH EQUIVALENT PERFORMANCE[b]

<<<<R-value @ thinnest section (Ra)	R-Value at thickest section (Rb)>>>>										
	20	25	30	35	40	45	50	55	60	65	70
1	6.34	7.46	8.53	9.56	10.57	11.56	12.53	13.48	14.41	15.33	16.24
5	10.82	12.43	13.95	15.42	16.83	18.20	19.54	20.85	22.13	23.39	24.63
10	14.43	16.37	18.20	19.96	21.64	23.27	24.85	26.40	27.91	29.38	30.83
15	17.38	19.58	21.64	23.60	25.49	27.31	29.07	30.79	32.46	34.10	35.70
20	******	22.41	24.66	26.80	28.85	30.83	32.74	34.60	36.41	38.18	39.91
25	******	******	27.42	29.72	31.91	34.03	36.07	38.05	39.98	41.86	43.71
30	******	******	******	32.44	34.76	36.99	39.15	41.24	43.28	45.27	47.21

a. R-values are in the following units: $(°F•ft^2•h)/Btu$

b. Equivalent Insulation R-Value=(Rb-Ra)/(ln(Rb/Ra)), where Rb is thickest, Ra is thinnest.

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TRADEOFF WORKSHEET SAMPLE # 1

The next page features a Tradeoff Worksheet filled in for a sample adobe solar house. In the top section, general information on the project is entered.

The climate zone, 5B, was determined by finding Santa Fe in the list of New Mexico towns in Chapter 3 of NMECC 2009.

The Proposed House is 1,544 ft^2, with a flat roof. It has 4 ft^2 of skylight, giving a net of 1,540 ft^2 for the ceiling area. The ceiling will be insulated with R-49 fiberglass batt insulation in 24" on center joists. Appendix A lists the R_o for this combination to be R-42.5. Appendix A also lists the R-value of a metal frame with thermal break, double glazed skylight as R-0.9.

The perimeter of the house is 212 linear feet and the walls are 8' high. This makes the total wall area 1,696 ft^2. For the adobe wall, see the New Mexico Alternative Wall R_o-Value. This example is using a 10" adobe with R-5 insulation on the exterior. From the table we get the R_o of R-9.1.

The direct gain solar heating feature is 186 ft^2. We use the Solar Heating Worksheet (see sample) to determine that all of this area meets the definition for a solar feature. We therefore enter the area in the Tradeoff Worksheet, but not the R_o or UA for the Solar Feature.

This house has 127 ft^2 of wood frame double glazed windows on the north, east, and west sides and 83 ft^2 of wood solid flush storm doors. Appendix A lists the R_o-Value of this type of window as R-1.82 and the R_o-Value of the doors as R-3.8. Manufacturer's data should be used, if available.

Subtracting the windows and doors from the total wall area, the area of the adobe wall is 1,300 ft^2.

The area of the slab edge insulation is the perimeter times the installed depth, or 424 ft^2. The slab insulation to be added is proposed to be 2 inches of R-5 foam, for an R_o of 10. The crawlspace wall, floor over crawlspace and basement wall sections are left blank, because the house has a heated slab floor.

To calculate the UA of the Proposed House, the area of each building component is divided by its R_o, and the result entered in the UA column. The Solar Direct Gain feature is exempt from this calculation, as per the Passive Solar Heating Worksheet. All the UA values are summed for a total UA of 287.47.

Using **Tables 402.1.1** and **402.1.3** in Chapter 4 of NMECC 2009 we get the requirements for the Code House section, and enter the data on the Worksheet. The applicable values are:

Ceiling,	U-0.026
Fenestration,	U-0.350
Walls,	U-0.082
Heated Slab Edge,	R-15
Slab Insulation Depth,	2'

Note that the U_o of 0.082 is from the Mass Wall U-Factor column, since the Proposed House is adobe and the insulation is on the exterior. When using U values, instead of R values, UA is the area multiplied by U_{req}.

The UA for the individual components of the code house are then summed. Since the total for the Proposed House is less than or equal to the total for the Code House, the thermal envelope is in compliance.

If the total for the Proposed House is greater than that for the Code house, the heat loss of the Proposed House must be reduced. This can be accomplished by increasing the R-value or decreasing the area of the components with the lowest R-values (most often the windows).

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TRADEOFF WORKSHEET

Project ID	Adobe Solar	Building Floor Area	1,544	Date	7/1/2011
Builder Name	John Doe Builders			**In Compliance**	
Builder Address	1001 Builder Road				
Submitted by	John Doe			Phone	505-555-1234
Building Address	100 Solar Drive				
Town	Santa Fe			Climate zone	5B

PROPOSED HOUSE (Area and R_o as designed)

Ceiling & Skylights

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Flat Ceiling	49.0	1540	/	42.5	=	36.24
Skylite		4	/	0.9	=	4.44
			/		=	
Total		1,544				

Walls & Openings

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Adobe 10" + R-5	5.0	1,300	/	9.1	=	142.86
Solar Direct Gain		186	/	N/A	=	
N, E, W Window		127	/	3.2	=	39.69
Doors, flush solid		83	/	3.8	=	21.84
			/		=	
Total		1,696				

Heated Slab Edge (when applicable)

Description	Insulation R-Value	Length * Depth, ft		/	R_o	=	UA
		Lentgh	Depth				
Total	10.0	212	2	/	10.0	=	42.40

Unheated Slab Edge (when applicable)

Description	Insulation R-Value	Length * Depth, ft		/	R_o	=	UA
		Lentgh	Depth				
Total				/		=	

Crawlspace Wall (when applicable)

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Total			/		=	

Floor Over Crawlspace (when applicable)

Description	Insulatio R-Value	Area, ft²	/	R_o	=	UA
Total			/		=	

Basement Wall (when applicable)

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Total			/		=	

Totals

Total Roof, Wall, Foundation	287.47

CODE HOUSE

Ceiling & Skylights

Same As Your House $U_{req.}$ from NMECC

Area, ft²	*	$U_{req.}$	=	UA
1,544	*	0.026	=	40.14

Walls & Openings

Area, ft²: 1,696

Maximum allowed Fenestration: 18% of total

Area, ft²	*	$U_{req.}$	=	UA
305	*	0.350	=	106.85

Walls: 82% of total

Area, ft²	*	$U_{req.}$	=	Area/$R_{req.}$
1391	*	0.082	=	114.04

Heated Slab Edge

Length * Depth, ft		/	R_{req}	=	UA
Lentgh	Depth				
212	2	/	15.0	=	28.27

UnheatedSlab Edge

Length * Depth, ft		/	R_{req}	=	UA
Lentgh	Depth				
		/		=	

Crawlspace Wall

Area, ft²	*	$U_{req.}$	=	UA
	*		=	-

Floor Over Crawlspace

Area, ft²	*	$U_{req.}$	=	UA
	*		=	-

Basement Wall

Area, ft²	*	$U_{req.}$	=	UA
	*		=	-

Totals

Total Roof, Wall, Found.	289.30

If the total for PROPOSED HOUSE is less than the total for CODE HOUSE, PROPOSED HOUSE is in compliance.

PASSIVE SOLAR HEATING WORKSHEET SAMPLE

The next page features the Passive Solar Heating Worksheet filled in for the above sample house.

In the top section, the same general information on the project is entered.

To qualify for use of the Passive Solar Heating Worksheet, all of the items for the direct gain system must be met. As each is reviewed, the applicant should indicate compliance in the box by that line.

The proposed house has the Direct Gain solar heating feature oriented 10º East of true south. This is within 25º east and 15º west, so the first line is confirmed.

The Direct Gain feature is double glazed, and the second line is confirmed.

The site features no significant obstruction to the sun on the south side of the house within the angles specified on the Worksheet, and thus the third and fourth lines are confirmed.

The Direct Gain feature is 186 square feet, or 12% of the adjoining floor area of 1544 square feet. The maximum percentage allowed without additional storage is 8%. This difference requires that storage mass be added for the 62 square feet of Direct Gain in excess of the 8%. To achieve “5x the area of south glazing”, 5•62, or 310 square feet of mass, at least 3” thick, must be added. The proposed building has 1544 square feet of slab floor and 1300 square feet of adobe exterior wall, much more than the required 310, and the fifth line is confirmed.

The Direct Gain feature is 186 square feet, or 12% of the adjoining floor area. The maximum percentage allowed for all solar features is 20%, and the sixth line is confirmed.

The sum of the north, east and west windows is 127 square feet, or 8 percent of the house floor area of 1544 square feet. A maximum of 12 % is allowed, so the seventh line is confirmed.

Since all of the conditions of the Direct Gain solar feature have been confirmed, the Passive Solar Worksheet is applicable to the proposed design. The entire 186 square feet is entered in the Total Direct Gain Glazing section, and in the line for the glazing in the Tradeoff Worksheet. This area is then **not** included in the Area/R_o calculation for the proposed building calculations, as described in the Tradeoff Worksheet instructions.

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PASSIVE SOLAR HEATING WORKSHEET

Project ID	Adobe Solar	Date	7/1/11
Builder Name	John Doe Builders		
Builder Address	1001 Builder Road		
Submitted By	John Doe Builders	Phone	505-555-1234
Building Address	100 Solar Drive		

Items meeting the listed criteria may be presented for simplified code compliance as solar features. All boxes by the system type definitions must be checked to certify compliance. The area in square feet of such features should be entered here and on the Tradeoff Worksheet with the other wall components. The Ro and A/Ro columns may be left blank on the Tradeoff Worksheet for these solar features.

All Solar Features

Orientation within 25° east and 15° west degrees of true South	OK
No significant obstructions to sun above 25° elevation, from bottom of feature	OK
No significant obstructions to sun within 45° horizontal from the east and west edges of the solar feature	OK
Solar features of all kinds no greater than 20% of heated floor area	OK
N + E + W windows not greater than 12% of heated floor area	OK
Overhangs that prevent sun on south-facing glazing on June 21st	OK

Direct Gain

Double glazed (minimum)		OK
If South windows greater than 8% of heated floor area, add thermal mass (at least 5x area of South glazing, at least 3" thick)		OK
TOTAL AREA DIRECT GAIN GLAZING	186	ft^2

Solar Mass Wall

Solid masonry wall, no vents		
TOTAL AREA MASS WALL GLAZING		ft^2

Attached Sunspace

Double glazed (minimum)		
Mass area at least 3x glazing area		
Operable windows or doors to living space, at least 15% of sunspace glazing area		
TOTAL AREA SUN SPACE GLAZING		ft^2

Note: This applications manual is not a solar heating design guide. The inclusion of solar features meeting the above definitions does not by guarantee correct solar heating performance for a building design. For example, solar features totaling 20% of heated floor area, while allowed by this manual, may be excessive in many applications. Passive solar heating features should be designed using appropriate design tools.

TRADEOFF WORKSHEET SAMPLE # 2

The next page features a Tradeoff Worksheet filled in for a sample wood frame house. In the top section, general information on the project is entered.

The climate zone, 3B, was determined by finding Roswell in the list of New Mexico towns in Chapter 3 of NMECC 2009.

The Proposed House is 1,750 ft^2, with a pitched roof. It has 9 ft^2 of skylight, giving a net of 1,741 ft^2 for the ceiling area. The ceiling will be insulated with R-38 fiberglass batt insulation in standard trusses. Appendix A lists the R_o for this combination to be R-33.3. Appendix A also lists the R-value of a metal frame with thermal break, double glazed skylight as R-0.9.

The perimeter of the house is 235 linear feet and the walls are 8' high. This makes the total wall area 1,880 ft^2. The wall is 2x4 frame construction with R13 insulation in the cavity and R5 continuous insulation on the exterior. From the Wood Frame Wall table we get the R_o of R-12.5 for the cavity and add R-5 for the continuous, for a total of R-17.5.

This house has 137 ft^2 of vinyl frame double glazed windows and 83 ft^2 of wood solid flush doors. Appendix A lists the R_o-Value of this type of window as R-2.38 and the R_o-Value of the doors as R-2.5. Manufacturer's data should be used, if available.

Subtracting the windows and doors from the total wall area, the area of the adobe wall is 1,660 ft^2.

No slab edge insulation is being propsed.

To calculate the UA of the Proposed House, the area of each building component is divided by its R_o, and the result entered in the UA column. All the UA values are summed for a total UA of 247.90.

Using **Tables 402.1.1** and **402.1.3** in Chapter 4 of NMECC 2009 we get the requirements for the Code House section, and enter the data on the Worksheet. The applicable values are:

Ceiling,	U-0.030
Fenestration,	U-0.350
Walls,	U-0.057
Heated Slab Edge,	R-15
Slab Insulation Depth,	2'

In this example the U_o of 0.057 is from the Frame Wall U-Factor column. When using U values, instead of R values, UA is the area is multiplied by U_{req}.

The UA for the individual components of the code house are then summed. Since the total for the Proposed House is less than or equal to the total for the Code House, the thermal envelope is in compliance.

If the total for the Proposed House is greater than that for the Code house, the heat loss of the Proposed House must be reduced. This can be accomplished by increasing the R-value or decreasing the area of the components with the lowest R-values (most often the windows).

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TRADEOFF WORKSHEET

Project ID	Wood Frame House	Building Floor Area	1,750	Date	7/1/2011
Builder Name	Stick Builders			**In Compliance**	
Builder Address	111 Calle Bosque				
Submitted by	Joe Woods			Phone	505-555-4321
Building Address	200 Central Drive				
Town	Roswell			Climate zone	3B

PROPOSED HOUSE (Area and R_o as designed)

Ceiling & Skylights

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Truss Ceiling	38.0	1741	/	33.3	=	52.28
Skylite		9	/	0.9	=	10.00
			/		=	
Total		1,750				

Walls & Openings

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
2x4 Frame Wall	R-13+5	1,660	/	17.5	=	94.86
Windows		137	/	2.4	=	57.56
Doors, flush solid		83	/	2.5	=	33.20
			/		=	
			/		=	
Total		1,880				

Heated Slab Edge (when applicable)

Description	Insulation R-Value	Length * Depth, ft		/	R_o	=	UA
		Lentgh	Depth				
Total				/		=	

Unheated Slab Edge (when applicable)

Description	Insulation R-Value	Length * Depth, ft		/	R_o	=	UA
		Lentgh	Depth				
Total	-	235	-	/		=	

Crawlspace Wall (when applicable)

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Total			/		=	

Floor Over Crawlspace (when applicable)

Description	Insulatio R-Value	Area, ft²	/	R_o	=	UA
Total			/		=	

Basement Wall (when applicable)

Description	Insulation R-Value	Area, ft²	/	R_o	=	UA
Total			/		=	

Totals

Total Roof, Wall, Foundation	247.90

CODE HOUSE

Ceiling & Skylights

Same As Your House — $U_{req.}$ from NMECC

Area, ft²	*	$U_{req.}$	=	UA
1,750	*	0.030	=	52.50

Walls & Openings

Area, ft²: 1,880

Maximum allowed Fenestration: 18% of total

Area, ft²	*	$U_{req.}$	=	UA
338	*	0.350	=	118.44

Walls: 82% of total

Area, ft²	*	$U_{req.}$	=	Area/$R_{req.}$
1542	*	0.057	=	87.87

Heated Slab Edge

Length * Depth, ft		/	R_{req}	=	UA
Lentgh	Depth				
		/		=	

UnheatedSlab Edge

Length * Depth, ft		/	R_{req}	=	UA
Lentgh	Depth				
235	-	/	-	=	

Crawlspace Wall

Area, ft²	*	$U_{req.}$	=	UA
	*		=	-

Floor Over Crawlspace

Area, ft²	*	$U_{req.}$	=	UA
	*		=	-

Basement Wall

Area, ft²	*	$U_{req.}$	=	UA
	*		=	-

Totals

Total Roof, Wall, Found.	258.81

If the total for PROPOSED HOUSE is less than the total for CODE HOUSE, PROPOSED HOUSE is in compliance.

AREA-WEIGHTED AVERAGE SAMPLES

The two worksheets below show examples of how to calculate the area-weighted averages for both U-factor and SHGC.

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U-Factor Area-weighted Average

Window Description	U_o	*	Area (ft^2)	UA
Window 1	0.30	*	100.0	30.0
Window 2	0.40	*	50.0	20.0
Window 3	0.35	*	50.0	17.5
		*		-
	Totals		**200.0**	**67.5**
	Average U_o (Total UA/Total SF)			**0.34**

In this example the proposed fenestration meets the requirements of U_{req} .35 for climate zones 3, 4 and 5.

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SHGC Area-weighted Average

Window Description	SHGC	*	Area (ft^2)	SHGC•A
Window 1	0.35	*	100.00	35.00
Window 2	0.50	*	50.00	25.00
Window 3	0.40	*	50.00	20.00
		*		-
	Totals		200.00	80.00
	Average SHGC (Total SHGC•A/Total SF)			0.40

In this example, the proposed fenestration meets the requirements of $SHGC_{req}$ .40 for climate zone 5, but does not meet the requirement of .35 for climate zones 3 and 4.