Garbage In, Garbage Out?

An understanding of how R-Values and EnerGuide 80 ratings are calculated reveals what's often overlooked: actual energy efficiency performance.

One of the most talked about trends in the home building industry today is energy efficiency, and many governments across North America are trying to get on board. Nowhere is this more evident than the introduction of EnerGuide 80 energy efficiency standards in many building codes.

British Columbia and Ontario, which together represent nearly half of all building starts in Canada, were among the first provinces to roll out such new measures. B.C.'s EnerGuide 80 plans are scheduled for implementation in the fall of 2011, while Ontario's corresponding Building Code revisions will come into effect in January 2012.

What few people realize is that the EnerGuide 80 model, and indeed building codes themselves, are based on a very serious flaw, right at their core: their dependency on R-Values. When one considers how R-Values are calculated in the laboratory, and how systematically they are used as a measure of energy efficiency, the expression "garbage in, garbage out" certainly comes to mind.

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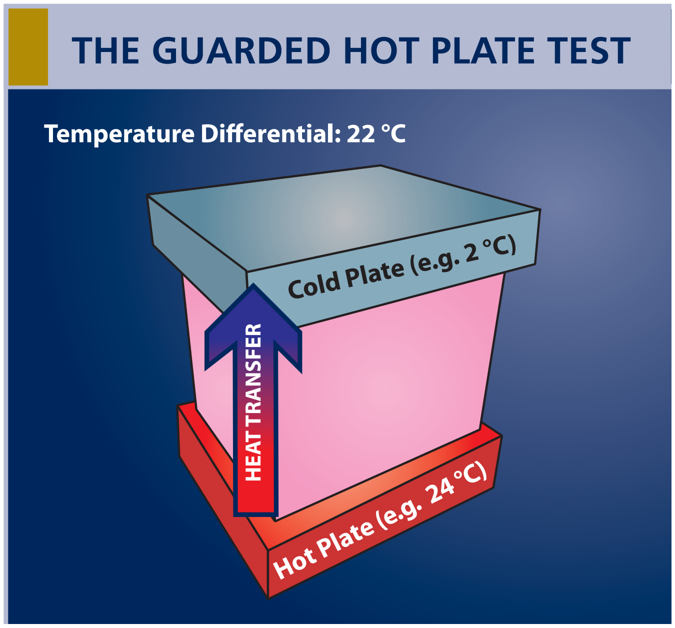
The Flaw with R-Values

An R-value is a measure of thermal resistance of a given material. The 1997 Model National Energy Code for Buildings (1997 MNECB) specifies two methods for rating the thermal properties of an insulator:

- ASTM Standard C518, "Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus."
- ASTM Standard C177, "Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus."

Both methods are based on the same principle. The insulation is placed in an enclosed box, sandwiched between two different temperature plates. Given two objects with different temperatures, heat always flows towards the object of lower temperature. The thermal performance of the insulation is therefore calculated by measuring how much heat is transferred from the hot plate to the cold plate, and this is expressed in terms of an R-Value.

The 1997 MNECB requires the ASTM C518 and ASTM C177 testing standards to be carried out an average temperature of 24°C (± 3°C) and under a temperature differential of 22°C (±2°C). This requirement is ambiguous because one plate's temperature can be 24°C (±3°C), simulating a building's indoor temperature, and the other plate temperature can be 46°C (±2°C) or 2°C (±2°C), simulating a building's outdoor temperature.



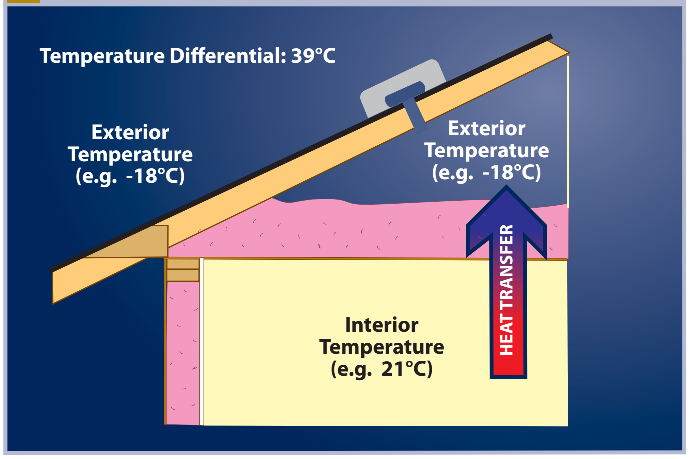
But in the real world, especially in cold weather climates such as Canada's, the indoor vs. outdoor temperature differential is much more extreme. The average low temperature in Ottawa in January is -15°C and a low of -35°C with wind chill is not uncommon during cold spells. So insulation in Ottawa homes has to regularly contend with temperature differentials of 35°C or even 55°C at times!

What exactly happens to insulation in real world conditions where temperature differentials are more extreme than in the hot box test? That's just what the U.S. Department of Energy's Oak Ridge National Laboratory set out to do in a groundbreaking study of attic insulation. It concluded that the thermal resistance of loose-fill fiberglass insulation is as much as cut in half when the outside temperature is -28°C. Specifically, insulation tested in a hot box at R-22 performed at a mere R-9 level!

> *"The building code even admits that prescriptive compliance packages are merely 'generally equivalent' to EnerGuide 80."*

Incidentally, the 1997 MNECB requires windows heat loss values to be calculated with indoor temperature of 21°C and outdoor temperature of -18°C, a temperature differential of 39°C. This seems to be a more reflective approach for simulating cold Canadian winter climates than is used for insulation.

REAL WORLD INSULATION PERFORMANCE



Another major flaw of the hot box approach for calculating R-Values is that it only considers one method of heat transfer: conduction. That involves heat transferred directly within a material, or between two materials that are in contact.

To measure conductive heat loss, the hot box completely seals the test materials from the outside environment, preventing air infiltration. But in an actual home situation, air infiltration through minute cracks in walls, ceilings, windows, doors and even through insulation material is a significant source of heat loss. As a result, the rated R-Value of any given insulation is not a full and accurate measure of the material's effectiveness in preventing heat loss.

Two Paths to EnerGuide 80: Prescriptive and Performance

The new EnerGuide 80 standards represent an effort to emphasize "actual" energy performance in building practices. Proponents may even point out that EnerGuide improves on the traditional code that relies exclusively on R-Values, which as we have seen, do not always reflect real world conditions.

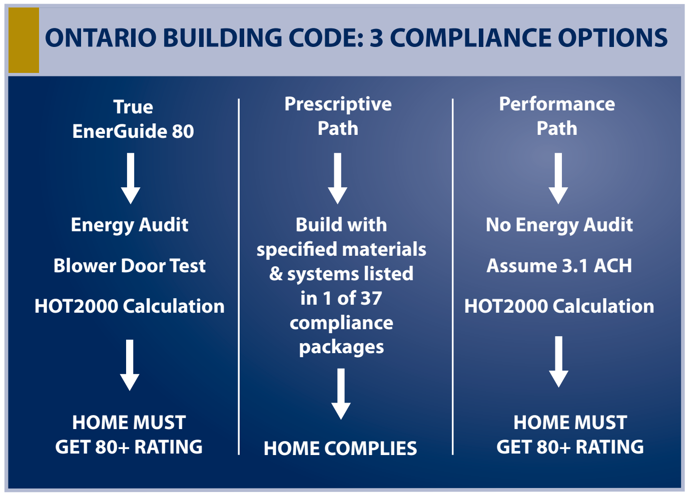
In an effort to quantify and measure performance, new home builders have to achieve an 80 rating on a 100 point scale. This is determined according to the national EnerGuide for New Houses program, whereby a rating is awarded **after** a home is fully constructed.

A certified energy advisor inspects the house to verify any energy efficient upgrades and performs a blower door test to measure airtightness. Details of a home's construction, such as insulation, windows and HVAC systems are keyed into a modelling simulation software package called "HOT2000". Other variables such as a home's geographic location and orientation are inputted as well. HOT2000 then calculates how much energy the home is expected to use in a year, from which an official EnerGuide rating is determined.

This HOT2000 method is known as the "Performance Path" to EnerGuide 80 compliance. However, both B.C. and Ontario have legislated alternative "Prescriptive Path" methods as well, at the insistence of the homebuilding industry. These detail specific materials and systems that allow builders to meet code without having to undergo a formal performance-based EnerGuide audit.

When Ontario's EnerGuide 80 regulations come into effect, there will be 37 different prescriptive "compliance packages" that the code considers *"generally equivalent to a rating of 80 or more."* Most of the packages share similar criteria when it comes to insulation: R-50 in the attic, R-24 for exterior walls, and R-20 for basement walls are among the common denominators in many of the compliance packages.

The obvious flaw with the prescriptive path is that it is based on construction inputs, most importantly the R-Value of insulation in the house. And as we now know from the discussion above, R-Values are based on temperatures that just don't reflect typical Canadian climates.



The Flaw with the Performance Path

One might think that the Building Code's performance path to achieving EnerGuide 80 standards would be more reflective of a home's actual energy consumption in the real world. But the performance path is equally as flawed as the prescriptive path.

When an energy evaluator simulates a home's energy consumption using HOT2000 software, he or she keys in the R-Value rating used in construction. But once again, the lab-determined approach to R-Values doesn't provide an accurate quantification of actual real-world energy efficiency performance.

In fact HOT2000 would give identical EnerGuide ratings to two identical homes, different only in the type of insulation used. However, all real-world evidence – from scientific studies to monthly heating bills – demonstrates that homes built with different types of insulation can experience much different levels of energy consumption, even if their R-Values are similar.

Another flaw with the Performance Path is how it addresses home airtightness. The tightness of a building is measured by "air changes per hour" (ACH), or how many times the entire volume of air in an area is exchanged in an hour. It is measured on site using a "blower door" test. Now while a true EnerGuide rating requires blower door results to be inputted into HOT2000, Ontario Building Code permits an arbitrary value of 3.1 ACH @ 50PA to be used in lieu, bypassing the blower door test entirely.

Data collected from over 8,000 blower door tests in homes built between 2000 and 2008 show an average leakage of 3.6 ACH @ 50PA. That's considerably tighter than the average home in Ontario (6.5 ACH @ 50PA), but far short of the standard of 1.5 ACH @ 50PA promoted by the R-2000 energy efficiency initiative. In fact only 4 percent of the houses in the study could claim a tightness of 1.5ACH or better. And 55 percent failed to even meet the 3.1 ACH value that builders are allowed to input into HOT2000!

Typical Air Leakage Estimates

A blower door test determines the airtightness of a house by measuring how many "air changes per hour" will occur at a given differential pressure.

Average Ontario home **~6.5 ACH (50 PA)**	Average home, built 1950 **~9 ACH (50 PA)**	Average home, built 2000 **~3-4 ACH (50 PA)**
Average home, built 1900 **~11-12 ACH (50 PA)**	Assumed value for OBC Performance Path **3.1 ACH (50 PA)**	R-2000 standard **1.5 ACH (50 PA)**

While it is true that new homes are being built more and more airtight nowadays, non-traditional insulation materials provide giant leaps in tightness, minimizing seams and gaps, and consequently air leakage. Homes constructed with structural insulated panels regularly achieve air tightness levels of 1 to 2 ACH @ 50 PA. These impressive results contribute directly to real world energy efficiency improvements.

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Clearly, the entire EnerGuide 80 movement towards energy efficiency in today's building code is predicated on a flawed approach of rating insulation R-Values in the laboratory, not in the real world.

But as a homeowner paying the monthly utility bills, or even as a concerned citizen hoping to promote better environmental practices, wouldn't you be most interested in actual performance, not lab performance?

So what's a prospective new home buyer to do? It all begins with education. When you recognize some of the limitations of the energy-efficiency provisions of building codes and conservation programs such as EnerGuide 80, non-traditional insulation materials become increasingly appealing. The knowledgeable homebuyer can significantly exceed their energy saving expectations by researching and insisting on insulation proven not just in the lab, but more importantly in the real world.

Tips for Prospective New Home Buyers

- **Undertake constructive dialog with your builder to communicate your expectations on energy efficiency.**
- **Insist on an air blower test to ascertain air tightness, otherwise an arbitrary value of 3.1 ACH @ 50PA may be used for EnerGuide calculations.**
- **Understand the limitations of R-Value calculations and how this undermines Building Codes and EnerGuide in their efforts to promote true energy efficiency.**
- **Regardless of the selected EnerGuide 80 compliance package, have your builder confirm the insulation material's actual performance in cold climates (e.g. -20°C).**

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