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A SIMPLE METHOD FOR COMPUTING WINDOW ENERGY PERFORMANCE FOR DIFFERENT LOCATIONS AND ORIENTATIONS

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ABSTRACT

A new energy standard for evaluating window thermal performance has been established in Canada. To allow for simple comparison of windows, a single energy rating number is calculated based on specific house and weather conditions that are intended to be an appropriate average for population centers across Canada. However, this method does not allow for a selective choice of windows based on window-specific applications or location and orientation. As a result, a simple method for evaluating window energy performance for different locations and orientations has been developed, and is presented in this paper.

Energy rating numbers, ERS, can be calculated based on the orientation of the window, the local environmental conditions, and the building characteristics (including building total heat losses and window area). This ERS is for residences only, and is intended primarily as a uniform basis for comparing windows in relation to their effect on seasonal energy requirements for heating. Negative ERS values indicate that the window arrangement considered will result in a net increase of the heating load of the house. ERS values that are positive indicate that over the heating season there will be a net gain in energy (therefore, a net reduction in heating requirements) attributed to the window.

Tables of climate-dependent factors used in the calculation of ERS have been established for 13 Canadian cities, 8 different orientations, and 2 house types (including a typical post-1975 Canadian house and a high-insulation house). However, similar tables can be established for virtually any location for which specific weather conditions are known. As a result, this ERS calculation procedure may serve as a basis for a universal method for comparing window performance.

INTRODUCTION

Background

A new standard of window energy performance that provides for a direct and simple comparison of window products (CSA 1991) has recently been developed in Canada. In particular, this standard provides a method for computing an energy rating number (ER) for windows under heating conditions in residential applications (Mayo and Carpenter 1989). It is based on specific house and weather conditions that are intended to be an appropriate average for population centers across Canada. This provides a standard basis for comparing window products based on their energy performance. This is thought to be a reasonable approach when climate and orientation are not specified, that is, for providing a national basis for energy rating of windows.

However, this method does not allow for a selective choice of windows based on window orientation and local environmental conditions. The values of incident solar radiation and, hence, the values of solar heat gain that are useful in offsetting house heating loads, are actually dependent on local climatic conditions and on the direction in which the window is facing when installed. Similarly, outdoor temperature and wind conditions, which determine heat losses by transmission and by air leakage, are dependent on location. As a result, a method for computing an energy rating value that is specific to location and orientation has been developed.

The Location/Orientation-Specific Energy Rating

The concept employed to establish location/orientation-specific energy rating values (ERS) is similar to that used for the national ER values in the Canadian standard. The ERS values are intended primarily as a uniform basis for comparing windows in relation to their effect on seasonal energy requirements for heating in single-family homes. ERS values for many window arrangements and orientations will be negative, indicating that they add to the energy requirement for heating; the greater the negative number, the more the net heat loss attributed to the window. Some window arrangements and orientations will have ERS values that are positive, indicating that over the heating season there is a net gain in energy (and net reduction in heating requirements) attributed to the window.

The equation to calculate ERS contains three terms—the first represents the average rate of usable solar heat gain through unit area of the window during the

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heating season, the second represents the average rate of heat loss through the window by transmission, and the third represents the average rate of heat loss through the window by infiltration.

$$\text{ERS} = q_s - q_t - q_i. \qquad (1)$$

The average seasonal rate of usable solar heat gain per unit area of window q_s can be expressed as a function of the solar heat gain coefficient for the particular window selected F_w, as follows:

$$q_s = F_s \cdot F_w \qquad (2)$$

where F_s, a climate-dependent factor, is as in Equation 6.

The seasonal average value of heat transmission loss rate per unit area of window q_t can be expressed as a function of the window U-value U_w by

$$q_t = (T_i - T_o) \cdot U_w \qquad (3)$$

where $(T_i - T_o)$ represents the average seasonal indoor/outdoor temperature difference. U_w, based on standard methods and design conditions, such as the ASHRAE winter conditions, is assumed to adequately represent the seasonal average U_w.

The average seasonal rate of heat loss due to air leakage per unit area of window q_i can be expressed by

$$q_i = F_i \cdot L_{75} / A_w \qquad (4)$$

where

L_{75} = window air leakage rate for the reference window measured at a pressure difference of 1.6 lb/ft^2 (75 Pa)

F_i = a climate-dependent factor, and is as in Equation 11.

Substituting Equations 2, 3, and 4 into Equation 1, values of ERS can be obtained from:

$$\text{ERS} = F_s \cdot F_w - U_w \cdot (T_i - T_o) - L_{75} \cdot F_i / A_w. \qquad (5)$$

In Equation 5, the only climate-dependent parameters are F_s, $(T_i - T_o)$, and F_i. Consequently, values of these three factors must be determined for the location and orientation specified for the calculation of the ERS.

CALCULATION OF USABLE SOLAR HEAT GAINS

The calculation of the seasonal average rate of usable solar heat gain is based on the method developed by Sander and Barakat (1983). It recognizes that not all solar heat gain can be used to reduce the amount of heat that must be provided by the house's heating system to maintain the house's temperature at the thermostat setpoint during the heating season. There will be times when the solar heat gain, together with the internal heat gain from house occupancy, exceeds the heat loss from the house. Under these conditions, the house temperature will rise above the thermostat setpoint and the excess heat will be stored in the construction materials and furnishings in the rooms. During periods when the indoor air temperature exceeds acceptable levels and action is taken by the occupant to reduce the solar heat gain or to increase ventilation, the solar heat gain is no longer useful in reducing the total heat supplied by the heating system. When the room temperature drops to the thermostat setting, a portion of the stored heat will become available as useful heat. The factor F_s in Equation 2 accounts for the effects of excess heat gains and storage. F_s is the multiple of incident solar radiation H_s, the off-normal angle of incidence factor F_Θ, and the solar utilization factor:

$$F_s = F_\Theta \cdot H_s \cdot \eta_s. \qquad (6)$$

An average value of 0.93 for F_Θ was assumed to be representative of average Canadian conditions (CHBA 1991). The solar utilization factor η_s represents the proportion of usable solar heat gains that is actually used to offset the house heat losses (minus internal heat gains). The smaller the solar heat gains in relation to house heat losses (minus internal heat gains), the larger the proportion of solar heat gains that are useful. Thus, the factor η_s is affected by the elements that determine the magnitude of heat losses from the house, by the magnitude of internal heat gains, and by those elements that determine the magnitude of solar heat gain such as window area, solar heat gain coefficient, and the rates of incident solar radiation. The rates of incident solar radiation are affected by the local climate and the orientation of the window.

Also, the greater the heat storage capacity of the house in relation to the magnitude of solar heat gain, the larger the utilization factor. In Canada, most single-family homes are of wood-frame construction, except for basements, and their heat storage capacity is similar and relatively small. Solar heat gains to basements are generally very small, so their heat-storage capacity does not contribute significantly to the utilization factor.

Computation of η_s

The solar utilization factor can be correlated with the ratio of seasonal solar heat gains to net house heat losses (house heat losses less internal heat generation) or gain-loss ratio (GLR), the ratio of the thermal storage capacity of the building interior (above grade) to the seasonal solar heat gain or mass-gain ratio (MGR), and different values of allowable increase in the house air temperature above the thermostat setting when solar heat gains exceeded net heat losses.

Equations representing the correlations of solar utilization factor with GLR, MGR, and allowable room temperature rise above the thermostat setting already have been incorporated in a computer program for residential building energy analysis (CHBA 1991). This computer program has been used to generate values of the solar heat gain utilization factor. However, for practical purposes, it was necessary to limit the range of values of the factors affecting η_s.

A two-story house of typical wood-frame construction was modeled with a typical "light" thermal mass (i.e., fixed MGR of 1) and two house heat loss characteristics—a conventional house construction and energy-efficient house construction. Component thermal characteristics of the model houses are given in Table 1. Additional model house characteristics are listed in Appendix A.

The gain-loss ratio, GLR, varies with the total solar heat gain. For particular climatic conditions, this, in turn, depends on the total window area and the window solar heat gain coefficient. For any specific thermal design standard, the house heat losses vary approximately with house floor area. To take account of the variables affecting η_s, a solar gain index, SGI, was defined as:

$$SGI = F_w \cdot A_{wt}/A_f \quad (7)$$

where

F_w = solar heat gain coefficient for window,
A_{wt} = total area of windows above grade, and
A_f = total above-grade floor area for house.

The ratio of window to floor area, A_{wt}/A_f, was varied between 10% and 20%, bracketing the values usually encountered. Equal window area was incorporated on the four sides of the house on the two floors above grade, with no window in the basement. The house was oriented in line with, and then at 45 degrees to, the four cardinal compass directions to establish values of F_s over the eight main directions. Solar heat gain coefficients for the windows were varied from 0.45 to 0.87. Values of the SGI typically range from 0.045 (10% floor area, SHGC of 0.45) to 0.174 (20% floor area, SHGC of 0.87) for residential windows. Values of F_s for those windows falling within the SGI range defined in the tables can be obtained based on a linear interpolation, as discussed below. Calculations were performed for the heating season, defined as October through April.

Discussion

In order to confirm that F_s could be taken as a linear function of SGI, values of F_s were computed for nine different house/window configurations, i.e., nine values of SGI, for both conventional and energy-efficient house types. These configurations included three different values of A_{wt}/A_f (i.e., 10%, 15%, and 20%) and F_w (i.e., 0.45, 0.61, and 0.87). Values of the usable incident solar radiation were then plotted as a function of the solar gain index. Based on a linear regression analysis, shown in Figures 1 and 2, it has been assumed that F_s can be adequately represented by a linear relationship as a function of SGI.

The method used for calculating the climatic factors is not the house balance temperature approach. In this paper, the time period and the indoor temperature were fixed (the indoor/outdoor temperature difference used was the actual difference). For the fixed period of time, the value of η_s varies to account for the variation in the solar gains and heat losses that are dependent on the house characteristics. For instance, if the SHGC value of the windows is increased, everything else being constant, the value of η_s will decrease to account for the additional input of solar heat that may contribute to overheating. This is in contrast with the balance temperature approach, in which a fixed balance temperature is selected and the number of heating hours during the year varies with the location.

It should also be noted that the computer program treats the whole house as a single zone, so that solar heat gain from any direction is assumed to affect the whole house uniformly. This is a reasonable approximation for compact houses with relatively free connections for air interchange between spaces and/or with an air recirculation system that operates continuously.

Calculation of Location/Orientation-Specific F_s

Values of F_s were determined, based on Equation 6, for the two house heat loss characteristics and two values of SGI—0.045 and 0.174—representing an appropriate range of values of the gain-load ratio. Monthly values of

TABLE 1
Component Characteristics of the Two Model Houses

COMPONENTS	AREA ft^2 (m^2)	R-VALUE REGULAR HOUSE h•ft²•°F/Btu (°C•m²/W)	R-VALUE HIGH INSUL. HOUSE h•ft²•°F/Btu (°C•m²/W)
Ceiling	1204 (111.9)	1.0 (5.6)	1.3 (7.6)
Main Walls	2582 (239.9)	0.6 (3.6)	0.9 (5.1)
Doors	61 (5.7)	0.1 (0.70)	0.1 (0.70)
Above Grade Basement Walls	333 (30.9)	0.4 (2.2)	0.7 (3.7)

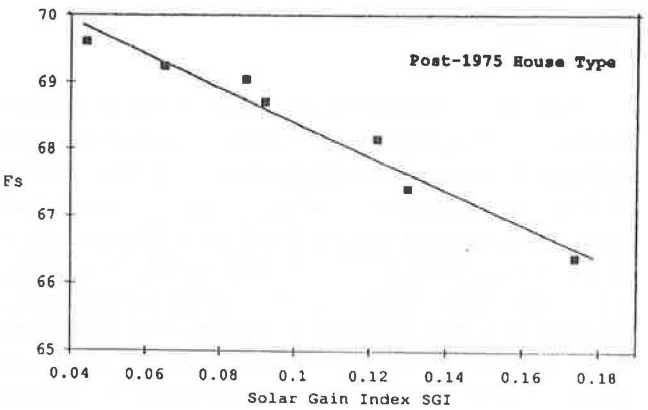

Figure 1 *Plot of the usable solar gain factor,* F_s, *vs. the solar gain index, SGI, for the post-1975 house.*

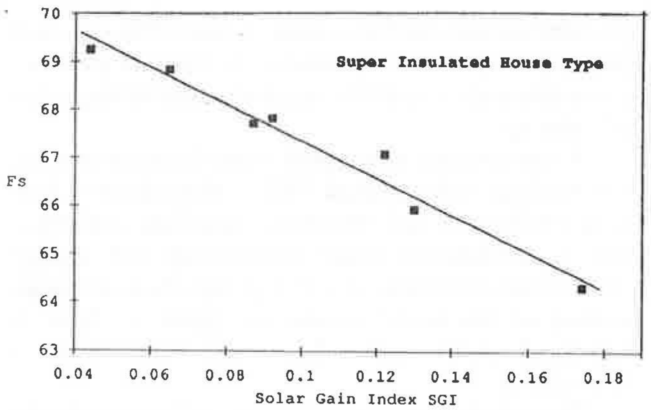

Figure 2 *Plot of the usable solar gain factor,* F_s, *vs. the solar gain index, SGI, for the super-insulated house.*

F_S were computed for the main eight directions, and average values were then determined over the heating season.

The computer program incorporates Canadian climatic data for 70 locations based on 25-year averages of weather records. F_S values were computed for 13 cities across Canada and are listed in Table 4.

CALCULATION OF HEAT TRANSMISSION LOSS RATES

Average values of outdoor temperature for the heating season for the locations in Table 4 were obtained from the computer program runs. The average indoor-outdoor temperature differences were then computed and incorporated in Table 4, based on an indoor temperature of 70°F (21°C). The seasonal average value of heat transmission loss rate per unit area of window is obtained based on Equation 3.

CALCULATION OF HEAT LOSS RATES FOR WINDOW AIR LEAKAGE

The approach to determining the effect of window air leakage on heat losses is the same as that used for the ER equation in the standard and is based on the house air leakage model developed by Sherman and Grimsrud (ASHRAE 1985). The method relates the equivalent leakage area of the house to the air leakage rate under specified conditions of indoor-outdoor temperature difference and wind velocity. Assumptions must be made with regard to the distribution of the leakage area in the house envelope and wind shielding conditions. In applying the method to predict the air leakage contribution of windows to the total house air leakage, it is assumed that the distribution of leakage area in the house is not altered by changes in window air leakage characteristics. The contribution of the window to the house air leakage rate is then

$$L_w = 0.138 \cdot L_{75} \cdot [((a(T_i - T_o) + bv^2))^{0.5}] \quad (8)$$

where

L_w = contribution of the window to the average house air leakage rate during the heating season
a = a stack coefficient for the house, related to the vertical distribution of the house leakage area
b = a wind coefficient for the house, related to the distribution of the house leakage area and the local wind shielding
v = average wind velocity during the heating season.

The value of a used for the calculations, 0.00376, is that for a two-story house with one-half the air leakage area in the walls and the remainder divided between the lower floor area and the ceiling; the value of b, 0.00299, is that for a two-story house and moderate local wind shielding.

The average seasonal rate of heat loss due to air leakage per unit area of window is then

$$q_i = (L_w/A_w) \cdot (\rho Cp/3.6) \cdot (T_i - T_o) \quad (9)$$

or, when combined with Equation 8,

$$q_i = 0.046 \cdot (L_{75}/A_w) \cdot [((0.00376 \cdot (T_i - T_o) + 0.00299 \cdot v^2))^{0.5}] \cdot (T_i - T_o). \quad (10)$$

Values of $q_i/(L_{75}/A_w)$ have been designated F_i:

$$F_i = 0.046 \cdot [((0.00376 \cdot (T_i - T_o) + 0.00299 \cdot v^2))^{0.5}] \cdot (T_i - T_o). \quad (11)$$

Values of F_i have been computed for each location in Table 4. In theory, the shorter period of time used for calculating F_i, the better the value. However, comparing an average value of all the F_i values in Table 4 with an F_i based on the average wind speed and indoor/outdoor temperature difference gave no difference. Consequently, seasonal average values of F_i, based on monthly values of wind and temperatures for each city, were assumed to be appropriate for the calculation of ERS numbers. The average seasonal rate of heat loss per unit area of the window due to air leakage is finally computed based on Equation 4.

PROCEDURE FOR CALCULATING ERS

Knowing the values of window solar heat gain coefficient F_w, overall heat transmission coefficient U_w, and window air leakage rate per unit area L_{75}/A_w, values of the average rate of net heat loss or heat gain for the heating seasons per unit area of window for specific locations and orientations (ERS) can be obtained from Equation 5. The climate-dependent factors, i.e., F_s, $(T_i - T_o)$, and F_i, are provided in Table 4. The other factors in Equation 5, i.e., F_w, U_w, A_w, and L_{75}, are window-dependent.

The procedure for calculating ERS using Table 4 is to

- Identify the city in Table 4 nearest the location for which ERS values are required.
- Determine which of the two house types best represents the thermal characteristics of the house of interest.
- Determine the approximate ratio of total window area to house floor area for above-grade floors. Where q_s values are required for general use, rather than for a specific installation, it is suggested that a value of 15% be used for A_{wt}/A_f. From the value of F_w, compute the value of the SGI $(F_w \cdot A_{wt}/A_f)$.
- Choose the orientations that best represent those of interest and determine the value of F_s for these orientations from Table 4. Multiply the values of F_s by the value of F_w for the window to obtain q_s for each orientation of interest. Where an average ERS value is required for windows on more than one orientation, an appropriate average value of q_s is obtained by area weighting:

$$q_s \text{ average} = (A_{w1} \cdot q_{s1} + A_{w2} \cdot q_{s2})/(A_{w1} + A_{w2}) \quad (12)$$

where

A_{w1}, A_{w2} = window areas for different orientations

q_{s1}, q_{s2} = average seasonal rate of solar heat gain.

Where there are approximately equal areas in each direction, area weighting is not required to obtain the correct average of q_s.

- Obtain q_t, determine the value of $(t_i - t_o)$ from Table 4 for the city of interest, and multiply this by the value of U_w for the window.
- Obtain q_l, determine the value of F_i from Table 4 for the city of interest, and multiply this by the value of L_{75} for the window.
- Calculate the value of ERS for the window arrangement of interest:

$$\text{ERS} = q_s - q_t - q_l. \quad (1)$$

Example Calculation for Two Windows

For illustrative purposes, energy ratings for two windows were calculated for an example location (Ottawa) and orientation (east) for the post-1975-type house. The windows include a double-hung, double-glazed vinyl window and a high-performance, triple-glazed wood window. The thermal characteristics of the window samples are listed in Table 2.

Table 3 lists the values for ERS calculated using Equation 5 and based on the climatic parameters listed in Table 4. The ERS value for the vinyl window is −27 and the ERS value for the wood window is −19. It should be remembered that these values—specific to the location, orientation, house type, and season selected in the calculation—are for comparative purposes only and should not be used for energy load calculations.

Discussion

Because the values of η_s were obtained using a uniform distribution of window area in the four directions around the model house, the method given above is most appropriate for this condition. If, for example, the area of south-facing windows substantially exceeds 25% of the total, the actual average value of η_s will be lower than that used to determine the values of F_s. The value of ERS determined using Table 4 will then be somewhat higher than it should be; if the area of south-facing windows is significantly less than 25%, the value of ERS determined using Table 4 will be lower than it should be. Similarly, if the layout of the house is such that the space containing

TABLE 2
Component Characteristics of the Two Window Samples

WINDOW SAMPLE#	AREA ft^2 (m^2)	U-VALUE Btu/h·ft^2·°F (W/°C·m^2)	SHGC	LEAKAGE cfm/ft (m^3/h/m)
1 (VINYL)	7.43 (0.69)	0.53 (3.03)	0.69	0.10 (0.55)
2 (WOOD)	3.55 (0.33)	0.30 (1.70)	0.33	0.10 (0.55)

TABLE 3
Calculation of ERS for Two Window Samples

ER COMPONENT	WINDOW #1	WINDOW #2
SOLAR	+44.54	+21.30
TRANSMISSION	-70.30	-39.44
LEAKAGE	- 1.12	- 1.11
TOTAL ER	-26.88	-19.25

the south-facing windows is not openly connected to the rest of the house, the value of η_s appropriate for the south-facing windows will be lower than that used to determine the values of F_s. The value of ERS determined using Table 4 will then be higher than it should be. Despite these limitations, the method of determining ERS values is appropriate for comparative rating of different windows with different climates and orientations.

An approximation of the total heat loss or heat gain through windows in a particular application can be obtained by multiplying the ERS values for each orientation by the total window area for that orientation and by the number of hours in the heating season:

$$Q_w = (\text{ERS}_1 A_1 + \text{ERS}_2 A_2 + \text{ERS}_3 A_3 + \text{ERS}_4 A_4) \times 5088 \qquad (13)$$

where

Q_w	=	total increase or decrease in seasonal energy use for heating due to windows
ERS_1, ERS_2	=	ERS values for windows in the different orientations
A_1, A_2	=	area of windows in the different orientations
5088	=	hours in the heating season (October through April).

If an estimate of the total seasonal energy required for heating is wanted for a specific house, a computer program such as the program used to derive Table 4 can be used.

CONCLUSIONS

A simple method for determining the thermal performance of windows for specified locations and orientations has been established. A procedure for calculating specific energy rating numbers, ERS, has been described, based on a standard method developed in Canada. Tables of weather factors have been developed to allow for the calculation of ERS values for the major Canadian cities and the eight main orientations. However, this method can serve as a basis for evaluating window performance, in a simple manner, for virtually any location and orientation. This may allow for a fair comparison of window products in specific locations, and will assist designers in comparing window options for specific applications.

NOMENCLATURE

A	=	area, ft^2 (m^2)
ERS	=	window energy rating for the heating season for a specific location and orientation, Btu/(h·ft^2) (W/m^2)
F_i	=	pressure factor, Btu/ft^3 (J/m^3)
F_s	=	usable solar gain factor, Btu/(h·ft^2) (W/m^2)
F_w	=	window solar heat gain coefficient for the reference size
F_Θ	=	off-normal incidence angle factor for solar radiation
H_s	=	average rate of solar radiation incident on a window for a specific location and orientation condition during the heating season
L_{75}	=	window air leakage rate at a pressure difference of 1.6 lb/ft^2 (75 Pa) for the reference size in Table 2, ft^3/h (m^3/h)
L_w	=	contribution of the window to the average house air leakage rate during the heating season, ft^3/h (m^3/h)
q_s	=	average seasonal rate of usable solar heat gain, Btu/(h·ft^2) (W/m^2)
q_t	=	average rate of heat loss by transmission, Btu/(h·ft^2) (W/m^2)
q_i	=	average rate of heat loss by infiltration, Btu/(h·ft^2) (W/m^2)
T	=	average air temperature during the heating season, °F (°C)
U	=	window U-value for the reference size, Btu/(h·ft^2·°F) (W/m^2·°C)
v	=	average wind velocity during the heating season, mph (m/s)
η_s	=	utilization factor for solar heat gain
ρC_p	=	thermal capacitance of air at standard conditions, 80.5 Btu/(ft^3·°F) (1.2 kJ/(m^3·°C))

Subscripts

f	=	floor
i	=	indoor, infiltration
o	=	outdoor
s	=	solar
t	=	transmission
w	=	window
wt	=	window, total
Θ	=	off-normal angle of incidence

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APPENDIX A

MODEL HOUSE SPECIFICATIONS

- single detached, rectangular shape
- two-story plus full basement
- floor area above grade: 2,409 ft^2 (223.8 m^2)
- house volume above grade: 27,369 ft^3 (775 m^3)
- envelope equivalent leakage area (ELA) at 0.21 lb/ft^2 (10 Pa):
  - conventional house: 1.18 ft^2 (0.11 m^2)
  - R-2000 house: 0.45 ft^2 (0.042 m^2)
- ventilation system:
  - conventional house: no ventilation system
  - R-2000 house: heat recovery ventilation
- internal heat gains: 7,640 Btu/h (7.24 MJ/h)

Allowed temperature swing:
For periods in which solar heat gain exceeded net house heat losses, the allowable increase in room temperature above the thermostat setpoint of 70°F (21°C) was taken as 4.95°F (2.75°C).

APPENDIX B

TABLE 4a
Values of F_s, $(T_i - T_o)$, and Pressure Index (F_i) for 13 Canadian Cities and the Post-1975 House Type

EDMONTON

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	145.17	116.93	65.74	37.26	32.53
0.174	140.01	112.51	62.81	35.55	31.19
	F_i = 0.479			$t_i - t_o$ = 27.30	

FREDERICTON

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	128.01	104.92	64.06	38.38	33.90
0.174	123.42	101.00	61.38	36.73	32.53
	F_i = 0.379			$t_i - t_o$ = 22.60	

HALIFAX

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	104.46	89.34	62.40	43.98	40.33
0.174	100.08	85.52	59.63	42.10	38.70
	F_i = 0.397			$t_i - t_o$ = 21.20	

MONTREAL

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	116.99	97.78	63.27	40.08	35.36
0.174	112.20	93.58	60.26	38.19	33.83
	F_i = 0.407			$t_i - t_o$ = 22.70	

OTTAWA

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	128.31	106.06	66.33	39.79	34.60
0.174	122.74	101.20	62.76	37.72	32.97
	F_i = 0.406			$t_i - t_o$ = 23.20	

QUEBEC

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	129.88	107.12	66.37	40.62	35.81
0.174	125.76	103.53	63.84	39.03	34.52
	F_i = 0.455			$t_i - t_o$ = 24.60	

ST-JOHN'S

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	90.69	76.89	52.28	37.06	34.41
0.174	88.83	75.22	51.00	36.11	33.56
	F_i = 0.474			$t_i - t_o$ = 21.20	

SASKATOON

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	160.68	128.62	70.87	38.00	32.57
0.174	154.91	123.73	67.68	36.23	31.21
	F_i = 0.553			$t_i - t_o$ = 28.60	

TORONTO

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	111.63	93.14	59.78	36.35	31.31
0.174	106.71	88.83	56.72	34.51	29.89
	F_i = 0.361			$t_i - t_o$ = 20.70	

VANCOUVER

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	87.04	71.60	43.68	25.70	22.12
0.174	81.29	66.58	40.14	23.49	20.35
	F_i = 0.212			$t_i - t_o$ = 15.10	

WHITEHORSE

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	114.16	91.70	50.02	28.42	24.54
0.174	110.76	88.69	47.85	27.03	23.43
	F_i = 0.564			$t_i - t_o$ = 30.30	

WINDSOR

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	121.85	102.22	67.06	41.98	36.64
0.174	112.00	93.70	61.14	38.42	33.81
	F_i = 0.344			$t_i - t_o$ = 19.00	

WINNIPEG

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	151.31	122.40	70.50	39.75	34.44
0.174	146.45	118.21	67.64	38.08	33.14
	F_i = 0.570			$t_i - t_o$ = 28.30	

TABLE 4b
Values of F_s, $(T_i - T_o)$, and Pressure Index (F_i) for 13 Canadian Cities and the Super-Insulated House Type

EDMONTON

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	145.08	116.83	65.66	37.21	32.50
0.174	136.85	109.83	61.06	34.54	30.39
	F_i = 0.479			$t_i - t_o$ = 27.30	

FREDERICTON

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	127.91	104.83	64.00	38.34	33.87
0.174	120.33	98.37	59.62	35.65	31.63
	F_i = 0.379			$t_i - t_o$ = 22.60	

HALIFAX

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	104.38	89.20	62.31	43.92	40.28
0.174	97.16	82.99	57.82	40.88	37.63
	F_i = 0.397			$t_i - t_o$ = 21.20	

MONTREAL

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	116.79	97.61	63.14	40.01	35.30
0.174	109.04	90.84	58.33	36.99	32.85
	F_i = 0.407			$t_i - t_o$ = 22.70	

OTTAWA

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	128.07	105.84	66.33	39.70	34.53
0.174	119.22	98.16	60.96	36.46	31.96
	F_i = 0.406			$t_i - t_o$ = 23.20	

QUEBEC

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	129.83	107.06	66.33	40.59	35.79
0.174	122.96	101.12	62.18	38.00	33.67
	F_i = 0.455			$t_i - t_o$ = 24.60	

ST-JOHN'S

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	90.69	76.89	52.28	37.06	34.41
0.174	87.36	73.93	50.04	35.41	32.93
	F_i = 0.474			$t_i - t_o$ = 21.20	

SASKATOON

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	160.61	128.54	70.79	37.96	32.54
0.174	151.91	121.17	66.00	35.30	30.51
	F_i = 0.553			$t_i - t_o$ = 28.60	

TORONTO

SGI	$F_s (W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	111.37	92.91	59.61	36.26	31.24
0.174	103.41	85.97	54.72	33.32	28.95
	F_i = 0.361			$t_i - t_o$ = 20.70	

VANCOUVER

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	86.57	71.18	43.38	25.51	21.97
0.174	77.56	63.35	37.91	22.12	19.23
	F_i = 0.212			$t_i - t_o$ = 15.10	

WINDSOR

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	120.94	101.43	66.52	41.67	36.41
0.174	106.24	88.75	57.73	36.38	32.16
	F_i = 0.344			$t_i - t_o$ = 19.00	

WHITEHORSE

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	114.06	91.60	49.93	28.36	24.49
0.174	108.72	86.91	46.60	26.24	22.79
	F_i = 0.564			$t_i - t_o$ = 30.30	

WINNIPEG

SGI	$F_s(W/m^2)$				
	South	SE/SW	E/W	NE/NW	North
0.044	151.25	122.34	70.44	39.71	34.42
0.174	143.32	115.54	65.88	37.06	32.34
	F_i = 0.570			$t_i - t_o$ = 28.30	