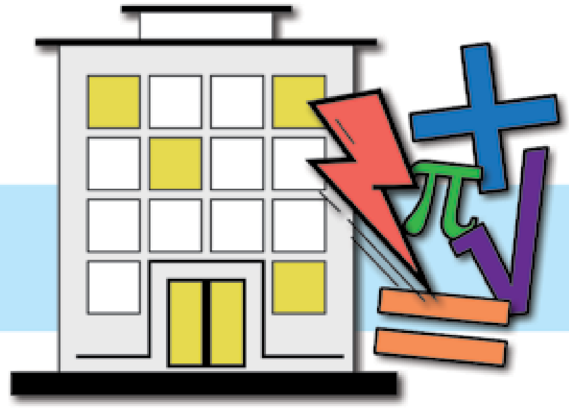
# Impact of Windows on Overall Building Energy Performance:



## *Using Science to Guide Building Thermal Performance Selections*

**By Michael Bousfield**

The assembly with the lowest thermal performance diminishes the effectiveness of all of the other thermally resistant assemblies in a building. Focus improvements here first.

*If a building has an R-40 roof, R-18 walls, and R-2 windows (pretty normal for many aluminum window types), then increasing the R-value of the windows from R-2 to R-3 will have more impact on the building than multiplying the R-value of the roof by 1,000,000!*

Often, building designers and developers quibble over small changes aimed at reducing heat loss in buildings. However, many are unaware of the effect—or lack thereof—that these changes have on the entire building. Adding insulation to already reasonably high-performance assemblies is nearly inconsequential if there are other common assemblies in the building with lower thermal performance, such as windows.

In some cases, this is akin to working on a car's flat tire while ignoring that the engine has blown up.

Looking at the big picture can help gain some perspective on whole-building effects. Here are steps to use to allow basic science to lead our logic for selecting building envelope assemblies for their thermal performance:

1. Identify a thermal performance target for the entire building envelope.
2. Understand the effective thermal performance of each envelope assembly.
3. Compare their contribution to heat loss, thereby highlighting which assembly can have the most positive impact if improved.

First, let us illustrate this idea with an analogy.

### KEEPING IT SIMPLE – AN ANALOGY OF HEAT LOSS

For a simple analogy, imagine yourself on a winter vacation at a mountainside ski resort. It's early morning, you have a beautiful room with a balcony, and the morning is bright, clear, and cold. Perfect. The sun shines off the frost on your balcony and off of the snow on roofs of other buildings around the resort (*Photo 1*).

What an opportunity to ease yourself into the day with a hot cup of coffee and a bit of cold, crisp, fresh air! Since it's winter, you put your ski jacket on over your housecoat before walking out onto your balcony with your coffee, and then lean against the railing. But something's wrong; your bare feet are getting really cold—really fast! It's not hard to imagine that your below-freezing balcony surface is a bit too cold for comfort.

So you walk back into the room, but don't want to abandon the morning. Round two: You add your partner's ski jacket over your own, and also grab your gloves, hat, and scarf. This will be twice as warm!

Back out onto the balcony.

Still bare feet.

And the cold balcony forces you back inside just as quickly as before. Not surprising.

Why? The heat that is leaving your body through your feet—at an uncomfortably fast rate—is not altered by adding clothing elsewhere. Perhaps your back or neck now lose heat slower as a result of the second layer of clothing, but that does nothing for your feet.

Finally, imagine the difference that a little pair of slippers would have made, rather than the whole second layer of jackets and other woolly things. There are some simple physics happening here: Adding more insulation to one area (your upper body clothing) does not reduce the heat flow leaving through a different, less-insulated area (your feet).

Therefore, the only rational thing to do to improve the heat loss of a whole body (or a whole building) is to target the thermally weakest area and improve it at least a little bit. This makes simple sense; find the assembly that loses heat fastest, and improve it to slow this down.

*Photo 1 – Kyber Himalayan Resort & Spa, Gulmarg, India. Photo courtesy of kyberhotels.com.*

## A CALCULATION MADE SIMPLE

Let's calculate the difference that the above approach makes, considering the most common assemblies in a building enclosure—the roof, the walls, and the windows.

What is the specific question? Here it is, with a hypothetical choice built in:

- If your objective is to improve the whole building's thermal performance, and you only have the budget to improve one of your three assemblies (roof, walls, and windows), which one should you focus on for the biggest bang-for-your-buck results?

This is a reasonably simple calculation; it's called an area-weighted average heat flow calculation. The idea is to determine the rate of heat flow through the whole building and what portion of that total is caused by each assembly.

The calculation inputs are the conductance of each of the assemblies and the percentage area that they represent. You could also start with effective thermal resistance (R-value$_{eff}$), rather than conductance (U-value). You'll just need to invert the R-values to become U-values prior to picking up your calculator.

- Conductance of each whole assembly (e.g., #1, 2, and 3) is expressed as:
  - — U-value$_1$ ($U_1$)
  - — U-value$_2$ ($U_2$)
  - — U-value$_3$ ($U_3$)
- Area covered by assembly #1, #2, and #3 is expressed as a fraction of 1 (e.g., 0.3 = 30% area):
  - — Area$_1$ ($A_1$)
  - — Area$_2$ ($A_2$)
  - — Area$_3$ ($A_3$)
- For an area-weight U-value calculation to determine a U-value for the whole enclosure, the equation is:

$$(U_1 \bullet A_1) + (U_2 \bullet A_2) + (U_3 \bullet A_3) = U \text{ overall}$$

- Then, to see the result as an effective R-value:

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

For those who understand this but would like to skip the math, Cascadia Windows & Doors has published an online area-weight R-value/U-value calculator to do this exact calculation. Just visit www.cascadiawindows.com, click on "Support," and choose the "R-value Calculator"; it's one of the first couple of options.

Try inputting this case study (with the author's house, seen in *Photo 2*), prior to running your own scenarios:

- For walls, enter R-10 effective and assume 40% area.
- For windows, enter R-2 effective (aluminum frames, double glazing), and assume 20% area.
- Add "roofs" as an additional assembly. Enter R-20 effective, at 40% area.

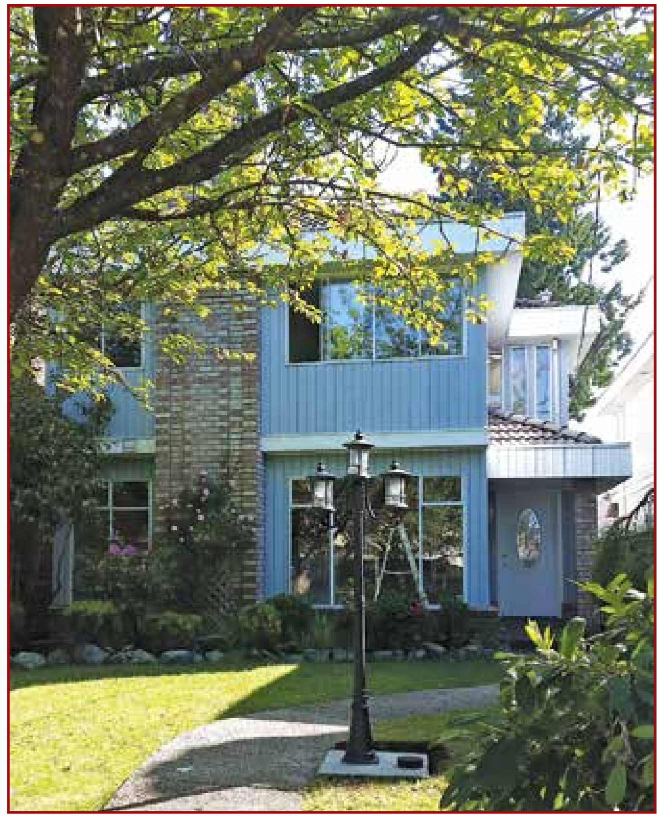


*Photo 2 – Author's former house, located in greater Vancouver, BC, Canada.*

Observe the whole-building effective R-value. It's R-6.25 (ft$^2$ °F hr./BTU). That's not awesome—especially for a wood-frame building. Let's look at the effect of improvements to each assembly in turn:

- Improve walls from R-$10_{eff}$ to R-$20_{eff}$. The net result on whole building: increase of R-0.89, to a new total of R-$7.14_{eff}$ (14% increase).
- Alternately, improve roof from R-$20_{eff}$ to R-$40_{eff}$. The net result is an increase of R-$0.42_{eff}$, to a new total of R-$6.67_{eff}$ (7% increase).
- Alternately, improve windows from R-$2_{eff}$ to R-$4_{eff}$ by changing window frame material to a low-conductivity type (in this example, fiberglass—still with double glazing). The net result is an increase of R-2.84, to a new total of R-$9.09_{eff}$ (45% increase).

The dramatic increase with the window example occurred simply from changing the material type of the frames—not the glazing—for the assembly that happened to have the least area (20% of building envelope).

Finally, just for fun, set the windows back to the original R-2, and now add roof insulation until the thickness would reach the moon. (Depending on your estimate, put in something like R-one billion!) As it turns out, this still only improves your whole building's R-value to R-$7.14_{eff}$—not even a whole R-1 increase over the starting point. Why? Because no matter how much you insulate one assembly (the roof in this case), it does not reduce the rate of heat loss from other assemblies (in particular, the windows).

If you're really cost-conscious, this analysis can actually help you—not with the goal of determining the best assembly to put more money into for better performance—but rather, with the goal of determining which assembly to improve. This will allow you to scale back, avoiding improvements on all other assemblies (leave them at code-minimum), and to still achieve a net savings!

Summing it all up:

1. Understand that the thermally weakest assembly leaks heat the fastest.
2. Identify the effective performance of each assembly (R-$value_{eff}$).
3. Improve the weakest assembly first, before spending any time or money elsewhere.

Happy calculating!

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*Michael Bousfield is well versed in fiberglass window and door technology. He completed the British Columbia Institute of Technology's architecture and building engineering technology program and was awarded its BCBEC/BCIT Building Science Award. He was employed by RDH Building Engineering as a building science technologist, where he performed forensic investigations, designed rehabilitations, and field review and testing for large-scale projects. Since 2009, when he joined Cascadia Windows Ltd., he has focused on windows, blending marketing and technical development, as well as speaking, educating, and training.*