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# The Frustrating Realities of Cold Climate Design: Piercing the Skin: Ins-U-lation versus Ins-O-lation

**Terri Meyer Boake B.E.S. B.Arch. M.Arch.**
Associate Professor
School of Architecture
University of Waterloo

*When glazing (windows and skylights) accounts for 7.5 to 19 times the losses based on the same area as the wall or roof they displace, even slight modifications in U-values can account for large variations in overall energy efficiency.*

**From First Principles:**

The first principle of energy efficient environmental building design for a cold climate is as follows: First INSULATE, and then INSOLATE. The use of passive solar design principles can be key to reducing the overall amount of energy consumed by residential buildings. Create warm tight walls, then, perforate with an adequate number of windows to absorb free energy. Ensure that there is adequate thermal mass present to absorb and then, later, reradiate the free heat. The principle is simple. Its detailed application is complex. Apertures effectively puncture the building skin, resulting in a discontinuity of the thermal integrity of the envelope. Piercing creates a thermal hiatus, as the thermal resistance of the windows is normally a fraction of the insulation value of the wall. Environmental concerns arise out of the loss of heat through these openings as well as the control of solar gain as it affects cooling loads. Orientation must be intrinsically considered for each and every opening. Shading devices need to be designed in order to manage the amount and quality of solar gain and light. Daylighting should also factor into the design equation, in its potential to reduce energy costs as well as a "D"esign element.

The art of creating adequately insulated wall assemblies has by and large been perfected. The Energy Crisis of the mid 1970's resulted in code and subsequent practice changes that succeeded in drastically increasing the minimum insulation values in cold climate building envelopes. Ensuing envelope research defined the need for an air barrier as a means to control infiltration and exfiltration through the building envelope. Even the simplest "skin" of the cold climate building has become an increasingly thick, multi-layered assembly. By code, it can be nothing less. Current building and energy codes mandate a high minimum level of thermal resistance in walls.

Glazing, on the other hand, in spite of major technical advancements to improve its energy performance, has remained a thin and relatively vulnerable design element. Windows are at risk as they are both fragile and costly. Whereas a reasonable minimum thermal performance standard can be easily maintained throughout the detailed design of the opaque portion of the building envelope, cost cuts will often decrease the level of quality, design and performance of the window systems actually installed in the building. Windows and glazing systems often appear as quite expensive single “line items” on preliminary cost estimates for construction. The environmental quality of a window is directly proportional to its cost. Highly efficient windows are many times as expensive as their low quality counterparts. Budgeted values for window systems are all too easy for clients to attack in the effort to save capital cost. Changes in manufacturer, quality, number of glazing layers, etcetera, can dramatically reduce the energy effectiveness of such systems. Unless designers provide accurate comparative energy simulation results, it becomes difficult to convince budget conscious clients to spend extra funds on Insolation.

**The Model National Energy Code of Canada for Houses 1997:**

The Model National Energy Code of Canada for Houses was published in 1997 and is intended as a “progeny” or stand-alone document. Unlike traditional model codes which normally address health and safety issues, it addresses the issues of environmental protection and resource conservation. The MNECH provides model national technical requirements for use or adoption, in whole or in part, by local or provincial authorities. These regulations can be ignored if they are not part of their government’s agenda. As such, the MNECH outlines a set of technical regulations that expect a higher standard than those outlined in the National Building Code of Canada. The NBC is the national model code, which is either adopted by the Province or improved upon in the creation of specific provincial codes such as the Ontario Building Code

According to the Model National Energy Code of Canada for Houses 1997, (for a specific region [1]), the minimum RSI and *R* values for a zone having up to 5000 Celsius *(9000 Fahrenheit)* Degree Days are as follows for above ground elements [2]

| | | | | |
|---|---|---|---|---|
| Attic-type roofs: | 5.6 $m^2x^oC/W$ | or a | U-value of | 0.178 $W/m^2x^oC$ |
| | *31.8 $hxft^2x^oF/Btu$* | | | *0.031 $Btu/hxft^2x^oF$* |
| All other roofs: | 4.3 $m^2x^oC/W$ | or a | U-value of | 0.233 $W/m^2x^oC$ |
| | *24.4 $hxft^2x^oF/Btu$* | | | *0.041 $Btu/hxft^2x^oF$* |
| Walls: | 2.9 $m^2x^oC/W$ | or a | U-value of | 0.345 $W/m^2x^oC$ |
| | *16.5 $hxft^2x^oF/Btu$* | | | *0.061 $Btu/hxft^2x^oF$* |
| Floors: | 4.5 $m^2x^oC/W$ | or a | U-value of | 0.217 $W/m^2x^oC$ |
| | *25.5 $hxft^2x^oF/Btu$* | | | *0.039 $Btu/hxft^2x^oF$* |

Windows[3], on the other hand, may demonstrate a maximum U-value of 2.60 $W/m^2x^oC$ *(0.457 $Btu/hxft^2x^oF$),* or a minimum RSI value of 0.385 $m^2x^oC/W$ *(R value of 2.2 $hxft^2x^oF/Btu$).* By piercing the wall envelope, we replace highly efficient walls with components that by area transmit 7.5 times as much heat per hour. Skylights are permitted to have a thermal transmission value of 3.4 $W/m^2x^oC$ *(0.599 $Btu/hxft^2x^oF$),* which will permit the loss of approximately 14.5 to 19 times as much heat as the roof areas they are replacing.

The values cited for windows are different for operable versus fixed versus sashless windows. It is accepted that operable windows will have poorer performance because the sashes and hardware needed to make the unit operable will have a negative effect on its energy efficiency. The frames for the operable portion decrease the glass to frame ratio for an operable unit versus a fixed unit. The various types of operable units incur air leakage as a result of the type of operation. Casement windows with pressure locking hardware will have a higher degree of efficiency than windows that slide. Fixed glazing without a sash is expected to perform substantially better than either operable or fixed windows with sashes.

**The Energy Rating (ER):**

The Guidelines of the Model National Energy Code for Canada 1997 outline minimum energy ratings for windows that meet CSA Standard A440.2: Energy Performance Evaluation of Windows and Other Fenestration. Until CSA Standard A440.2 was developed, it was not possible to compare the overall energy performance of different windows. If energy performance information was provided by the manufacturer, it was often quoted as the R-value or the U-value for the center-of-glass area. This did not take into account the effect of the frame and sash, so it usually over-represented the energy performance of the entire window. In addition to outlining a method for the calculation of solar heat gain coefficients, U-values and air leakage, CSA Standard A440.2 also provides a method for calculating an overall Energy Rating (ER) for a window to be used in a self-contained low-rise residential building by combining the three properties

(a) solar heat gain coefficient (SHGC);
(b) overall heat transmission coefficient (U-value); and
(c) air leakage

into a single overall rating. The ER provides a means to compare the energy performance of one window for use in a low-rise residential building with another. The Energy Rating (ER) provides a method of rating the relative thermal performance of windows that gives, in a single number to a window's *combined response* to solar heat gain, conductive heat loss and air leakage in typical Canadian climatic conditions. It is based on the total performance of all window components, including glazing, spacers, glass and frame.

However, because of the manner in which the ER is determined, there are limitations to its applicability. ER is only applicable when comparing windows and sliding glass doors that will be used in houses under specified heating conditions. The ER calculation assumes vertical installation in a typical residence and is based on average conditions for solar radiation incident on windows facing the four cardinal compass directions (north, east, south, and west) and for representative climate zones in Canada. The ER may be positive or negative. A positive ER indicates that the window generally gains more energy through solar gain than it loses over the heating season. Most ER ratings for windows are negative. This means that the window loses more energy over the heating season than it gains from solar exposure. This is the typical case.

Additionally, the ER value is derived as an average of the performance of windows facing north, south, east and west. This is a suitable approach if designing for general energy efficiency rather than passive solar design. For example, where traditional builders are constructing a subdivision, there will be approximately the same numbers of windows facing each direction. Builders normally will use the same type of window throughout the project. The ER will provide a fairly accurate overall picture of the energy efficiency of the development.

For passive solar design, it is absolutely necessary to differentiate the ER for all orientations. Passive solar design may specify different types of windows and glazings for the various directions as a direct result of the solar design strategy. Where Low-E glass may be suitable to decrease conductive losses on shaded elevations, its incorporation will be detrimental if used on south elevations. The Low-E coating will decrease heat losses, but will at the same time, decrease solar gains by increasing the value of the shading coefficient. CSA Standard A440.2 does include a methodology for the differentiated calculations of ER values as depended on various exposures.

Where the Energy Rating can be an excellent “general” means of comparing the quality of glazing products, the ER value is typically not the information required for input into many thermal performance computer simulation programs. Energy-10, being a U.S. based product, requires U-values and SHGC values in order to run a simulation.

**The Ontario Building Code 1997: Requirements for Window Design**

The 1997 Ontario Building Code adopted parts of the window criteria as posed by the MNECH 1997. The OBC differentiates between window/glazing requirements for “standard” building design and “Thermal Design” (a.k.a. Passive Solar Design). The thermal insulation requirements for “standard” residential buildings are assumed to work with the table of “minimum” window area requirements, below. The assumption seems to be that builders who use this portion of the Code will be working to more “cost effective” minimum standards. The thermal integrity of these types of buildings is not likely to be compromised by the inclusion of excessive amounts of windows.

***Glass Areas for Rooms of Residential Occupancies:*** [4]

| Location | Minimum Unobstructed Glass Area | |
|---|---|---|
| | With No Electric Lighting | With Electric Lighting |
| Laundry, basement, recreation room, unfinished basement | 4% of area served | Windows not required |
| Water closet room | $0.37m^2$ | ($4\ ft^2$) |
| Kitchen, kitchen space, kitchen alcove | 10% of area served | Windows not required |
| Living rooms and dining rooms | 10% of area served | 10% of area served |
| Bedrooms and other finished rooms not mentioned above | 5% of area served | 5% of area served |

For windows that meet the above criteria, the only energy requirements are:

(a) Air infiltration shall not exceed 0.775 dm3/s for each meter (0.5 cfm for each foot) of sash crack when tested at a pressure differential of 75 Pa (0.011 psi))

(b) All glazing that separates heated space from unheated space shall have a thermal resistance of not less than 0.30 $m^{2o}C/W$ (1.70 $ft^2xhx^oF/Btu$)

The OBC requirements are slightly more stringent for residences with electric heating and copy the MNECH in their requirement of an ER of not less than –13 for operable windows and sliding glass doors, and an ER of 0 for fixed glazing.

Additionally, the Code requires that the maximum amount of glazing (including windows, skylights and doors) can not exceed 20% of the floor area of the story being served by the glazing nor exceed 40% of the total area of the walls of that story.

**The OBC Regulations: Glazing and Passive Solar Design**

The Ontario Building Code uses a separate set of requirements for glazing in the case of "Thermal Design". The Code states that this section applies to the thermal design of a building of residential occupancy where such design is an *alternative* to the normal thermal insulation requirements.[5] This section of the Code creates a series of alternate regulations that take into account the use of windows of a higher thermal value, modifications as a result of shading coefficients, and the need to increase the area of glazing to achieve passive solar design. Passive thermal design is regulated for buildings with thermal values for windows that exceed the 0.30 $m^{2o}C/W$ (1.70 $ft^2xhx^oF/Btu$) set point. The MNECH presents a similar set of guidelines that are designed to "prevent this Code's limitation of window area from being an impediment to the intelligent incorporation of passive solar heating in house design"[6].

The 20%/40% rule may be broken, i.e. the amount of glazing increased, if the thermal values for the windows are higher than 0.30 $m^{2o}C/W$ (1.70 $ft^2xhx^oF/Btu$). To meet the 20%/40% rule, the actual amount of glazing is calculated as being equal to the actual area of window, multiplied by the ratio of the required thermal resistance divided by the actual thermal resistance of the window. For example, if the Code permitted the building of $10m^2$ of window with a resistance value of 0.30 $m^{2o}C/W$ (1.70 $ft^2xhx^oF/Btu$), if you selected a window with an insulation value of 0.40 $m^{2o}C/W$ (2.27 $ft^2xhx^oF/Btu$), your ratio would be 0.30/0.40 = 0.75. You could actually have 13.3 $m^2$ of windows as when 13.3 is multiplied by 0.75, it translates to the value of $10m^2$. Therefore, the higher the thermal value for the window, the proportionally higher amount of glazing is permitted – resulting in theoretically identical heat losses.

Glazing areas can also be increased where the design is using passive solar gain principles on "south" facing orientations. In such cases the glazing area may be calculated at 50% of what is actually being constructed, provided that:

(a) the area contains clear glass or has a shading coefficient of more than 0.70 (the MNECH uses a value of 0.61), *and*

(b) faces a direction within 45$^o$ of due South, *and*

(c) is unshaded in the Winter (calculating angles based on Dec. 21 at noon), *and*

(d) the building is designed with a system that is capable of distributing the solar gain from such glazed areas throughout the building.

Where houses are designed for cooling, window areas cannot be increased, as outlined above, except where the glazing is shaded in the summer with exterior devices. The shading is to be calculated using noon sun angles for June 21.

The minimum accepted values for air infiltration are the same for both Passive and standard building types.

**The Difficult Task of *Finding* the *Right* Information:**

Now we know the rules. But, before the merits of any glazing design can be assessed, the designer faces the task of gathering technical information about the specific types of glazing and windows. This can be a very difficult and frustrating task. Whereas the thermal resistance values of opaque building materials are readily available, thermal resistance or more normally, conductance values of glazing products, glass block and windows are not generically listed in the same publications. These items are excluded from the broad category of "building materials". The resistance and conductance values for glazing materials are specifically attached to proprietary products. The values are highly dependent on the conducting of tests which must account for glass types, thicknesses, coatings, air spaces, spacer types, glass to frame ratios for each window size, frame materials, operability, air leakage, and shading coefficients. The final values are available only from the manufacturer because of their product specific nature. The values are produced sometimes in cooperation with CSA or ASTM approved testing agencies, and at other times by independent testing agencies whose services are purchased by the window manufacturer.

To add to the frustration, Standards, Testing Methods, Computer Simulation Programs and product information are available in an inconsistent combination of SI and Imperial Units. The U-value and R-value are universal terms whose units may be readily converted from SI to Imperial and vice versa. The Solar Heat Gain Factor, values for UV Blockage and Light Transmittance are standardized percentages. The ER rating is specifically Canadian. Although a useful value, it is not available for the majority of products that are produced by U.S. based manufacturers.

As a result, specific information is required in order to properly assess the thermal performance of windows, and subsequently produce accurate heat loss/gain calculations for the entire building. This information is difficult to obtain and often unreliable. Where practitioners and researchers may have the facility to keep up to date catalogues on a wide range of glazing products at their fingertips, most students do not. The two most readily used sources that students use for finding building information are the Internet and Sweets Catalogue. The 2000 Sweets Catalogue CD, under Division 8: Windows and Doors, lists a great number of manufacturers of window products and is a good place to start. Many of the sections also provide hot links to manufacturers' web sites that may have more and more up to date information. On the surface, this is a great resource, however, a review reveals that the information provided is very inconsistent from manufacturer to manufacturer. Some manufacturers provide detailed descriptions, specifications and details, and, some do not. Because of their different frame to glass ratios, different values are required for operable versus fixed glass units. These values could not be found in the manufacturers specifications.

The most common piece of technical information listed was the coefficient of airtightness. A rare few manufacturers listed any information regarding conductance, solar heat gain factor or light or UV transmission. Many are quick to proclaim their product as "Insulating", "Energy Efficient", thermally broken, or having low-e glass with argon fill. Few manufacturers back up these claims with data. This becomes very problematic when attempting to create an accurate estimate of the contribution windows make towards the energy efficiency of the overall building envelope.

When glazing (wall windows and skylights) accounts for 7.5 to 19 times the losses based on the same area as a wall or roof, even slight modifications in U-values can account for large variations in overall energy efficiency. Many manufacturers may quote thermal resistance values for the center of glazing in their windows. This value is always higher than the effective thermal resistance of the window when the effects of the edge seal and window frame are taken into account. If these values are used instead of a lower, more accurate thermal resistance value, the calculations of overall losses can be erroneous. It is also a problem when a U- or R-value is quoted for a glazing unit and the manufacturer is unclear as to whether the value is for the center of glass or overall performance.

The Canadian Wood Frame House Construction Handbook 1997/8 cites the following table to compare "typical" window thermal efficiencies. The comparison is only based upon a casement style window.

***Comparison of Typical Window Thermal Efficiencies:***

| **Thermal Performance of a Typical Casement Window with Low Conductivity Edge Seal** | | | |
|---|---|---|---|
| ***Glazing Type:*** | ***Aluminum Frame with Thermal Break*** | ***Wood or Vinyl Frame*** | ***Fiberglass Frame*** |
| | ***R (RSI)/ Energy Rating*** | ***R (RSI)/ Energy Rating*** | ***R (RSI)/ Energy Rating*** |
| *Double Glazed Clear with Air Fill* | 1.59 (0.28)/ -40.6 | 2.04 (0.36)/ -24.9 | 2.38 (0.42)/ -19.0 |
| *Double Glazed Low-E with Air Fill* | 1.99 (0.35)/ -32.7 | 2.67 (0.47)/ -17.1 | 3.12 (0.55)/ -11.5 |
| *Double Glazed Low-E with Argon* | 2.10 (0.37)/ -29.0 | 2.90 (0.51)/ -13.3 | 3.46 (0.61)/ -8.0 |
| *Triple Glazed Clear with Air Fill* | 1.99 (0.35)/ -32.7 | 2.84 (0.50)/ -11.8 | 3.18 (0.56)/ -10.8 |
| *Triple Glazed Low-E with Air Fill* | 2.21 (0.39)/ -27.9 | 3.41 (0.60)/ -9.5 | 3.86 (0.68)/ -6.2 |

The guidelines in the Canadian Wood Frame House Construction Handbook also make recommendations with respect to the minimum standards for energy efficient windows. It concurs with the MNECH that at the minimum windows should have an ER of –13 or higher. This translates into a double-glazed window with Low-E coating and argon gas fill. Higher efficiency windows are recommended for the colder regions of Canada. A glance at the chart above would indicate that thermally broken aluminum frame windows would never meet the ER criteria. Only wood, vinyl and fiberglass frame windows with higher quality glazing would meet the ER rating conditions. However, only one window would fail to meet the OBC code requirement of 0.30 $m^{2o}C/W$ (1.70 $ft^2 x h x ^oF/Btu$). The Handbook makes no mention of Shading Coefficients.

Comparing this type of "idealized" data with actual manufacturers' test results is interesting. The only window manufacturer that I could find on the "web" that published a thorough spreadsheet of test values was Loewen Windows[7]. They had complete spreadsheets for all of its wood and door types, both metal clad and non clad, including Canadian ER ratings, NFRC total unit SHGC and Visible Light Transmittance Factors and Imperial U-values. The Velux Roof Windows and Skylights website had similar, although less comprehensive, charts of statistical data.[8] The chart below is an excerpt for the purposes of comparing the test values for casement windows with the CHMC chart.

***Loewen Windows Test Data:***

| **Thermal Performance of a Typical Casement Window with Low Conductivity Edge Seal** | | |
|---|---|---|
| ***Glazing Type:*** | ***Metal Clad Wood Frame*** | ***Non Clad Wood Frame*** |
| | ***R (RSI)/ Energy Rating/ SHGC*** | ***R (RSI)/ Energy Rating/ SHGC*** |
| *Double Glazed Clear with Air Fill* | 2.04 (0.36)/ -27 0.52 | 2.13 (0.38)/ -25 0.51 |
| *Double Glazed Low-E with Argon* | 2.13 (0.38)/ -25 0.29 | 2.22 (0.39)/ -22 0.28 |
| *Triple Glazed Clear with Air Fill* | 2.86 (0.50)/ -14 0.47 | 2.94 (0.52)/ -12 0.46 |
| *Triple Glazed Low-E with Air Fill and Argon* | 3.57 (0.63)/ -18 0.26 | 3.85 (0.69)/ -16 0.26 |
| *Triple Glazed 2 Low-E with Argon* | 4.17 (0.73)/ -14 0.24 | 4.55 (0.80)/ -12 0.24 |

Compared to the generalized “ideal” results table posed by the Canadian Wood Frame House Construction Handbook, the Loewen results would indicate that only 2 of their windows would meet the ER criteria of a maximum rating of –13. Both of these windows types call for triple glazing – a type I would suggest is beyond the budget of most housing. All of these windows, however, exceed the minimum thermal rating of 0.30 $m^{2o}C/W$ (1.70 $ft^2xhx^oF/Btu$) as described in the Ontario Building Code. All would be able to be used in “Thermal Design” as a means to increase the maximum allowable glass (the 20%/40% rule). None of these windows has a high enough SHGC to allow for an increase in area based upon thermal solar gain principles.

The best source that I have found thus far, limited to window types available in the Canadian market, and that have been tested and rated, is available for free download on the Enermodal Engineering web site. It can be found at

http://www.enermodal.com/catalognew.html.

This links to CATALOGUE, a very comprehensive listing of all energy rating criteria for a wide range of residential windows and does include ER values – values that cannot be found elsewhere. Enermodal Engineering is one of the new genre of consultancies that has chosen to specialize in the design and testing of windows and is also producing other software that can be used to design/evaluate sustainable buildings.

**The Balancing Game: Comparing the Merits of Ins-U-lation versus Ins-O-lation**

The thermally efficient detailed design of the typical exterior wall or roof is a relatively straightforward task. Codes, combined with tested practice, have given us rather formulaic assemblies for standard wall compositions: brick veneer, precast concrete veneer, EIFS systems and metal cladding on a choice of wood frame, concrete block, or steel stud backup systems. There have been adequate research documents produced that publish details that address the more difficult construction issues associated with standard envelope or cladding systems. In addition, it is a relatively straightforward task to perform quick comparative overall thermal resistance calculations for typical wall or roof assemblies using easily accessible tables of thermal resistance or conductance values for a wide range of wall and roofing materials. Thermal performance simulation programs make fast work of predicting overall loss values for a number of scenarios where materials and insulation types and thicknesses can be changed. Values are typically based on calculations of losses and do not take into account solar gains, shading or orientation. The focus of the thermal resistance calculations for opaque portions of the building envelope is on INSULATION.

There are two routes that can be taken when designing/selecting windows. The “easy way” is to simply specify windows that meet the minimum standards as set by the Code. The task of designing *thermally effective* openings – windows or skylights – is a much more complicated undertaking – a balancing game. Not only must the INSULATION value of the openings be calculated, but in order to be accurate, their INSOLATION values must also be incorporated. Including the Insolation values will help to offset the considerable heat losses created by window openings. If using a computer simulation program to perform the energy calculations, it is also possible to incorporate the effect that Daylighting has on the overall energy picture.

There are significantly more variables to incorporate when accounting for the effectiveness of the insolation value of openings. To properly calculate the role of the “window” elements as they pierce the thermal effectiveness of the building envelope we must look carefully at three primary areas:

1. INSULATION:

Calculate Heat Loss: this requires that an *accurate* R or U-value be attached to the area of the window. Certain calculation methods will also account for airtightness/leakage values. The windows must meet or exceed Code requirements. *(This is the minimum that is required by Code).*

2. INSOLATION:

Calculate Heat Gain: this requires accounting for a Shading Coefficient of the glass (knowledge of the actual type of glass); precise orientation of each glazed portion; local site shading characteristics that may affect each glazed unit; design/ use of shading devices; use and extent of thermal mass.

3. DAYLIGHTING:

Calculate Daylighting Payoffs: determine the amount of energy that can be offset where daylighting can complement or displace the need for electric lighting.

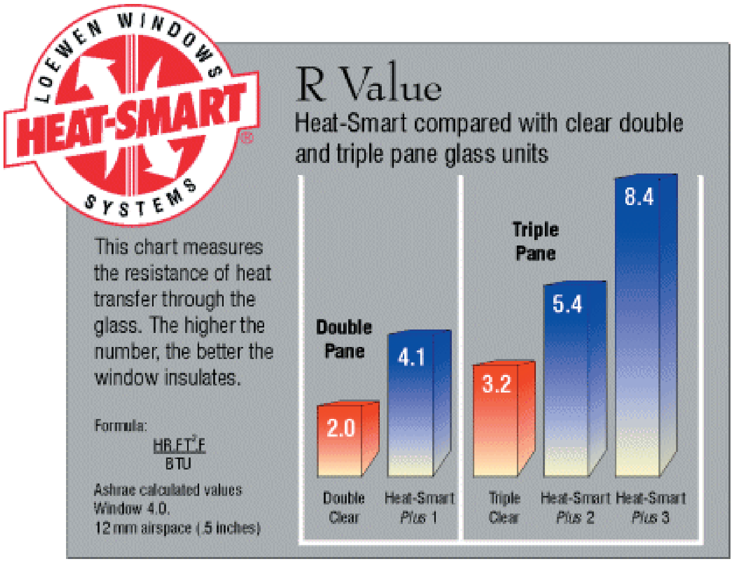
Looking at windows in this way asks that Architects take a more challenging and comprehensive approach to the question than is legally required. The Building Code normally requires insulation calculations. Codes have varied responses or even rules to account for the incorporation of Insolation strategies. Daylighting is only required in residential buildings to meet minimum health and safety requirements and is not generally considered as an energy strategy.

**Selling Energy Efficient Window Design:**

When looking at window design and selection, the standards that are mandated “by law”, fall well short of providing an energy efficient solution to a high standard. Manufacturers are successfully selling windows that do not meet the Code requirements. Responsible architecture should strive to pierce building skins with environmentally effective openings. Architectural education can play a very important role is encouraging future Architects to approach window design in a thorough and environmentally responsible manner – in spite of relatively lax legal requirements.

The majority of clients and builders regard Codes and Standards as maximums rather than minimums from a performance point of view. Their viewpoint is based on budget-founded decisions. Better windows, more windows, shading devices and thermal mass cost money. How can an Architect or Designer encourage that kind of expenditure when the Code is being met? In order to sell clients on energy efficient window strategies that are going to increase their capital cost, it is necessary to provide easy to understand, cost reflective data, to substantiate the claims that environmental payback will be created by passive solar design strategies.

Both Energy-10, from the United States (Imperial Units), and Hot-2000, from Canada (SI Units), provide computer simulation machines that are, to varying degrees, capable of handling the task of energy efficient window design that goes beyond insulation values. They can also run comparative simulations so that various energy strategies can be assessed as to their relative value (both dollar and environmental). Questions can be posed. Is it worthwhile to increase the thermal resistance value of a window? Is there any benefit to adding shading devices or thermal mass? Does daylighting substantially reduce the requirement for electric lighting? Does daylighting negatively impact heat loss? These questions should be answered, with numerical data, in order to back up and verify the employment of many passive design strategies.




*Increasingly environmentally interested clients will be seeking products that provide accurate, comparative information, related to the thermal performance of windows.*

**In Conclusion:**

We can identify three "levels" of energy efficiency that can rate the environmental aspects of windows.

Level One, *minimum efficiency*, is by far the simplest method. It entails specifying windows and skylights that simply *meet* the minimum energy standards as set by the Building Code. Some quality control is required during installation to ensure that air leakage is also minimized. This method produces openings that still account for 7.5 to 19 times the heat losses based on the same area of wall or roof. Meeting minimum standards does not constitute responsible energy efficient or environmentally conscious design. Losses can be drastically reduced if additional energy efficient strategies are applied.

Level Two, *medium efficiency*, suggests the adoption of the Model National Energy Code for Houses. This simply applied strategy raises the standards of window selection/specification to meet the National Model Energy Code. This code requires that window specification be related to the environmental characteristics of the primary fuel source, requiring better windows where fuel is more "expensive". This approach limits the range of windows and skylights that meet the criteria, as well as decreases general heat losses = fuel burned. It also requires quality control on site installation against air leakage. The NMECH, which bases its chart on average orientation is suitable for "builders" as it adopts rules that work irrespective of solar orientation, hence not requiring much "thought".

Level Three, *high efficiency*, aims even higher and asks that designers account for a combination of the Insulation, Insolation and Daylighting potential of openings. This necessitates the incorporation of passive solar design strategies. This level of energy efficiency requires that windows be "designed", not just "specified". Orientation and interior building materials (thermal mass), and colors (daylighting) must be accounted for. Different window construction will be required on the different cardinal directions. The Appendix of the NMECH gives some procedures that can be followed. There are many computer programs that can be used to make the task "simpler", although even these launch the energy efficient design in windows into a realm that will be beyond the patience of most designers. It begins to open up a field for yet another area of specialization and consultancy.

To properly design energy efficient openings for cold climate applications is not an easy task. It is, however, essential.

## Notes:

[1] National Model Energy Code for Houses 1997. Appendix A. Ontario. Region A - <5000 C Degree Days. Table A-3.3.1.1 Prescriptive Requirements for Above Ground Assemblies

[2] Considering Natural Gas Heat. The tables note more stringent values for Oil and Electric heating.

[3] Windows that do not meet CSA Standard A440.2: Energy Efficiency Values for Windows; i.e. are not tested and labeled as such.

[4] Ontario Building Code 1997. Table 9.7.1.2. Forming part of sentence 9.7.1.2.(1)

[5] Ontario Building Code 1997. Section 9.38. Thermal Design, Sentence 9.38.1.1. Application

[6] MNECH 1997. E-3.3.1.5.(2) South Facing Glass

[7] Loewen Windows information can be found at http://www.loewen.com/heatsmart.html

[8] The Velux glazing descriptions can be found at: <http://193.163.166.226/252.asp>