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Pacific Northwest
NATIONAL LABORATORY

RES*check*™ Technical Support Document

March 2019

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U.S. DEPARTMENT OF
ENERGY

Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

To help builders comply with the Model Energy Code (MEC) and International Energy Conservation Code (IECC) requirements, and to help the U.S. Department of Housing and Urban Development (HUD), the U.S. Department of Agriculture (via Rural Econoic and Community Development [RECD] [formerly Farmers Home Administration]), and state and local code officials enforce these code requirements, the U.S. Department of Energy (DOE) tasked Pacific Northwest National Laboratory (PNNL) with developing the MEC*check*™ compliance materials. In November 2002, MEC*check* was renamed RES*check*™ to better identify it as a residential code compliance tool. The “MEC” in MEC*check* was outdated because it was taken from the Model Energy Code, which has been succeeded by the IECC. The “RES” in RES*check* is also a better fit with the companion commercial product, COM*check*™.

PNNL has developed RES*check* compliance materials for three different editions of the MEC (CABO 1992, 1993, and 1995) and all editions of the IECC (ICC 1998, 1999, 2003, 2006, 2007, 2009, 2012, 2015, and 2018). However, per DOE policy (dated March 18, 2014), only IECC editions 2009, 2012, 2015, and 2018 are presently supported in the software with the long term intent to support only the three most recent code cycle editions. This report explains the methodology used to develop version 4.6.5 of the RES*check* software in order to support compliance determination for IECC editions 2009, 2012, 2015, and 2018.

Acknowledgments

The authors would like to acknowledge the efforts of previous colleagues at the Pacific Northwest National Laboratory (PNNL) codes team who contributed to a prior report on which this work is based: LM Connell, K Gowri, RG Lucas, and JD Wiberg.

Acronyms and Abbreviations

ACEEE	American Council For an Energy-Efficient Economy
AFUE	Annual Fuel Utilization Efficiency
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CABO	Council of American Building Officials
CMU	Concrete masonry units
DOC	Department of Commerce
DOE	Department of Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
G	gravity
Gu	green specific gravity
GAMA	Gas Appliance Manufacturers Association
HC	Heat capacity
HSPF	Heating Seasonal Performance Factor
HUD	Housing and Urban Development
HVAC	Heating, ventilation, and air conditioning
ICC	International Code Council
ICF	Insulated concrete forms
IECC	International Energy Conservation Code
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
Mc	Moisture content
Mcf	Moisture content at fiber saturation
MEC	Model Energy Code
NAECA	National Appliance Energy Conservation Act
NAHB	National Association of Home Builders
NCECC	North Carolina Energy Conservation Code
NFRC	National Fenestration Rating Council
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NYCECC	New York City Energy Conservation Code
OC	On center
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
PRREC	Puerto Rico Residential Energy Code
RECD	Rural Economic & Community Development

RESNET	Residential Energy Services Network
SC	Shading coefficient
SEER	Seasonal Energy Efficiency Ratio
SG	Specific gravity
SHGC	Solar heat gain coefficient
SIP	Structural Insulated Panel
SLA	specified leakage area
TMY	Typical Meteorological Year
UA	U-factor x Area
UECC	Utah Energy Conservation Code
USGS	United States Geological Service
VRBES	Vermont Residential Building Energy Standards

Contents

Tables

1.0 Introduction

The Energy Policy Act of 1992 (EPAct, Public Law 102-486) established the 1992 Model Energy Code (MEC), published by the Council of American Building Officials (CABO), as the target for several energy-related requirements for residential buildings (CABO 1992). The U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Agriculture (via Rural Economic and Community Development [RECD] [formerly Farmers Home Administration]) are required to establish standards for government-assisted housing that "meet or exceed the requirements of the Council of American Building Officials Model Energy Code, 1992." CABO issued 1992, 1993, and 1995 editions of the MEC (CABO 1992, 1993, and 1995).

Effective December 4, 1995, CABO assigned all rights and responsibilities for the MEC to the International Code Council (ICC). The first edition of the ICC's International Energy Conservation Code (IECC) issued in 1998 (ICC 1998) therefore replaced the 1995 edition of the MEC. The 1998 IECC incorporates the provisions of the 1995 MEC and includes the technical content of the MEC as modified by approved changes from the 1995, 1996, and 1997 code development cycles. The ICC has subsequently issued the edition of the IECC on a three-year update cycle.

To help builders comply with the MEC and IECC requirements, and to help HUD, RECD, and state and local code officials enforce these code requirements, the U.S. Department of Energy (DOE) tasked Pacific Northwest National Laboratory (PNNL) with developing the MEC*check*™ compliance materials. In November 2002, MEC*check* was renamed RES*check*™ to better identify it as a residential code compliance tool. The "MEC" in MEC*check* was outdated because it was taken from the Model Energy Code, which has been succeeded by the IECC. The "RES" in RES*check* is also a better fit with the companion commercial product, COM*check*™.

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Section 2.0 provides a summary of the methodologies supported in the RES*check* software. Section 3.0 presents the discussion of the methodology to support the Total UA Alternative. Section 3.0 presents the discussion of the methodology to support the Simulated Performance Alternative. Section 5.0 discusses weather data used in the software. Section 6.0 presents details on compliance determination and reports. Section 7.0 addresses addition and alteration project support. All references cited in this report are identified in Section 7.0. Appendix A–Appendix H document the various state specific energy codes that are supported in RES*check* with the intent to describe how they differ from the standard features that support compliance with the national model codes.

2.0 Methodology Summary

Users can apply the RES*check* software to demonstrate compliance with the IECC residential thermal envelope Uo[1] (thermal transmittance) requirements by one of two methods: Total UA Alternative methodology (Section R402.1.4 in 2009/2012 IECC and Section R402.1.5 in 20015/2018 IECC) and Section R405 Simulated Performance Alternative. Both of these methods effectively allow envelope assembly trade-offs to be considered when determining compliance with the applicable energy code. That is, trade-offs allow parts of a residential building to not meet individual envelope component requirements if other components exceed the requirements. The RES*check* software thus promotes design flexibility while still meeting code requirements. The RES*check* software does not support the R-value method (Section R402.1.1 in 2009/2012 IECC and Section R402.1.2 in 20015/2018 IECC), the prescriptive U-factor method (Section R402.1.2 in 2009/2012 IECC and Section R402.1.3 in 20015/2018 IECC), or the Energy Rating Index Compliance Alternative (2015/2018 IECC Section R406).

The Total UA methodology exercises U-factor x Area (UA, the heat loss/gain rate) calculations for each proposed building assembly then sums each assembly UA to determine the proposed building Total UA. The code building Total UA, derived from application of the code[2] requirements, is computed in turn and compared against the proposed building UA. If the total heat loss (represented as a UA) through the envelope of the user's building design does not exceed the total heat loss from the building conforming to the code, then the user's design passes. Equation (2.1) is used to compute both the UA for the user's proposed building and the UA for the code building:

$$\text{Total UA} = U_1 \times \text{Size}_1 + U_2 \times \text{Size}_2 + \ldots + U_n \times \text{Size}_n \tag{2.1}$$

where

U_n = the U-factor or F-factor of component n (component U-factors and F-factors may be different for the proposed and code buildings), and

Size_n = the area (ft^2) or the perimeter (linear ft) of component n (component sizes are the same for both the proposed and code buildings).

The alternative envelope trade-off method, Section 405 Performance Alternative (performance path), determines compliance using simulated energy performance analysis. RES*check* uses the DOE-2[3] simulation engine for this purpose and implements the requirements of Section 405 that in effect prevents the trade-off between envelope performance and heating, ventilation, and air-conditioning (HVAC) equipment but does allow for envelope assembly performance trade-offs and trade-offs due to solar heat gain coefficients (SHGC) and orientation. Because of this limitation, the performance compliance index calculated by RES*check* does not represent the true above code performance and therefore should not be used for any other purpose outside the scope of RES*check*. Compliance is calculated based on the annual energy cost of the proposed design and standard reference design models (referred to below as the proposed building and code building). Again, if the energy cost factor of the proposed design is not greater than the energy cost factor of the code building energy cost factor then the project passes compliance in so far as the envelope thermal requirements are concerned.

[1] Throughout this document, the term "Uo" is the overall conductive thermal transmission coefficient of an envelope component or the envelope of the entire residential structure. This coefficient excludes, for example, the effects of mechanical ventilation and natural air infiltration.

[2] In this document, "the code" refers to the 2009, 2012, 2015, and 2018 editions of the IECC.

[3] DOE-2.1E, Lawrence Berkely National Laboratory, Adapted By Finite Technologies Incorporated, 3763 Image Drive, Anchorage, AK 99504.

The user-specified envelope data applicable to UA trade-off compliance is also used for defining the DOE-2 simulation inputs. Additional data requirements for the performance alternative method include conditioned floor area, orientation of the building front, a minimum of four walls having unique orientations, and a minimum of one roof and one floor or basement. While the user is asked to enter details about the proposed HVAC equipment when using the performance alternative, the code requires both the proposed and code building simulations to be based on the proposed building equipment efficiency entered by the user. If no equipment systems are specified, federal minimum efficiency systems are considered.

3.0 Total UA Methodology

With respect to the Total UA Alternative, the RES*check* software performs a simple UA calculation for each building assembly in the user's proposed building then sums all assembly UAs to determine the overall UA of the building. This result constitutes the 'proposed building total UA'. Next, the total building UA that would result from a building conforming to the envelope component requirements in the code is computed and referred to as the 'code building total UA'. If the proposed building total UA does not exceed the code building total UA, then the software reports that the building complies with the code. In addition to meeting the UA compliance, some locations must also meet an SHGC requirement for the fenestration components of a building. This requirement applies to climate zones 1 through 4 (except marine) for all editions of IECC except 2009 IECC where the requirement only applies to Climate Zones 1 through 3. The energy codes permit the maximum SHGC requirement to be met using the area-weighted average SHGC. Failure to meet the SHGC requirement will be reported to the user in the software.

Sections 3.1 through 3.2 describe the methodology used by the RES*check* software in determining the UA for the proposed building, the code building, and individual building components, respectively. Section 3.4 discusses the solar heat gain compliance requirement.

3.1 Proposed Building UA Calculation

Equation (3.1) in Section 3.3 is used to compute whole-building UAs. Although this equation uses envelope component U_o-factors, the RES*check* software does not allow the user to enter these U_o-factors directly (except for glazing and door assemblies and "other" assembly types). Table 3.1 lists all of the construction types represented in the software and shows which inputs are required ("X") by the software to establish the component Uo-factors and sizes used in Equation (3.1). The calculations for determining component U_o-factors for components are described in Section 3.3.

3.2 Code Building UA Calculation

The overall UA for the proposed building is compared against the UA from a building just meeting the code requirements, referred to here as the "code building". The building design entered by the user applies to both the proposed building and the code building). The code building U_o-factors for each envelope component are specified by the applicable energy code.

In the remainder of this document the term "Code U-Factor Table" is used to refer to the IECC energy code tables: Table 402.1.3 (2009 IECC) and Table R402.1.4 (2012/2015/2018 IECC).

Table 3.1. Construction Types Offered by RES*check* Software and Required Inputs

Component Description	Cavity Insulation R-Value	Continuous Insulation R-Value	Assembly U-Factor	Size
Ceiling Assemblies				
Flat Ceiling or Scissor Truss	X	X		Gross Area (ft^2)
Cathedral Ceiling (no attic)	X	X		Gross Area (ft^2)
Raised or Energy Truss	X	X		Gross Area (ft^2)
Steel Truss	X	X		Gross Area (ft^2)
Steel Joist/Rafter 16" o.c.	X	X		Gross Area (ft^2)

Component Description	Cavity Insulation R-Value	Continuous Insulation R-Value	Assembly U-Factor	Size
Steel Joist/Rafter 24” o.c.	X	X		Gross Area (ft^2)
Structural Insulated Panels (SIPs)		X		Gross Area (ft^2)
Other	X		X	Gross Area (ft^2)
Above-Grade Walls				
Wood Frame, 16 in. O.C.	X	X		Gross Area (ft^2)
Wood Frame, 24 in. O.C.	X	X		Gross Area (ft^2)
Steel Frame, 16 in. O.C.	X	X		Gross Area (ft^2)
Steel Frame, 24 in. O.C.	X	X		Gross Area (ft^2)
Solid Concrete or Masonry				
Exterior Insulation	X	X		Gross Area (ft^2)
Interior Insulation	X	X		Gross Area (ft^2)
No Insulation				Gross Area (ft^2)
Masonry Block with Empty Cells				
Exterior Insulation	X	X		Gross Area (ft^2)
Interior Insulation	X	X		Gross Area (ft^2)
No Insulation				Gross Area (ft^2)
Masonry Block with Integral Insulation				
w/ Additional Exterior Insulation	X	X		Gross Area (ft^2)
w/ Additional Interior Insulation	X	X		Gross Area (ft^2)
w/ No Additional Insulation				Gross Area (ft^2)
Log (5 to 16-in. diameters)	X			Gross Area (ft^2)
Structural Insulated Panels		X		Gross Area (ft^2)
Insulated Concrete Forms		X		Gross Area (ft^2)
Other			X	Gross Area (ft^2)
Basement and Crawl Space Walls[(a)]				
Solid Concrete or Masonry	X	X		Gross Area (ft^2)
Masonry Block with Empty Cells	X	X		Gross Area (ft^2)
Masonry Block with Integral Insulation	X	X		Gross Area (ft^2)
Wood Frame	X	X		Gross Area (ft^2)
Insulated Concrete Forms		X		Gross Area (ft^2)
Other			X	Gross Area (ft^2)
Floors				
All-Wood Joist/Truss	X	X		Gross Area (ft^2)
Steel Frame, 16 in. O.C.	X	X		Gross Area (ft^2)
Steel Frame, 24 in. O.C.	X	X		Gross Area (ft^2)
Slab-On-Grade [(b)]		X		Perimeter (ft)
Structural Insulated Panels		X		Gross Area (ft^2)
Other			X	Gross Area (ft^2)
Windows, Skylights, Doors				
Windows			X	Unit Area (ft^2)
Skylights			X	Unit Area (ft^2)
Doors			X	Unit Area (ft^2)

(a) The user is required to enter the wall height, depth below grade, and depth of insulation on the wall for basement and crawl space constructions, as well as the depth below inside grade for crawl space walls.

(b) The user is required to enter the depth of the installed insulation.

3.3 Individual Component UA Calculations

To compute the whole-building UA, a UA must first be established for each component listed by the user. A component UA is the product of its U_o by the area (or perimeter in the case of slab-on-grade). In general, the U_o-factor for all components except glazing, doors and "other" assembly types are derived by inverting the sum of all R-values associated with each assembly's various materials (e.g., cavity and continuous insulation, framing, etc) including exterior and interior surface air film. The largest contributing materials are typically the cavity and continuous insulation R-value entered by the user. The R-value for other constituents are sometimes referred to as the assemblies "balance of assembly" or BOA. The following sections describe the constituents and assumptions for each component and how they contribute to determination of the components U_o-factor.

The code generally presents envelope component requirements in U_o-factors. The U_o-factor is a measure of the rate of conductive heat transfer per unit area of any material(s). The RES*check* software allows the user to specify most components in terms of R-values. Specifying inputs and requirements in terms of R-value is advantageous because insulation R-values correspond to the products purchased by builders and inspected by code officials.

Note that construction materials and techniques often vary from those assumed here and described below, yet these differences will generally not have a significant impact on the resulting U_o-factors.

The equation for calculating heat flow through building envelope components is

$$U_o = [U_1 \times \text{Area}_1 + U_2 \times \text{Area}_2 + \ldots] / [\text{Area}_1 + \text{Area}_2 + \ldots] \quad (3.1)$$

where the subscripts identify different series of materials that present a different path of heat transfer; e.g., Area_1 is the area between the framing and Area_2 is the area of the framing. Again, the U-factor is the inverse of the sum of all the material R-values for each path of heat transfer and includes the insulating value of surface air films. Equation (3.2) is sufficiently accurate unless any of the construction material is highly conductive (e.g., steel framing).

As an example, for envelope components with wood frame construction, Equation (3.1) becomes

$$U_o = \frac{\text{Area}_{\text{STUDS}} / \sum R_{\text{FRAMING PATH}} + \text{Area}_{\text{INSULATION}} / \sum R_{\text{INSULATION PATH}}}{\text{Area}_{\text{STUDS}} + \text{Area}_{\text{INSULATION}}} \quad (3.2)$$

Table 3.2 lists the limitations on selected inputs. If the user tries to enter a value outside the ranges specified in this table, RES*check* issues a warning message and restores the number to its previous value. The input limitations are imposed to ensure that the calculations for computing the associated component U_o-factors can be executed within the boundaries of accepted parameters and to ensure that inputs reflect common building practices.

Table 3.2. Input Ranges Allowed by RES*check* Software

Type of Input	Allowable Range
Cavity Insulation R-Value	0 – 60
Continuous Insulation R-Value	0 – 40
Glazing and Door U-Factor	>0.0 – 2.00 (0.0 is invalid)

Type of Input	Allowable Range
Basement Wall Height	0 – 12 ft
Basement Insulation Depth	0 – 12 ft
Basement Depth Below Grade	0 – 12 ft
Slab Insulation Depth	0 – 6 ft
Crawl Space Wall Height	0 – 7 ft
Crawl Space Insulation Depth	0 – 7 ft
Crawl Space Depth Below Grade	0 – 7 ft

3.3.1 Ceilings

The U_o-factor for ceilings is computed based on the cavity insulation R-value and the continuous insulation R-value (if used), both of which are entered by the user.

Two common types of roof/ceiling construction are ceilings separated from roofs by an attic space and ceilings without attics (flat, vaulted, or cathedral). Because of construction differences, the U_o-factors for these two ceiling types are slightly different for equal insulation R-values. The software includes the following ceiling options:

- Flat Ceiling or Scissor Truss
- Cathedral Ceiling (no attic)
- Raised or Energy Truss
- Structural Insulated Panels (SIPs)
- Other

3.3.1.1 Ceiling: Flat Ceiling or Scissor Truss; Raised or Energy Truss

This section describes the algorithm used for flat ceilings and scissor trusses, as well as raised-truss ceilings.

The use of blown fiberglass insulation is assumed in these assemblies, although batt insulation in ceilings is also common. Insulation is assumed to cover the ceiling joists so that “voids” are negligible. Equivalent batt and blown insulation R-values achieve similar U_o-factors, so the assumption of insulation type has little effect. Ceiling joists or rafters are assumed to be at 24 in. on center (O.C.), occupying 7% of the ceiling area for both ceiling types (ASHRAE 1989).

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) recommends an attic ventilation rate of 0.5 cfm/ft^2 of ceiling area to control moisture (ASHRAE 1989). A fully vented attic is assumed with a still-air film resistance above the insulation layer and a 1-in. space between the insulation and the roof near the eaves for ventilation (the venting negates the R-value of the roof materials). A prefabricated truss system is assumed because this system is most common in new residential construction (Anderson and McKeever 1991). For truss members, 2x4 framing (DeCristoforo 1987) and a roof slope of 4/12 were assumed. Table 3.3 shows the heat flow paths for ceilings, and Equation (3.3) uses these results to compute the final U_o-factor of the ceiling component.

Table 3.3. Heat Flow Paths for Ceilings

Description	R-Value at Joists	R-Value at Insulation
Percentage of Ceiling Area	7%	93%
Attic Air Film	0.61	0.61
Batt or Blown Insulation	Rij	Ric
Sheathing	Rs	Rs
Joists	4.38	--
1/2-in. Drywall	0.45	0.45
Inside Air Film	0.61	0.61
Total Path R-Value	6.05 + Rij + Rs	1.67 + Ric + Rs

$$\text{Ceiling } U_o = \frac{0.07}{6.05 + Rij + Rs} + \frac{0.93}{1.67 + Ric + Rs} \tag{3.3}$$

where

Rij = the effective overall R-value of the insulation above the ceiling joists as computed by Equation (3.5).

Ric = the effective overall R-value of the ceiling cavity insulation between joists as computed by Equation (3.4).

Rs = the rated R-value of the insulating sheathing (if any).

The effective insulation R-value may be less than the rated R-value because of limited space at the eaves. Equations (3.4) and (3.5) account for the limited space for insulation at the eaves, which can be alleviated by raising the trusses or using an oversized truss. For a standard truss, the space available at the eaves was assumed to be 3.86 in. For a raised truss, the space available at the eaves was assumed to be 15.86 in. (3.86 in. + 12.0 in.). Equation (3.4) shows how the effective overall R-value of the ceiling cavity insulation (Ric) is calculated. The effective insulation R-value is equal to the rated R-value if adequate space for the full insulation thickness exists at the eaves.

$$Ric = \frac{Ric_{nominal}}{1 + \left(\frac{yic_{full}}{\text{roof height}}\right) \ln\left(\frac{yic_{full}}{yic_{eave}}\right) - \left(\frac{yic_{full} - yic_{eave}}{\text{roof height}}\right)} \tag{3.4}$$

where

$Ric_{nominal}$ = the rated R-value of the cavity insulation

yic_{full} = the full thickness in inches of the cavity insulation

= $Ric_{nominal}$ / 2.5 (for blown fiberglass)

yic_{eave} = the thickness in inches of the cavity insulation at the eaves. The space available at the eaves is assumed to be 3.86 in. for a standard truss. If yic_{full} is greater than 3.86 in., yic_{eave} is set to 3.86 in. For a raised truss, the space available is assumed to be 15.86 in. (3.86 in. + 12.0 in.). If yic_{full} is greater than 15.86 in., yic_{eave} is set to 15.86 in.

roof height = the maximum height in inches at the center line of the house. A 56-in. height was assumed, which corresponds to a 28-ft roof with a rise of 1 ft for each 3 ft across.

Equation (3.5) shows how the effective overall R-value of insulation is calculated for the insulation above the ceiling joists (Rij). Equation (3.5) is the same as Equation (3.4), except 3.5 in. is subtracted from the full insulation depth to account for the insulation displaced by the 2x4 joist. If the truss is not raised, the height of the insulation at the eaves cannot be greater than 0.36 in. (3.86 in. - 3.5 in.). If the truss is raised, the height of the insulation above the eaves cannot be greater than 12.36 in. (15.86 in. - 3.5 in.).

$$\mathrm{Ric} = \frac{\mathrm{Ric}_{\mathrm{nominal}}}{1 + \left(\frac{\mathrm{yij}_{\mathrm{full}}}{\text{roof height}}\right) \ln\left(\frac{\mathrm{yij}_{\mathrm{full}}}{\mathrm{yij}_{\mathrm{eave}}}\right) - \left(\frac{\mathrm{yij}_{\mathrm{full}} - \mathrm{yij}_{\mathrm{eave}}}{\text{roof height}}\right)} \tag{3.5}$$

where

$\mathrm{Rij}_{\mathrm{nominal}}$	=	the R-value of the insulation above the joist, which is the rated insulation R-value ($\mathrm{Ric}_{\mathrm{nominal}}$) minus the joist height (assumed to be 3.5 in.) x the resistance (assumed to be 2.5°F·ft^{2}h/Btu·in.).
	=	$\mathrm{Ric}_{\mathrm{nominal}}$ – (3.5 x 2.5)
$\mathrm{yij}_{\mathrm{full}}$	=	the full thickness of the insulation above the joist (in inches).
	=	($\mathrm{Ric}_{\mathrm{nominal}}$ / 2.5) – 3.5.
$\mathrm{yic}_{\mathrm{eave}}$	=	the thickness (in inches) of the insulation above the joists at the eaves. The space available at the eaves is assumed to be 0.36 in. for a standard truss (3.86 in. – 3.5 in.). If $\mathrm{yij}_{\mathrm{full}}$ is greater than 0.36 in., $\mathrm{yij}_{\mathrm{eave}}$ is set to 0.36 in. For a raised truss, the space available is assumed to be 12.36 in. (15.86 in. – 3.5 in.). If $\mathrm{yij}_{\mathrm{full}}$ is greater than 12.36 in., $\mathrm{yij}_{\mathrm{eave}}$ is set to 12.36 in.
roof height	=	the maximum height in inches at the center line of the house. A 56-in. height was assumed, which corresponds to a 28-ft roof with a rise of 1 ft for each 3 ft across.

Table 3.4 shows some U_o-factors for ceilings calculated using this methodology.

Table 3.4. Sample U_o-Factors for Ceilings

Nominal R-Value	Average Insulation R-Value (Ric)	Insulation R-Value Above Joists (Rij)	U_o-Factor of Ceiling Including Framing
11	11.0	2.2	0.082
19	18.5	9.2	0.051
30	27.3	15.9	0.035
38	32.5	19.1	0.030
38 + Raised Truss	38.0	29.2	0.025
49	38.0	22.2	0.026
49 + Raised Truss	48.6	39.9	0.020

3.3.1.2 Ceiling: Cathedral Ceiling (no attic)

For ceilings without attics the analysis assumed a fully vented ceiling with a still-air film resistance above the insulation. Batt insulation was assumed because vaulted ceilings typically have inadequate space for blown insulation. The rafters were modeled as 2x8 or 2x10 studs at 24 in. O.C. However, the effective thickness of the rafters was set equal to the thickness of the insulation because heat flows directly out the side of the wood beyond the depth of the insulation. Table 3.5 shows the heat flow paths for ceilings without attics, and Equation (3.6) uses these results to compute the final U_o-factor of the ceiling component.

$$Ceiling\ U_o = \frac{0.07}{1.67 + Rr + Rs} + \frac{0.93}{1.67 + Ri + Rs} \tag{3.6}$$

where

Rr	=	the R-value of the wood rafters, which was assumed to be the thickness of the cavity insulation multiplied by 1.25. The thickness of the batt cavity insulation was assumed to be equal to the R-value of the cavity insulation (Ri) divided by 3.0 (i.e., 1.25 x (Ri ÷ 3.0)).
Ri	=	the rated R-value of the cavity insulation.
Rs	=	the rated R-value of the insulating sheathing if any.

Table 3.5. Heat Flow Paths for Ceilings Without Attics

Description	R-Value at Rafters	R-Value at Insulation
Percentage of Ceiling Area	7%	93%
Ceiling Air Film	0.61	0.61
Batt Insulation	--	Ri
Sheathing	Rs	Rs
Rafters	Rr	--
1/2-in. Drywall	0.45	0.45
Inside Air Film	0.61	0.61
Total Path R-Value	1.67 + Rr + Rs	1.67 + Ri + Rs

3.3.1.3 Ceiling: Comparison of U_o-Factors for Ceilings With and Without Attics

For typical construction, the overall ceiling U_o-factors for buildings with and without attics are very close. The two ceiling types were offered as separate options in RES*check* primarily for clarification rather than computational accuracy.

Table 3.6 compares U_o-factors for ceilings with and without attics as calculated using the methodologies described above. This table shows that, for insulation R-values commonly used in ceilings without attics, the difference in the U_o-factors between the two construction types is small.

Table 3.6. Comparison of U_o-Factors for Ceilings With and Without Attics

Batt Insulation R-Value	U_o-Factor for Ceilings With Attics	U_o-Factor for Ceilings Without Attics	Difference Between Construction Types
19	0.051	0.052	2%
30	0.035	0.034	3%

3.3.1.4 Ceiling: Structural Insulated Panels

At the time RES*check* was developed, no studies or reports were available for roof construction of SIP panels. An approximate roof adjustment was made using wall correction factors listed in the Whole-Wall Thermal Performance Calculator (ORNL) for stress-skin walls. A conservative approach assumes that the window, door, and corner framing of the walls are analogous to the roof ridge framing in the ceilings. If the heat flow through the wall/floor framing is removed from consideration, the total heat flow would be 46.21 ($ft^2 \cdot °F \cdot hr$)/Btu (48.07 - 1.86). This heat flow is approximately 92% of the clear-wall heat flow, so an adjustment of 8% is warranted. An additional 1% was added for the wood portion of the joist members, as was done for floors.

RES*check* requires the user to provide a clear-wall R-value of the stress-skin ceiling panel. As such, a total adjustment factor of 9% was adopted for use in calculating the overall R-value of SIP ceilings (an 8% adjustment plus 1% for the webs). Because the manufacturer-reported R-values do not include air films, we assumed the heat flow paths shown in Table 3.7.

Table 3.7. Assumed Heat Flow Paths for SIP Roof Panels

Description	R-Value
Ceiling Air Film	0.61
Roof Panels	Rm * 0.91
1/2-in. Drywall	0.45
Inside Air Film	0.61
Total Path R-Value	1.67 + (Rm * 0.91)

Rm = the manufacturer's reported R-value.

3.3.1.5 Ceiling: Steel-Frame Joist/Rafter

Equation (3.1), which calculates heat loss rates through parallel paths of heat transfer (i.e., framing and insulation), is not accurate for steel-frame joist/rafters because of the high conductivity of the steel framing members. For this reason a correction factor is applied to the cavity insulation R-values (Ric) to more accurately account for the metal stud conductivity. The correction factors used are shown in the following two tables. Applying a correction factor to cavity insulation, the steel-frame ceiling U_o-factors are the inverse of the sum of the ceiling layer R-values as determined and shown by Equation (3.7). When the cavity R-value falls between the stated R-values of Table 3.8 and Table 3.9 (ICC 2003, Table 502.2.1.2), a linearly interpolated correction factor will be computed. Heat flow paths for steel-frame joist/rafter assembly ceilings are shown in Table 3.10.

$$\text{Steel-Frame Ceiling } U_O = \frac{1.0}{1.67 + \text{Rs} + (Fcor * Ric)} \tag{3.7}$$

where

Rs = the R-value of the insulating sheathing.
Fcor = Correction factors for Roof/Ceiling assemblies as given by Table 502.2.1.2 (ICC 2003, page 27), listed in Table 3.8 and Table 3.9 below.
Ric = Cavity insulation between ceiling members

Table 3.8. Correction Factors for Steel Framed Roof/Ceiling Joist/Rafter Assemblies (16-in. framing spacing)

Member Size	R-19	R-30	R-38	R-49
2 x 4	0.90	0.94	0.95	0.96
2 x 6	0.70	0.81	0.85	0.88
2 x 8	0.35	0.65	0.72	0.78
2 x 10	0.35	0.27	0.62	0.70
2 x 12	0.35	0.27	0.51	0.62

Table 3.9. Correction Factors for Steel Framed Roof/Ceiling Joist/Rafter Assemblies (24-in. framing spacing)

Member Size	R-19	R-30	R-38	R-49
2 x 4	0.95	0.96	0.97	0.97
2 x 6	0.78	0.86	0.88	0.91
2 x 8	0.44	0.72	0.78	0.83

Member Size	R-19	R-30	R-38	R-49
2 x 10	0.44	0.35	0.69	0.76
2 x 12	0.44	0.35	0.61	0.69

3.3.1.6 Ceiling: Steel-Frame Truss

For steel-framed truss ceiling assemblies a correction factor of 0.864 is applied to cavity insulation, as indicated in Equations 5-7 – 5-9 of the 2003 IECC. The "Total Path R-value" (excluding cavity and sheathing R-values) is dependent on the user-provided sheathing R-value, which is used to determine the balance of assemblies (BOA) R-value, as shown in Table 3.10. These values are then used to compute the steel-frame ceiling U_o factor, as shown in Equation (3.8).

Table 3.10. Construction Material R-Values for Steel Framed Truss Ceilings (excluding cavity and sheathing R-values)

Sheathing R-value	BOA
< 3.0	0.33
>= 3.0 and less than 5.0	1.994
>= 5.0	2.082

$$\text{Steel-Frame Ceiling } U_o = \frac{1.0}{\text{BOA} + \text{Rs} + (0.864 * Ric)} \tag{3.8}$$

where

Rs = the R-value of the insulating sheathing.
BOA = Balance of assembly R-values (construction materials) as determined by Table 3.10
Ric = Cavity insulation between ceiling members

Table 3.11. Heat Flow Path for Steel Framed Joist/Rafter Ceilings

Description	R-Value at Insulation
Attic Air Film	0.61
Batt or Blown Insulation	Ric
Sheathing	Rs
Joists	--
½-in. Drywall	0.45
Inside Air Film	0.61
Total Path R-Value	1.67 + Ric + Rs

3.3.2 Above-Grade Walls

This section describes the calculation of wall U_o-factors, excluding windows and doors.

3.3.2.1 Above-Grade Wall: Wood-Frame

The U_o-factor for all frame walls is based on the R-value of cavity insulation and continuous insulation (if used). If the user does not enter a continuous insulation (sheathing) R-value (or enters a value of 0.0), the software assumes a sheathing R-value of 0.83. This default value gives credit for some minimal type of sheathing material (such as plywood) under the siding.

Wall materials are assumed to be plywood siding, plywood structural sheathing, and foam insulation sheathing on the framing exterior, batt insulation, wood framing, and 1/2-in. gypboard on the interior. The entire wall is assumed to have structural sheathing. When continuous foam insulation is specified, 100% of the wall is assumed to be covered at the specified R-value.

Based on the assumptions in the ASHRAE (2017) handbook, the 16 in. O.C. translates to a framing percentage of 25% of the opaque wall area and the 24 in. O.C. translates to a framing percentage of 22% of the opaque wall area. The 1995 MEC (CABO 1995) and later editions of the code reference the *ASHRAE Handbook: Fundamentals*. Wall construction heat flow paths are shown in Table 3.12.

Equation (3.9) shows how opaque wall U_o-factors are calculated. Table 3.13 shows wall U_o-factors for 16-in. O.C. walls and common insulation R-values. In addition to the framing percentages, the wall Uo factor calculations takes the insulation sheathing coverage into account. If insulating sheathing is used, only 80% of the net wall is assumed to be covered by the insulating sheathing. The other 20% is assumed to be covered with plywood.

$$\text{Wall } U_o = \left[\frac{0.25 \text{ or } 0.22}{1.97 + Rs + Rw} + \frac{0.75 \text{ or } 0.78}{1.97 + Rs + Ri}\right] 0.80 + \left[\frac{0.25 \text{ or } 0.22}{1.97 + 0.83 + Rw} + \frac{0.75 \text{ or } 0.78}{1.97 + 0.83 + Ri}\right] 0.20 \tag{3.9}$$

where

Rs = the R-value of the insulating sheathing (entered in the software as continuous insulation). If no insulating sheathing is indicated, the sheathing is assumed to be plywood with an R-value of 0.83. If insulating sheathing is used, only 80% of the net wall is assumed to be covered by the insulating sheathing. The other 20% is assumed to be covered with plywood (R-value = 0.83).

Rw = the R-value of the wood framing members. The R-value of the wood framing members was assumed to be R-4.38 for 2x4 construction and R-6.88 for 2x6 construction.

Ri = the rated R-value of the cavity insulation.

Table 3.12. Heat Flow Paths for Wood-Frame Walls

Description	R-Value at Studs	R-Value at Insulation
Outside Air Film	0.25	0.25
Plywood Siding	0.59	0.59
Sheathing	Rs	Rs
Wood Studs	Rw	--
Insulation(a)	--	Ri
1/2-in. Gypboard	0.45	0.45
Inside Air Film	0.68	0.68
Total Path R-Value	1.97 + Rs + Rw	1.97 + Rs + Ri

(a) If the nominal R-value is less than R-11, R-0.9 is added to account for the air space.

Table 3.13. Sample U_o-Factors for 16-in. O.C. Wood-Frame Walls

Batt Insulation R-Value	Sheathing Insulation R-Value	Framing R-Value	Wall U_o-Factor[(a)]
11	0.83	4.38	0.089
13	0.83	4.38	0.082
19	0.83	6.88	0.060
21	0.83	6.88	0.057
19	4	6.88	0.055
19	5	6.88	0.054
19	7	6.88	0.052

3.3.2.2 Above-Grade Wall: Steel-Frame

Equation (3.1), which calculates heat loss rates through parallel paths of heat transfer (i.e., framing and insulation), is not accurate for steel-frame walls because of the high conductivity of the steel studs. Combined stud/insulation R-values (Re), which more accurately account for the metal stud conductivity, were calculated from Table 502.2.1b of the 1995 MEC (CABO 1995). Table 3.14 shows these combined stud/insulation R-values, which are referred to as equivalent R-values. Given these equivalent R-values, the steel-frame wall U_o-factors are the inverse of the sum of the wall layer R-values as shown in Table 3.15 and Equation (3.10).

Table 3.14. Equivalent R-Values for Steel-Frame Walls

Nominal R-Value of Insulation	Equivalent R-Value (16-in. framing spacing)	Equivalent R-Value (24-in. framing spacing)
0.0 - 10.9	0.0	0.0
11.0 - 12.9	5.5	6.6
13.0 - 14.9	6.0	7.2
15.0 - 18.9	6.4	7.8
19.0 - 20.9	7.1	8.6
21.0 - 24.9	7.4	9.0
25.0+	7.8	9.6

Table 3.15. Heat Flow Paths for Steel-Frame Walls

Description	R-Value
Outside Air Film	0.25
Plywood Siding	0.59
Sheathing	Rs
Equivalent R-Value[(a)]	Re
1/2-in. Gypboard	0.45
Inside Air Film	0.68
Total Path R-Value	1.97 + Rs + Re

(a) If the nominal R-value is less than R-11, R-0.9 is added to account for the air space.

$$\text{Steel-Frame Wall } U_o = \frac{1.0}{1.97 + \text{Rs} + \text{Re}} \tag{3.10}$$

where

Rs	=	the R-value of the insulating sheathing. If no insulating sheathing is indicated, the sheathing is assumed to be plywood with an R-value of 0.83. The entire wall was assumed to be covered with insulating sheathing.
Re	=	the equivalent R-value, determined by the rated cavity insulation R-value and the spacing of the framing members. Table 3.14 lists the equivalent R-values used.

3.3.2.3 Above-Grade Wall: Mass Walls

The Code U-Factor Table lists U-factor requirements for mass walls with exterior insulation. Table 3.16 shows the U-factor requirements when more than half the insulation is on the interior of the wall as directed by footnote b of the Code U-Factor Table.

Table 3.16. U-factor Requirements for Mass Walls with Interior Insulation

Climate Zone	2009 IECC Required U-Factor	2012/2015/2018 IECC Required U-Factor
1	0.17	0.17
2	0.14	0.14
3	0.12	0.12
4 except marine	0.10	0.087
5 and marine 4	0.057	0.065
6	0.057	0.057
7	0.057	0.057
8	0.057	0.057

RES*check* uses the same three mass wall types for above-grade mass walls, basement walls, and crawl space walls. Table 3.17 lists these wall types and gives the R-value assigned to the uninsulated wall type in RES*check*. The following sections describe how these assembly types were chosen, how their uninsulated wall R-values were assigned, and how the U_o-factors for the entire mass wall assemblies are calculated for the proposed building in the RES*check* software. Note, RES*check* also includes an option for log walls, which may be considered mass walls as well, however log walls are treated differently and are discussed in Section 3.3.2.5.

Table 3.17. RES*check* Mass Wall Types and R-Values

Mass Wall Type	Uninsulated Wall R-Value
Solid Concrete or Masonry	R-1.6
Masonry Block with Empty Cells	R-1.8
Masonry Block with Integral Insulation	R-2.4

Above-Grade Wall: Selection of Mass Wall Types

In looking at the small differences between the three mass wall R-values given in Table 3.17, it is arguable whether the three mass wall options are necessary, for the Total UA compliance option. They could be combined into a single category as was done in previous versions of RES*check*. However, concern that users would incorrectly enter the R-value of masonry core inserts under the *Cavity R-Value* field, supported the inclusion of *Masonry Block with Integral Insulation* option. When *Masonry Block with Integral Insulation* is selected, the software issues a warning message that informs users to not enter the R-value of the inserts as they are already accounted for through the R value of the mass wall.

As discussed in the following sections, differences in concrete wall characteristics (such as thickness, density, and web characteristics) generally have less than a R-1 impact, but some of the systems described in the section titled "Other Wall R-Values," have a more significant impact. Direct support for these specialty products is not provided in RES*check* even though coverage of these options would allow users to more accurately model mass wall types. Not including these options makes it more difficult for builders to use the specialty products and does not help support the more energy-efficient products mentioned. However, adding these options could complicate the software for other users. Concrete above-grade exterior walls only comprise about 4.4% of residential construction, with most of this construction in the South (DOE 1995a). Specialty systems would comprise an even smaller percentage. Making RES*check* more complex in an attempt to address the needs of this small percentage and all of the other variations on mass walls was deemed unnecessary.

Another difficulty in directly supporting specialty products is determining the R-value to assign to those products. In some cases, manufacturer-reported values for some specialty products may be inflated. As an example, ICON block inserts were reported by the manufacturer to have a system R-value of 5.8, but tests revealed a measured R-value of only 3.5 (*Energy Design Update* 1993). High-mass products may report an "effective" R-value that gives a substantial credit for thermal mass, while the credit for thermal mass is provided elsewhere in the code (and in RES*check*) and should not be included in the R-value.

Above-Grade Wall: Solid Concrete or Masonry Wall R-Value

Solid Concrete or Masonry wall types are defined as solid precast or poured-in-place concrete as well as concrete masonry units (CMUs) with grouted cells having grout in 50% or more of the CMU cells. The R-value of grouted masonry more closely resembles solid concrete than masonry with empty cells.

According to Construction Technology Laboratories, Inc., concrete with a density of 144 lb/ft^3 is by far the most common in residential construction.[1] For basements, the nominal thickness of plain concrete walls should be 8 in. or more for walls 7 ft. or more below grade.[2] Table 3.18 and Table 3.19 show R-values for solid concrete of various densities and thicknesses from ASHRAE Standard 90.1, Appendix A (2013) and U-factors for stone and gravel or stone aggregate concrete from the 2017 *ASHRAE Handbook: Fundamentals* (ASHRAE 2017), respectively. As can be seen from these tables the variation of R-value over common ranges of density and thickness is less than R-1. This small variance does not merit breaking down the wall assembly categories further by density or thickness.

Using the ASHRAE 2017 handbook as the primary reference, wall thickness is assumed to be 8" for both solid concrete and masonry assembly types for both above-grade and below-grade walls, with a R-value of R-1.6 for the uninsulated wall. This value includes air films of R-0.25 (exterior) + R-0.68 (interior).

Table 3.18. R-Values (U-Factors) from Standard 90.1

	Solid Concrete	
Density (lb/ft^3)	6-in. Thickness	8-in. Thickness
85	R-2.3 (0.44)	R-2.7 (0.37)
115	R-1.5 (0.65)	R-1.8 (0.57)
144	R-1.2 (0.81)	R-1.4 (0.74)

[1] Assumptions and equivalent R-values for solid concrete constructions based on a personal communication with Martha Van Geem who at the time of REScheck development was associated with Construction Technology Laboratories, Inc. At this time, Ms. Geem is a member of the ASHRAE 90.1 SSPC Envelope Subcommittee.
[2] See *Building Foundation Design Handbook*, Table 7-11, page 184 (Labs et al. 1998).

Table 3.19. U-Factors from ASHRAE 2017 Fundamentals Handbook

Density (lb/ft^3)	Stone and Gravel or Stone Aggregate Concretes R-Value per in.	Median R-Value for 8 in. thick wall	R-Value with Air Films (0.25+0.68)
130	0.08-0.14	0.88	1.81
140	0.06-0.11	0.67	1.60
150	0.05-0.10	0.60	1.53

Above-Grade Wall: Masonry Block with Empty Cell Wall R-Value and Masonry Block with Integral Insulation Wall R-Value

From ASHRAE Standard 90.1R (2013) *Masonry Block with Empty Cells* is defined as CMUs with at least 50% of the CMU cells free of grout while *Masonry Block with Integral Insulation* is defined as CMUs with integral insulation such as perlite or rigid foam inserts.

To derive a common and standard set of practices to support in RES*check* the following references were considered: 1) Bruce Wilcox indicated that 8-in. medium-weight, partially-grouted CMU was commonly used for residential construction[3], 2) Kosny and Christian (1995) report that “normal-weight” (120-to-144 lb/ft^2) blocks are by far the most common; and 3) Steve Szoke indicated the high end of medium-weight blocks are common, and suggested using ungrouted as a default.[4] Table 3.20 and Table 3.21 show the R-values and U-factors from ASHRAE Standard 90.1R (2013) and U-factors from the *2017 ASHRAE Handbook: Fundamentals* (2017).

Table 3.20. R-Values and U-Factors (including air films) from Standard 90.1

Density (lb/ft^3) and Thickness	Solid Grouted	Partial Grouted, Cells Empty	Partial Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
85					
6 in.	R-1.8 (0.57)	R-2.2 (0.46)	R-2.9 (0.34)	R-2.5 (0.40)	R-5.0 (0.20)
8 in.	R-2.0 (0.49)	R-2.4 (0.41)	R-3.6 (0.28)	R-2.7 (0.37)	R-6.6 (0.15)
115					
6 in.	R-1.5 (0.66)	R-1.9 (0.54)	R-2.4 (0.41)	R-2.2 (0.46)	R-3.8 (0.26)
8 in.	R-1.7 (0.58)	R-2.1 (0.48)	R-2.8 (0.35)	R-2.3 (0.43)	R-4.8 (0.21)
135					
6 in.	R-1.4 (0.73)	R-1.7 (0.60)	R-2.0 (0.49)	R-1.9 (0.53)	R-2.9 (0.35)
8 in.	R-1.5 (0.65)	R-1.8 (0.55)	R-2.4 (0.42)	R-2.0 (0.49)	R-3.6 (0.28)

Table 3.21. U-Factors from ASHRAE 2017 Fundamentals Handbook

	Normal Weight Aggregate (sand and gravel), 8 in.	
Type	R-Value of Block Only	R-Value with Air Films (0.25+0.68)
Empty	0.97-1.11	1.90-2.04
Perlite Fill	2.0	2.93
Vermiculite Fill	1.37-1.92	2.30-2.85

[3] Assumptions and equivalent R-values for block masonry constructions were based on a personal communication with Bruce Wilcox, Berkeley Solar Group.
[4] Assumptions and equivalent R-values for block masonry constructions were based on a personal communication with Stephen Szoke, Portland Cement Association.

Kosny and Christian (1995) report 2-core 12-in. blocks have an R-value of slightly less than R-2 (apparently this R-value does not include air films).

Over common densities, the density and thickness make a difference of less than R-1.4. Insulated cells do not have a significant impact, particularly when grouting is used, suggesting that it is not important to allow the user to specify these inputs. The Standard 90.1R table was used to establish default values because the table covers the variety of concrete blocks. The software currently assumes an 8–in. 135-lb/ft^3 block with partial grouting based on a recommendation by Bruce Wilcox and because assuming partial grouting is more conservative than assuming no grouting. The software assumes that the *Masonry Block with Empty Cells* option allows for up to 50% grouting. R-1.8 is used for this option, based on *Partial Grouted, Cells Empty* in the Standard 90.1R table. R-2.4 is used for *Masonry Block with Integral Insulation*, based on *Partial Grouted, Cells Insulated* in the Standard 90.1R table. Both values include air films of R-.25 + R-.68.

3.3.2.4 Above-Grade Wall: Mass Wall U_o-Factors

U_o-factors for mass walls are determined by considering the R-value for the uninsulated wall and the insulation system (the later of which incorporates impacts from air films and other materials). For exterior insulation, the insulation has been assumed to cover the entire wall. Equation (3.11) computes the U-factor of a mass wall with interior and/or exterior insulation. For interior insulation, an interior furring system has been assumed. Table 3.22 lists equivalent R-values for interior furring and insulation systems.

Table 3.22. Effective R-Values for Interior Furring Systems[(a)]

Nominal R-Value	Thickness of Framing (in.)	Effective R-Value
0	0.75	1.4
1	0.75	1.4
2	0.75	2.1
3	0.75	2.7
4	1.0	3.4
5	1.5	4.4
6	1.5	4.9
7	2.0	5.9
8	2.0	6.4
9	2.5	7.4
10	2.5	7.9
11	3.5	9.3
12	3.5	9.8
13	3.5	10.4
14	3.5	10.9
15	3.5	11.3
16	5.5	13.6
17	5.5	14.2
18	5.5	14.7
19	5.5	15.3
20	5.5	15.8
21	5.5	16.3

(a) The framing thickness varies with R-value. All values include 0.5-in. gypsum wallboard on the inner surface (interior surface resistances not included). The framing was assumed to be 24-in. on-center, and the insulation was assumed to fill the furring space. The framing was assumed to have an R-value of 1.25/in.

$$\text{MassWall } U_o = \frac{1}{\text{Reff} + \text{Rwall} + \text{Rcont}} \quad (3.11)$$

where

Reff = the effective R-value of an interior furring and insulation system (including air films) as determined by the rated R-value of the cavity insulation.
Rwall = the R-value of the uninsulated wall (as determined in the previous sections).
Rcont = the rated R-value of the exterior continuous insulation.

3.3.2.5 Above-Grade Wall: Log Walls

The proposed U-factor calculation for log walls considers log wall species and log diameter to arrive at conductivity, R-value, and heat capacity. The list of wood species and the specific gravity associated with each are listed in Table 3.23. More specifically, the specific gravitymakes it possible for some species of wood with 5-in and 6-in nominal diameters to receive mass wall credit and is based on the work of the ICC log wall standard consensus process.

Using the known green specific gravity (Gu), as shown in Table 3.23, the density and conductivity for each species are calculated. The moisture constant (as denoted by ‘a’ in Equation (3.12)) is calculated from the Moisture Content at Fiber Saturation (MCfs) and the Moisture Content of Service (MCs) which varies by climate zone. This is used to calculate the specific gravity (G) for each species in Equation (3.13) [Equation 3-5 from the Wood Handbook FPL-GTR-113 (USDA 1999)].

$$a = (MCfs - MCs)/MCfs \quad (3.12)$$

where

MCfs for each species is determined by Table 304.2.1 (a) of the ICC International Code Council, *Standard on Log Construction* (ICC IS-Log)(ICC 2005)
MCs varies by climate zone as defined in the IECC.
MCs = 10% for Dry climate
MCs = 13% for Moist climates
MCs = 15% for Marine climates
MCs = 14% for Warm-Humid climates
MCs = 12% for all other climates

$$G = Gu / (1 - (0.265 \cdot a \cdot Gu)) \quad (3.13)$$

where Gu is given in Table 3.23 for each species and a is calculated based on Equation (3.12).

The thermal addition to the ICC IS-Log committee also includes improved methods for calculating the R-value of log walls based on the Wood Handbook (USDA 1999) Equation 3-7. Thermal conductivity is calculated as shown in Equation (3.14).

$$k = G (B + C(MCs)) + A \quad (3.14)$$

where

A = 0.129 (Specific gravity greater than 0.30)
B = 1.34 (Design temperature at 75 F)
C = 0.028 (Moisture content less than 25%)

Table 3.23 shows the calculated conductivity based on Equation (3.12) and the assumed specific gravity for the species.

Table 3.23. Calculated Conductivity and Assumed Specific Gravity for Species Represented in RES*check*

Wood Species Group	Species Label	Specific Gravity (Gu)	Calculated k for Dry Climate (Btu-in/ (h-ft2-F)	Calculated k for Moist Climate Btu-in/ (h-ft2-F)	Calculated k for Warm-Humid Climate Btu-in/ (h-ft2-F)	Calculated k for Marine Climate Btu-in/ (h-ft2-F)
White Cedar (WC)	WC	0.3	0.6422	0.664316	0.671607	0.678857
Red Cedar (RC)	RC	0.31	0.660297	0.683031	0.690522	0.697971
Western Red Canadian Cedar (WRC-N)	WRC-N	0.31	0.650231	0.669576	0.675904	0.682174
Western Red Cedar (WRC)	WRC	0.31	0.650231	0.669576	0.675904	0.682174
Sugar Pine (SUP)	SUP	0.34	0.714999	0.739532	0.747606	0.75563
Incense Cedar (IC)	IC	0.35	0.73337	0.758485	0.766747	0.774956
Eastern White Pine (EWP)	EWP	0.35	0.73337	0.758485	0.766747	0.774956
Western White Pine (WWP)	WWP	0.35	0.73337	0.758485	0.766747	0.774956
White Fir (WF)	WF	0.37	0.770321	0.796571	0.805201	0.813771
W. Spruce-Pine-Fir (WSPF)	WSPF	0.37	0.770321	0.796571	0.805201	0.813771
E. Spruce-Pine-Fir (ESPF)	ESPF	0.38	0.788901	0.815706	0.824514	0.83326
Eastern Softwoods (ESW)	ESW	0.38	0.788901	0.815706	0.824514	0.83326
Eastern Spruce (ES)	ES	0.38	0.788901	0.815706	0.824514	0.83326
Western Softwoods (WS)	WS	0.38	0.788901	0.815706	0.824514	0.83326
Hem-Fir (HF)	HF	0.39	0.807552	0.834901	0.843884	0.852803
Lodgepole Pine (LPP)	LPP	0.39	0.807552	0.834901	0.843884	0.852803
Ponderosa Pine (PP)	PP	0.39	0.807552	0.834901	0.843884	0.852803
Red-Canadian Pine (RP-N)	RP-N	0.39	0.807552	0.834901	0.843884	0.852803
Yellow Cedar (YC)	YC	0.42	0.863932	0.892856	0.902346	0.911761
Red Pine (RP)	RP	0.42	0.863932	0.892856	0.902346	0.911761
Baldcypress (CYP)	CYP	0.43	0.882869	0.912299	0.92195	0.931524
Douglas Fir-Larch (DFL)	DFL	0.45	0.918526	0.948129	0.957818	0.96742
Loblolly Pine (LBP)	LBP	0.47	0.959346	0.990697	1.000961	1.011135
Shortleaf Pine (SLP)	SLP	0.47	0.959346	0.990697	1.000961	1.011135
Mixed Southern Pine (MSP)	MSP	0.48	0.97865	1.010455	1.020864	1.031179
Southern Pine (SP)	SP	0.48	0.972637	1.002473	1.012211	1.021849
Tamarack (TAM)	TAM	0.49	0.998029	1.030278	1.040827	1.051279
Longleaf Pine (LLP)	LLP	0.54	1.096057	1.13036	1.141558	1.152642
Slash Pine (SHP)	SHP	0.54	1.096057	1.13036	1.141558	1.152642
Red Oak (RO)	RO	0.57	1.155799	1.191199	1.202741	1.214156

Wood Species Group	Species Label	Specific Gravity (Gu)	Calculated k for Dry Climate (Btu-in/ (h-ft2-F)	Calculated k for Moist Climate Btu-in/ (h-ft2-F)	Calculated k for Warm-Humid Climate Btu-in/ (h-ft2-F)	Calculated k for Marine Climate Btu-in/ (h-ft2-F)
White Oak (WO)	WO	0.62	1.256948	1.29394	1.305974	1.317865

Since 2015 IECC, the code explicitly states that the heat capacity (HC) of a wall must be 6 Btu/ft^2 F or higher in order to be considered a mass wall. This criteria was deemed a reasonable and conservative threshold to maintain for 2009/2012 IECC as well. Assuming the specific heat of wood (c) is 0.39 Btu/lb-F, the heat capacity is calculated from the species density as shown in Equation (3.15).

$$D = 62.4 \cdot [G / (1+ (0.009 \cdot G \cdot MCs))] \cdot (1+ MCs/100) \tag{3.15}$$

where D is log density (lb/ft^3) based on section 302.2.3.7 of ICC IS-LOG

$$HC = D \cdot c \cdot (Nd/12) \tag{3.16}$$

where

D = log density (lb/ft^3) based on Section 302.2.3.7 of ICC IS-LOG
C = specific heat 0.39 lb-F for all species
Nd = the Nominal Width of the log wall in inches

3.3.2.6 Above-Grade Wall: Structural Insulated Panels

Above-Grade SIP: Wall Panels

SIPs typically have ½-in. fiberboard sheathings and an EPS foam core. Panels have an edge stiffener, which is also used as the nailing strip for connections. Corners and window/door openings all require the foam core be replaced with wood framing members. RES*check* instructs users to provide the manufacturer-reported R-value of the SIP panel in the continuous R-value field. Manufacturer-reported R-values are typically clear-wall R-values–they do not include connections and framing effects.

For SIP panels, Oak Ridge National Laboratory (ORNL) has reported the difference between the clear-wall R-value and overall wall R-value as 12.5% (ASHRAE 1998). The ORNL Whole-Wall Thermal Performance Calculator estimates the whole-wall R-value to be 88.3% of the clear-wall R-value in a typical single-family dwelling (an 11.7% difference) (ORNL 2001).

Based on these results, RES*check* uses an adjustment factor of 12.5% for calculating the overall R-value of SIP exterior walls, which is the more conservative of the two results. The manufacturer-reported R-values do not include air films, hence the heat flow paths shown in Table 3.24 have been used.

This assemblies U_o, when applied in RES*check*, is 1 divided by Total Path R-Value.

Table 3.24. Assumed Heat Flow Paths for Wall Panels

Description	R-Value
Outside Air Film	0.25
Wall Panels	Rm * 0.875
1/2-in. Gypboard	0.45
Inside Air Film	0.68

Total Path R-Value	1.38 + (Rm * 0.875)

Rm = the manufacturer's reported R-value.

3.3.2.7 Above-Grade Wall: Insulated Concrete Forms

Insulated concrete forms (ICFs) consist of two rigid-board insulation sheathings that serve as a permanent form for poured-in-place concrete walls. The insulation sheathings are connected by plastic or metal links that keep the sheathings in position and also serve as stirrups or reinforcements for the concrete wall. RES*check* instructs users to provide the manufacturer-reported R-value of ICFs in the continuous R-value field. Manufacturer-reported R-values are typically clear-wall R-values–they do not include connections and framing effects.

The ORNL tests (ASHRAE 1998), show that the difference between the clear-wall R-value and the overall wall R-value is 9.5%. These calculations take into account the additional framing in corners, window/door frames, and wall/roof and wall/floor interfaces. A typical ICF wall analyzed using the ORNL Whole-Wall Thermal Performance Calculator shows that the whole-wall R-value is 89% of the clear-wall R-value (an 11% difference) (ORNL 2001).

Assuming that the RES*check* user provides a clear-wall R-value of an ICF construction, an adjustment factor of 11% was adopted for use in determining the overall effective R-value, which is the more conservative of the two results. Table 3.25 and Table 3.26 list the R-values used to calculate the overall effective R-value for above- and below-grade ICF walls.

This assemblies U_o, when applied in RES*check*, is 1 divided by Total Path R-Value.

Table 3.25. Above-Grade ICF Walls

Description	R-Value
Outside Air Film	0.25
ICF Clear Wall	Rm * 0.89
1/2-in. Gypboard	0.45
Inside Air Film	0.68
Total Path R-Value	1.38 + (Rm * 0.89)

Rm = the manufacturer's reported R-value.

Table 3.26. Below-Grade ICF Walls

Description	R-Value
ICF Clear Wall	Rm * 0.89
Inside Air Film	0.68
Total Path R-Value	0.68 + (Rm * 0.89) + Soil Impact

Rm = the manufacturer's reported R-value.

3.3.3 Floors Over Unheated Spaces

The U_o-factor for floors over unheated spaces is based on the R-value of the cavity and/or continuous insulation.

3.3.3.1 Floors: All-Wood Joist/Truss

RES*check* assumes that wooden joist or truss floors over unheated spaces are constructed of batt insulation, wood framing, a ¾-in. wood subfloor, and carpet with a rubber pad. The floor joists are modeled as 2x10 studs at 16-in. O.C. (DeCristoforo 1987) occupying 10% of the floor area. The effective depth of the joists for the thermal calculation was set equal to the depth of the insulation. This thickness was used because heat flows directly out of the sides of the joists beyond the depth of the insulation. Table 3.27 shows the heat flow paths for floors over unheated spaces, and Equation (3.17) uses these results to compute the final floor component U_o-factor. Table 3.28 shows some U_o-factors for floors over unheated spaces as calculated by this methodology.

$$Floor\ U_o = \frac{0.1}{4.01 + Rj} + \frac{0.9}{4.01 + Ri} \tag{3.17}$$

where

Rj = the R-value of the wood joists, which was assumed to be the thickness of the cavity insulation multiplied by 1.25. The thickness of batt cavity insulation was assumed to be R-3.0 per inch (i.e., 1.25 x (Ri ÷ 3.0)).

Ri = the rated R-value of the cavity insulation.

Table 3.27. Heat Flow Paths for Floors Over Unheated Spaces

Description	R-Value at Joists	R-Value at Insulation
Percentage of Floor Area	10%	90%
Unheated Space Air Film	0.92	0.92
Insulation	--	Ri
Joists	Rj	--
Carpet and Pad	1.23	1.23
¾-in. Wood Subfloor	0.94	0.94
Inside Air Film	0.92	0.92
Total Path R-Value	4.01 + Rj	4.01 + Ri

Table 3.28. Sample Uo-Factors for Floors Over Unheated Spaces

Batt R-Value	U_o-Factor of Floor Including Framing
0	0.250
11	0.072
13	0.064
19	0.047
30	0.033

3.3.3.2 Floors: Structural Insulated Panels

At the time RES*check* was being developed, studies or reports on SIP panel floor construction were not available, therefore an approximate floor adjustment is made using wall correction factors listed in the Whole-Wall Thermal Performance Calculator (ORNL 2001) for stress-skin walls. The only heat flows considered applicable to the floor are the clear-wall (42.42 $(ft^2\cdot°F\cdot hr)/Btu$) and wall/floor (1.86 $(ft^2\cdot°F\cdot hr)/Btu$) heat flows. Adding these heat flows gives 44.28 $(ft^2\cdot°F\cdot hr)/Btu$, which is approximately 96% of the clear-wall heat flow. Therefore, an adjustment of 4% is warranted.

Adjoining floor panels are typically connected with spline joints. Based on the percentage of joint area of a typical 4-x 8-ft panel, the overall joint area comprises about 1% of the floor area. The adjustment factor is increased by 1% to account for the heat flow through the joints.

Assuming that the RES*check* user provides a clear-wall R-value of the stress-skin floor panel, a total adjustment factor of 5% was adopted for use in calculating the overall R-value of SIP floors (a 4% adjustment plus 1% for the webs). The manufacturer-reported R-values do not include air films which have also been included., The heat flow paths are shown in Table 3.29.

This assemblies U_o, when applied in RES*check*, is 1 divided by Total Path R-Value.

Table 3.29. Assumed Heat Flow Paths for Floor Panels

Description	R-Value
Unheated Space Air Film	0.92
Floor Panels	Rm * 0.95
Carpet and Pad	1.23
Inside Air Film	0.92
Total Path R-Value	3.07 + (Rm * 0.95)

Rm = the manufacturer's reported R-value.

3.3.3.3 Floors: Steel Frame

Section 502.2.1.3 of the 2003 IECC includes steel-frame floors over unheated spaces. Due to the high conductivity of the steel framing members, a correction factor is applied to the cavity insulation R-values (Ric) to account for the metal stud conductivity. The correction factors shown in the following two tables are used. Applying a correction factor to cavity insulation, the steel-frame floor U_o-factors are the inverse of the sum of the floor layer R-values as determined and shown by Equation (3.18). When cavity R-value falls between the stated R-values of Table 3.30 (ICC 2003, Table 502.2.1.3a) and Table 3.31 (ICC 2003, Table 502.2.1.3b), a linearly interpolated correction factor is computed. Cavity insulation credit is limited by the framing member size as indicated by "NA" in Table 3.30 (ICC 2003, Table 502.2.1.3a) and Table 3.31 (ICC 2003, Table 502.2.1.3b). The user is permitted to enter higher R values, but an information message is presented to indicate that the maximum R-value credit will be that defined in Table 3.30 (ICC 2003, Table 502.1.1.3a) and Table 3.31 (ICC 2003, Table 502.2.1.3b).

Table 3.30. Correction Factors for Steel Framed Floor Assemblies (16-in. framing spacing)

Member Size	R-19	R-30	R-38
2 x 6	0.70	NA	NA
2 x 8	0.35	NA	NA
2 x 10	0.35	0.27	NA
2 x 12	0.35	0.27	0.24

Table 3.31. Correction Factors for Steel Framed Floor Assemblies (24-in. framing spacing)

Member Size	R-19	R-30	R-38
2 x 6	0.78	NA	NA
2 x 8	0.44	NA	NA
2 x 10	0.44	0.35	NA
2 x 12	0.44	0.35	0.32

Table 3.32. Heat Flow Paths for Steel framed Floor Assemblies (over unheated spaces)

Description	R-Value at Insulation
Unheated Space Air Film	0.92
Insulation	Ric
Sheathing	Rs
Joists	--

Carpet and Pad	1.23
¾-in. Wood Subfloor	0.94
Inside Air Film	0.92
Total Path R-Value	4.01 + Ri + Rs

$$\text{Steel-Frame Floor } U_o = \frac{1.0}{4.01 + Rs + (Fcor * Ric)} \tag{3.18}$$

where

Rs = the R-value of the insulating sheathing.

Fcor = Correction factors for floor assemblies as given by Table 502.2.1.3 of ICC 2003

Ric = Cavity insulation between ceiling members

Note: Floors over outside air are evaluated the same as Ceilings/Roofs as stated in Section 502.2.1.3 of the 2003 IECC.

3.3.4 Basement Wall

The basement wall code requirement applies only to the net basement wall area (not including basement windows and/or doors).

Because heat transfer through soil affects heating and cooling loads, RES*check* accounts for the heat flow through the adjacent soil in the proposed building. The software uses the R-value of the insulation, the wall height, the depth below grade, and the depth of the insulation as inputs into this computation.

Section 402.2.7 (2009 IECC), R402.2.8 (2012 IECC), R402.2.9 (2015/2018 IECC) states: Walls associated with conditioned basements shall be insulated from the top of the basement wall down to 10 feet below grade or to the basement floor, whichever is less.

A basement wall with insulation only part way down can be considered to be two "assemblies" (the top part insulated and the bottom part not insulated), with a distinct U_o for each assembly. This situation is permissible if the total heat loss for the entire building (the overall UA) remains the same or is reduced; i.e., if this lack of insulation at the bottom of the basement wall is adequately compensated for by extra insulation in any other part of the building envelope. Therefore, the software allows for and gives credit to basement walls insulated from the top of the wall to any depth (i.e., full basement wall insulation is not required). The basement UA for the code building is calculated assuming the insulation goes the full depth of the basement wall.

The methodology for calculating heat loss through basement walls was adapted from the 1993 ASHRAE Handbook: Fundamentals (ASHRAE 1993, p. 25.10-25.11). The proposed UA calculations take into account the effect of the soil surrounding below-grade walls.

The soil R-value is applied for each 1-ft increment of wall height below grade, based on the user inputs for 'Wall Height' and 'Depth Below-Grade'. Table 3.33 gives the heat loss factors for an uninsulated wall as specified in the 2017 ASHRAE handbook (ASHRAE 2017). The combined R-value of the uninsulated wall and air-films was determined to be approximately R-1.6. Column D of Table 3.33 gives the R-value attributed to the soil at each 1-ft. increment after the wall R-value of R-1.6 has been deducted.

3.3.4.1 Basement Wall: Proposed UA

To compute the proposed UA for the basement wall, the foundation dimensions and insulation characteristics are obtained from the user. These include:

- height of wall
- depth of wall below grade
- depth of insulation
- R-value of insulation
- wall area.

The “depth of insulation” refers to the distance the insulation extends vertically from the top of the foundation wall downward. No additional credit is given for insulation depths greater than the height of the wall.

The basement wall UA is calculated by multiplying the basement wall area by the U_o of the basement wall. The U_o of the basement wall (Equation (3.19)) is the sum of the U_o for the above-grade (AG) wall section (if any), the U_o of the below-grade (BG) wall section that is insulated (if any), and the U_o of the below-grade wall section that is uninsulated (if any).

$$\text{proposed basement wall Uo} = \text{AG wall Uo} + \text{BG insulated wall Uo} + \text{BG uninsulated wall Uo} \quad (3.19)$$

The U_o calculations for the above-grade wall section are described in sections 3.3.4.2-5 below according to construction type. Soil R-values are not factored into U_o for above-grade sections of wall. The U_o calculations for the insulated and uninsulated below-grade wall sections are described in Equations (3.20) and (3.21), respectively. These equations can be described generally as follows: To compute the below-grade wall U_o, the below-grade wall height is parsed into 1 foot sectional or unit parts each of which has a U_o calculated for it that is based on that sections insulation characteristics, wall type, depth below-grade, and soil R-value. If, or when, the proposed wall height or insulation depth has a fractional height then the associated 1 foot section U_o calculation will make the necessary adjustment to reflect the partial or fractional contribution it makes to that 1 foot wall section. The total below-grade wall U_o is the sum of each 1 foot sections U_o. Table 3.33 gives the soil R-values used in calculations for each 1 foot wall section.

$$\text{proposed Insulated BG Uo} = \sum_{n}^{i\text{-}1} \left(\frac{1}{\text{wall R value[i]} + \text{soil R value [i]}} \right) * \text{height fraction}$$

(3.20)

where

wall R-value[i]	=	the R-value of the insulated wall assembly for increment i, based on the wall type and the insulation configuration.
soil R-value[i]	=	the R-value of the soil for increment i, based on the depth below grade of increment i (see Table 3.33).
height fraction[i]	=	1 when wall R-value is constant over full 1 foot height of insulated wall, fractional when wall R-value is not constant over full 1 foot height of insulated wall (e.g., wall insulation terminates part way through 1 foot wall height.
n	=	the insulated wall height, rounded up to the nearest whole number.

$$\text{proposed Uninsulated BG Uo} = \sum_{n}^{i\text{-}1} \left(\frac{1}{\text{wall R value[i]} + \text{soil R value [i]}} \right) * \text{height fraction}$$

(3.21)

where

wall R-value[i]	=	the R-value of the uninsulated wall assembly for increment i, based on the wall type.
soil R-value[i]	=	the R-value of the soil for increment i, based on the depth below grade of increment i (see Table 3.33).
height fraction[i]	=	1 when wall R-value is constant over full 1 foot height of uninsulated wall, fractional when last 1 foot wall height section is less than a full 1 foot height.
n	=	the uninsulated wall height, rounded up to the nearest whole number.

Table 3.33. Soil R-Values

A Depth Below Grade (ft)	B Heat Loss (Btu/ft²●h●°F) for Uninsulated Wall	C R-Value of Uninsulated Wall and Soil (1/B)	D R-Value of Soil Only (C – 1.6)
0-1	0.410	2.439	0.839
1-2	0.222	4.505	2.905
2-3	0.155	6.452	4.852
3-4	0.119	8.403	6.803
4-5	0.096	10.417	8.817
5-6	0.079	12.658	11.058
6-7	0.069	14.493	12.893
7-8	0.061	16.393	14.793
8-9	0.055	18.182	16.582
9-10[a]	0.049	20.408	18.808

(a) Depths below 10 ft assume the 9-to-10-ft soil R-value.

3.3.4.2 Basement Wall: Wood-Frame

Wood-frame basement wall R-values are established similar to above-grade wood-frame walls. Table 3.34 gives the assumed heat flow paths for basement wood-frame walls. Equation (3.22) gives the wall R-value. 2x6 16-in. O.C. construction is assumed. A wall R-value is appliced to Equations (3.19)–(3.21). For basement walls 25 percent of the wall area is assumed to be comprised of framing while 75 percent comprised of cavity space.

$$\text{Basement Wall R-value} = \Big(\big(0.25 * (9.03\text{+Rcont})\big) + \big(0.75 * \ (2.15\text{+Rcont+Rcavity})\big) \Big) \quad (3.22)$$

where

Rcont	=	the R-value of the insulating sheathing (entered in the software as continuous insulation).
Rcavity	=	the rated R-value of the cavity insulation.

Table 3.34. Heat Flow Paths for Wood-Frame Basement Walls

Description	R-Value at Studs	R-Value at Insulation
Outside Air Film	0.25	0.25
Plywood	0.77	0.77
Continuous Insulation	Rcont	Rcont
Wood Studs	6.88	--
Cavity Insulation	--	Rcavity
1/2-in. Gypboard	0.45	0.45
Inside Air Film	0.68	0.68
Total Path R-Value	9.03 + Rcont	2.15 + Rcont + Rcavity

3.3.4.3 Basement Wall: Insulated Concrete Forms

For ICF basement walls, the calculation procedure is the same as above-grade ICF walls, discussed in Section 3.3.2.7. The depth of insulation is assumed to be the same as the wall height. Below-grade ICF wall R-values are calculated as:

$$\text{ICF R-value} = 0.68 + \text{Rm} \times 0.89 \tag{3.23}$$

where Rm is the manufacturer’s reported R-value, as entered by the user.

3.3.4.4 Basement Wall: Solid Concrete and Masonry Block

Table 3.35 shows the R-values used for uninsulated solid concrete and masonry block walls. The uninsulated wall R-value assigned to these three wall types is the same as is used for above-grade mass walls, as discussed in Section 3.3.2.3.

Table 3.35. Basement Wall Types and R-Values

Mass Wall Type	Uninsulated Wall R-Value
Solid Concrete or Masonry	R-1.6
Masonry Block with Empty Cells	R-1.8
Masonry Block with Integral Insulation	R-2.4

The insulated wall R-value is

$$\text{BasementWallRval} = \text{Reff} + \text{Rwall} + \text{Rcont} \tag{3.24}$$

where

Reff = the effective R-value of an interior furring and insulation system as determined by the rated R-value of the cavity insulation as well as surface air films (see Table 3.22).

Rwall = the R-value of the uninsulated wall (see Table 3.35).

Rcont = the rated R-value of the continuous insulation.

3.3.4.5 Basement Wall: Other

For *Other* wall types, the depth of insulation is assumed to be the same as the wall height. The user must enter and be prepared to justify an assembly U-factor.

3.3.5 Crawl-Space Wall

As with basements, when computing the U-factor of crawl space wall components, the software accounts for the heat flow through the adjacent soil for the same reason given above for basement walls. The software uses the inputs for R-value of the insulation, the wall height, the depth below grade, the depth below inside grade, and the depth of the insulation as inputs into this computation. The methodology for calculating heat loss through crawl space walls is identical to that described in Section 3.3.4 for basement walls.

The crawl space wall calculation requires the same inputs as the basement wall calculation. In computing the code building UA, the same inputs are used except for the insulation R-value, which is based on the code requirement. The code requires the insulation to extend a maximum of 12 in. below the outside grade for crawlspace walls which extend 12 in. or more below the outside finished ground surface. In this case, the code building in the UA comparison is assumed to be fully insulated above outside grade and insulated to 12 in. below outside grade.

For crawl space walls having an inside ground surface less than 12 in. below outside grade, the code requires the insulation extend downward vertically and inward horizontally a total distance of 24 in. from the outside grade surface. In this case, it is necessary to account for the horizontal insulation required by the code in the RES*check* software (DOE 1995d). The *1989 ASHRAE Handbook: Fundamentals* does not provide an estimate of the effect of horizontal insulation on the heat loss through the crawl space floor (ASHRAE 1989). Therefore, the horizontal insulation is accounted for in the UA calculation by assuming both the insulation and the wall extend down vertically 24 in. below the outside grade. In the UA calculation, this assumption increases the area of the crawl space wall beyond the actual vertical wall area. This vertical insulation assumption, when the insulation is actually horizontal, is reasonable because the length of the heat flow path through the soil to bypass the insulation is about the same in either case. The same assumption is made for both the code building and the proposed building.

3.3.6 Slab-On-Grade Floor

If a slab-on-grade floor component (referred to as "slab") is selected, the user is required to enter the slab floor perimeter, R value of the insulation and depth of the insulation. RES*check* computes an F-factor for slab assemblies based on the R-value of the slab insulation and the depth of the insulation. An F-factor is the heat loss rate through the slab per linear foot of perimeter length(Btu/ft·h·°F). For the proposed building, the the insulation depth can range from 0 to 6 ft. For insulation extending beyond 4 ft, the user does not receive any additional credit toward compliance. For the code building, the insulation depth is either 2 ft (Climate Zones 4 and 5) or 4 ft (Climate Zones 6 – 8).

To calculate foundation heat losses, heat loss values for slabs were taken from Huang et al. (1988).[5] In this methodology, the heat loss unit for below-grade foundations is in terms of linear feet of perimeter (F-factor) instead of square feet of surface area (U_o-factor). As described in the paper, heat loss is calculated by multiplying U_o-factors by the surface area of each applicable surface and the heating or cooling degree-days of the building location to obtain the total heat loss or heat gain. However, for slabs, an F-factor is multiplied by the perimeter length and heating or cooling degree-days of the building location to obtain the total heat loss or heat gain. These F-factors are shown in Table 3.36. The F-factors are given in the referenced paper for insulation both on the exterior and interior of the foundation wall. The F-factors vary only slightly by insulation placement, so the average of the exterior and interior insulation placement

[5] Sufficient data were not available from this source to model heat losses from common basement and crawl space insulation configurations, so this source was used only for slab-on-grade foundations.

was used. The same F-factors were used for heated and unheated slabs. Huang et al. (1988) did not present F-factors for insulation levels above R-10 for slab insulation 2-ft deep; therefore, in RES*check*, F-factors were considered to be constant for insulation levels above R-10 for this configuration. Additionally, F-factors were considered to be constant for all insulation levels above R-20, regardless of insulation depth. This assumption was deemed reasonable because little is gained by the additional insulation (above R-20, most of the heat loss occurs under and around the insulation).

In the RES*check* software, slab perimeters can be insulated to a depth up to 4 ft (DOE 1995d). To calculate heat loss for a combination of insulation depth and R-value, quadratic curves were fit through the data and the coefficients for each curve are listed in Table 3.36. The resulting quadratic Equation (3.25) gives the F-factor as a function of insulation depth. The applicable coefficients for Equation (3.25) are given in Table 3.37 and are determined by the insulation R-value. R-values range from R-0 to R-20.

Table 3.36. Slab-On-Grade Floor F-Factors

Insulation R-Value	F Factor (2-ft Insulation Depth)	F Factor (4-ft Insulation Depth
R-0	1.043	1.041
R-5	0.804	0.744
R-10	0.767	0.684
R-15	0.767	0.654
R-20 and Above	0.767	0.636

$$\text{F-factor} = \text{intercept} + \text{coef 1} \times \text{depth} + \text{coef 2} \times \text{depth}^2 \quad (3.25)$$

where depth is the distance the insulation extends downward (or downward and outward) in feet.

Table 3.37. Coefficients for Slab F-Factor Equation (3.25)

R-Value	intercept	coef 1	coef 2
R-0	1.042	0.0013	-0.0004
R-1	1.042	-0.0967	0.0144
R-2	1.042	-0.1293	0.0188
R-3	1.042	-0.1459	0.0207
R-4	1.042	-0.1562	0.0217
R-5	1.042	-0.1635	0.0223
R-6	1.042	-0.1692	0.0227
R-7	1.042	-0.1739	0.0230
R-8	1.042	-0.1781	0.0233
R-9	1.042	-0.1819	0.0236
R-10	1.042	-0.1855	0.0240
R-11	1.042	-0.1836	0.0231
R-12	1.042	-0.1819	0.0222
R-13	1.042	-0.1805	0.0215
R-14	1.042	-0.1792	0.0208
R-15	1.042	-0.1780	0.0203
R-16	1.042	-0.1770	0.0197
R-17	1.042	-0.1760	0.0193
R-18	1.042	-0.1751	0.0188
R-19	1.042	-0.1743	0.0184
R-20	1.042	-0.1735	0.0180

3.4 Solar Heat Gain Compliance

In addition to meeting the UA compliance some locations must also meet solar heat gain coefficient (SHGC) compliance for the fenestration components of a building.

To meet SHGC compliance the area-weighted average SHGC for a proposed building must be less than or equal to the code requirement. The user is responsible for entering the SHGC value for each window, skylight, and/or glass door. The SHGC for each assembly type is area-weighted then averaged for the building as a whole.

Section R402.5 of the IECC specifies mandatory maximum U-factor and SHGC limits.

RES*check* calculates the area-weighted average SHGC of all proposed fenestration components to comply with the requirements in IECC Section 402.6 as listed in Table 3.38. Proposed fenestration includes windows, skylights and doors with a glazing area exceeding 50%.

Table 3.38. Maximum U-Factor and SHGC Limits for Fenestration and Skylights

Fenestration			Skylight Max.
Climate Zone	Max. U-factor	Max. SHGC	U-factor
1, 2, 3	NA	0.50	NA
4, 5	0.48	NA	0.75
6, 7, 8	0.40	NA	0.75

4.0 Simulated Performance Alternative

4.1 Scope and Limitations

The RES*check* software allows a user to demonstrate energy code compliance by using either the IECC's Total UA Alternative (Section 402.1.4) or the Performance Alternative (Section 405). The Performance Alternative (performance path), determines compliance using simulated energy performance analysis. RES*check* uses the DOE-2 simulation engine for this purpose and implements the requirements of Section 405 that in effect allows for envelope assembly performance trade-offs and trade-offs due to solar heat gain coefficients (SHGC) and orientation. Compliance is calculated based on the annual energy cost of the proposed design and standard reference design models (referred to below as the proposed building and code building). If the energy cost factor of the proposed design is not greater than the energy cost factor of the code building energy cost factor then the project passes compliance in so far as the envelope thermal requirements are concerned.

Using the performance alternative requires additional inputs, including conditioned floor area, orientation of the building, a minimum of four walls having unique orientations, and a minimum of one roof and floor. The user-specified envelope data applicable to UA trade-off compliance are also used for defining the DOE-2 simulation inputs. The code requires that both the proposed and code building simulations are to apply the proposed mechanical equipment efficiency. In the RES*check* software the user can specify their proposed mechanical equipment however, it requires the equipment efficiency input to be equal to or better than the federal minimum requirements. The prevailing federal minimum equipment efficiency enforced in the software are detailed in Table 4.1.

Table 4.1. Federal Minimum Efficiency Requirements for Residential Mechanical Equipment

Equipment Type	Cooling Efficiency	Heating Efficiency
Forced Air Gas Furnace	NA	78.0 AFUE
Gas-Fired Steam Boiler	NA	75.0 AFUE
Other Boiler (Except Gas-Fired Steam)	NA	80.0 AFUE
Air Source Heat Pump	13.0 SEER	7.7 HSPF
Air-conditioner (Electric)	13.0 SEER	NA

Multifamily buildings and residences with multi-zone heating/cooling equipment are beyond the scope of the performance alternative implemented in RES*check*.

The simulation modeling approach provides no credit for the following building characteristics that could significantly impact energy performance:

- Projection factor
- Air tightness of the building envelope
- Sun rooms/passive solar characteristics
- Mechanical ventilation effectiveness
- Duct leakage
- Detailed equipment performance characteristics.

The process for creating the standard design model follows the specification provided in IECC Table 405.5.2(1) of the IECC. RES*check* assumptions for creating the DOE-2 simulation model for the proposed and standard designs are grouped into the following categories:

i. Climate data
ii. Building orientation and geometry
iii. Envelope components
iv. Internal gains (people, lights, occupancy schedule, etc.)
v. Infiltration and mechanical ventilation
vi. HVAC equipment
vii. Service water heating.

4.2 Climate Data

RES*check* uses typical meteorlogical year (TMY) weather data files for the DOE-2 simulation based on user input of state and city (or county) where the proposed house will be built. This state and city/county information is mapped to the closest matching weather station for which TMY weather data is available. RES*check* provides 280 TMY weather data files covering about 22,000 locations. These weather data files are available from the BECP web site for automatic downloading by the user when required by the DOE-2 simulation engine. Both the proposed and standard designs use the same TMY weather data.

4.3 Building Orientation and Geometry

The user must specify the orientation of the house by selecting the cardinal direction (or the angle from North) of the front face of the house. This building orientation is used in conjunction with the envelope component orientation (front, back, left, right) to provide the DOE-2 azimuth input for each component. At the building level, the building azimuth is specified as facing North and the envelope components azimuth are specified appropriately to represent the actual orientation.

RES*check* assumes a single-story home with an average ceiling height of 9 ft. and a square floor plan for both the proposed and standard designs. The conditioned floor area is multiplied by 9 ft. to calculate the building volume for the DOE-2 simulation. The conditioned floor area and volume are assumed to be the same for both the proposed and standard designs.

RES*check* uses a single story, single zone thermal model of the conditioned space for the DOE-2 simulation. An unconditioned attic zone is defined for all ceiling assemblies with a joist/truss/rafter structure supporting the roof. Floors over unconditioned space and slabs-on-grade are assumed to have an unconditioned space below grade.

4.4 Envelope Components

RES*check* input for envelope components typically includes the following:

- assembly type
- assembly area, or perimeter length (in the case of slabs/basement walls)

- insulation levels (one or more of the following)
  - cavity R-value
  - continuous R-value
  - U-factors
  - SHGC.
  - Insulation depth

Though this set of inputs is adequate for the UA trade-off calculation, this does not provide all of the necessary data for detailed component modeling in DOE-2 which requires thermal properties of each layer in the construction of the assembly. Rather than modeling each opaque assembly explicitly as individual construction layers and multiple parallel assemblies to account for thermal bridging effects, all non-earth-contact opaque assemblies are modeled in RES*check* as a single homogeneous layer having an overall U-factor and thermal mass matching the assembly it represents. This modeling approach enables matching the desired U-factor and thermal mass values without requiring additional details necessary to model individual layers. The assumptions for defining DOE-2 model geometry and thermal characteristics for each envelope assembly vary as described below.

4.4.1 Ceilings

RES*check* provides seven ceiling assembly types for the proposed design. The DOE-2 model geometry for each ceiling assembly is assumed to have a square surface representing the ceiling area or roof area depending on the assembly type. All ceiling assemblies with joist/truss/rafter as identified in Table 4.2 are assumed to have an attic. The attic roof area is calculated from the ceiling area assuming a 5/12 pitch, and roof area is equally distributed in roof components facing the four cardinal directions, making the configuration orientation neutral. Attic space volume is calculated assuming a gable roof and a truss span of 24 ft. measured perpendicular to the ridge. This set of assumptions leads to a roughly 5 ft. ridge height above the insulation and an average attic space height of 2.5 ft. The attic volume is then assumed to be 2.5 times the ceiling area. The attic is assumed to be unconditioned and modeled with identical geometry and material properties in both the proposed and standard designs. Roofs with no attic are assumed to have cathedral ceilings with a roof slope of 5/12, and the roof area is equally distributed along the four cardinal directions making the configuration orientation neutral.

Table 4.2. DOE-2 Modeling of RES*check* Ceiling Assemblies

RES*check* Ceiling Type	DOE-2 Model
Flat Ceiling or Scissor Truss	Attic
Raised or Energy Truss	Attic
Steel Truss	Attic
Steel Joist/Rafter	Attic
Cathedral Ceiling (no attic)	No Attic
Structural Insulated Panel	No Attic
Other	No Attic

Table 4.3 summarizes the DOE-2 input for ceiling/roof assemblies for the proposed and standard designs. All DOE-2 input of material properties, layer definitions and constructions except the assembly U-factor are the same for both the proposed and standard designs. The proposed U-factors for these assemblies are calculated by using the parallel path approach described in Equation (3.2).

Table 4.3. DOE-2 Input for Ceiling/Roof Assemblies

DOE-2 Input	Standard Design	Proposed Design
Area	Gross roof area	Net roof area as proposed excluding skylights
U-factor	From Code U-Factor Table	Based on the ceiling type and R-values entered by user
Density	Same as proposed design (lb/ft^3)	Based on ceiling assembly type as per Table 4.4 (lb/ft^3)
Absorptance	0.75	0.75
Specific Heat	0.2 Btu/lb-F	0.2 Btu/lb-F
Roughness	3 (DOE-2 code number)	3 (DOE-2 code number)
Thickness	5 in.	5 in.
Roof slope	22.6° (5/12 roof slope)	22.6° (5/12 roof slope)

The ceiling and roof material properties are defined by a single layer of homogenous material representing the combined properties of the various components of the proposed ceiling assembly. The exterior roof layer is assumed to consist of composition shingles over 5/8" plywood roof sheathing. The insulated flat ceiling assembly and the exterior roof assembly are both assumed to be 5 inches thick. The material density of all the layers is combined into one aggregate layer with a thickness of 5 inches, assuming a specific heat of 0.2 and an assembly heat capacity as listed in Table 4.4. The steel joist/truss and "Other" roof assemblies are assumed to have the same ceiling layer density as the wood joist/roof.

Table 4.4. DOE-2 Density Input for Ceiling/Roof Assemblies

Assembly Type	Assembly Layers	Density (lb/ft^3)	Assembly Heat Capacity (Btu/ft^2 F)
Ceiling with Attic (All-Wood Joist/Rafter/Truss and Raised Truss)	Batt or Blown Insulation (9 in., 93%) Wood Joists (9 in., 7%) 1/2-in. Gypsum Wall Board	4.80	2.00
Roof over Attic	Composition Shingles (1/8-in., 100%) Plywood (5/8-in., 100%)	3.33	1.39
Cathedral Ceiling (Roof/Ceiling, no attic)	Composition Shingles (1/8-in., 100%) Plywood (5/8-in., 100%) Batt or Blown Insulation (9 in., 93%) Wood Joists (9 in., 7%) 1/2-in. Gypsum Wall Board	5.94	2.47
Structural Insulated Panels (6" Thick)	Plywood (1/2-in., 100%) Expanded Polystyrene (4.5-in., 100%) Plywood (1/2-in., 100%) 1/2-in. Gypsum Wall Board	4.81	2.01

4.4.2 Skylights

The RES*check* input for skylights is specified as part of the ceiling/roof assemblies. The ceiling/roof assembly area represents the gross ceiling/roof area including the skylight area, if present.

In the proposed design, each skylight is attached to a ceiling/roof assembly, is defined by equally distributing the skylight area along the four cardinal orientations of a cathedral roof assembly, and all skylights are assumed to be square. If the proposed ceiling assembly has a joist/truss/rafter roof, then a fictitious cathedral roof with a 5/12 roof slope is defined for modeling the skylight. The skylight material properties are represented by defining a glass type with the user-specified U-factor for glass and frame conductance and shading coefficient based on the SHGC input.

4.4.3 Walls

Exterior walls in RES*check* are defined by the assembly type, gross wall area, cavity/continuous R-value (U-factor for *Other* walls) and orientation. All exterior walls are assumed to be of regular rectangular shape with an average wall height of 9 ft., and the wall width is calculated from the gross area as input by the user. The proposed design wall geometry represents each envelope assembly as entered by the user, whereas the standard design uses an aggregated geometry assuming wood-frame 2x6 (24 in. O.C.) construction with its area equally distributed on all four cardinal directions. For example, the proposed design may have two different wall assemblies present in each orientation with a varying amount of wall areas in each orientation, and this will be represented in the standard design as one wood frame wall with the total wall area distributed equally in each of the four cardinal orientations.

There are several wall assembly types available in RES*check* and each assembly type has a varying number of layers of construction. Each proposed wall assembly is represented as a single layer of 5 in. thickness with material properties as listed in Table 4.5 and Table 4.6.

Table 4.5. DOE-2 Input for Wall Assemblies

DOE-2 Input	Standard Design	Proposed Design
Area	Same as proposed design	Gross wall area
U-factor	From Code U-Factor Table	Based on the wall type and R-values entered by user
Orientation	Distributed equally on all four cardinal directions	As specified by user
Density	Same as proposed design (lb/ft^3)	Based on wall assembly type as per Table 4.6 (lb/ft^3)
Absorptance	0.75	0.75
Specific Heat	0.2 Btu/lb-F	0.2 Btu/lb-F
Roughness	5 (DOE-2 code number)	5 (DOE-2 code number)
Thickness	5 in.	5 in.

Table 4.6. Wall Assembly Density Inputs and Heat Capacities

Assembly Type	Assembly Layers	Density (lb/ft^3)	Assembly Heat Capacity (Btu/ft^2 F)
Wood Frame, 16" o.c.; Cavity Insulation <= 15	1/2-in. Plywood Siding 1/2-in. Sheathing 2x4 Wood Studs (3.5 in., 25%) Batt or Blown Insulation (3.5 in., 75%) 1/2-in. Gypsum Wall Board	31.44	2.62
Wood Frame, 16" o.c.; Cavity Insulation > 15	1/2-in. Plywood Siding 1/2-in. Sheathing 2x6 Wood Studs (5.5 in., 25%) Batt or Blown Insulation (5.5 in., 75%) 1/2-in. Gypsum Wall Board	38.76	3.23
Wood Frame, 24" o.c.; Cavity Insulation <= 15	1/2-in. Plywood Siding 1/2-in. Sheathing 2x4 Wood Studs (3.5 in., 22%) Batt or Blown Insulation (3.5 in., 78%) 1/2-in. Gypsum Wall Board	30.12	2.51
Wood Frame, 24" o.c.; Cavity Insulation > 15	1/2-in. Plywood Siding 1/2-in. Sheathing 2x6 Wood Studs (5.5 in., 22%) Batt or Blown Insulation (5.5 in., 78%) 1/2-in. Gypsum Wall Board	36.6	3.05
Steel Frame, 16" o.c.; Cavity Insulation <= 15	1/2-in. Plywood Siding 1/2-in. Sheathing 1.25-in. x 3.5-in. Steel Studs (22%) Batt or Blown Insulation (3.5 in., 78%) 1/2-in. Gypsum Wall Board	21.72	1.81
Steel Frame, 16" o.c.; Cavity Insulation > 15	1/2-in. Plywood Siding 1/2-in. Sheathing 1.25-in. x 5.5-in. Steel Studs (22%) Batt or Blown Insulation (5.5 in., 78%) 1/2-in. Gypsum Wall Board	23.04	1.92
Steel Frame, 24" o.c.; Cavity Insulation <= 15	1/2-in. Plywood Siding 1/2-in. Sheathing 1.25-in. x 3.5-in. Steel Studs (19%) Batt or Blown Insulation (3.5 in., 81%) 1/2-in. Gypsum Wall Board	21.6	1.80
Steel Frame, 24" o.c.; Cavity Insulation > 15	1/2-in. Plywood Siding 1/2-in. Sheathing 1.25-in. x 5.5-in. Steel Studs (19%) Batt or Blown Insulation (5.5 in., 81%) 1/2-in. Gypsum Wall Board	22.92	1.91
Solid Concrete or Masonry	6-in. Concrete, Sand and Gravel Aggregate 2x4 Wood Studs (3.5 in., 25%) Batt or Blown Insulation (3.5 in., 75%) 1/2-in. Gypsum Wall Board	210.0	17.50
CMU with Empty Cells	8-in. Medium-Weight Ungrouted Block 2x4 Wood Studs (3.5 in., 25%) Batt or Blown Insulation (3.5 in., 75%) 1/2-in. Gypsum Wall Board	116.28	9.69
CMU with Integral Insulation	8-in. Medium-Weight Ungrouted Block	121.32	10.11

Assembly Type	Assembly Layers	Density (lb/ft^3)	Assembly Heat Capacity (Btu/ft^2 F)
	Integral Loose-Fill CMU Insulation 2x4 Wood Studs (3.5 in., 25%) Batt or Blown Insulation (3.5 in., 75%) 1/2-in. Gypsum Wall Board		
Structural Insulated Panels (5" Thick)	Plywood Siding (1/2-in., 100%) Expanded Polystyrene (3.5-in., 100%) Plywood (1/2-in., 100%) 1/2-in. Gypsum Wall Board	23.52	1.96
Insulated Concrete Forms (8" Thick)	1/2-in. Plywood Siding (100%) 2-in. Expanded Polystyrene (100%) 4-in. Concrete (100%) 2-in. Expanded Polystyrene (100%) 1/2-in. Gypsum Wall Board	142.68	11.89

Note: Log-wall assembly densities are defined based on wood species type and normalized to 5 inch wall thickness, assuming default specific heat of 0.20.

4.4.4 Windows and Doors

The RES*check* inputs for windows and doors include the area, U-factor and SHGC (for windows and glazed doors). Windows are described by the framing type, glazing type and the number of panes. The DOE-2 geometry of windows is assumed to be rectangular with an average height of 4 ft., and doors are assumed to have an average height of 6.5 ft. The DOE-2 input for modeling windows and doors is summarized in Table 4.7.

For the proposed design, the window/door orientation is as specified by the user. For the standard design, the window/door area is equally distributed along each cardinal orientation. The total area of windows and glazed doors in the standard design is the same as the total area of windows and glazed doors in the proposed design, or 15% of conditioned floor area, whichever is less.

Window width is set to window area (either as input by the user or as stipulated for the standard design) divided by window height. This results in windows wider than the walls that contain them for window-to-wall ratios greater than 44%. This situation is very unlikely and will produce a warning from the DOE-2 simulation, but is not a terminal simulation error. Door width is set to the door area divided by the assumed door height of 6.5 ft.

The standard design glazing SHGC is set to match the code requirements and set to 0.40 for locations with no requirement. DOE-2 requires shading coefficient (SC), so all SHGC values are converted to SC using the following conversion factor:

$$SC = SHGC/0.87 \tag{4.1}$$

The SHGC may not be adjusted for interior blinds or curtains, as identical assumptions regarding interior shading devices and the schedule of their deployment are applied to the proposed and standard designs. No external shading devices can be specified and no projection factor credit is available.

Table 4.7. DOE-2 Input for Window and Door Assemblies

DOE-2 Input	Standard Design	Proposed Design
Area	Windows and glazed doors: As proposed or 18% of conditioned floor area whichever is smaller Opaque doors: 40 ft^2	As specified by user
U-factor	From Code U-Factor Table	As specified by user
SHGC	Code Requirement	As proposed (applicable only for windows and glazed doors)
Orientation	Windows and glazed doors: Distributed equally on all four cardinal directions Opaque doors: North	As specified by user
Number of Panes	Same as proposed design	Based on user-specified glazing type (applicable only for windows and glazed doors)

When 2009 IECC is the energy code, Table 404.5.2(1) allows application of an interior shading adjustment to both the proposed and standard designs to reflect the fact that occupants use curtains and blinds to reduce glare and unwanted solar heat gains. These are implemented using a shading schedule in DOE-2, which acts as a multiplier on glass shading coefficient but does not affect window conductance.

The shading schedule is as follows:

- Summer shading multiplier of 0.7 effective April 15 to Oct 15
- Winter shading multiplier of 0.85 effective Oct 16 to April 14.

These dates were selected to affect an appropriate division between hot and cold seasons for most locations and to provide an equal split between summer and winter schedules. Because shading schedules are applied equally to the proposed and standard designs, the schedule has no impact on the stringency of the code requirements related to shading coefficient.

When 2012, 2015, or 2018 IECC is the energy code, Table 404.5.2(1) allows consideration of interior shading (for the full year) to be a multiplier equal to 0.92-(0.21 * SHGC code requirement) for the code building and 0.92-(0.21 * proposed SHGC) for the proposed building model.

4.4.5 Basement Walls

Basement walls with an average depth of 50% or more below grade are input as one component including the above-grade portions of below-grade walls. DOE-2 modeling of basement walls is represented in three parts: (i) above-grade portion of walls, (ii) below-grade portion of walls and (iii) slab floor. The below grade wall model is based on a procedure developed by Winkleman (1998) using effective U-factor and defining fictitious layers to account for thermal mass effects of underground surfaces.

The basement wall construction is defined as consisting of four layers - a fictitious soil insulation layer, a foot of dirt layer, a concrete wall layer and an interior insulation layer. The thermal resistance of the fictitious soil insulation layer is calculated from the effective U-factor of basement walls determined from the F-factor of the wall assembly based on the depth below grade and the below grade insulation level using the thermal conductivity values for various insulation depths provided by Winkleman (1998). A fictitious floor slab with infinite thermal resistance is defined to model the basement floor. The area of the basement floor is calculated from the perimeter of the basement wall which is calculated from the gross wall area and assuming 8 ft. average wall height and using an aspect ratio of 1:1.5. Table 4.8 shows a summary of the DOE-2 inputs for basement walls.

If there are windows/doors in the basement walls, they are modeled in the proposed design as individual windows/doors attached to the walls, similar to the above grade wall model. However, the standard design does not include any windows/doors. The basement window/door areas are included with the above-grade window/door areas in the standard design and are subject to the fenestration area limitation and are distributed equally along the four cardinal orientations.

Table 4.8. DOE-2 Input for Basement Wall Assemblies

DOE-2 Input	Standard Design	Proposed Design
Area	Same as proposed design	Gross wall area
U-factor	As per U-Factor Requirement Table of the IECC	Based on the wall type, average wall height, depth below grade and depth of insulation and R-values entered by user
Density	Same as proposed design (lb/ft^3)	Based on wall assembly type as per Table 4.9 (lb/ft^3)
Absorptance	0.7	0.7
Specific Heat	0.2 Btu/lb-F	0.2 Btu/lb-F
Roughness	2 (DOE-2 code number)	2 (DOE-2 code number)
Thickness	8 in.	8 in.

Table 4.9. Basement Wall Assembly Density Inputs and Heat Capacities

Assembly Type	Assembly Layers	Density (lb/ft^3)	Assembly Heat Capacity (Btu/ft^2 F)
Solid Concrete or Masonry	8-in. Concrete, Sand and Gravel Aggregate 1-1/2-in. Expanded Polystyrene (100%)	248.52	20.71
CMU with Empty Cells	8-in. Medium-Weight Ungrouted Block 1-1/2-in. Expanded Polystyrene (100%)	92.88	7.74
CMU with Integral Insulation	8-in. Medium-Weight Ungrouted Block Integral Loose-Fill CMU Insulation 1-1/2-in. Expanded Polystyrene (100%)	97.92	8.16
Wood Frame	3/4-in. Plywood 2x6 Wood Studs (5.5 in., 25%) Batt or Blown Insulation (5.5 in., 75%)	27.24	2.27
Insulated Concrete Forms	1/2-in. Plywood (100%) 2-in. Expanded Polystyrene (100%) 4-in. Concrete (100%) 2-in. Expanded Polystyrene (100%)	131.04	10.92

4.4.6 Crawl Walls

The crawl walls of conditioned crawl spaces are modeled with geometry and material properties assumptions similar to that of basement walls described above except that the floor slab construction is replaced with a single layer of one foot of dirt. Crawl walls are assumed to have an average wall height of 4 ft. for calculating the floor perimeter and area.

4.4.7 Slab-On-Grade

The slab-on-grade perimeter entered by the user is assumed to be rectangular with an aspect ratio of 1.5:1 and the perimeter is converted to area using the aspect ratio. The slab perimeter is assumed to be the same in both the proposed and standard designs. The slab construction is represented by three layers: earth, a fictitious layer of insulation and the concrete slab. The fictitious layer is assumed to have infinite resistance (1000.0), the earth layer is assumed to have unit conductivity, and the concrete slab is assumed to have a conductivity of 0.7576 (taken from the DOE-2 material library). The slab construction is defined with an effective U-factor (slab F-factor) as per the modeling procedure developed by Winkleman (1998). The F-factor of the proposed design is based on the slab insulation thermal resistance and depth of insulation. The F-factors are assumed to be the same for both heated and unheated slabs. The standard design F-factor is determined based on the slab R-value and depth requirement specified in Table 402.1.1 of the 2006 IECC.

4.4.8 Floors Above Unconditioned Space

All floors are assumed to be square and modeled as one layer of construction with composite material properties as summarized in Table 4.10. The floor density is calculated based on the heat capacity as shown in Table 4.11. *Steel Joist* floors and *Other* floors are assumed to have the same heat capacity as *Wood-Framed* floors. Floors over unconditioned spaces are modeled as adjacent to an unconditioned space by defining an unconditioned zone with fictitious walls and floors made of one foot of dirt using the basement and slab modeling procedure developed by Winkleman (1988).

Table 4.10. DOE-2 Input for Floor Assemblies

DOE-2 Input	Standard Design	Proposed Design
Area	Same as proposed design	Floor area
U-factor	As per Table 402.1.3 of the 2006 IECC	Based on the floor type and R-values entered by user
Density	Same as proposed design (lb/ft^3)	Based on floor assembly type as per Table 4.11 (lb/ft^3)
Absorptance	0.7	0.7
Specific Heat	0.2 Btu/lb-F	0.2 Btu/lb-F
Roughness	2 (DOE-2 code number)	2 (DOE-2 code number)
Thickness	5 in.	5 in.

Table 4.11. Floor Assembly Density Inputs and Heat Capacities

Assembly Type	Assembly Layers	Density (lb/ft^3)	Assembly Heat Capacity (Btu/ft^2 F)
All-Wood Joist/Truss	Batt or Blown Insulation 2x Structural Wood Framing 3/4-in. Plywood Subfloor Carpet with Rubber Pad	26.64	2.22
Structural Insulated Panels (6" Thick)	Plywood (1/2-in., 100%) Expanded Polystyrene (4.5-in., 100%) Plywood (1/2-in., 100%) Carpet with Rubber Pad	15.60	1.30

4.5 Internal Gains

The same internal load density, occupant loads and schedules are assumed for both the proposed and the standard designs.

Table R405.5.2(1) (in 2009 IECC refer to Table 405.5.2(1)) of the code specifies the internal gains as a function of conditioned floor area and the number of bedrooms. The following formula is used assuming 3 bedrooms.

$$IntGain_{\text{total}} = (17{,}900 + 4{,}104 \text{ x } 3) + (23.8 \text{ x } CFA) \quad (4.2)$$

where $IntGain_{total}$ is the total internal sensible gains for lights, appliances, and people, and CFA is the conditioned floor area of the dwelling.

The IECC does not separate sensible and latent loads. In order to account for latent load, RES*check* assumes 20% of total gain as latent load consistent with the Residential Energy Services Network's RESNET Standards Section 303.5.1.3 (RESNET, 2006). Both latent and sensible gains are based on the same internal load schedule as shown in Table 4.12. The sensible heat gains from lights, appliances, and occupants is implemented using the lighting loads input in DOE-2, and the latent heat gains from cooking, bathing, and occupants are implemented using the equipment latent loads input in DOE-2.

Sensible (80% of total) and latent (20% of total) heat gains due to occupant load are represented by a total of 400 Btu/h with the occupancy schedule shown in Table 4.13. The internal mass is assumed to be 8 lb/ft^2 of furniture as specified in the IECC and modeled identically in both the proposed and the standard designs.

Table 4.12. Internal Load Schedule

Hour	Percent	Hour	Percent	Hour	Percent
1	0.16	9	0.19	17	0.34
2	0.15	10	0.16	18	0.55
3	0.16	11	0.12	19	0.55
4	0.18	12	0.11	20	0.88
5	0.23	13	0.16	21	1.00
6	0.45	14	0.17	22	0.86
7	0.40	15	0.25	23	0.51
8	0.26	16	0.27	24	0.28

Table 4.13. Occupancy Schedule

Hour	Percent
1-5	0.85
6-8	1.00
9-15	0.50
16	0.85
17	0.90
18-22	1.00
23-24	0.85

4.6 Infiltration and Mechanical Ventilation

The DOE-2 model for both the proposed and the standard designs uses the infiltration requirements specified in Table R405.5.2(1) (in 2009 IECC refer to Table 405.5.2(1))of the code for the standard design and no mechanical ventilation is modeled. The DOE-2 infiltration model uses the Sherman-Grimsrud methodology with a fractional leakage area (or Specified Leakage Area, SLA) of 0.00036, assuming no energy recovery.

4.7 HVAC Equipment

Table 4.1 of this document shows the five equipment types supported in RES*check.* The mechanical equipment model uses the DOE-2 "RESYS" system type. This system type is adequate for single zone models and supports infiltration modeling and duct losses. For the proposed and standard design, the user-entered heating and cooling efficiencies are implemented. The software user interface enforces that equipment efficiencies are at or above the federal minimum standard.

The equipment efficiency and performance curve fit coefficients are adapted from Building America Performance Analysis Procedures (NREL 2004) and example DOE-2 input files provided by the Building America teams. These system variables are defined to have the same values for both the proposed and the standard designs as detailed in Table 4.14. Space thermostat set points are defaulted to 68ºF for heating and 78ºF for cooling. These set points are identical in both the proposed and the standard designs as per code requirements. No set back thermostats are assumed in the simulation model. The seasonal availability of equipment is defined based on the climate zones with schedules for heating and cooling as shown in Table 4.15 and Table 4.16.

The DOE-2 systems model uses auto-sizing to determine the capacity of heating and cooling equipment based on the thermal loads. That is, the peak system loads are adjusted using the DOE-2 system sizing option to account for the difference between the thermostat set point assumptions between the loads (constant 73°F) and systems (68ºF for heating and 78ºF for cooling) parts of DOE-2 simulation. The systems model assumes that distribution ducts are located in unconditioned spaces. A default distribution system efficiency of 0.88 is used for both the heating and cooling systems.

Table 4.14. DOE-2 Systems Definition Variables

DOE-2 Variable	Value	Description
COOLING-EIR	0.941/(SEER/3.413)	Based on cooling equipment efficiency provided in SEER
	0.582/(HSPF/3.413)	For heat pump heating efficiency provided in HSPF
HEATING-EIR	For AFUE > 0.835 1.0/((1.1116*AFUE) – 0.098185)) For AFUE <= 0.835 1.0/((0.2907*AFUE) + 0.5787)	For furnaces and boilers, heating efficiency AFUE provided as a fraction
COOL-EIR-FPLR	0.000352822, 1.19199, -0.246716, 0.0546566	Coefficients defined for REVPLR parameter with curve type: *Cubic*
HEAT-EIR-FPLR	0.000352822, 1.19199, -0.246716, 0.0546566	For heat pumps, coefficients defined for RHTFPLR parameter, with curve type: *Cubic*
	0.011771251, 0.98061775, 0.11783017, -0.11032275	For furnaces and boilers, coefficients defined for FRFPLR parameter, with curve type: *Cubic*
COOL-EIR-FT	((67, 95, 1.0), (67, 82, Neirb), (67, 110, 1.174), (67, 105, 1.113), (67, 70, Neiradj), (80, 95, 0.897), (50, 95, 1.070))	Data defined for COOL-EIR-SEER parameter with curve type: *Bi-quadratic Neirb and Neiradj* are calculated based on cooling efficiency, supply fan power and delta-T

Table 4.15. Heating Equipment Availability Schedule

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	**ON**	**ON**	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	**ON**
2	**ON**	**ON**	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	**ON**
3	**ON**	**ON**	**ON**	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	**ON**	**ON**
4	**ON**	**ON**	**ON**	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	**ON**	**ON**	**ON**
5	**ON**	**ON**	**ON**	**ON**	*OFF*	*OFF*	*OFF*	*OFF*	**ON**	**ON**	**ON**	**ON**
6	**ON**	**ON**	**ON**	**ON**	**ON**	*OFF*	*OFF*	*OFF*	**ON**	**ON**	**ON**	**ON**
7	**ON**	**ON**	**ON**	**ON**	**ON**	*OFF*	*OFF*	*OFF*	**ON**	**ON**	**ON**	**ON**
8	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**

Table 4.16. Cooling Equipment Availability Schedule

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**
2	*OFF*	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	*OFF*
3	*OFF*	*OFF*	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	*OFF*	*OFF*
4	*OFF*	*OFF*	*OFF*	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	*OFF*	*OFF*	*OFF*
5	*OFF*	*OFF*	*OFF*	*OFF*	**ON**	**ON**	**ON**	**ON**	**ON**	*OFF*	*OFF*	*OFF*
6	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	**ON**	**ON**	**ON**	**ON**	*OFF*	*OFF*	*OFF*
7	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	**ON**	**ON**	*OFF*	*OFF*	*OFF*	*OFF*
8	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*	*OFF*

4.8 Service Water Heating

No hot water equipment is modeled for simulation, but water heater annual energy consumption is calculated assuming a natural gas water heater and it is included in determining the annual energy cost.

The energy consumption of a water heater is a function of the hot water load and the efficiency of the heater. Hot water usage is calculated using the following equation:

$$G_{dhw} = 30 + (10 \text{ x } N_{br}) \tag{4.3}$$

where G_{dhw} is water use (gal/day) and N_{br} is the number of bedrooms (assumed to be 3).

In order to calculate the hot water load, the water usage is converted to Btu/day:

$$L^{dhw} = G^{dhw} \times HC \times (T_{set} - T^{inlet}) \tag{4.4}$$

where

L_{dhw}	=	daily water heating load (Btu)
T_{inlet}	=	average inlet temperature of water in °F, default is 67°F
T_{set}	=	hot water temperature set point in °F, assumed to be 120°F
HC	=	heat capacity of water (Btu/gal-°F), assumed to be 8.34

The average inlet water temperature (T_{inlet}) is assumed to be the same as the average ground temperature extracted from the TMY or TMY2 weather file data. The annual energy consumption is estimated by dividing the hot water load by the heater's energy factor and summing over the days in a year:

$$E_{dhw} = 365 \times \frac{L_{dhw}}{EF} \tag{4.5}$$

where E_{dhw} is the annual energy consumption of a water heater (Btu) and EF is the energy factor of a water heater.

The energy factor of the water heater is calculated assuming a natural gas water heater and using the following equation from Table 404.2 of the IECC:

$$EF = 0.62 - 0.0019 \times V \tag{4.6}$$

where V is the rated storage volume of the hot water tank (gal), assumed to be 40 gallons

The water heating energy is assumed to be the same for both the proposed and standard designs. There is no trade-off available in RES*check* to allow improved water heater efficiency to be credited against the proposed design's insulation requirements.

4.9 Compliance Determination

The RES*check* compliance index is calculated comparing the annual energy cost of the proposed design to that of the standard design. The annual energy cost is calculated from the DOE-2 plant summary reports of energy use by fuel type and using the state average fuel prices available from EIA's State Energy Price and Expenditure Report (EIA 2003), duplicated in Table 4.17. The compliance index calculation includes the heating and cooling equipment energy use from DOE-2 simulation and service water heating energy use calculated as per 4.8. The compliance index is calculated using the formula shown below:

$$\text{PCI} = 100 * (\text{STDEC} - \text{PDEC}) / \text{STDEC} \tag{4.7}$$

where

PCI = RES*check* Performance Compliance Index (%)
PDEC = Design Energy Cost of the Proposed Design ($)
STDEC = Design Energy Cost of the Standard Design ($)

Table 4.17. State Average Fuel Prices for Natural Gas and Electricity (EIA 2003)

State	Natural Gas $/therm	Electricity $/kWh	State	Natural Gas $/therm	Electricity $/kWh
Alabama	1.192	0.074	Montana	0.716	0.076
Alaska	0.433	0.12	Nebraska	0.783	0.069
Arizona	1.129	0.083	Nevada	0.879	0.09
Arkansas	0.982	0.072	New Hampshire	1.203	0.120
California	0.894	0.12	New Jersey	0.814	0.107
Colorado	0.662	0.081	New Mexico	0.831	0.087
Connecticut	1.270	0.113	New York	1.109	0.143
Delaware	1.009	0.086	North Carolina	1.099	0.083
District of Columbia	1.294	0.078	North Dakota	0.747	0.065
Florida	1.501	0.086	Ohio	0.891	0.083
Georgia	1.135	0.077	Oklahoma	0.858	0.075
Hawaii	2.605	0.167	Oregon	0.950	0.071
Idaho	0.740	0.062	Pennsylvania	1.032	0.096
Illinois	0.865	0.084	Rhode Island	1.150	0.116
Indiana	0.914	0.07	South Carolina	1.105	0.080
Iowa	0.906	0.086	South Dakota	0.830	0.075
Kansas	0.859	0.077	Tennessee	0.931	0.065
Kentucky	0.889	0.058	Texas	0.795	0.092

Louisiana	0.979	0.078	Utah	0.689	0.069
Maine	1.065	0.124	Vermont	0.999	0.128
Maryland	1.069	0.077	Virginia	1.143	0.078
Massachusetts	1.190	0.116	Washington	0.825	0.063
Michigan	0.732	0.084	West Virginia	0.850	0.062
Minnesota	0.849	0.076	Wisconsin	0.919	0.087
Mississippi	0.993	0.076	Wyoming	0.680	0.070
Missouri	0.933	0.070			

5.0 Weather Data Used in the Software

The RES*check* software allows the user to select from a list of cities or a list of counties in each state. The "cities" version contains weather data for over 22,000 cities. The "counties" version requires the user to select a county, not a city.

The cities' weather data included with the software comes from the Populated Places (PPL) database which is part of the Geographic Names Information System of the U.S. Geological Survey (USGS 2000) The methodology for selecting locations to include in the software was principally determined on population estimates. More specifically, if a location had a "<1" designator (which indicates low or unknown population) then it was not included in the final list of locations. Longitude and latitude coordinates were used from the PPL to identity National Oceanic and Atmospheric Administration (NOAA) locations. The NOAA location data include heating and cooling degree days and served to identify the nearest TMY weather data sites. The TMY sites were mapped to their appropriate TMY2 weather files to use when exercising DOE-2 energy performance simulations.

The 2006 IECC introduced a new set of climate zones and moisture regimes. These have remained unchanged in newer versions of the IECC and have been integrated into the "cities" and "counties" weather location files discussed above. City zones and moisture regimes are identical to those associated with the county the city resides within.

6.0 Compliance Determination and Reports

The compliance certificate report identifies all the user specified data necessary for determining energy code compliance including the method of compliance that was selected. If the “Total UA” method was selected then the results will state “Passes/Fails on UA”, otherwise it will state “Passes/Fails on Performance Alternative”. Locations that have SHGC requirements will be output to the compliance certificate as well.

The computation of the compliance index is shown in Equation (6.1). If proposed building Total UA is less than or equal to code building Total UA the absolute value result will be shown as a “+” index otherwise a “-“ index will be applied to the index.

$$\text{Compliance index} = \text{Abs}((1.0 - \text{PBTUA} / \text{CBTUA}) * 100.0) \tag{6.1}$$

where PBTUA = Proposed Building Total UA and CBTUA = Code Building Total UA.

The Inspection Checklist is generally structured for the benefit of the code official tasked with handling plan reviews and site visits. More specifically, inspection checklists are organized by stage-of-construction: Pre-inspection/Plan Review, Foundation Inspection, Framing/Rough-In Inspection, Insulation Inspection, and Final Inspection. To the extent possible the listed requirements are specific to the project details provided by the user.

The ‘Panel Certificate’ summarizes the envelope insulation levels and equipment efficiency levels as required by Section R401.3 of the IECC in a 5”x7” label format that can be placed on or near the main electrical panel.

7.0 Additions and Alterations

RES*check* supports addition/alteration projects. A set of exemptions is available for alteration projects. Depending upon the assemblies entered, these exemptions are displayed from which the user identifies those that apply. The software lists the exemptions in the compliance reports but does not include exempted assemblies in the compliance determination. If no exemption applies to an assembly, RES*check* applies the proposed and required U-factors in the UA trade-off algorithms. The exemptions include:

- Storm windows installed over existing fenestration
- Glass only replacements in an existing sash and frame
- Existing ceiling, wall or floor cavities exposed during construction provided that these cavities are filled with insulation
- Construction where the existing roof, wall or floor cavity is not exposed.

All addition projects are evaluated using the Total UA method. The Total UA alternative is used for 2009/2012 IECC alteration projects. The prescriptive U-factor alternative is used to determine compliance for 2015/2018 IECC. Prescriptive U-factor alternative does not consider envelope assembly trade-offs; each assembly has to be in compliance on its own merit.

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Appendix A

Florida

Appendix A

Florida

RES*check* implements the “2017 Florida Building Code, Energy Conservation”, based on the 2015 IECC.

Florida implements an Energy Performance Level card in place of the Energy Compliance Panel certificate and does not allow the use of RES*check* support for the Performance Alternative. Climate Zone 1 fenestration U-factors are modified to reflect “Not Required”. For these units RES*check* sets the Required U-factor equal to the proposed U-factor so that tradable credit does not occur.

The Inspection Checklist differs from 2015 IECC in the following sections, as requested by the state:

- Duct Construction
- Wall Insulation
- Air Leakage
- Controls
- HVAC Equipment
- Air-Handling-Units
- Ventilation
- Pool/Spa Heater Efficiency and Controls.

Appendix B

Georgia

Appendix B

Georgia

RES*check* implements the “2011 Georgia State Minimum Standard Energy Code”, based on the 2009 IECC. Georgia Table 402.1.1 combines and amends the 2009 IECC R-value and U-factor requirements tables. Georgia Table 402.1.4 Summary of Minimum Insulation R-values and Maximum U-Factors for Envelope Components When Trade-Offs Are Used represents an absolute minimum or “backstop” level of component thermal conductivity.

To address the kneewall mandatory requirement, an additional construction detail was added for wood and steel framed walls that identifies the wall as kneewall if applicable.

The Inspection Checklist differs from 2009 IECC in the following sections, as requested by the state:

- Duct and Envelope Tightness
- Air Leakage
- Power Attic Ventilation
- Lighting Equipment.

Appendix C

Massachusetts

Appendix C

Massachusetts

RES*check* implements the “780 CMR 51.00: Massachusetts Residential Code, 9th Edition, Energy Efficiency”, based on the 2015 IECC. The Massachusetts code requires fenestration U-0.30.

The Inspection Checklist differs from 2015 IECC in the following sections, as requested by the state:

- Duct and Envelope Tightness
- Ventilation
- Solar Readiness.

Appendix D

New York City

Appendix D

New York City

RES*check* implements the "2016 New York City Energy Conservation Code" (NYCECC), based on the 2015 IECC. NYCECC amended the application of Table R402.1.4 Equivalent U-Factors table such that when complying with the NYCECC the requirements applicable to Climate Zone 6 are to apply excepting ceiling and skylight U-factors.

The Inspection Checklist differs from 2015 IECC in the following sections, as requested by the state:

- Blower Door Testing
- Solar Readiness
- Fireplace Tightness
- Outdoor Pools
- Dwelling Unit Metering.

Appendix E

North Carolina

Appendix E

North Carolina

RES*check* implements the “2012 North Carolina Energy Conservation Code” (NCECC), based on the 2009 IECC. The NCECC makes changes to Climate Zone 3 fenestration and basement wall U-factors and the above-grade frame wall U-factors in Climate Zones 4 and 5. Maximum or “backstop” U-factor and SHGC requirements are applicable in NCECC.

The Inspection Checklist differs from 2009 IECC in the following sections, as requested by the state:

- Floor and Slab-On-Grade Insulation
- Sunroom Insulation
- Crawl Space Wall Insulation
- Air Sealing
- Controls
- Duct and Envelope Tightness
- Poor Covers
- Lighting Equipment.

Appendix F

Puerto Rico

Appendix F

Puerto Rico

RES*check* implements the "Puerto Rico Residential Energy Code" (PRREC), based on the 2009 IECC. The PRREC makes available a mechanism to adjust the required SHGC depending on fenestration orientation and projection factors. Required U-factors are generally less stringent than the 2009 IECC requirements.

The Inspection Checklist differs from 2009 IECC in the following sections, as requested by the state:

- Envelope and Fenestration Air Leakage
- Cool Roof
- Pools
- Solar Water Heaters
- Provisions for Renewable Energy.

Appendix G

Utah

Appendix G

Utah

RES*check* implements the “Utah Energy Conservation Code” (UECC), based on the 2012 IECC. Amended U-factor requirements for UECC are shown in Table G.1. Requirement allowances for ceilings with and without attic spaces, and fenestration that were permitted in 2006 IECC but disallowed in 2012 IECC are once again permitted in UECC. The italicized values in Table G.1 reflect requirements that are amended from 2012 IECC.

Table G.1. Equivalent U-Factors

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Ceiling U-Factor	Frame Wall U-Factor	Mass Wall U-Factor	Floor U-Factor	Basement Wall U-Factor	Crawl Space Wall U-Factor
3	*0.65*	*0.65*	*0.035*	*0.082*	*0.141*	0.047	*0.360*	0.136
5	*0.35*	*0.60*	*0.030*	*0.060*	0.082	0.033	*0.059*	*0.065*
6	*0.35*	*0.60*	0.026	*0.060*	0.060	0.033	*0.059*	*0.065*

The UECC allows the performance simulation alternative to trade-off credit between HVAC equipment and envelope assemblies. The stipulation for doing so is that at least one of the HVAC equipment specified must be better than federal minimum efficiency standards.

The Inspection Checklist differs from 2012 IECC in the following sections, as requested by the state:

- Duct Insulation and Testing
- Air Leakage
- Pipe Insulation
- Mechanical Ventilation
- Lighting Equipment.

Appendix H

Vermont

Appendix H

Vermont

RES*check* implements the "2011 Vermont Residential Building Energy Standards" (VRBES), based on the 2009 IECC. Vermont requested that the requirement U-factors to apply when using VRBES were to be recomputed based on the prescriptive R-value requirements. The recalculation was to be done using RES*check*. This would ensure that prescriptive R-values were consistent with equivalent U-factor requirements. The results from this effort are reported in Table H.1.

Table H.1. Equivalent U-Factors

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Ceiling U-Factor	Frame Wall U-Factor	Mass Wall U-Factor	Floor U-Factor	Basement Wall U-Factor	Crawl Space Wall U-Factor
6	0.35	0.60	0.026	0.057	0.057	0.033	0.050	0.050

The Inspection Checklist differs from 2009 IECC in the following sections, as requested by the state:

- Insulation Installation
- Duct Insulation and Testing
- Air Leakage
- Sunroom
- Vapor Retarders
- Thermostat Controls
- Circulating Hot Water Systems
- Electric Resistance Heating Equipment
- Equipment Sizing
- Lighting Equipment.

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