WASHINGTON STATE UNIVERSITY
Energy Program

2018-2021 Washington State Energy Code-Residential FAQs:

U-Factors for Non-Prescriptive Building Assemblies

October 2023

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)[1] 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:

$$\text{Heat Loss} = \text{U-factor x Area x (Indoor Temperature - Outdoor Temperature)}$$

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:

$$\text{R} - \text{value} = \frac{1}{\text{U} - \text{factor}}$$

and equivalently

$$\text{U} - \text{factor} = \frac{1}{\text{R} - \text{value}}$$

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.

How are U-factors used in the WSEC-R?

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). 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

[1] Everything that pertains to winter heat loss in this FAQ is also true for summer heat gains.

- "13+10" in Table R402.1.3 refers to R-13 cavity insulation plus R-10 continuous insulation[2]

You are not required to follow these prescriptive building assemblies, however. These typical constructions were defined for convenience in meeting code requirements. That is, if you follow the prescriptive assembly you do not necessarily need to worry about determining the U-factor of your assembly.

If you *choose* to construct a building assembly that is different than the prescriptive building assemblies, however, WSEC-R defines maximum U-factors that are equivalent to these prescriptive constructions in Table R402.1.3 in 2018 and Table R402.1.2 in 2021. For above-grade walls, for example, the equivalent maximum U-factor to meet baseline code requirements is **0.045** under 2021 WSEC-R. In this case, 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.

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

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 always be accepted by building officials.

For example, from Table A103.3.1(8), you will find that an advanced-framed 2x8 above-grade wall with R-25 fiberglass batt cavity insulation without continuous insulation and lapped wood siding has a U-value of 0.045, which meets the baseline requirements for 2021 WSEC-R (Refer to Figure 1).

[2] 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.

Figure 1. Extract from WSEC-R Appendix A Table A102.2.1(8) for 2x8 single stud walls with R-25 batt cavity insulation. The U-factor for the case of advanced framing with no continuous insulation is circled in red.

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

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

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
2	0.045	0.043	0.041	0.047	0.044	0.042

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

There are many examples of above-grade wall constructions that have a U-factor of 0.045 or less that do not include continuous insulation. The 2x8 R-25 wall in the previous question is one example. Another example is a double 2x4 wall with R-19 plus R-11 insulation, as shown in Table A103.3.3(2). (Refer to Figure 2.)

Avoiding rigid foam continuous insulation does require framing larger wall cavities to accommodate thicker layer(s) of cavity insulation, however. You will trade off the expense of installing continuous insulation for the expense of more framing.

Figure 2. WSEC-R Appendix Table A103.3.3(2) for double 2x4 walls.

TABLE A103.3.3(2)
2 X 4 + 2 X 4: DOUBLE WOOD STUD

Batt Configuration			Siding Material/Frame Type			
			Lapped Wood		T1-11	
Exterior	Middle	Interior	STD	ADV	STD	ADV
R-11	--	R-11	0.050	0.046	0.052	0.048
R-19	--	R-11	0.039	0.037	0.043	0.039
R-11	R-8	R-11	0.037	0.035	0.036	0.036
R-11	R-11	R-11	0.032	0.031	0.033	0.032
R-13	R-13	R-13	0.029	0.028	0.029	0.028
R-11	R-19	R-11	0.026	0.026	0.027	0.026

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-ace-2013/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), shown in Figure 1 above.

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.

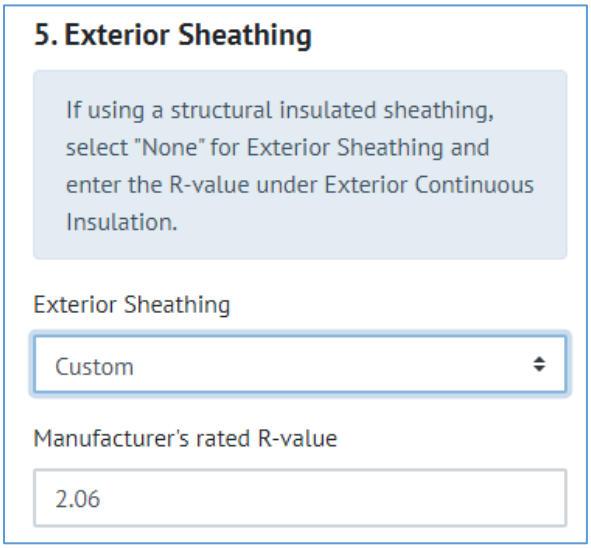
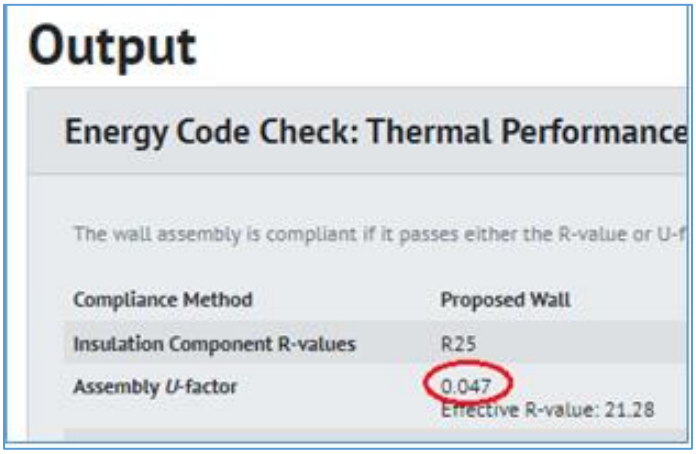


Figure 5. Output section of the Applied Building Technology Group's wood-framed wall calculator at https://www.appliedbuildingtech.com/fsc/woodcalculator for 2x8 wall with R-25 batt insulation, intermediate framing (22%), lap siding, 1/2" plywood insulation



How do I determine if a non-standard wall construction meets the U-value requirement for Option 1 energy credits?

The efficient building envelope energy credits in Options 1.x of Section R406 have prescriptive descriptions of constructions without specifying maximum U-values. You can nevertheless substitute an alternative assembly that has an equivalent or better U-factor for the prescriptive assembly.

To do this, first, determine the U-factor for the component of the prescriptive construction of the Option you want to substitute for in the same manner as discussed above – by looking it up in Appendix A, calculating it with the ABGT calculator, or etc. Next find the U-factor of your proposed alternative to ensure that it is equal to or less than the prescriptive assembly.

For example, instead of the "wood-frame wall R-21 int plus R-12 ci" of Option 1.3 in 2021 WSEC-R, say you want to use a double-frame wall. From Table A103.3.1(5) we find that the U-factor of the prescriptive wall assembly is **0.031** (refer to Figure 3 below). Now find a double-wall that is equivalent using Table A103.3.3(2). (Refer to Figure 2 above.) A double 2x4 wall with R-11 batts in the exterior, middle and interior also has a U-factor of 0.31 and therefore is equivalent to the prescriptive description in Option 1.3.

As a second example, using the ABGT calculator, we can find that a 2x12 wall insulated with R-40 insulation also has a U-factor of **0.031** and so is also equivalent to the prescriptive "wood-frame wall R-21 int plus R-12 ci".

Note Option 1.3 also requires R-38 floors, U-0.18 fenestration, advanced frame R-60 ceilings, and so on, in addition to R21+R12ci walls. If you want to make more than one substitution in this prescriptive description, you will need to calculate the UA-value of your building's thermal envelope, not just the U-factor of a single building component. Our Code Compliance Calculator was developed to facilitate such a UA trade off analysis. Contact our office if you need assistance getting started with a UA analysis. [3]

[3] **What is a UA-value?** The heat loss in the winter or the heat gain in the summer of a house depends not just on how well insulated it is. It also depends on the size of the home, as well as its air leakage rate. The UA-value of a building assembly equals the assembly's area A multiplied by its U-factor. In this way, the UA-value quantifies the energy efficiency of a building component taking both its size and insulating value into account. The topic of UA-values, UA trade off analyses and using the Code Compliance Calculator will be covered in an upcoming FAQ.

Figure 6. Extract from WSEC-R Table A103.3.1(1) for 2x6 R-21 above-grade walls. The U-factor of the prescriptive "wood-frame wall R-21 int plus R-12 ci" is circled in red.

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

NOTE:	R-value of Foam Board	Siding Material/Framing Type					
		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
Installed Batt R-value: R-21 in 5.5 inch cavity	12	0.032	0.031	0.031	0.033	0.032	0.031

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.

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

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