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Misleading R-Value and the Need to Reframe Insulation Scales By James, Leaman, Charles Hendricks **DOWNLOAD** THE PDF VERSION OF THIS ARTICLE. (370.31 KB)

The use of R-value as a measure of the effectiveness of building insulation can create significant confusion, resulting in poor choices and wasteful consumption. Construction professionals and their clients need better thermal performance data and a more robust scale for comparing competing insulation products and product combinations. In this article, we review

how insulation standards and regulations have evolved, explain strengths and weaknesses of the current model, and suggest how to provide industry professionals with better tools for supporting efficient buildings. Resistance to Conductive Heat Flow by R-Value

100 90 80 70 60 50 40 30 20 10 0 20 30 40 50 R-4=75% R-12=92% R-8=88% R-16=94% R-24=96% R-32=97% R-40=98% R-48=98%

promulgated by the U.S. Federal Trade Commission (FTC), which continues to support the metric as an industry standard through regulation, referred to in the industry as the "R-value Rule." This regulation requires insulation manufacturers to disclose a product's thermal performance based on uniform testing procedures, and its stated purpose is to provide

This graph, along with the table showing R-values as a percentage of resistance to heat flow, illustrates the diminishing returns that result

The R-value system originated in the United States in 1945 and was an important first step toward a science-based and

standardized system for evaluating insulation products. As its use grew more widespread, it was eventually recognized and

consumers with objective performance data to inform their purchasing decisions among competing products; indeed, insulation products in most markets overtly display the R-value rating. However, the scaling metric of R-value is not optimal for understanding the practical efficacy of insulation or for comparing products, thicknesses, and product combinations. Additionally, the rating does not account for the effects of air leakage and other thermal losses. R-value as a metric is mathematically sound, as it measures an insulating material's resistance to conductive heat flow; the problem lies with what the R-value number means in practice. A building code may require R-15 insulation in walls, but that static rating communicates little about how well that R-value works against a standard or relative benchmark. Additionally, insulation products are rated across a broad scale, and without qualification about

diminishing returns to thickness, many consumers and even industry professionals assume proportional efficacy based on

the R-value numbering scale. A further complication is that windows, doors, and skylights are typically rated on a different

scale (U-value or U-factor), which obscures relative insulating performance among various elements of the thermal envelope. Before offering solutions, we discuss four problem areas with the use of R-value and other insulation metrics: scale, diminishing returns, other losses, and different rating systems. These all impact how industry professionals convey value to clients about choices in the thermal envelope. Scale The first and most critical weakness of R-value is the scale's disconnect from practical understanding and application. The

scale derived naturally from a mathematical formula (R-value = temperature difference across the insulation barrier divided by heat flux through the insulation barrier), but most people cannot extract actionable meaning from a static R-value rating. Benchmarking the percentage of conductive heat flow resisted by an insulation material against 100% (0 to 100% scale) would more intuitively communicate its relative effectiveness compared with competing products. R-value does have the

from scaling R-value.

helpful feature of being additive, meaning that insulating products may be stacked (or different insulation products combined) to achieve a cumulative R-value sum. Conversely, a percentage metric is not additive, which we discuss in the next section, but this difference could be clearly explained in labeling. The R-value of an insulation product is the reciprocal of its thermal conductivity coefficient (TCC), and the percentage of heat flow blocked or resisted by that material is one minus the TCC. As an example, the TCC of an R-16 product is 0.0625 (1/16), and the percentage of conductive heat flow blocked or resisted (under typical conditions) is 94% (1 - 0.0625, rounded). Labeling an insulation product as achieving 94% resistance to heat flow would be far more instructive to decision makers than R-16. The "under typical conditions" qualifier above is needed for both R-value and its associated percentage

of resistance to heat flow, as both metrics will vary slightly based on operating temperature, temperature difference across

the insulation plane, and the building plane on which the insulation is installed (driving force). But the variances are small,

and a more actionable number with caveats would be more practical than a precise metric that means little to consumers.

One simple improvement would be to require labeling that includes the percentage of conductive heat flow resisted. For the

example above, the product might be labeled R-16=94%*. The asterisk is needed to qualify the additive differences between

these two metrics, to acknowledge ratings under typical conditions, and to disclose limitations against other forms of heat flow. This is discussed in more detail in "Summary and Solutions," below. **Diminishing Returns** The second weakness with the R-value metric is that it ignores the diminishing returns of adding more of the same insulation, or stacking insulating products, which results in misconceptions about the value of increasing insulation levels (see "Resistance to Conductive Heat Flow by R-Value," above, for an illustration of the diminishing returns of scaling R-

value). We have noted the helpful feature of R-value being stackable. However, without the percentage scale outlined above,

most consumers will assume that insulating value is proportional to the combined R-value rating. For example, if we go from standard cavity insulation in a 2x4 wall (R-11) to a 2x6 wall (R-19), we do gain 42% more R-value (an increase of R-8). But many, even those who work in the building industry, assume that we get 42% greater resistance to heat flow, which is

false. The 2x6 wall slows heat flow by only 4% more than the 2x4 wall.

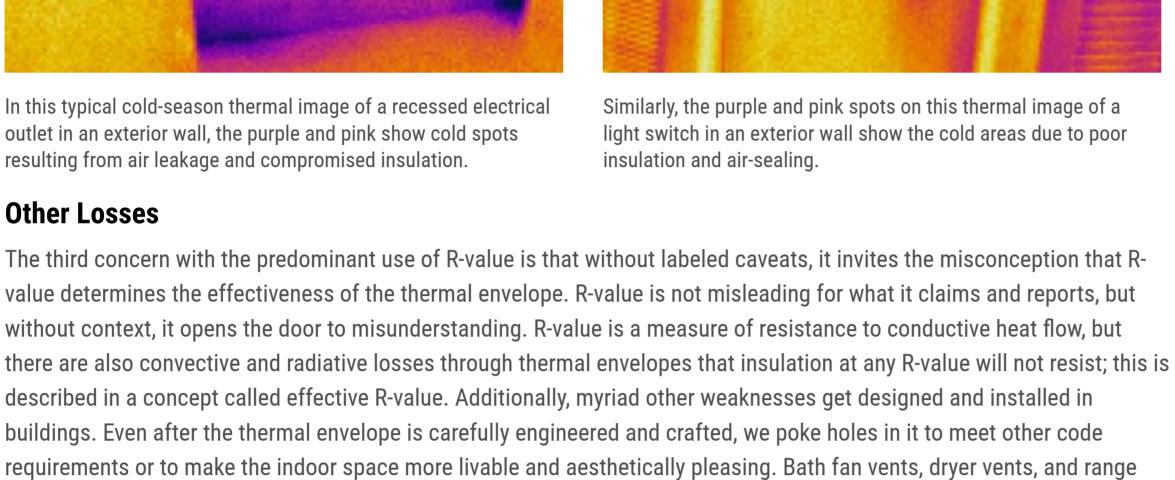
The R-values that building codes in most temperate climates currently require in floors, walls, and ceilings are on the waning end of diminishing returns. In many cases, adding thickness (and additional R-value) of the same insulation only negligibly reduces heat loss while incurring significant financial and environmental costs. To restate this concern, there may be fractional advantages in reduced conductive heat flow by increasing R-value beyond the code requirements, yet there will also be added labor and material costs, affecting both finances and resources. The returns are less than optimal for the individual payer and society at large, yet the perception persists of net benefits gained by bulking up the thermal envelope with insulation R-values. Depending on the building structure, it is often advantageous to combine different insulating products to reduce heat flow. The thermal advantages come from factors other than conductive losses, such as limiting thermal bridging and convection. One common example is continuous exterior rigid insulation, which, in combination with

stud cavity insulation to meet R-value code for walls, helps reduce convection losses and breaks thermal bridging through framing members. **\$FLIR \$FLIR**

Similarly, the purple and pink spots on this thermal image of a

light switch in an exterior wall show the cold areas due to poor

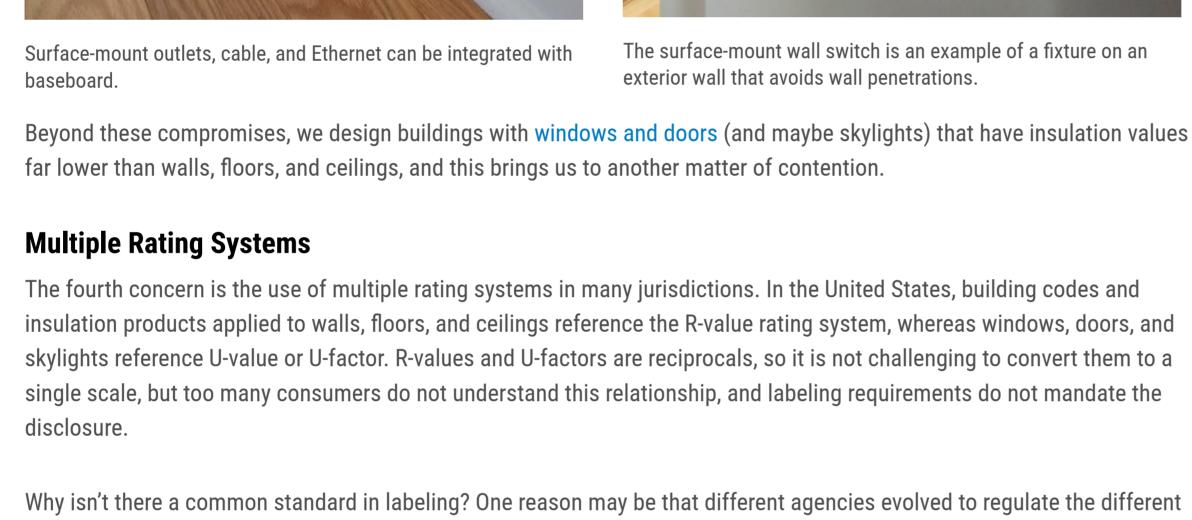
insulation and air-sealing.



(minimal R-value and ripe for convective losses). Beyond those perpetual passive intrusions, occupants use those vents to force conditioned air outside during operation, pulling in unconditioned air as replacement—a significant heat loss unrelated to thermal envelope insulation. Utility penetrations also impact the thermal envelope. With careful planning, most plumbing pipes can be kept out of insulation planes, but required drain stack vents are open holes through the ceiling and roof, and they are often sealed with a single membrane around larger gaps in the upper thermal insulation plane. Electrical outlet and switch boxes are required by residential codes at prescribed spacing around walls, including exterior walls. These displace insulation and dramatically reduce R-value, creating permanent and excessive weak points in the thermal envelope, as illustrated by the thermal images above. Though this issue is independent of our call for improved metrics and labeling, it is further evidence that required R-values in building codes alone are not a sufficient measure of thermal effectiveness. Regardless of wall thickness or installed R-

value, pulling electrical boxes out of insulation cavities will avoid significant compromises of the thermal plane. Below are a

hoods vented to the outside open holes through the thermal envelope and are often dampered with just a thin rigid flap



the R-value rating.

100

90

80

70

60

50

40

Summary and Solutions

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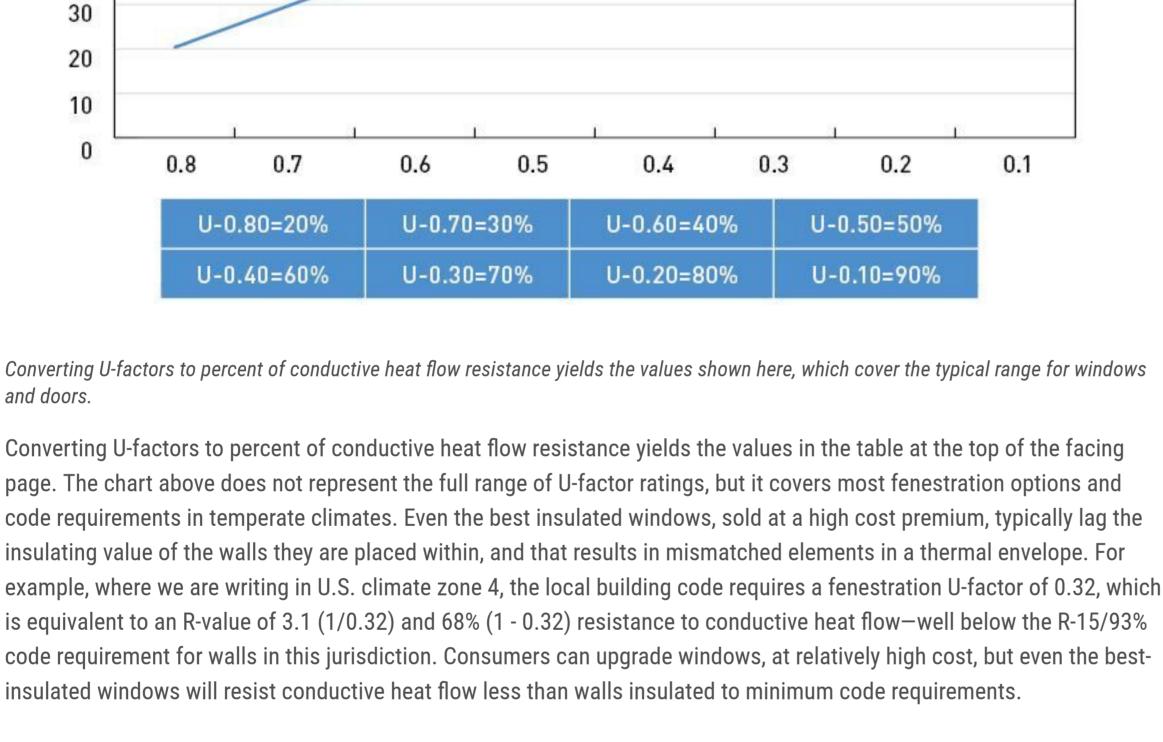
value.

compare with wall assemblies.

Architects, both in Harrisonburg, Va.

couple of examples of functional surface-mount options.

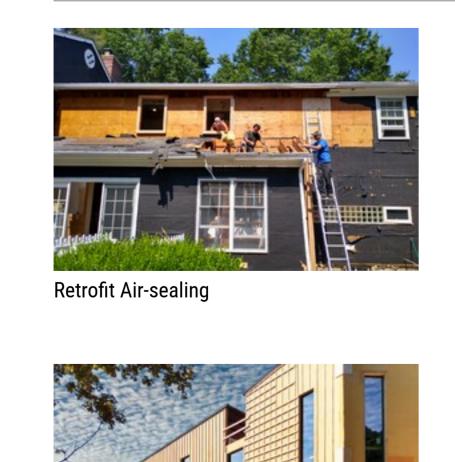
added to the U-factor rating as well. That would create a standardized link between R-value and U-factor and provide an actionable metric for consumers to make informed choices. The calculation to provide the percentage resistance to conductive heat flow from a U-factor rating is simple: One minus the



This rating is limited to conductive typically have better resistance to R-24=96%* R-24=96%* 68% resistance to 94% resistance to conductive heat flow. R-values, heat transfer and does not account conductive heat flow* conductive heat flow* R-32=97%+ R-32=97%* for other forms such as convection which are used for walls and or radiation. R-values are additive/ ceilings, are provided so consumers R-40=98%* R-40=98%* stackable, whereas heat flow can understand and compare value R-48=98%* resistance percentage is not. R-48=98%* across products. The authors propose a labeling scheme like this for insulation products (above left) and windows, doors, and skylights (above right) to better convey to buyers the effectiveness of the products to limit heat flow. The U-factor label also helps buyers understand the link between Ufactor and R-value.

those also need to be included. The Federal Trade Commission (FTC) and National Fenestration Rating Council (NFRC) should want to improve information to consumers about the products and systems they regulate, and these samples provide what we believe are needed additions to product labeling. These changes will better inform consumers of the effectiveness of the insulation products they buy, provide a linking standard to compare U-factor and R-value ratings, and begin dispelling the misconceptions associated with diminishing returns to R-value.

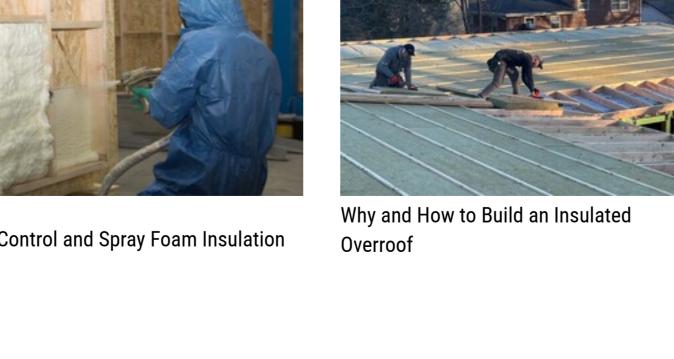
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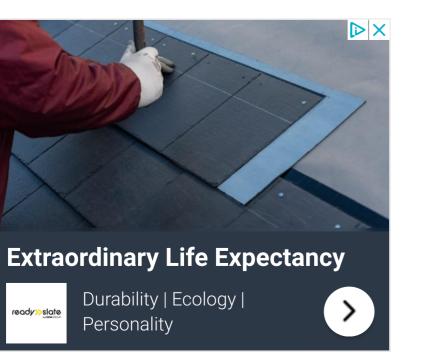


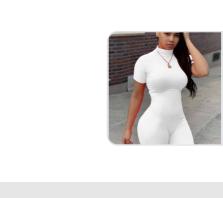
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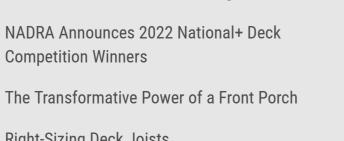
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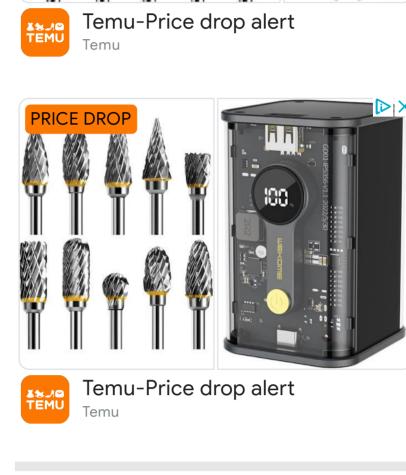
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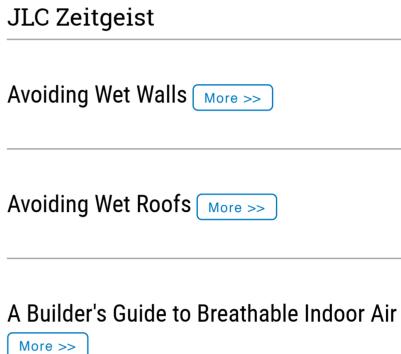
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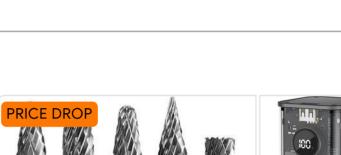
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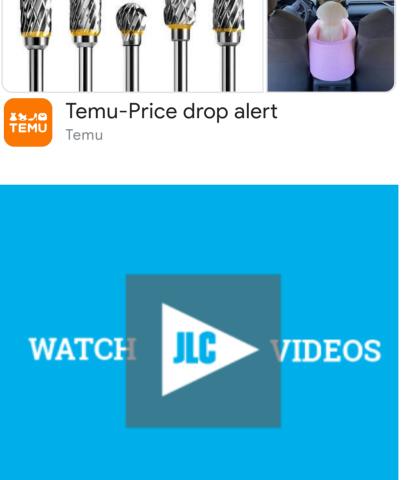


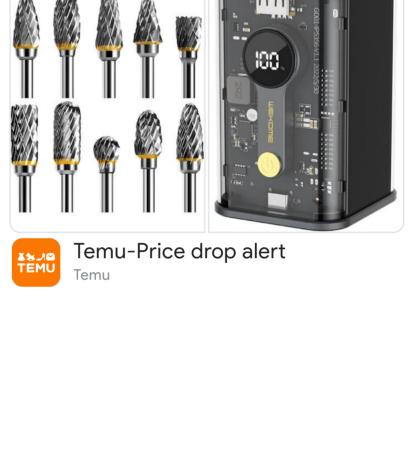


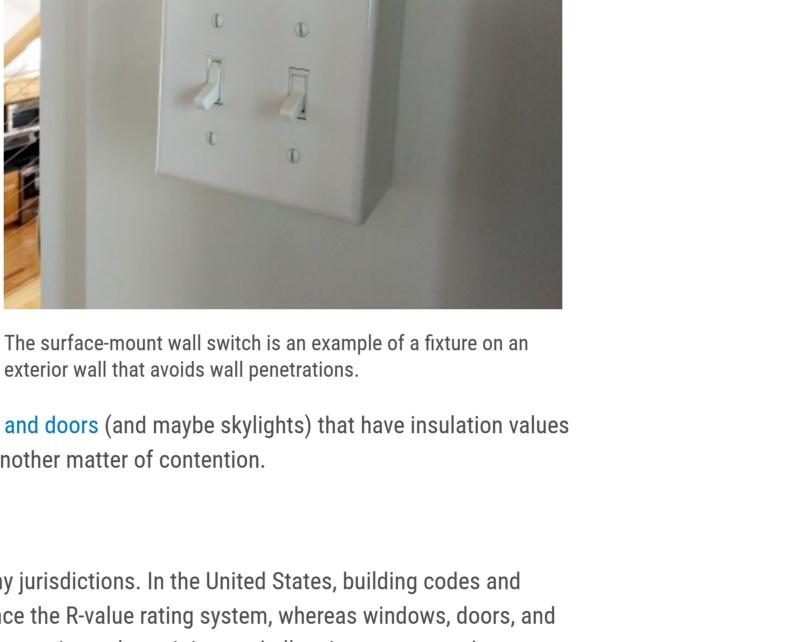


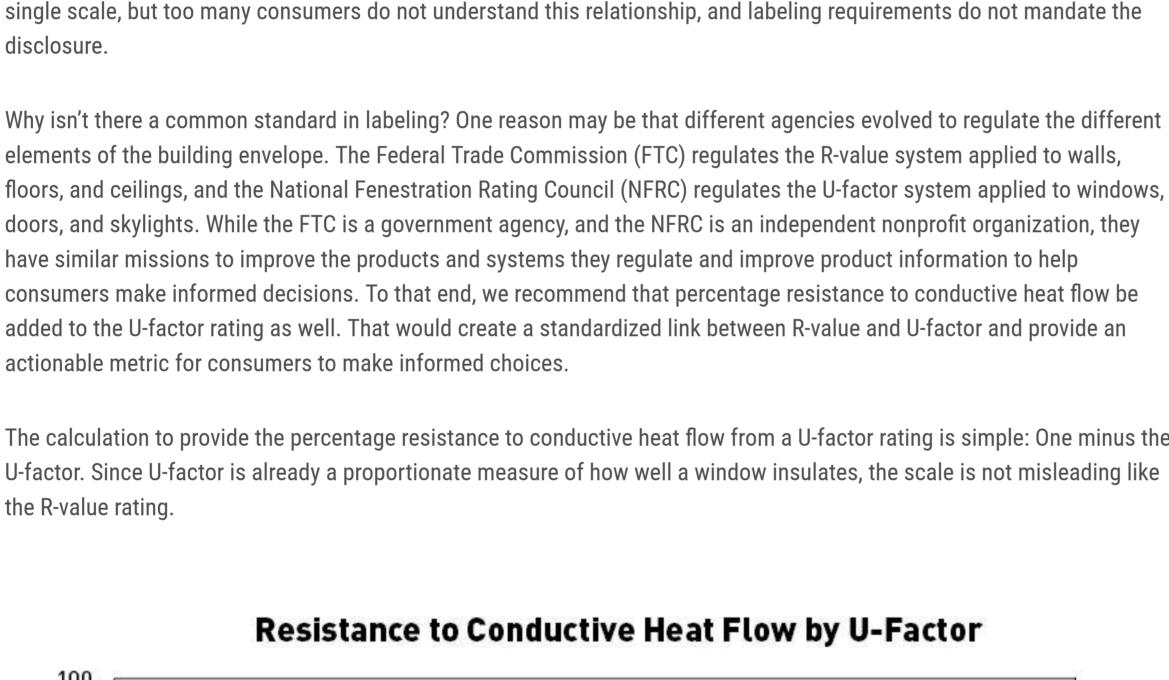
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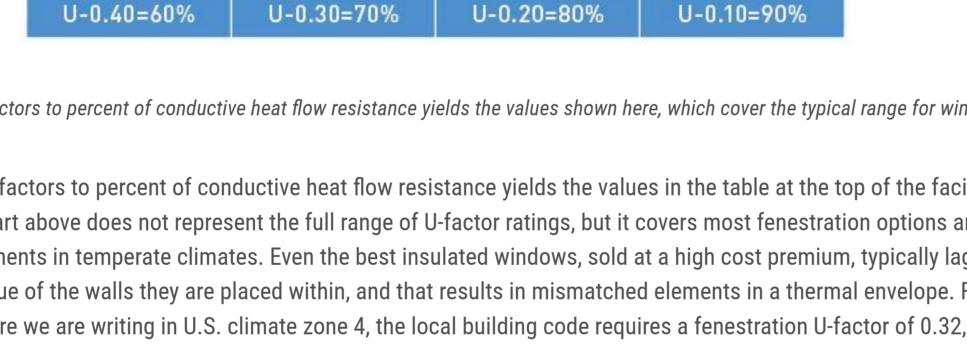
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R-4=75%* R-4=75%+ *This rating is limited to *The percentage of heat flow resisted by associated R-values conductive heat transfer and does R-8=88%* R-8=88%+ not account for other forms such as and heat flow resistance percentage ratings vary by convection or radiation. Windows R-12=92%+ R-12=92%* R-16=94% U-0.32=68% operating conditions (temperature, and doors are placed in walls, and R-16=94%* R-16=94%*

skylights in ceilings, both of which

We have argued that current metrics for rating insulation do not provide the most helpful information for consumers to

the different elements that form a complete thermal envelope. R-value is ingrained in the lexicon of the construction

these metrics be replaced, but rather that they be augmented with additional information.

location, and installation quality).

make informed decisions. Instead, they create confusion and misconception, and multiple rating systems do not connect

industry, if not the broader society, and it remains valuable because of its stackable feature. We are not recommending that

The sample labeling scheme shown above would be one way to include the percentage resistance to conductive heat flow, which is an immediately actionable metric that's critically important for comparing different insulation products. Listing a broader range of the R-value scale would help consumers place specific products in the scope of possibility, and this range with the percentage scale would clearly reveal the diminishing returns to R-value. Finally, caveats could be added to disclose known limitations.

The U-factor scale does not suffer from the diminishing returns problem associated with R-value, but as a static metric, it

does not support an intuitive understanding of heat flow. Also, it's egregious that we have no requirements for linking U-

factor and R-value. The sample labeling scheme shown below would be one way to include the percentage resistance to

conductive heat flow, which is an immediately actionable metric that would also provide the link between U-factor and R-

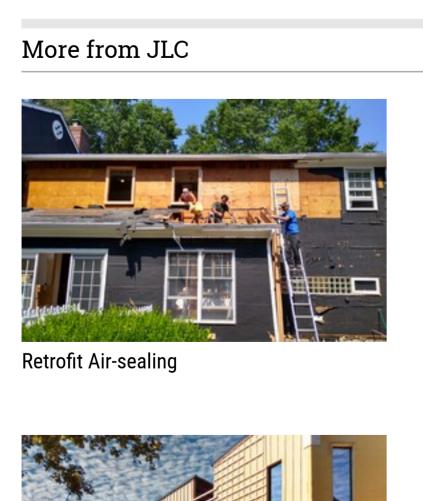
Additionally, listing an R-value range on the U-factor label would help consumers consider how fenestration products

Finally, as suggested with R-value labeling, caveats could be added to U-factor labels to disclose known limitations.

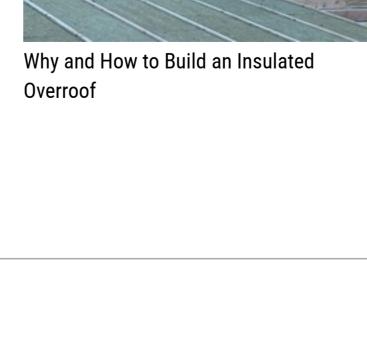
Windows have other important specifications, like solar heat gain coefficient, visible transmittance, and air leakage, and

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