WASHINGTON STATE UNIVERSITY
Energy Program

2018-2021 Washington State Energy Code-Residential FAQs: U-Factors for Non-Prescriptive Building Assemblies

What is a U-factor? What is an R-value?

The U-factor measures the rate of heat transfer through a material, while R-value measures how much resistance a material has to heat transfer. Both quantify the energy efficiency of a building material or assembly, although through different means.

The U-factor is directly proportional to the heat loss (or gain) through a building assembly for a given area and temperature difference across the wall. This means *the lower* the U-factor, *the better* insulated the assembly is.

The U-factor is used to calculate heat loss through an assembly with this equation:

Heat Loss = U-factor x Area x (Indoor Temperature - Outdoor Temperature)

The R-value is the inverse of the U-factor. That is, the *greater* the R-value, the *better* the insulation is. The R-value and U-factor are related by the equations:

R – value = 1/U-factor

and equivalently

U – factor = 1/R – value

For example, if a window has a U-factor of 0.20, then its R-value is equal to 1 divided by 0.2 – or 5. As another example, a wall with a U-value of 0.05 has an R-value of 1 divided by 0.05 – or 20.

By convention, the insulating value of windows, walls and other *assemblies* is generally quantified by U-factors and the insulating value of insulation and other building *materials* is generally quantified by R-values. This is just convention and either quantity conveys the same information. One can be converted into the other for easier comparison.

Which compliance paths require meeting U-factor requirements in Table R402.1.2?

First a bit of background on compliance paths is helpful. For more on WSEC-R compliance paths, refer to our FAQ on this topic on our website.

Briefly, the Washington State Energy Code, Residential (WSEC-R) permits designers to select between several alternatives in meeting the code. A home designer may choose, for example, to follow U-factor requirements in selecting insulation materials and construction types for building components, which may allow greater flexibility of design. Alternatively, they may choose to select from pre-defined prescriptive constructions that meet requirements, for example, which may be more straightforward but less flexible. Compliance paths are defined in the energy code in Section R401.2 "Compliance." There are a total of **five** compliance paths. As summarized in Table 1, in 2021 WSEC-R these are:

- **U-factor Path:** Section R401.2 "*Insulation and fenestration criteria*" refers to U-factor requirements in Table R402.1.2. For example, if following this path, a floor must be insulated such that the U-factor of the floor assembly is 0.029 or less.
- **R-value Alternative or Prescriptive Path:** Sections R401.3 "*R-value alternative*" refers to prescriptive requirements for building components in Table R402.1.3 and to requirements for R-value computation in Section R401.4. For example, if following this path, the joist cavities of framed floors must be insulated with R-30 insulation.
- **Total UA Alternative:** Section R401.4 "*Total UA alternative"* the proposed UA of your design must be equal to or less than the target UA. The proposed UA of the building's thermal envelope is calculated according to WSEC-R Equation 2 and compared to a target UA, which is calculated according to WSEC-R Equation 1.
- **Total Building Performance Path:** *Section R405* "*Total Building Performance"* establishes criteria for compliance using total building performance software to simulate the energy use of your proposed design and compare it to the simulated energy use of a standard reference design.
- **Passive House Certification Path:** *Section R407* "*Certified Passive House"* requires compliance with PHIUS+ Passive Building Standard. For more information, refer to the website of the Passive House Institute of the United States (PHIUS) at https://www.phius.org/.

Table 1. Summary of five compliance paths in 2021 WSEC-R

Path No.*	Description	Defining Section	Referenced Summary Table, Equations or Standard	Section R406 Credits Required?
1a	U-Factor Path	R402.1.2	Table R402.1.2 (U-factors)	For dwelling and sleeping units
1b	R-value Alternative or Prescriptive Path	R402.1.3 and R402.1.4	Table R402.1.3	For dwelling and sleeping units
1c	Total UA Alternative	R402.1.5	Table R402.1.2 (U-factors), Eq. 1 for Target UA, Eq. 2 for Proposed UA	For dwelling and sleeping units
2	Total Building Performance Path or Simulated Performance Path	R405	Table R402.1.2 (U-factors), Table R405.2(1) for Standard Reference	No
3	Passive House Certification	R407	PHIUS+ 2018 Passive Building Standard **	No

* Per Section 401.2 "Compliance". Path 1 has three distinct paths defined within it, which can be numbered 1a, 1b and 1c, for convenience.

** PHIUS+ 2018 Passive Building Standard https://www.phius.org/

The three compliance paths that require meeting the U-factor requirements in Table R402.1.2 are:

- U-factor Path
- Total UA Alternative
- Total Building Performance Path

Do I have to calculate U-factors for my building design? No

Both the 2018 and 2021 versions of the WSEC-R define standard prescriptive building assemblies that meet baseline energy code requirements (refer to Table R402.1.1 in 2018 and Table R402.1.3 in 2021). These typical constructions were defined for convenience in meeting code requirements. That is, if you choose to follow the R-value Alternative or Prescriptive Path, you do not necessarily need to worry about determining the U-factor of your assembly.

For example, in 2021 WSEC-R, there are two prescriptive constructions for above-grade walls:

- "20+5" in Table R402.1.3 refers to R-20 cavity insulation plus R-5 continuous insulation

- "13+10" in Table R402.1.3 refers to R-13 cavity insulation plus R-10 continuous insulation[1]

For ceiling insulation, the prescriptive construction is defined as "R-60". No framing requirement is specified, which means standard-framing (i.e., tapering of insulation depth around the perimeter) is allowed.

Where do I look first when I need to determine the U-factor of my assembly? Appendix A

If you choose not to use prescriptive requirements of the R-value Alternative, you have the extra task of determining the U-factor (or F-factor for slabs) "from measurement, calculation or an approved source" (see footnote "a" to Table R402.1.2). The problem then becomes a matter of finding the appropriate sources of U-factors, calculating the U-factor using an approved method, or using an approved calculator. By "approved" it is meant that you will need to submit your sources, references, calculations, and/or calculator results to your building official for their review to obtain their approval.

The first reference to check is Appendix A of the WSEC-R itself where you will find the U-factors of many common building assemblies. Section R402.1.5 states that values from Appendix A "shall be used for all calculations" unless the "proposed construction assemblies are not represented in Appendix A." This means the U-factors you look up in Appendix A will be always accepted by building officials (assuming your assembly corresponds correctly to the value you select from the table.)

For example, from Table A103.3.1(5), you will find that an intermediate-framed 2x6 above-grade wall with R-21 fiberglass batt cavity insulation without continuous insulation and T1-11 siding has a U-value of 0.056, which meets the baseline requirements for 2021 WSEC-R (circled in red in Figure 1 below). As a second example, a 2x4 wall with standard framing requires R-15 cavity insulation with R-4 continuous insulation to achieve a U-factor of 0.056, as shown in Figure 2 below.[2]

[1] In 2021 WSEC there is not a requirement for intermediate framing. Descriptions of standard, intermediate and advanced framing are given in Appendix A Section A103.2.

[2] Standard, intermediate and advanced-framed walls are described in WSEC-R Appendix A Section A103.2 "Framing Description". For example, intermediate-framed walls have "studs framed on 16-inch centers with double top plate and single bottom plate. Corners use two studs or other means of fully insulating corners, and each opening is framed by two studs. Headers consist of double 2x material with R-10 insulation. Interior partition wall /exterior wall intersections are fully insulated in the exterior wall."

Figure 1. Extract from WSEC-R Appendix A Table A103.3.1(5) for 2x6 single stud walls with R-21 batt cavity insulation. Value, for example meeting U-factor requirement for above-grade walls is circled.

TABLE A103.3.1(5)
2 x 6 Single Wood Stud: R-21 Batt

NOTE:	Siding Material/Framing Type						
	R-value of Foam Board	Lapped Wood			T1-11		
		STD	INT	ADV	STD	INT	ADV
Nominal Batt R-value:	0	0.057	0.054	0.051	0.060	0.056	0.053
R-21 at 5.5 inch thickness	1	0.054	0.051	0.048	0.056	0.053	0.050
	2	0.050	0.048	0.045	0.052	0.050	0.047

Figure 2. Extract from WSEC-R Appendix A Table A103.3.1(3) for 2x4 single stud walls with R-15 batt cavity insulation. Value, for example meeting U-factor requirement for above-grade walls is circled.

TABLE A103.3.1(3)
2 x 4 Single Wood Stud: R-15 Batt

NOTE:	Siding Material/Framing Type				
	R-value of Foam Board	Lapped Wood		T1-11	
		STD	ADV	STD	ADV
Nominal Batt R-value:	0	0.076	0.071	0.081	0.075
R-15 at 3.5 inch thickness	1	0.069	0.065	0.073	0.069
	2	0.064	0.061	0.068	0.069
Installed Batt R-value:	3	0.060	0.057	0.063	0.059
R-15 in 3.5 inch cavity	4	0.056	0.053	0.059	0.056
	5	0.053	0.051	0.055	0.052

Does 2021 WSEC-R require continuous insulation on above-grade walls? Yes and No

Yes – if you choose to follow the R-value Alternative or Prescriptive Path continuous insulation is required.

No – if you choose to follow the other compliance paths continuous insulation is not required.

Section R402.1.3 specifies two prescriptive constructions for above-grade walls and both include continuous insulation. Furthermore, it is stated in Section R402.1.4 that "continuous insulation alone shall be used to determine compliance with the continuous insulation R-value requirements in Table R402.1.3" – making it absolutely clear that no exceptions without continuous insulation are allowed when following the Prescriptive Path.

How do I determine the U-factor of ICF, SIPs, ZIP or other pre-manufactured wall products?

Pre-manufactured wall products are not included in Appendix A. We suggest that you first contact the manufacturer and obtain documentation of the overall U-factor of their product (not just the R-values of insulation layers) for submission to your building official. If manufacturer's data is not available, there are two references we recommend for products including structural insulated panels (SIPs) and insulating concrete forms (ICFs). The first is the default U-values used in REM/Rate. These default values for ICF and SIPs are shown in Figure 3. Another good source of U-factors for ICF, SIPS and many other constructions is California's Code Ace website. You can find the database for walls at https://energycodeace.com/site/custom/public/reference-ace2013/index.html#!Documents/ja43walls.htm.

Figure 3. REM/Rate default U-factors for SIPs and ICF above-grade walls.

Component Description	Reference	Wall U
ICF, R20	NEEA REMRate	0.045
ICF, R22	NEEA REMRate	0.042
ICF, R24	NEEA REMRate	0.038
ICF, R25	NEEA REMRate	0.037
ICF, R28	NEEA REMRate	0.033
SIPS, 8"	NEEA REMRate	0.030
SIPS, 10"	NEEA REMRate	0.024
SIPS, 12"	NEEA REMRate	0.020

Are there online calculators you would recommend if I can't find my wall construction in Appendix A?

Applied Building Technology Group (ABTG) offers a number of useful resources for building designers at https://www.appliedbuildingtech.com/content/building-designer-resources. They have two very nice calculators for walls:

Wood-framed walls: https://www.appliedbuildingtech.com/fsc/woodcalculator

Metal-framed walls: https://www.appliedbuildingtech.com/fsc/steelcalculator

The calculators can be used for above-grade walls that are single-wall with or without continuous insulation with stud sizes up to 2x12. Many common materials are included on the drop down menus. In addition, the calculators allow custom R-values for all material layers to be entered. This means the materials it can handle is essentially unlimited, as long as you have an R-value from an approved source for the material you would like to use. The primary limitation we have found is that the calculator does not allow custom values for framing factors and does not include the default framing factors in Appendix A for either standard- or advanced-framed walls. For

intermediate-framed walls, select a framing factor of 22%, which is the sum for studs, plates and headers in Appendix A Section A103.2.2.

To use the calculator, enter the details of your wall construction under "Wall Assembly Inputs", using the drop down menus and input boxes. Notice you can disregard inputs for energy code & year, climate zone, and all inputs in the net permeance calculator, if you would like. This is because for our task we only need to pay attention to the numerical value of the "assembly U-factor" in the Output on the right to ensure it meets our target U-factor. Figure 4 shows the result of **0.047** for a 2x8 wood-framed wall with intermediate framing (22% framing factor), 1/2" gypsum on the interior, wood lapped siding and

½" plywood sheathing. (Notice this value also agrees with the U-factor found in Appendix A Table A103.3.1(8), as shown in the excerpt below in Figure 6. So in this case, we could have just looked it up.)

For building materials that are not on the calculator's drop down menus, look up default R-values from Table A101.5 of Appendix A for building products. You may also use manufacturer's listed R-values, values from ASHRAE *Handbook of Fundamentals*, or other approved reference. These values can be entered into the calculator by selecting "Custom" on the relevant drop downs.

You can also get to this calculator from the Continuous Insulation website at continuousInsulation.org.

Figure 4. Example entering the default R-value of 0.45 for 0.78" of fiberboard sheathing from Appendix A Table A101.5 in Step 5 using the ABGT wood-framed wall calculator.

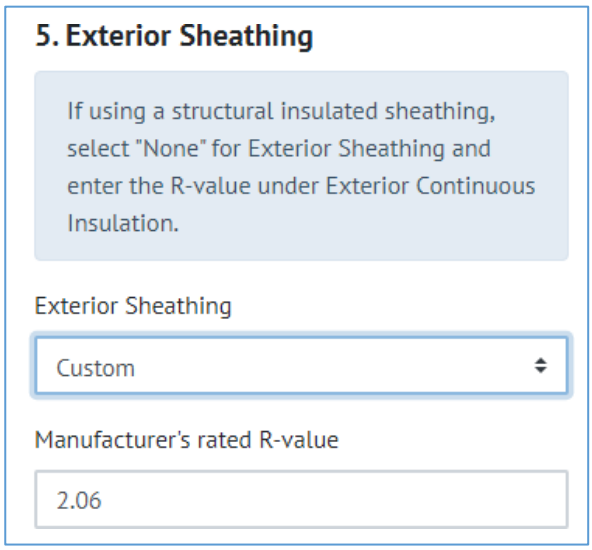

Figure 5. Output section of the Applied Building Technology Group's wood-framed wall calculator at https://www.appliedbuildingtech.com/fsc/woodcalculator for 2x8 wall with R-25 batt insulation, intermediate framing (22%), lap siding, 1/2" plywood insulation

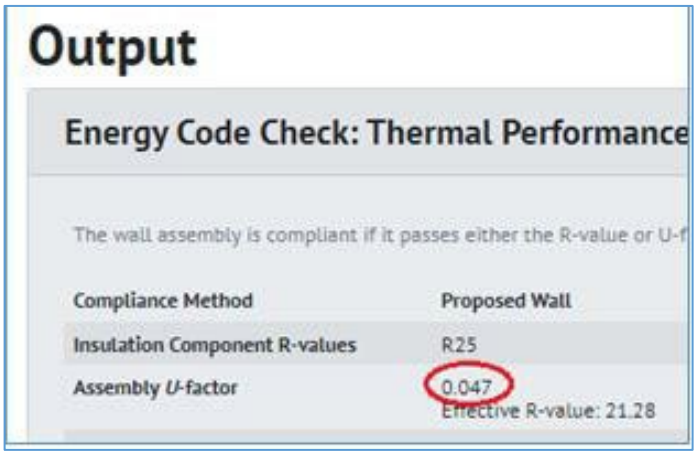

Figure 6. Extract from WSEC-R Appendix A Table A103.3.1(8) for 2x8 single stud walls with R-25 batt cavity insulation.

TABLE A103.3.1(8)
2 x 8 Single Stud: R-25 Batt

R-value of Foam Board	Siding Material/Framing Type					
	Lapped Wood			T1-11		
	STD	INT	ADV	STD	INT	ADV
0	0.051	0.047	0.045	0.053	0.049	0.046
1	0.048	0.045	0.043	0.049	0.046	0.044

NOTE:
Nominal Batt R-value:
R-25 at 8 inch thickness

Can I use insulation materials such as sawdust, straw or sheep's wool as insulation instead of batt and foam insulation products?

Section R303.1.1 requires that the R-value of insulation products be listed on the manufacturer's certification. Sawdust and straw are not materials that have listed R-values that we are aware of and we do not recommend them as insulation products. On the other hand, insulation consisting of sheep's wool is commercially available by manufacturers that have obtained listed R-values for their products.

For all insulation products that your building official may not be familiar with, be sure to include the manufacturer's insulation certificate with your submittals.

Knowing manufacturer's listed R-value for your product, you can enter this into the Applied Building Technology Group's calculators discussed above to determine the U-value of your assembly.

I can't determine the U-factors for my wood-framed wall using any of the references discussed above. How do I calculate the U-factor for a wood-framed wall?

There are many less common assemblies that are not found in Appendix A or not calculable with the Applied Building Technology Group's calculators. In these cases, your U-factor may need to be calculated.

For above-grade wood-framed constructions, the U-factors can be calculated assuming parallel heat transfer through the framing and insulation in accordance with the ASHRAE *Handbook of Fundamentals*. Guides that are much easier to read than the *Handbook of Fundamentals* can be found in articles such as "The Fundamentals of Series and Parallel Heat Flow" on the Green Building Advisor website at https://www.greenbuildingadvisor.com/article/the-fundamentals-of-series-and-parallel-heat-flow.

It is worth emphasizing that the parallel heat transfer calculation method described in the Green Building article does not apply to constructions where the assumption of parallel heat transfer is not valid. This includes metal-framed walls and ground-connected walls and slabs. In these constructions, heat transfer is a complex three dimensional phenomenon that does not lend itself to the simplifying assumption of parallel heat transfer.

Here are other comments to keep in mind as you read background articles on the calculation method:

- U-factors are calculated for the complete assembly, not just for the insulation, using methods outlined in Appendix A of the WSEC. This means it must take framing or other thermal bridges into consideration. Refer to https://sbcc.wa.gov/sites/default/files/2021-01/2018%20WSEC_R%20Final%20package2.pdf.
- The method does not apply to metal-frame constructions or below-ground walls or slabs or other constructions where heat transfer is far from parallel.
- All materials in the construction must be accounted for.
- Any materials the go *through* the wall perpendicular to the face are treated in the same manner as studs or rafters (parallel calculation).
- Any materials that are in continuous layers (such as gypsum, sheathing or air spaces) parallel to the face are treated in the same manner as continuous insulation (series calculation).
- The R-value of air films depends on the direction of heat transfer (up, down or horizontal) and whether the surface is interior and exterior. Look up default air-film R-values in Section A101.3.
- Descriptions of framing types for walls (standard, intermediate and advanced) and the corresponding framing factors are included in Section A103.2. You can find typical framing factors for roofs in references such as

http://www.bchousing.org/publications/Illustrated-Guide-R30-Effective-Vaulted-and-Flat-Roofs.pdf

What is an F-value? What is a UA-value? What is a UA trade-off analysis?

These related questions will be addressed in an upcoming FAQ. Please refer to our website to download all our FAQs at https://www.energy.wsu.edu/BuildingEfficiency/EnergyCode/AdditionalResources.aspx#FAQs

Can you recommend someone who can help me with these calculations?

We can assist you with U-factor calculations provided you provide us with a summary of all the details of your construction, including dimensions, materials and framing description (or framing factor if it is an unconventional framing). If the assistance you require is beyond the scope of our funding, we suggest you contact an energy professional. The raters that are highlighted in blue on our list at https://www.energy.wsu.edu/Documents/HomeEnergyRaters.pdf have expressed interest in providing assistance with the WSEC-R.

Selected Tables from Appendix A

TABLE A102.1
DEFAULT U-FACTORS FOR CEILINGS

	Standard Frame	Advanced Frame
Ceilings Below Vented Attics		
Flat	**Baffled**	
R-19	0.049	0.047
R-30	0.036	0.032
R-38	0.031	0.026
R-49	0.027	0.020
R-60	0.025	0.017
Scissors Truss		
R-30 (4/12 roof pitch)	0.043	0.031
R-38 (4/12 roof pitch)	0.040	0.025
R-49 (4/12 roof pitch)	0.038	0.020
R-30 (5/12 roof pitch)	0.039	0.032
R-38 (5/12 roof pitch)	0.035	0.026
R-49 (5/12 roof pitch)	0.032	0.020
Vaulted Ceilings	**16" O.C.**	**24" O.C.**
Vented		
R-19 2x10 joist	0.049	0.048
R-30 2x12 joist	0.034	0.033
R-38 2x14 joist	0.027	0.027
Unvented		
R-30 2x10 joist	0.034	0.033
R-38 2x12 joist	0.029	0.027
R-21 + R-21 2x12 joist	0.026	0.025
Roof Deck	**4x Beams, 48" O.C.**	
R-12.5 2" Rigid insulation	0.064	
R-21.9 3.5" Rigid insulation	0.040	
R-37.5 6" Rigid insulation	0.025	
R-50 8" Rigid insulation	0.019	

TABLE A103.3.1(2)
2 x 4 Single Wood Stud: R-13 Batt

NOTE:
Nominal Batt R-value:
R-13 at 3.63 inch thickness

Installed Batt R-value:
R-12.7 in 3.5 inch cavity

R-value of Foam Board	Siding Material/Framing Type			
	Lapped Wood		T1-11	
	STD	ADV	STD	ADV
0	0.082	0.078	0.088	0.083
1	0.075	0.072	0.080	0.076
2	0.069	0.066	0.073	0.070
3	0.065	0.062	0.068	0.065
4	0.060	0.058	0.063	0.061
5	0.057	0.055	0.059	0.057
6	0.053	0.052	0.056	0.054
7	0.051	0.049	0.052	0.051
8	0.048	0.047	0.050	0.048
9	0.046	0.045	0.047	0.046
10	0.044	0.043	0.045	0.044
11	0.042	0.041	0.043	0.042
12	0.040	0.039	0.041	0.040

TABLE A103.3.1(5)
2 x 6 Single Wood Stud: R-21 Batt

NOTE:
Nominal Batt R-value:
R-21 at 5.5 inch thickness

Installed Batt R-value:
R-21 in 5.5 inch cavity

R-value of Foam Board	Siding Material/Framing Type					
	Lapped Wood			T1-11		
	STD	INT	ADV	STD	INT	ADV
0	0.057	0.054	0.051	0.060	0.056	0.053
1	0.054	0.051	0.048	0.056	0.053	0.050
2	0.050	0.048	0.045	0.052	0.050	0.047
3	0.048	0.045	0.043	0.049	0.047	0.045
4	0.045	0.043	0.041	0.047	0.045	0.043
5	0.043	0.041	0.040	0.044	0.042	0.041
6	0.041	0.039	0.038	0.042	0.041	0.039
7	0.039	0.038	0.036	0.040	0.039	0.037
8	0.038	0.036	0.035	0.039	0.037	0.036
9	0.036	0.035	0.034	0.037	0.036	0.035
10	0.035	0.034	0.033	0.036	0.035	0.033
11	0.033	0.033	0.032	0.034	0.033	0.032
12	0.032	0.031	0.031	0.033	0.032	0.031

For More Information:

ASHRAE, American Society of Heating, Refrigerating and Air-Conditioning Engineers, *Handbook of Fundamentals*, 2021

"The Fundamentals of Series and Parallel Heat Flow" on the Green Building Advisor website at https://www.greenbuildingadvisor.com/article/the-fundamentals-of-series-and-parallel-heat-flow.

California Code Ace, Above-Grade Wall U-factors, https://energycodeace.com/site/custom/public/reference-ace-2013/index.html#!Documents/ja43walls.htm

Applied Building Technology Group website, https://www.appliedbuildingtech.com

Continuous Insulation website of the Applied Building Technology Group, https://www.continuousinsulation.org/

Rem/rate, https://www.remrate.com/. REM/*Rate*™ is a user-friendly, yet highly-sophisticated, residential energy analysis, code compliance and rating software developed by NORESCO LLC, specifically for the needs of HERS® providers.

"Is there a downside to lumpy attic insulation?" on the Green Building Advisor website at https://www.greenbuildingadvisor.com/article/is-there-a-downside-to-lumpy-attic-insulation

Disclaimer

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