Natural Resources Canada
Ressources naturelles Canada

Windows: The Science of Good Window Design and Selection

March 2025

Canada

Agenda

7:30 – 8:00	Registration and Breakfast
8:00 – 8:50	Presentation 1: The Science of Good Window Design and Selection
8:50 – 9:50	Presentation 2: Window Selection Tools, Energy, Carbon, HVAC, Thermal Comfort Analysis and Costs
9:50 – 10:05	Break
10:05 – 11:00	Presentation 3: Design Detailing & Installation for Durability per CSA A440
11:00 – 11:40	Video: Spray Rack Test Results and Installation Commentary
11:40 – 12:00	Manufacturer Panel Discussion
12:00	Closing Remarks

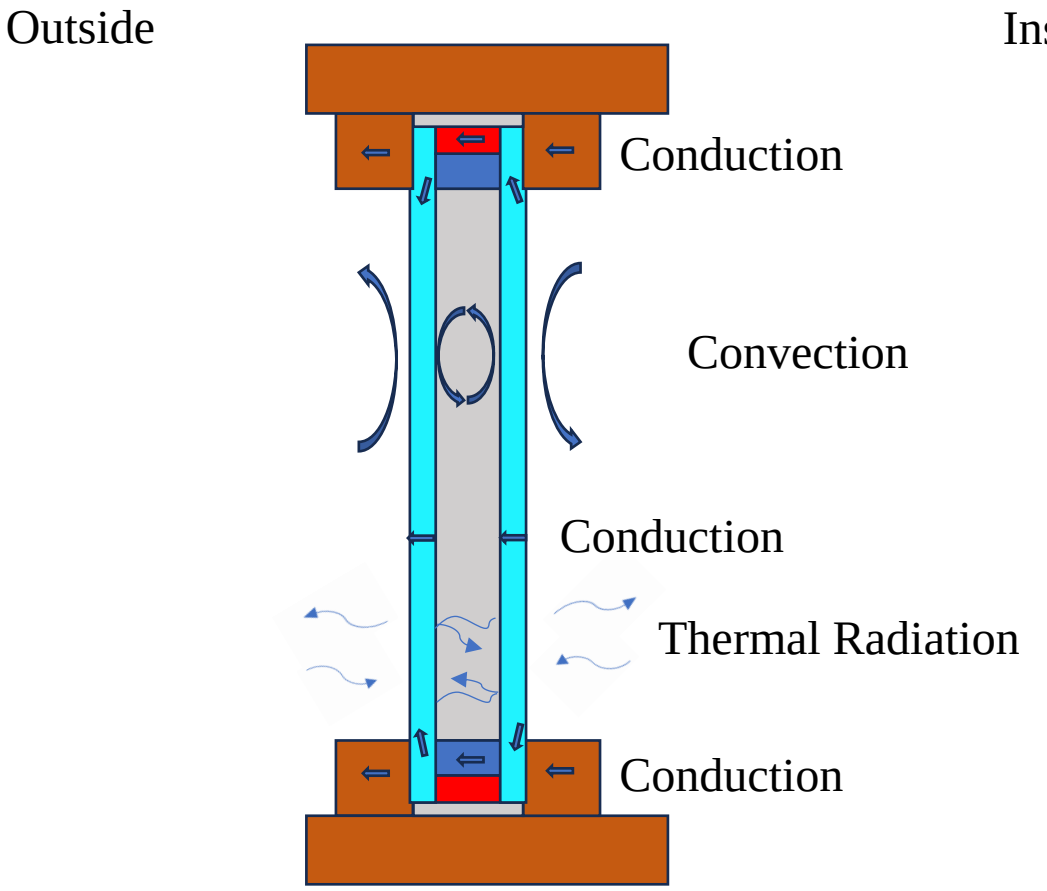
Outline

- Window Technology for Energy Efficiency
- Window Heat Transfer
- Insulating Glass
- Window Frame Heat Transfer
- Window Types
- Path to Window Aspirational Goal
- New Technology

Window Technology for Energy Efficiency

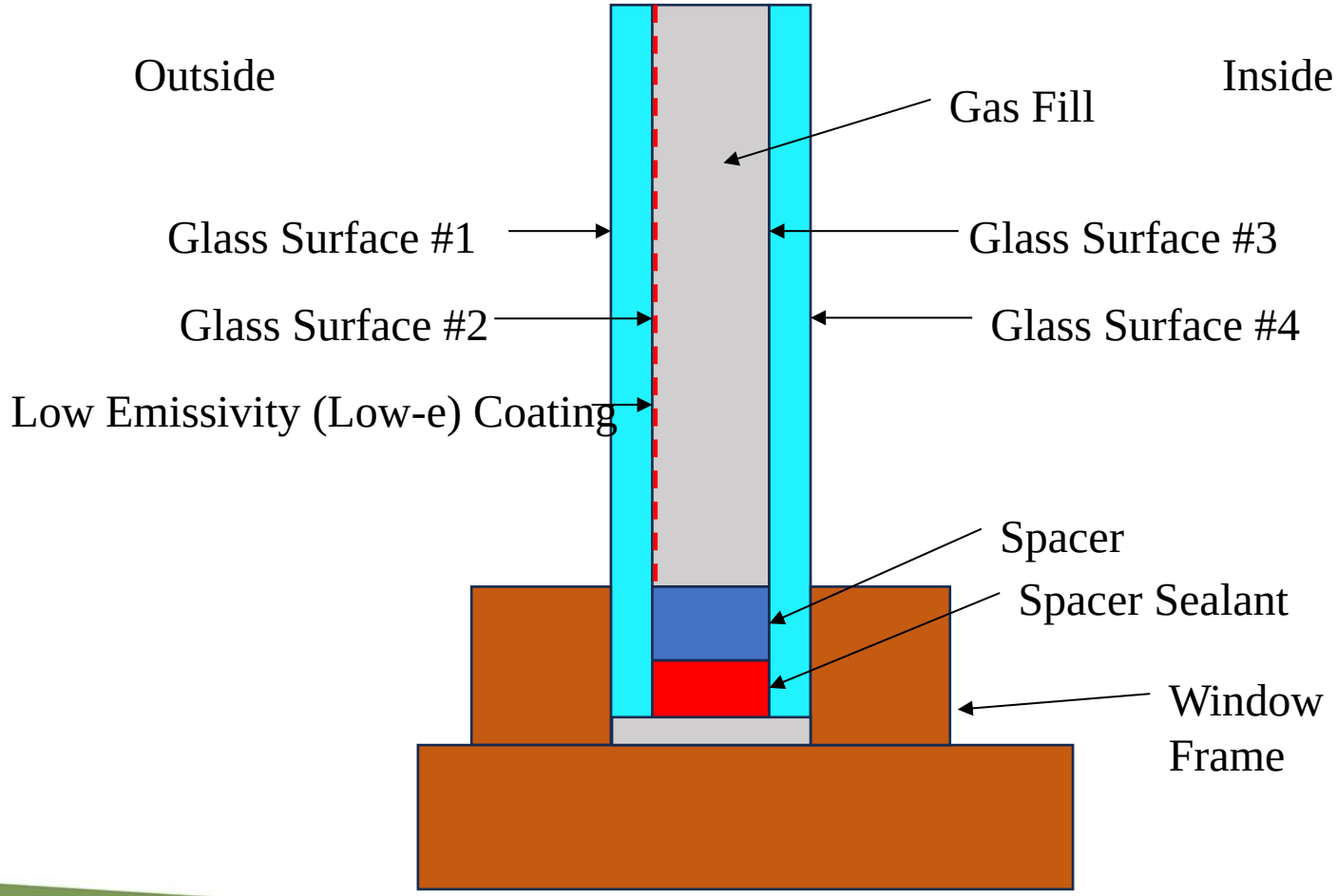
- At the Energy and Mines Minister's Conference in 2017 aspirational goals for product were introduced as part of the Pan Canadian Framework for Clean Growth and Climate Change. An aspirational goal for windows with a U-factor of 0.82 W/m^2K by 2030 was established in 2018.
- Many in the window industry are working toward this goal. The National Building Code is moving in this direction. Net Zero buildings will need windows of this performance level.
- This presentation will take a look at the technology in windows for energy efficiency and what will be needed to achieve this aspirational goal

Window Heat Transfer



- Conduction
  - The movement of heat through a solid
- Convection
  - The movement of heat through a gas or liquid
- Thermal Radiation
  - The movement of heat from one object to another without the need of a material

Window Heat Transfer

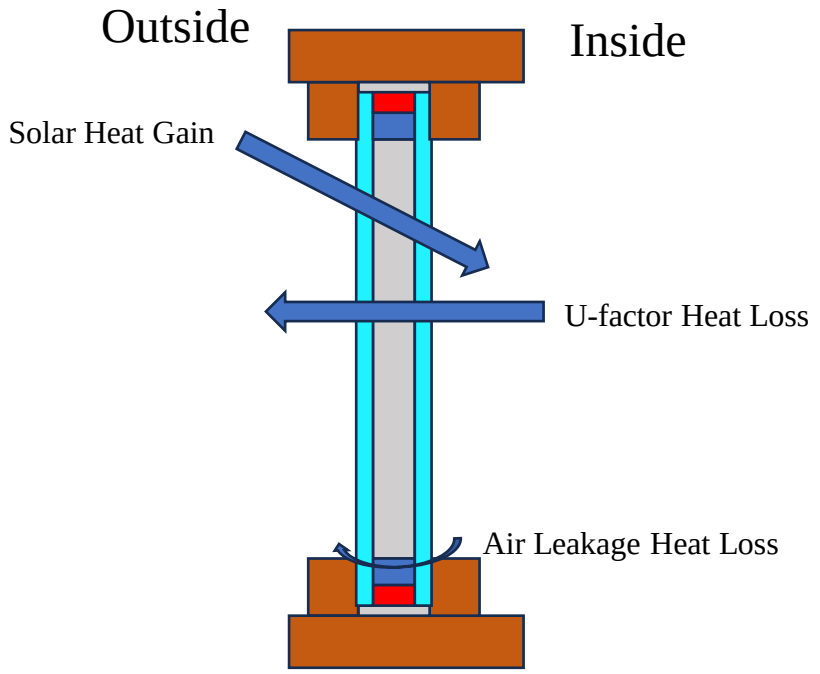


Window Heat Transfer

- U-factor
  - Measures how much heat is lost out of a window. The lower the better.
- Solar Heat Gain Coefficient (SHGC)
  - Defines how much solar energy gets through the window into the building.
  - The higher the SHGC the more solar heat gain into the building.
- Visible Transmittance (VT)
  - VT is a measure of the visible light entering the building through the window
  - The higher the VT the more visible light that gets into the building.

Window Heat Transfer

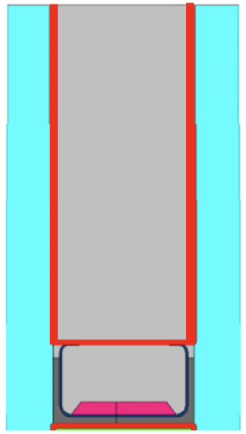
- CSA Energy Rating (ER)
  - The ER number is a weighting of the SHGC, U-factor and Air Leakage over the heating season
  - SHGC is a heat gain into the building
  - U-factor and Air Leakage are heat losses from the building
  - ER = SHGC – U-factor – Air Leakage + Constant
  - The higher the ER the higher the energy performance of the window in the heating season.

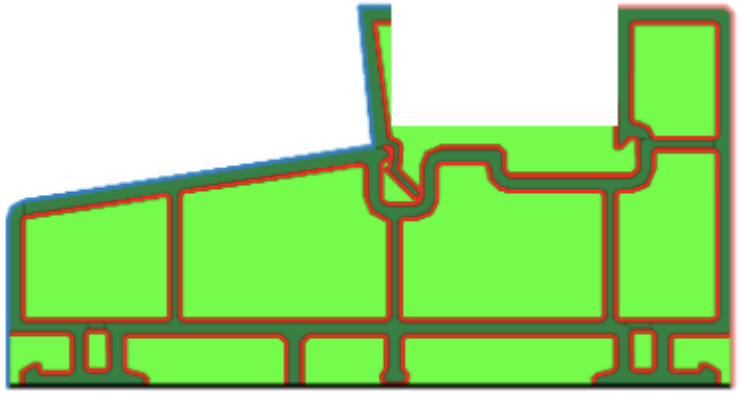


ER = SHGC – U-factor – Air Leakage + Constant

Window Heat Transfer

- Window Components
  - Insulating Glass Unit (IGU)
    - The IGU includes the glass and spacer separating the glass layers and the gas fill between the glass layers
  - Window Frame
    - The window frame includes all the elements of the frame that hold the IGU in place
  - These two elements each impact the heat transfer through the window in different ways.





Insulating Glass Unit (IGU)

- The IGU is made up of multiple glass layers, coatings on the glass, a spacer separating the glass layers and a gas fill between the glass layers
  - Number of glass layers
  - Low emissivity coatings
  - Gas fill
  - Spacer System and Spacer Width

Insulating Glass Unit (IGU)

- Number of Glass Layers
  - Double glazed windows were first developed in the 1930s.
  - Triple glazed windows have been available in western Canada since the early 1980s.
  - Quadruple glazed windows are available in windows used in the far north.
  - There is a governmental aspirational goal to achieve very high-performance windows ($U \leqq 0.82\ W/m^2K$) by 2030 that would require triple glazing as a minimum.
  - This presentation will focus on doubles and triples.

Insulating Glass Unit (IGU)

History of Low Emissivity Glass

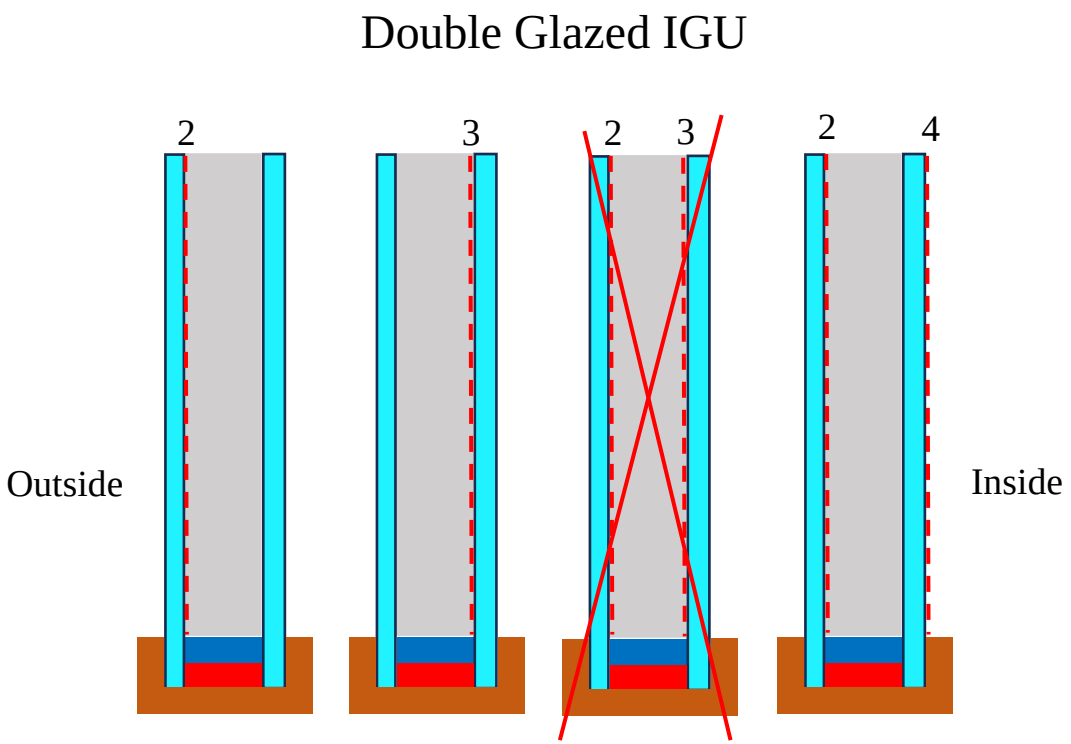
1. **1960s-1970s**: Early developments in low-e coatings, primarily for applications in the aerospace industry
2. **1980s**: Research and development with significant improvements in low-e coatings, making them more durable and effective for architectural applications.
3. **1990s**: Low-e glass technology continued to advance, refining the coatings to improve their performance in terms of reducing heat transfer and improving energy efficiency in buildings.
4. **2000s-present**: Continued research and development have led to further advancements in low-e glass technology with greater choice. Modern low-e coatings are highly energy efficient while allowing visible light to pass through, helping to reduce energy costs for heating and cooling buildings.

Insulating Glass Unit (IGU)

- Low Emissivity Coatings (Low-e) Types
  - There are two types manufacturing processes that generate low-e coatings
    - Pyrolytic coatings
    - Vacuum sputtered coatings
  - Pyrolytic coatings
    - High solar gain only
  - Vacuum Sputtered coatings
    - High solar gain
      - Also known as single silver coating as they have only one layer of silver
    - Medium solar gain
      - Also known as double silver coating as they have two layers of silver
    - Low solar gain
      - Also known as triple silver coating as they have three layers of silver

Insulating Glass Unit (IGU)

Low-e Coating Locations

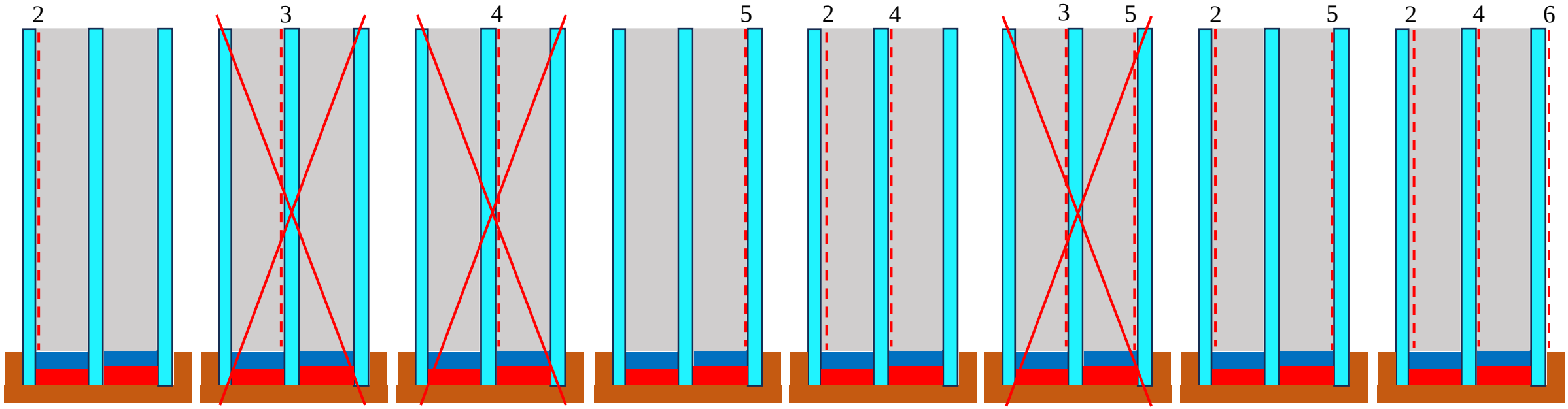


- Coating Use
  - Surface 2
    - High, Medium or Low Solar Gain coatings
  - Surface 3
    - High Solar Gain Coatings only
  - Surface 4
    - Specialty interior facing coatings

Insulating Glass Unit (IGU)

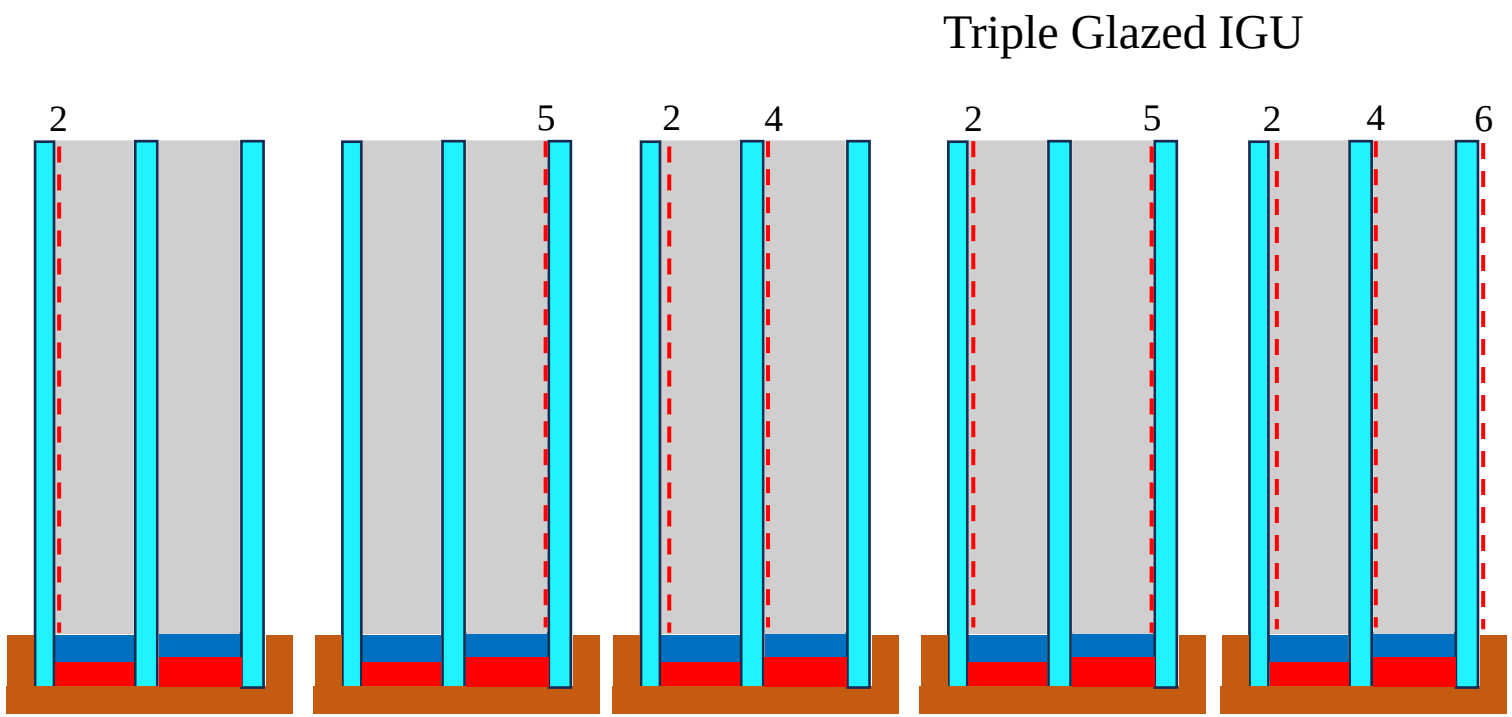
Low-e Coating Locations

Triple Glazed IGU



Insulating Glass Unit (IGU)

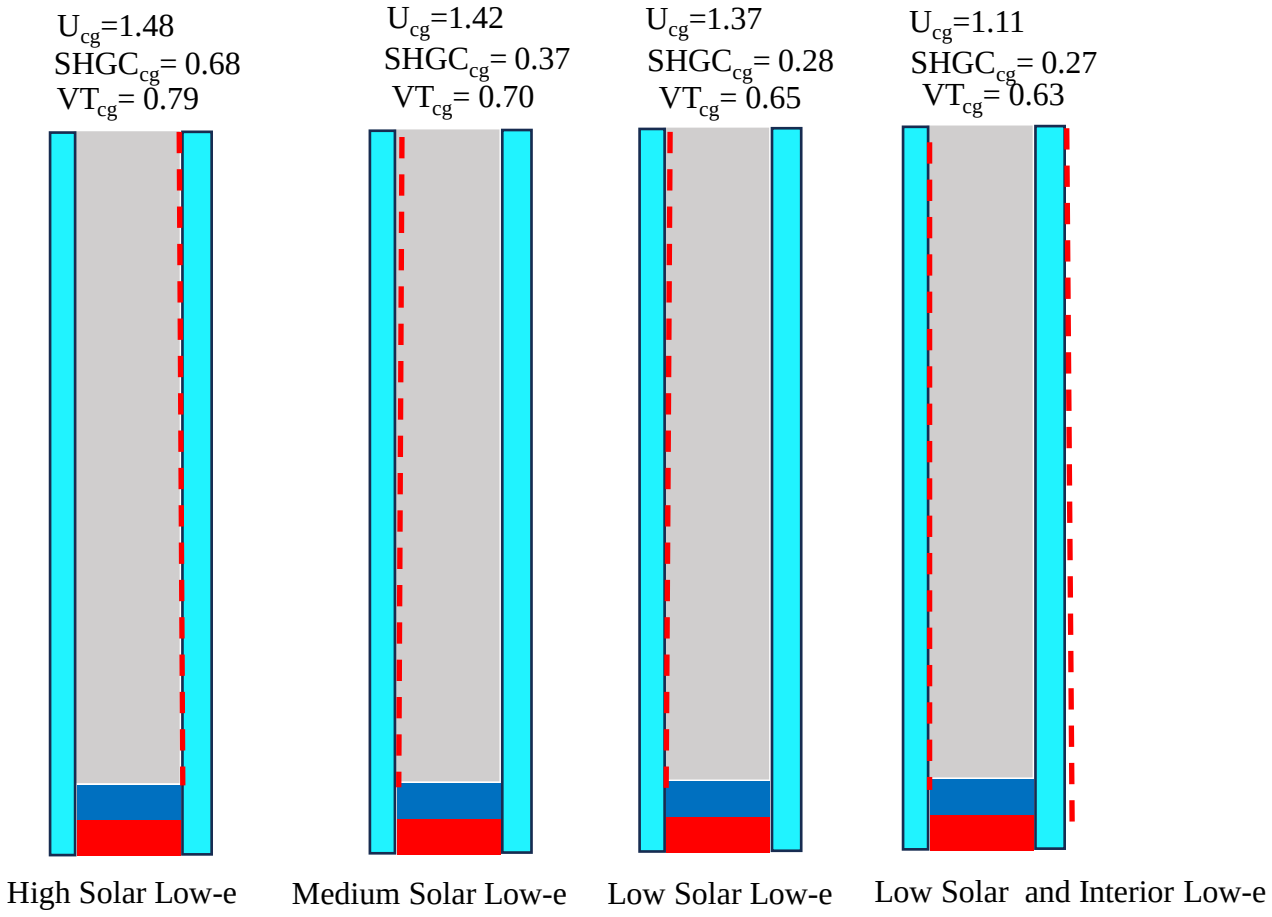
Low-e Coating Locations



- Coating Use
  - Surface 2
    - High, Medium or Low Solar Gain coatings
  - Surface 5
    - High Solar Gain Coatings only
  - Surface 4
    - Caution needs to be taken with the coating choice, a high solar gain low-e is the better choice
  - Surface 6
    - Specialty interior facing coatings

Insulating Glass Unit (IGU)

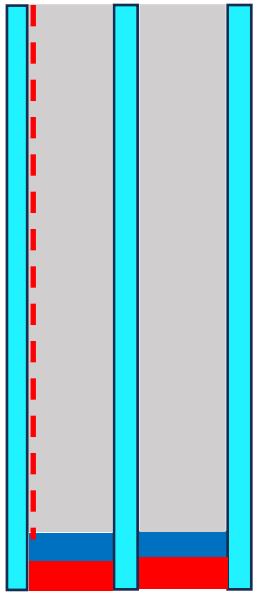
Center-of-Glass U-factor Double glazed, 12mm argon filled, 3mm glass



Insulating Glass Unit (IGU)

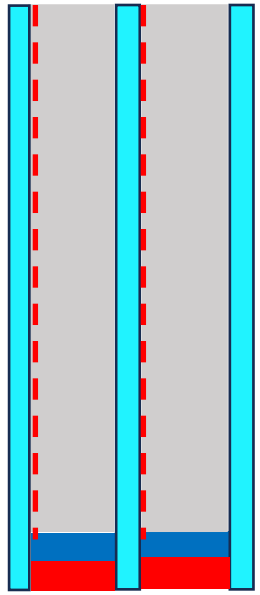
Center-of-Glass U-factor, Triple glazed 12mm argon cavity, 3mm glass

U_{cg}=1.03
$SHGC_{cg}$= 0.25
VT_{cg}= 0.59



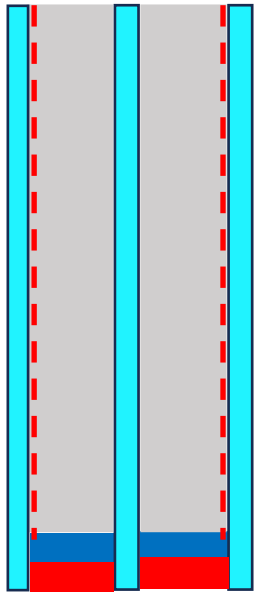
Low Solar Low-e

U_{cg}=0.72
$SHGC_{cg}$= 0.24
VT_{cg}= 0.57



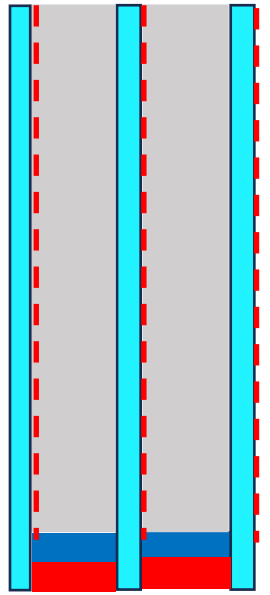
Low Solar Low-e (2)
High Solar Low-e (4)

U_{cg}=0.72
$SHGC_{cg}$= 0.25
VT_{cg}= 0.57



Low Solar Low-e (2)
High Solar Low-e (5)

U_{cg}=0.64
$SHGC_{cg}$= 0.24
VT_{cg}= 0.56

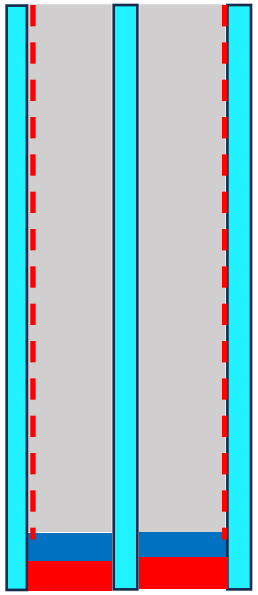


Low Solar Low-e (2)
High Solar Low-e (4)
Interior Low-e (6)

Insulating Glass Unit (IGU)

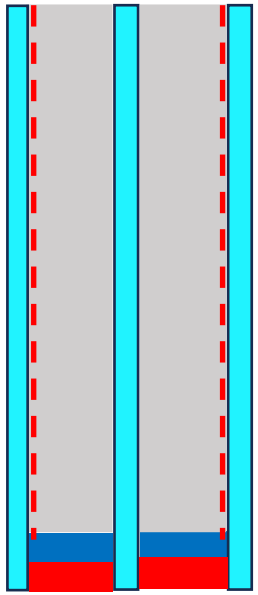
Center-of-Glass U-factor, Triple glazed 12mm argon cavity, 3mm glass

U_{cg}=0.75
$SHGC_{cg}$= 0.56
VT_{cg}= 0.70



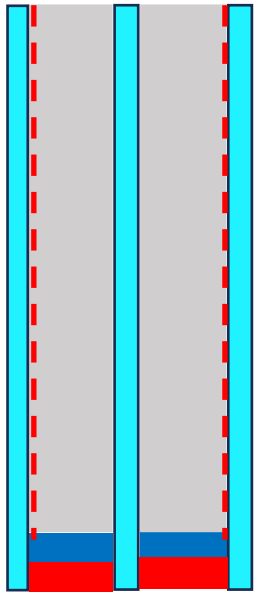
High Solar Low-e (2)
High Solar Low-e (5)

U_{cg}=0.74
$SHGC_{cg}$= 0.37
VT_{cg}= 0.63



Medium Solar Low-e (2)
High Solar Low-e (5)

U_{cg}=0.72
$SHGC_{cg}$= 0.25
VT_{cg}= 0.57



Low Solar Low-e (2)
High Solar Low-e (5)

Insulating Glass Unit (IGU)
Gas Fill

- Replacing the air inside an IGU with an inert gas reduces the convection inside the IGU and reduces the heat loss.

- Argon
  - Prices between $30-50 dollars per tank
  - Argon is the only realistic gas filling option

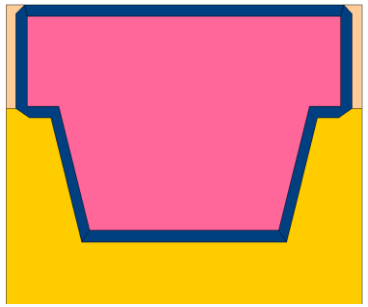
- Krypton
  - Prices between $30K and $50K per tank
  - Krypton does get used in windows but very rarely

Insulating Glass Unit (IGU)

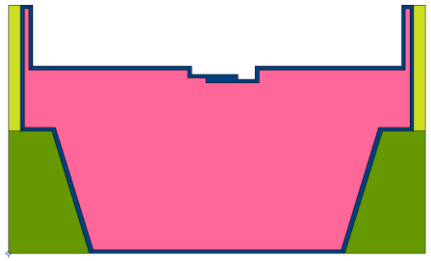
Spacer Systems

- The spacer separating the layers of glass in an IGU is an important design element of the window.
- As the IGU improves in performance with low-e coatings and argon gas filling the spacer system becomes a significant area of heat loss.
- The early spacer systems used an aluminum spacer bar, but aluminum is a highly conducting material.
- There are many “warm edge” spacer systems on the market today ranging from stainless steel to foam.

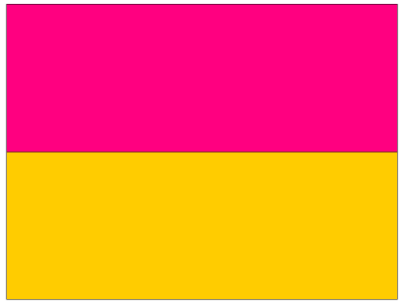
Aluminum Spacer System



Stainless Steel System



Foam Spacer System

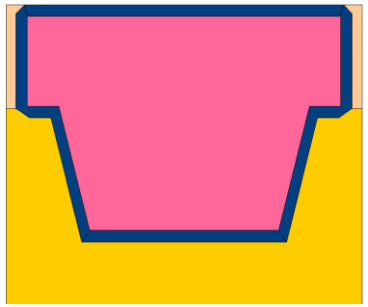


Insulating Glass Unit (IGU)

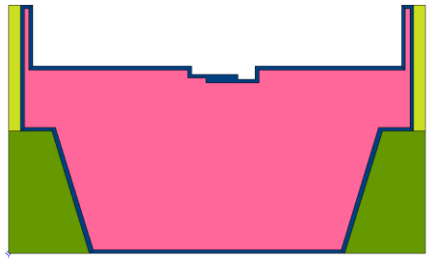
Spacer Width

- The width of the spacer separating the layers of glass in an IGU is an important design element of the window.
- There is an optimum spacing for the type of gas filling the IGU cavity
- Air is about 13mm, Argon is about 12mm, and Krypton is about 9mm
- Spacing less than than the optimum will have higher U-factors
- Spacing greater than the optimum will have a slightly higher U-factor

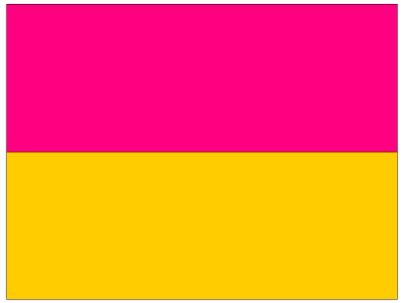
Aluminum Spacer System



Stainless Steel System



Foam Spacer System

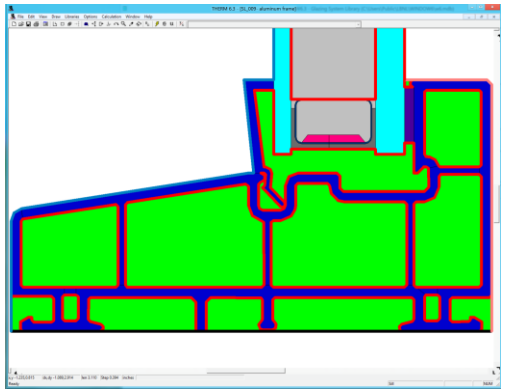


Window Frame Heat Transfer

- Frame Materials

Aluminum

U_{frame}= 7.86 W/m^{2}K

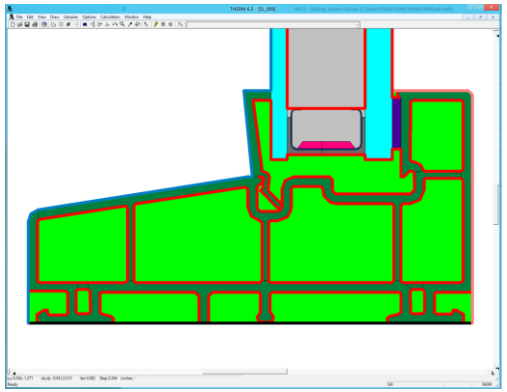


Thermally Broken Aluminum

U_{frame}= 4.57 W/m^{2}K

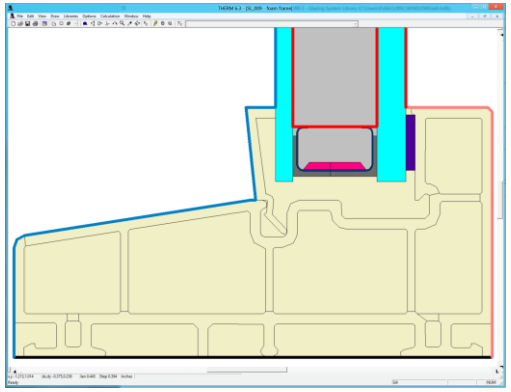
PVC

U_{frame}= 1.80 W/m^{2}K



Foam

U_{frame}= 0.76 W/m^{2}K

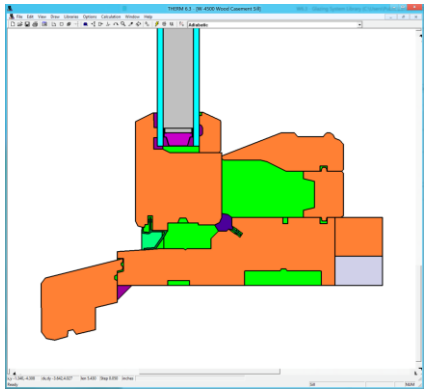


Window Frame Heat Transfer

- Frame Materials

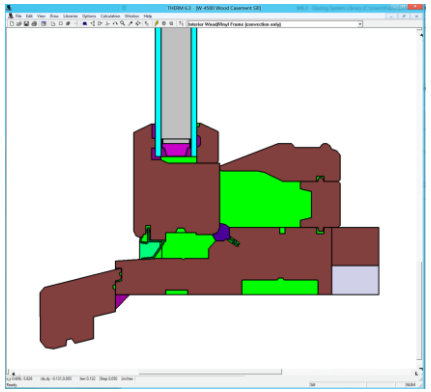
Ponderosa Pine

U_{frame}= 1.66 W/m^{2}K



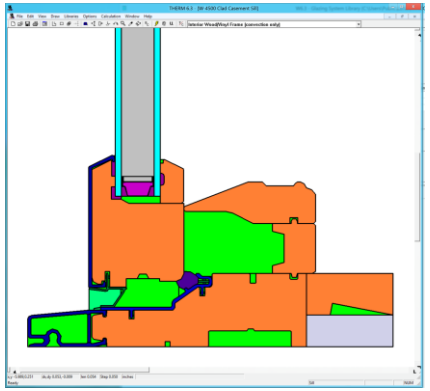
Hardwood

U_{frame}= 1.91 W/m^{2}K



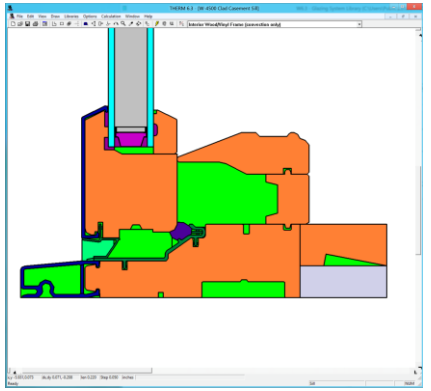
Aluminum Under Sash

U_{frame}= 2.52 W/m^{2}K



PVC Under Sash

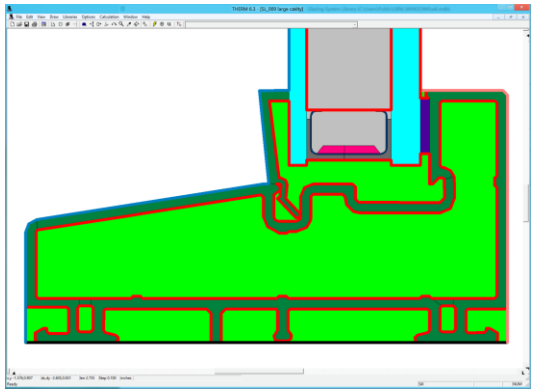
U_{frame}= 1.73 W/m^{2}K



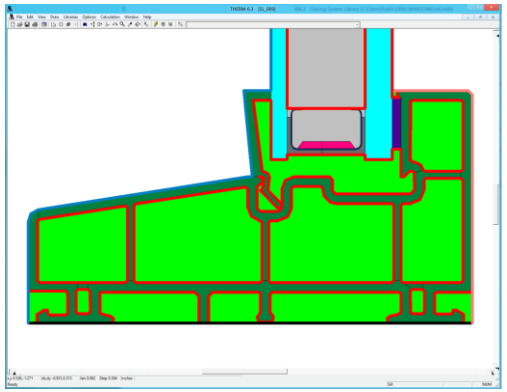
Window Frame Heat Transfer

- Frame Cavities

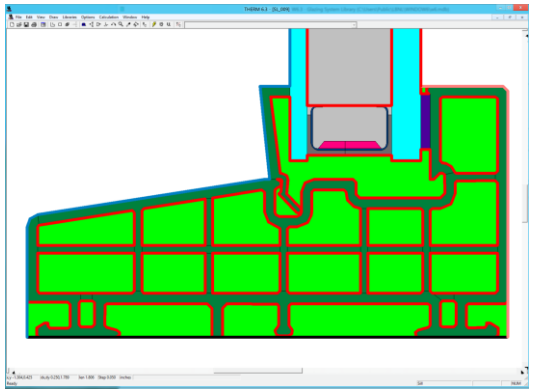
U_{frame}= 2.57 W/m^{2}K



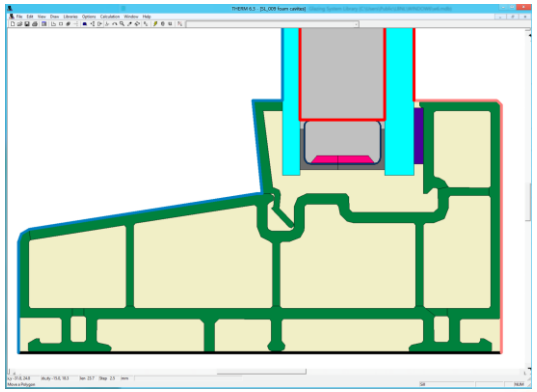
U_{frame}= 1.80 W/m^{2}K



U_{frame}= 1.74 W/m^{2}K



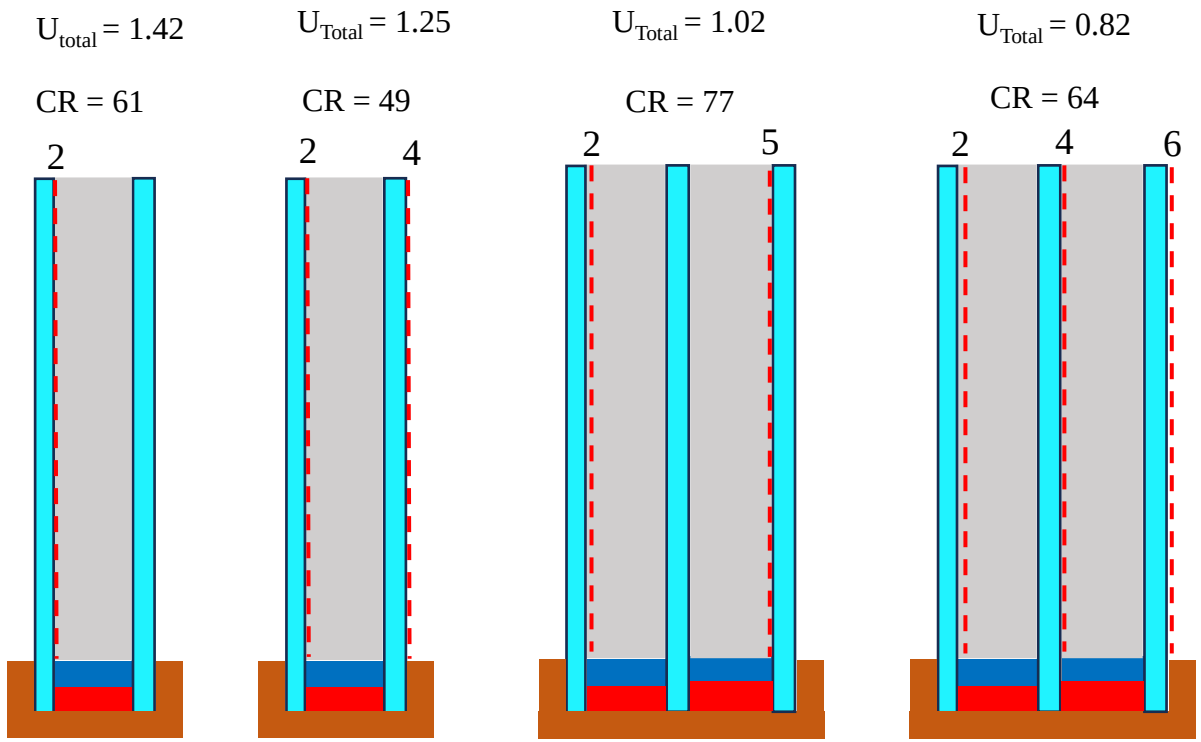
U_{frame}= 1.22 W/m^{2}K



Condensation Resistance

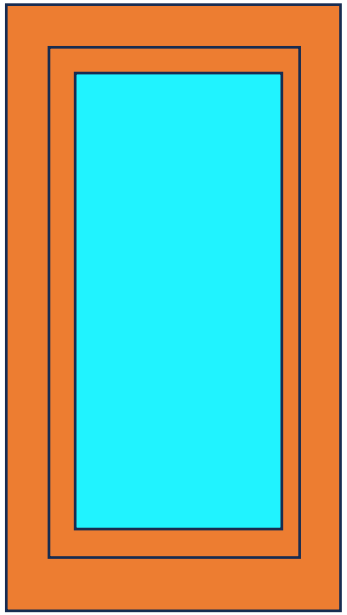
- Condensation on Windows
- NFRC Condensation Resistance number (CR)
- Higher CR greater condensation resistance
- Generally, lower U-factor - higher CR but with interior facing low-e coatings this is not the case

Condensation Resistance

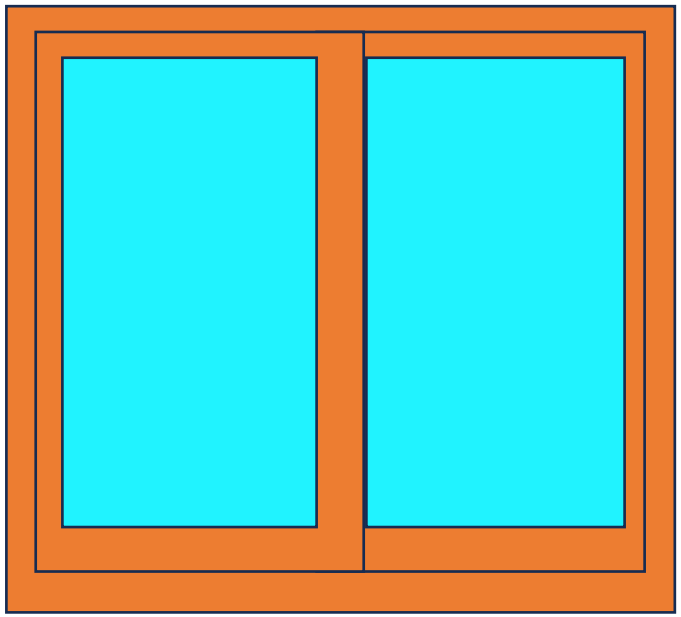


Window Types

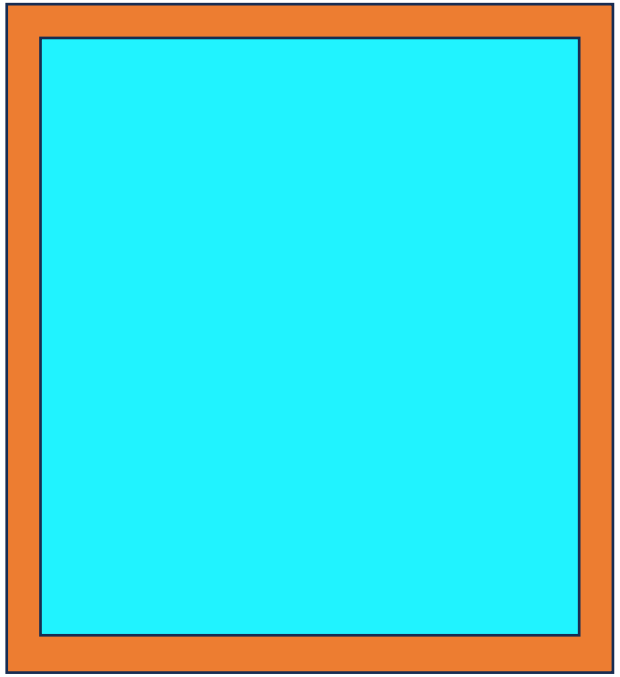
NFRC Model Sizes



Casement Window



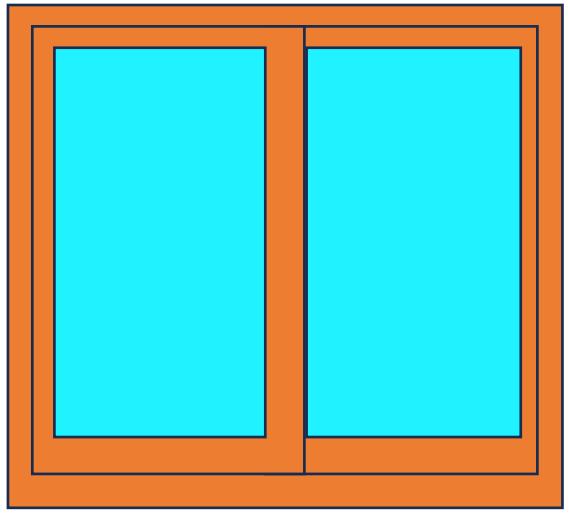
Horizontal Sliding Window



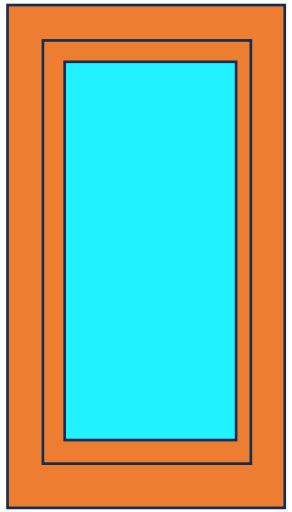
Fixed Window

Window Types
Air Infiltration and Exfiltration

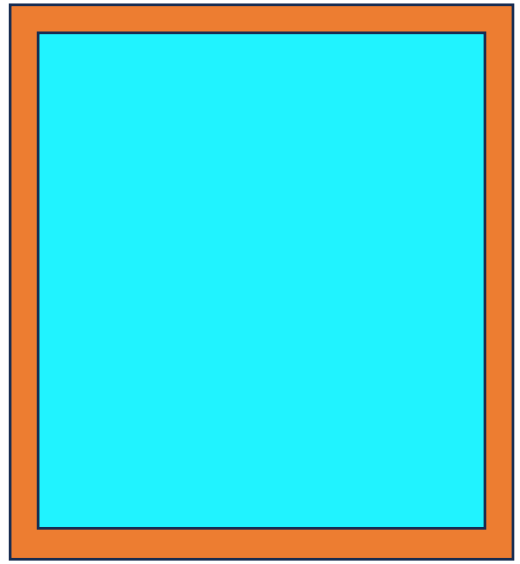
- Air Infiltration and Exfiltration is measure in L/s/m^2 for windows (L75) rating.



Horizontal Sliding Window
L75 ≤ 1.5 L/s/m^2



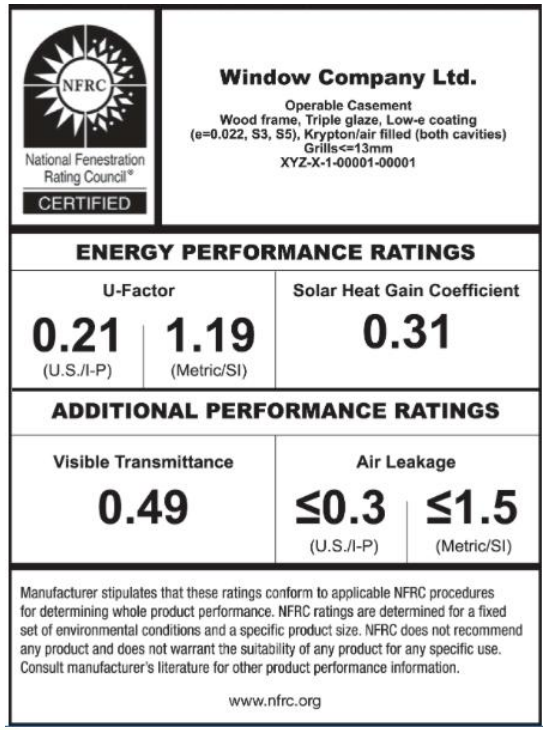
Casement Window
L75 ≤ 0.5 L/s/m^2



Fixed Window
L75 ≤ 0.2 L/s/m^2

Window Labels

- Look for the label and leave the label on the window for final inspection



National Fenestration Rating Council®
CERTIFIED

Window Company Ltd.
Operable Casement
Wood frame, Triple glaze, Low-e coating
(e=0.022, S3, S5), Krypton/air filled (both cavities)
Grills<=13mm
XYZ-X-1-00001-00001

ENERGY PERFORMANCE RATINGS

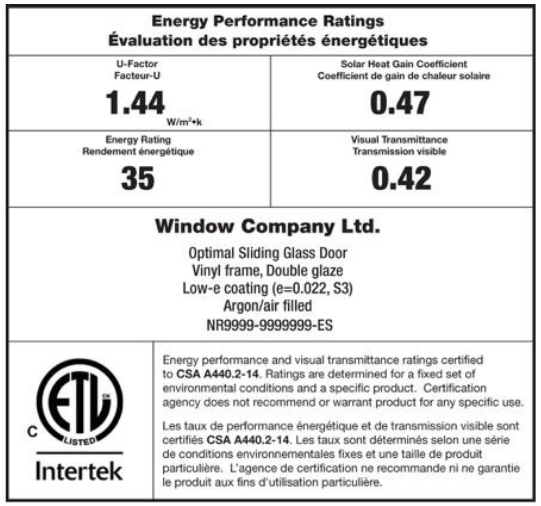
U-Factor		Solar Heat Gain Coefficient
0.21 (U.S./I-P)	1.19 (Metric/SI)	0.31

ADDITIONAL PERFORMANCE RATINGS

Visible Transmittance	Air Leakage	
0.49	≤0.3 (U.S./I-P)	≤1.5 (Metric/SI)

Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information.

www.nfrc.org



Energy Performance Ratings
Évaluation des propriétés énergétiques

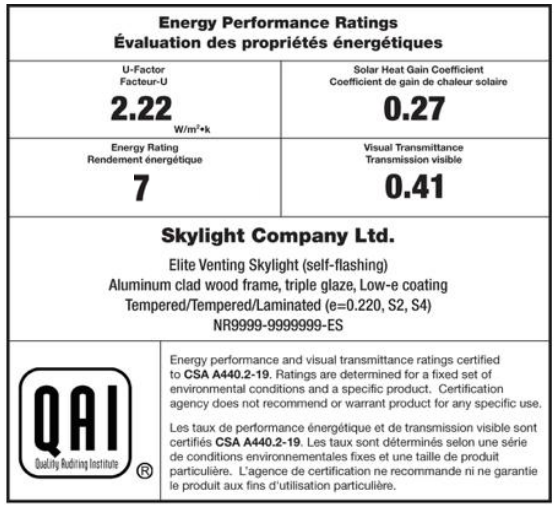
U-Factor / Facteur-U	Solar Heat Gain Coefficient / Coefficient de gain de chaleur solaire
1.44 W/m²•k	0.47
Energy Rating / Rendement énergétique: 35	Visual Transmittance / Transmission visible: 0.42

Window Company Ltd.
Optimal Sliding Glass Door
Vinyl frame, Double glaze
Low-e coating (e=0.022, S3)
Argon/air filled
NR9999-9999999-ES

Intertek

Energy performance and visual transmittance ratings certified to **CSA A440.2-14**. Ratings are determined for a fixed set of environmental conditions and a specific product. Certification agency does not recommend or warrant product for any specific use.

Les taux de performance énergétique et de transmission visible sont certifiés **CSA A440.2-14**. Les taux sont déterminés selon une série de conditions environnementales fixes et une taille de produit particulière. L'agence de certification ne recommande ni ne garantie le produit aux fins d'utilisation particulière.



Energy Performance Ratings
Évaluation des propriétés énergétiques

U-Factor / Facteur-U	Solar Heat Gain Coefficient / Coefficient de gain de chaleur solaire
2.22 W/m²•k	0.27
Energy Rating / Rendement énergétique: 7	Visual Transmittance / Transmission visible: 0.41

Skylight Company Ltd.
Elite Venting Skylight (self-flashing)
Aluminum clad wood frame, triple glaze, Low-e coating
Tempered/Tempered/Laminated (e=0.220, S2, S4)
NR9999-9999999-ES

QAI Quality Auditing Institute

Energy performance and visual transmittance ratings certified to **CSA A440.2-19**. Ratings are determined for a fixed set of environmental conditions and a specific product. Certification agency does not recommend or warrant product for any specific use.

Les taux de performance énergétique et de transmission visible sont certifiés **CSA A440.2-19**. Les taux sont déterminés selon une série de conditions environnementales fixes et une taille de produit particulière. L'agence de certification ne recommande ni ne garantie le produit aux fins d'utilisation particulière.

Energy Performance Ratings
Évaluation des propriétés énergétiques

U-Factor / Facteur-U	Solar Heat Gain Coefficient / Coefficient de gain de chaleur solaire
1.10 W/m²•k	0.35
Energy Rating / Rendement énergétique: 36	Visual Transmittance / Transmission visible: 0.53

Window Company Ltd.
Triple X Operable Casement
Vinyl frame, triple glaze, Low-e coating (e=0.022, S3, S5)
Krypton/air filled (both cavities), Grills <=13mm
WCTXCAP0.022G

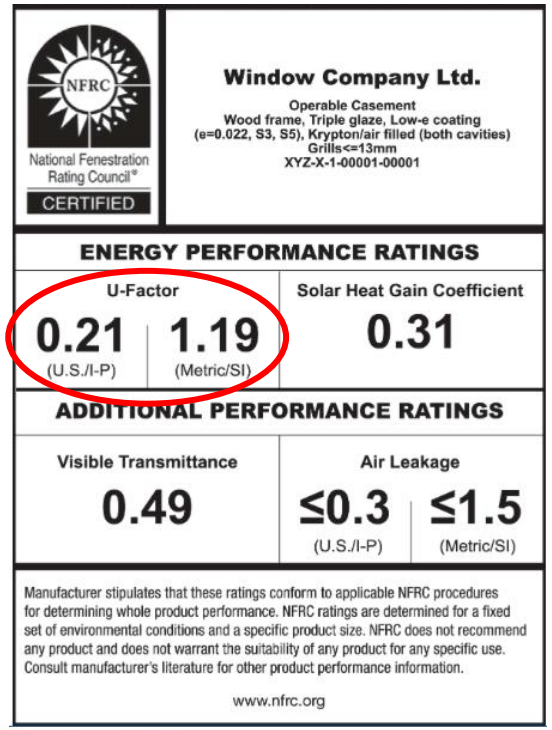
CSA®

Energy performance and visual transmittance ratings certified to **CSA A440.2-14**. Ratings are determined for a fixed set of environmental conditions and a specific product. Certification agency does not recommend or warrant product for any specific use.

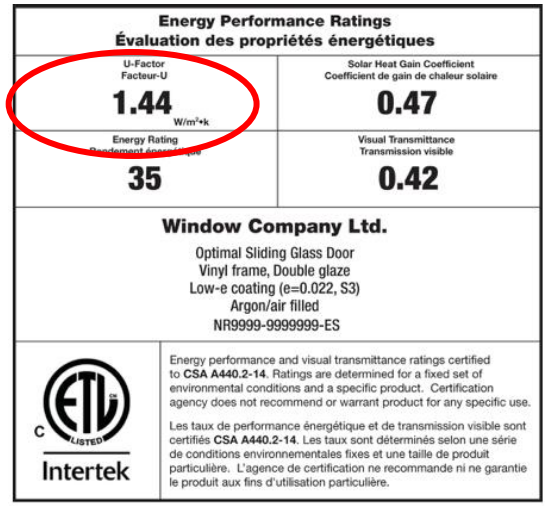
Les taux de performance énergétique et de transmission visible sont certifiés **CSA A440.2-14**. Les taux sont déterminés selon une série de conditions environnementales fixes et une taille de produit particulière. L'agence de certification ne recommande ni ne garantie le produit aux fins d'utilisation particulière.

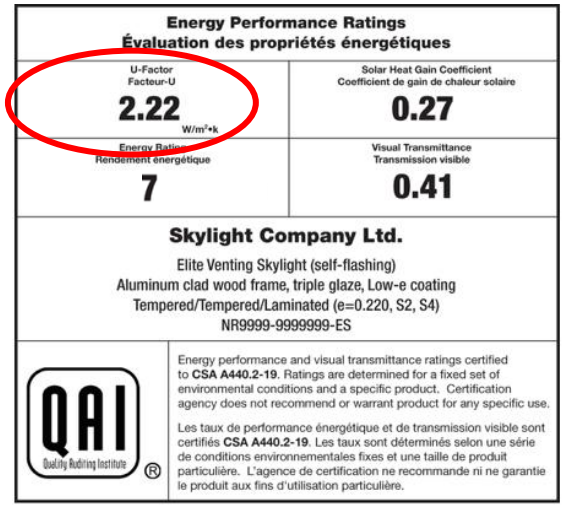
Window Labels

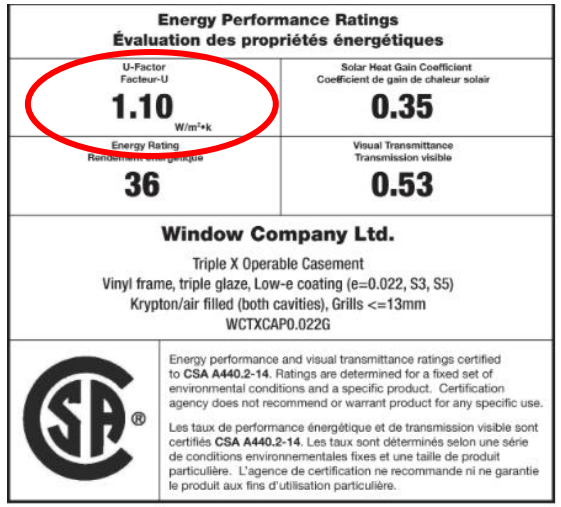
- Look for the label and leave the label on the window for final inspection



U-factors







Window Labels

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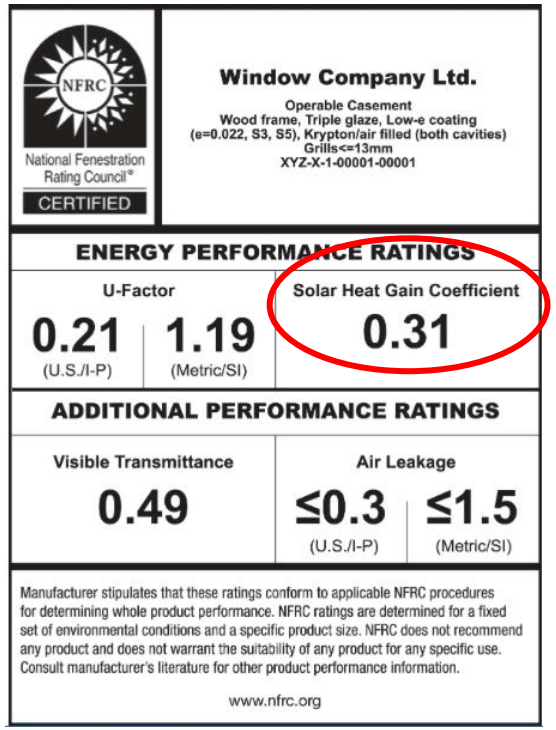
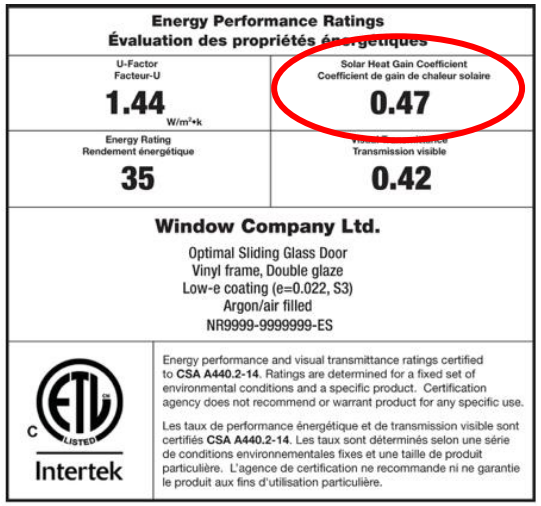
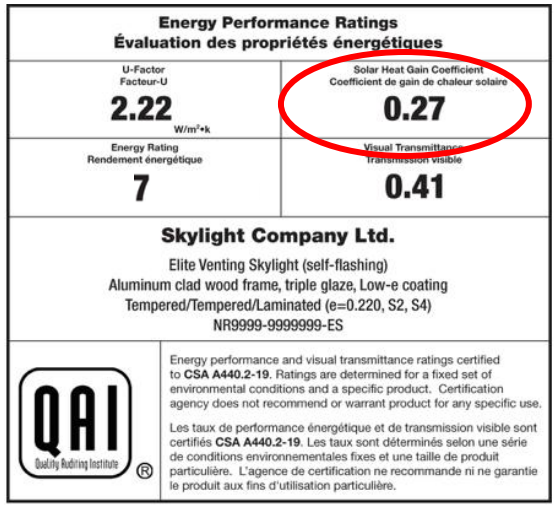
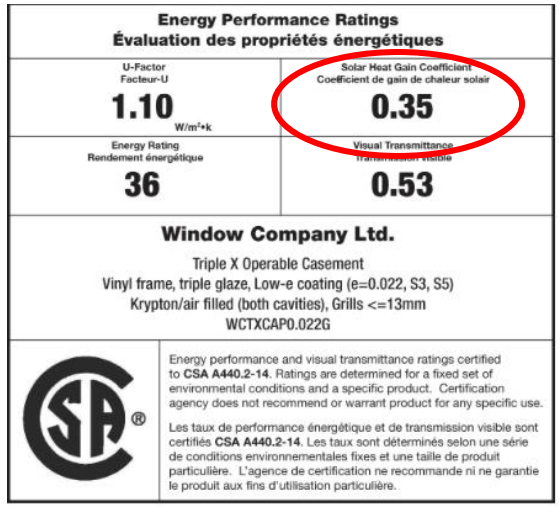


Solar Heat Gain Coefficient (SHGC)

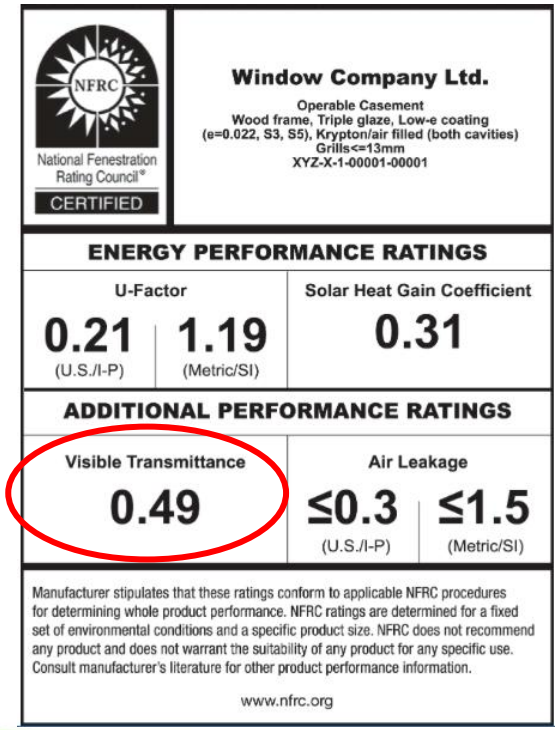




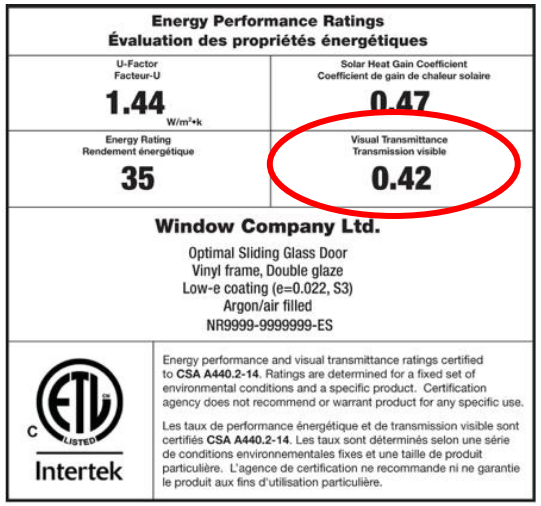


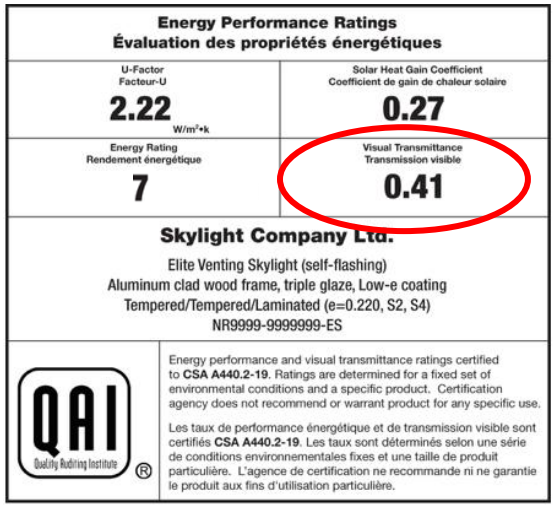
Take Away

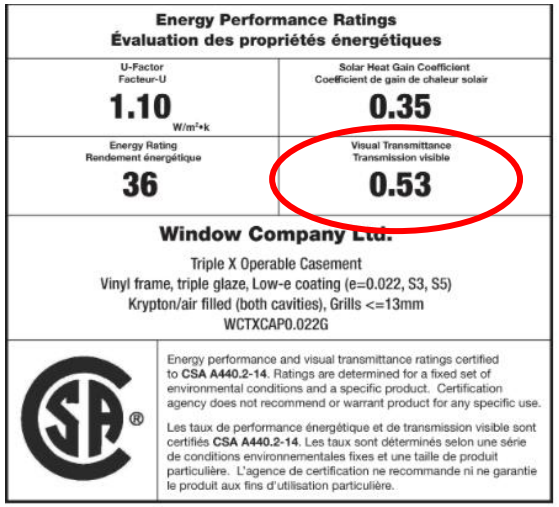
- Look for the label and leave the label on the window for final inspection



Visible Transmission (VT)







Window Labels

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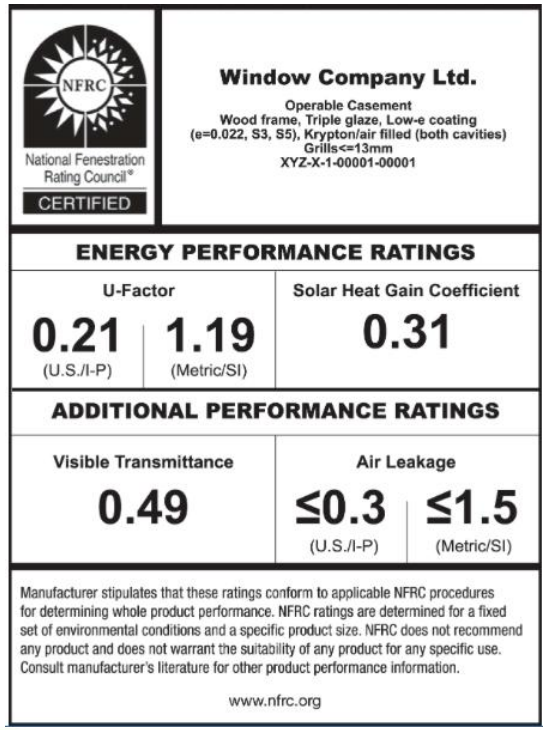
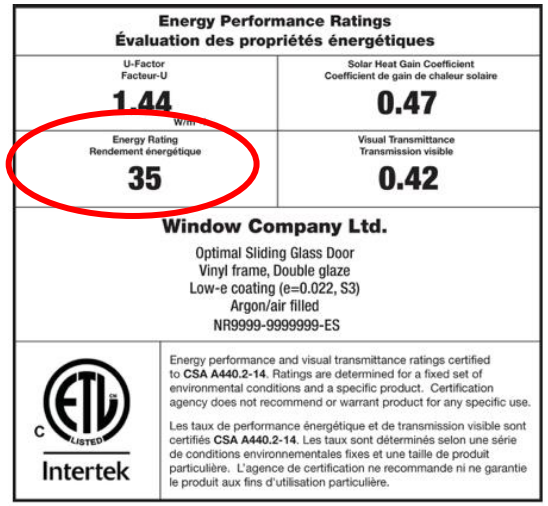
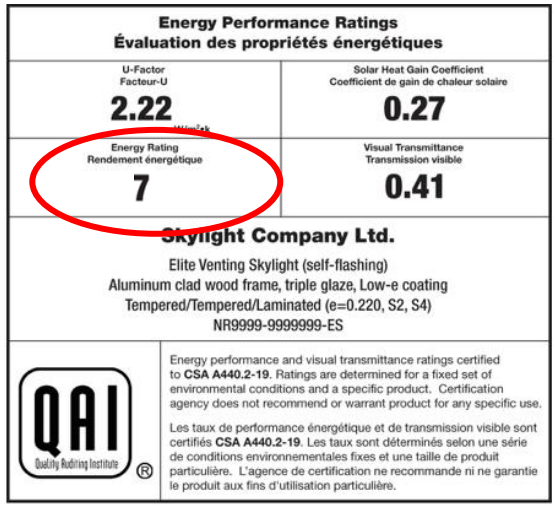
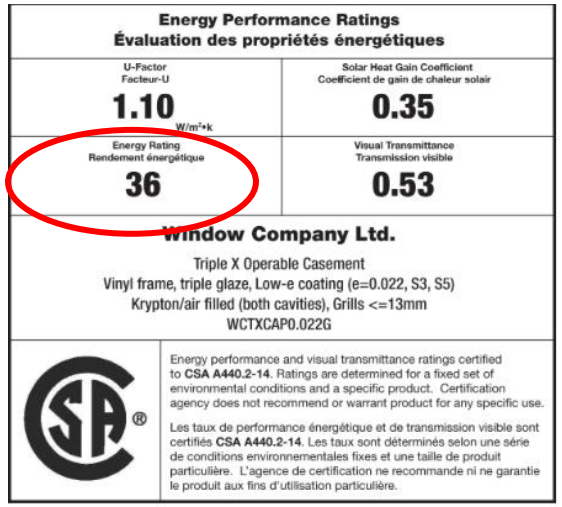


Energy Rating (ER)



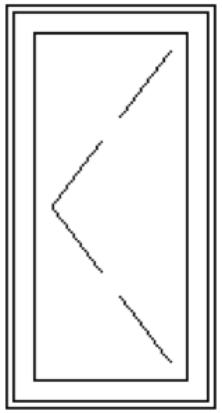




Where Else Will You See These Values

- Manufacturer Quote Sheet

LINE NO.	LOCATION SIZE INFO	BOOK CODE DESCRIPTION	QTY
Line-1		JWCCA-023044	
Rough Opening: 24 X 45		Frame Size: 23 x 44 (584mm x 1118mm) DF Vinyl , JWC8500 Casement , 1 Wide Casement , Left Ext Colour: White , Int Colour: White , Ext Options: No Nailing Fin (No Brickmould) , Overall depth(including moulding): 4 9/16 ", Int Option: Integrated 1/2" Drywall (Open) , Pre-drilled Triple, SunResist 2 Low-E Argon gas , L/a 5 sqft, Anneal/ Anneal, Grille: No Grilles , Contemporary Multipoint Hardware & Nesting Handle , Standard Hinge Meets Canadian Egress , FLEXSCREEN, Screen Installed Std Packaging R/O: 24 x 45	



Viewed from Exterior. Scale: 1/2" = 1'

ENERGY STAR QUALIFIED,(NFRC CPD# JEL-M-971-00445-00001),
ER: 30, U-Factor: 0.91, SHGC: 0.18

NAFS: CW-PG65 +3120/-3120 Pa 720 Pa A3
Weight: 38.83 lb
PEV 2024.1.0.4464/PDV 7.409 (02/28/24) DF

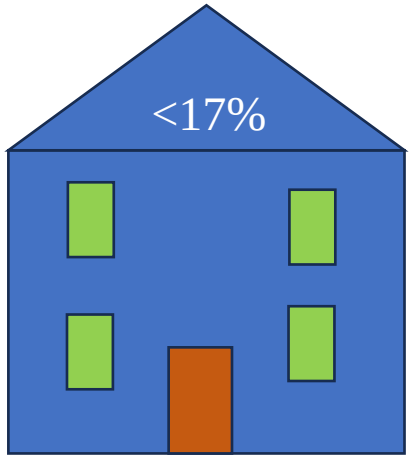
Where Else Will You See These Values

- Manufacturer Quote Sheet

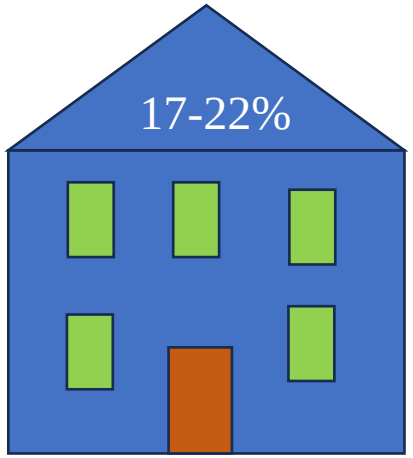
Qty	Line	Pos	Unit Type / Dimensions	Unit Width	Unit Height	Unit Sqft	Total Sqft	U-Value	SHGC	VLT	ER
1	100	A1	100REC3036	35 1/2"	41 1/2"	10.23	10.23	0.23	0.32		
1	200	A1	100REC3036	35 1/2"	41 1/2"	10.23	10.23	0.23	0.32		
1	300	A1	100REC3036	35 1/2"	41 1/2"	10.23	10.23	0.23	0.32		
1	400	A1	100CS3036	35 1/2"	41 1/2"	10.23	10.23	0.24	0.27		
1	500	A1	100CS3036	35 1/2"	41 1/2"	10.23	10.23	0.24	0.27		

What Type of Window Works Best

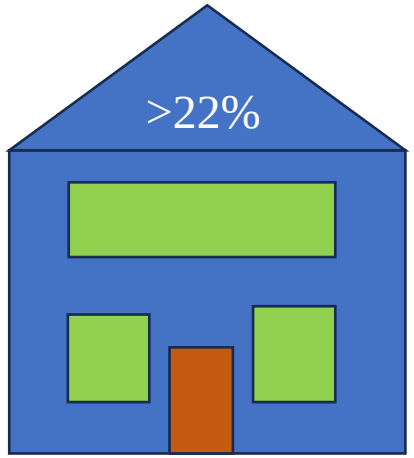
- Looking at the Current Ontario Code window performance requirements increase with the fenestration and door to wall ratio (FDWR)
  - Ontario breaks it down as <17%, 17-22%, and >22% FDWR



U≤1.6, or ER≥25
SHGC 0.65-0.45



U≤1.4, or ER≥29
SHGC 0.45-0.30



U≤1.2, or ER≥34
SHGC ≤ 0.30

SHGC is not in the code but these value are a rule of thumb for FDWR

Path to Window Aspirational Goal

- Natural Resources Canada Study
- Window design elements reviewed in this study
  - Frame Material (new or additional materials)
  - Percent Frame Area (less frame area)
  - Number of Glass Layers (minimum triple glazed IGU)
  - Gas Fill (argon)
  - Overall IG Unit Thickness (optimized for spacer and gas choice)
  - Spacer System Type (lower conductance spacers)

Design Elements Needed to Achieve U-factor performance

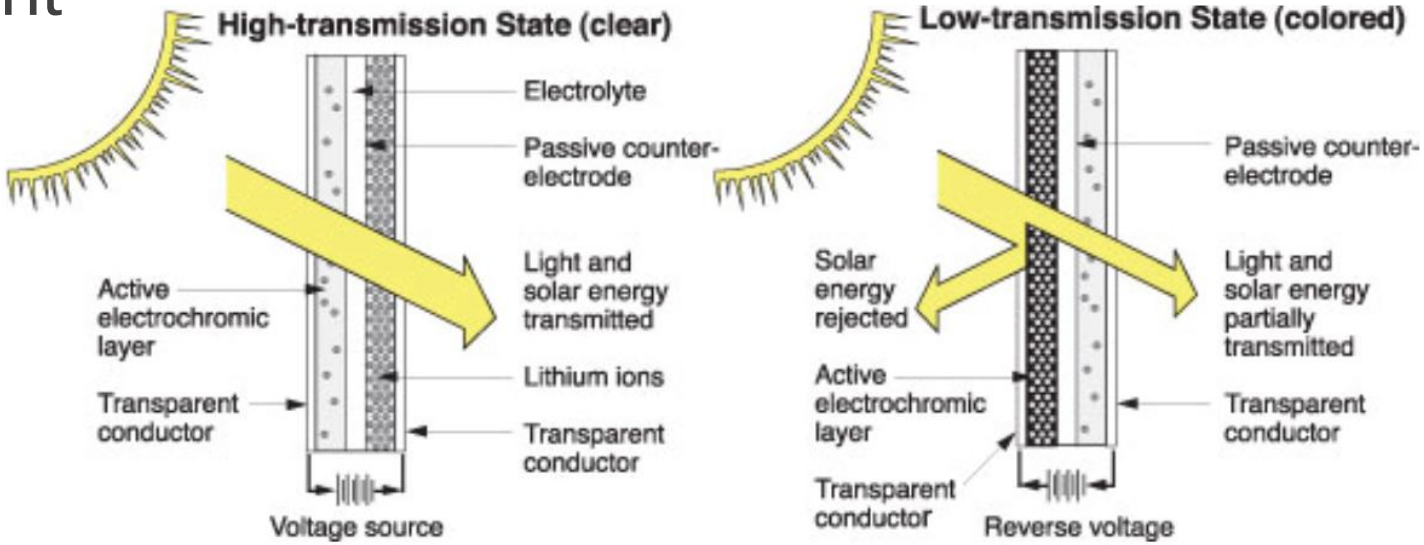
U-factor Range (W/m^2K)	Window Design Elements Needed
1.05-0.95	3 to 4 elements
0.94-0.83	4 to 5 elements
0.82-0.65	5 to 6 elements

New Technology

- Electrochromic Glazing
- Vacuum Glazing
- ~~Thin Triples~~ Light Weight Triples

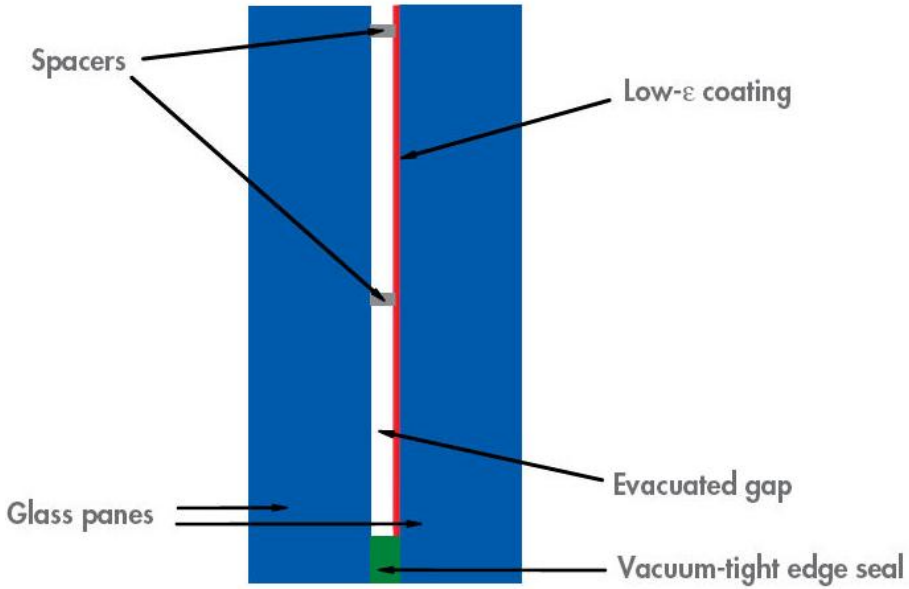
New Technology

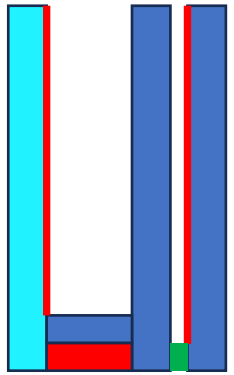
- Electrochromic Glazing
  i. A very thin electrochromic film stack is deposited on the glass
  ii. When a low voltage is applied the film can be changed from clear to a blue/gray tint



New Technology

- Vacuum Glazing
  a. R&D at University of Sydney in the early 1990s
  b. Commercially available for many years
  c. Early commercial versions had size limitation, current versions much larger
  d. Vacuum pressure is critical
  e. A number of companies are producing vacuum glazing
  f. May need to be a hybrid IG unit with a vacuum layer

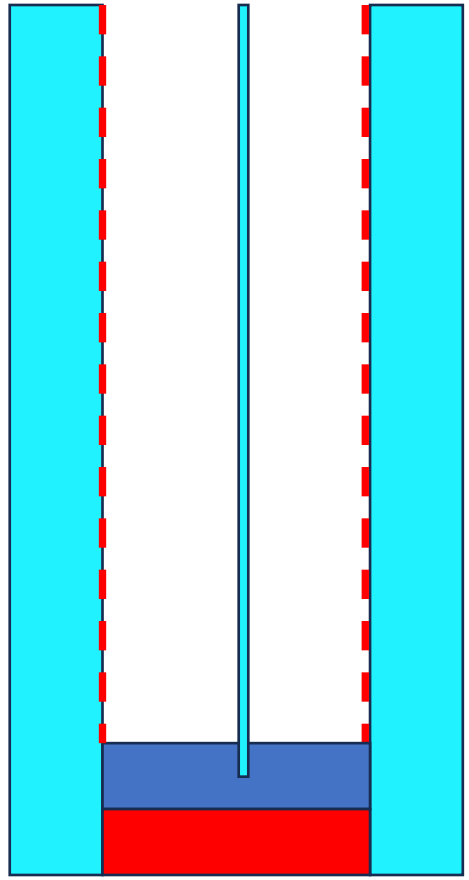




Hybrid vacuum IGU

New Technology

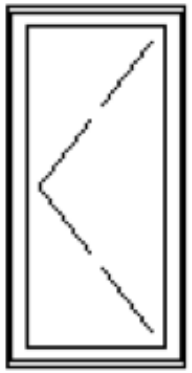
- ~~Thin Triples~~ Light Weight Triples
- Thin triples need krypton fill to achieve very low U-factors, but krypton is very expensive
- Thin triples are designed to fit into existing frames
- Light weight triples using the very thin middle layer of glass designed with optimum glass spacing for argon fill are a much better product for the Canadian market



Take Away

- Look for the Performance Data on Manufacturer Quote Sheets

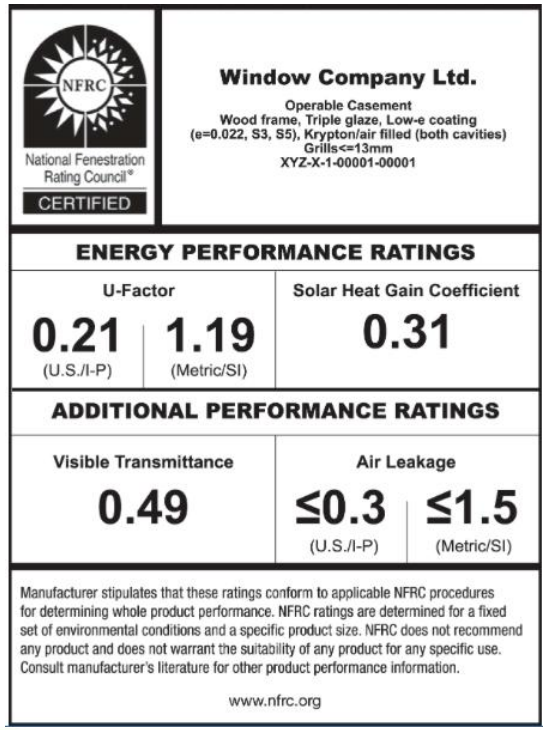
LINE NO.	LOCATION SIZE INFO	BOOK CODE DESCRIPTION	QTY
Line-1	RR-MBED/ENS	C2856-1	
Rough Opening: 29 X 57		V Csmnt 1W (Frame= 28 x 56) **(Ext= Chestnut Bronze)** : L , 7 3/8 , 7 3/8 ,Parent Jamb 0 Warm Edge Tr - 3mmLowE/13mm/3mm/13mm/3mmLowE **(Argon Gas)** Dual Arm Operator **(Folding Handle)** **(Multi-Point Lock)** No Nail Fin , L/a 7.52 , , Egress: Bedroom , , U-Factor: 1.08 , Energy Rating: 37 , SHGC: 0.38 , ,WT: 65.39 lb NRCan No NR5692-12164026-ES PGR: CW-PG70-C , Air: A3 , DP: +3360/-3360 Pa , Water: 730 Pa STCP1-31 Product Qualifies For Canadian ENERGY STAR PEV 2023.3.0.4144/PDV 6.815 (07/28/23) UW	

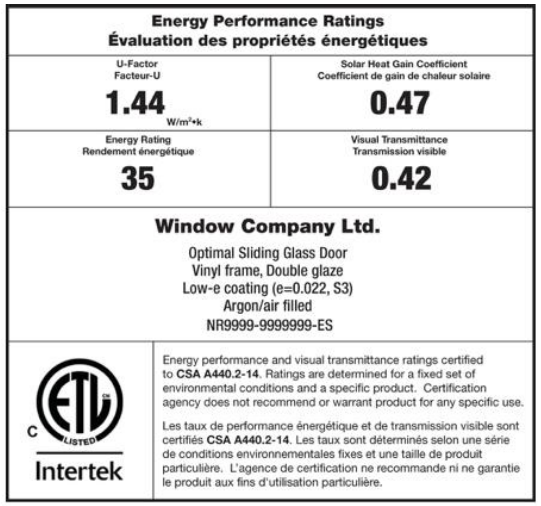


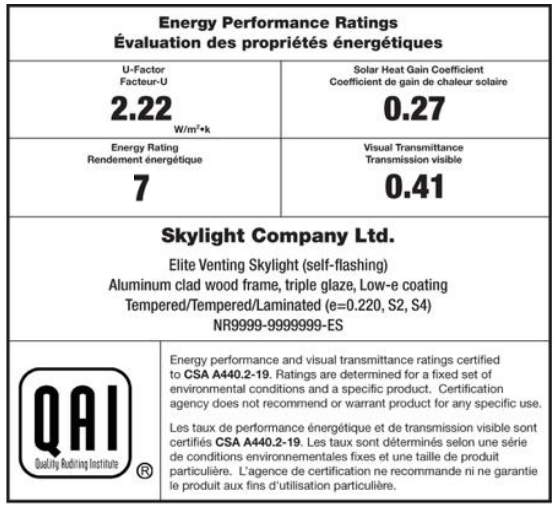
Viewed from Exterior. Scale: 1/4" = 1'

Take Away

- Look for the label and leave the label on the window for final inspection

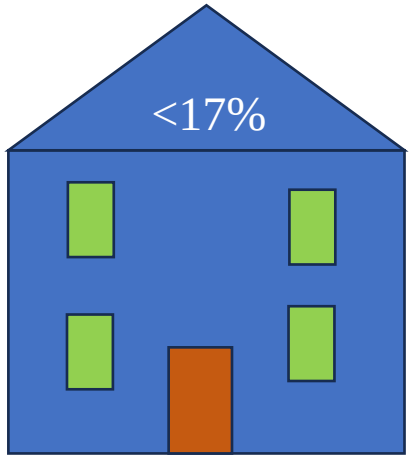




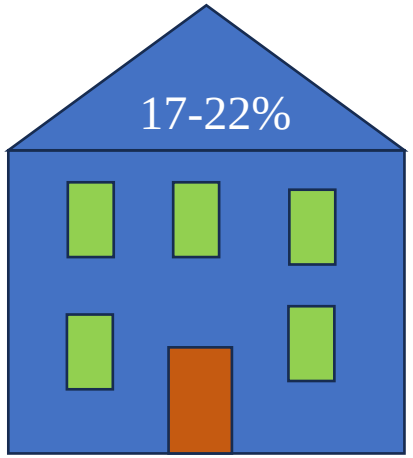


Take Away

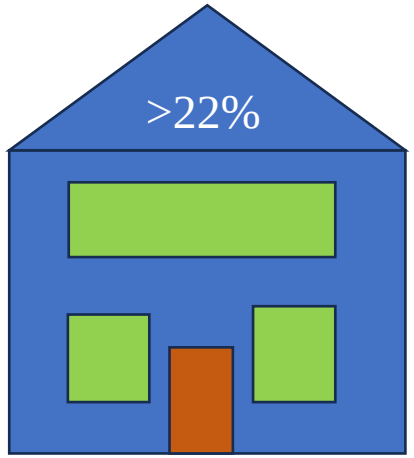
- Greater Fenestration and Door to Wall Ratios need lower SHGC values



U≤1.6, or ER≥25
SHGC 0.65-0.45



U≤1.4, or ER≥29
SHGC 0.45-0.30



U≤1.2, or ER≥34
SHGC ≤ 0.30

SHGC is not in the code but these value are a rule of thumb for FDWR

Thank You