A Comparison of the NFRC and CEN Thermal Transmittance Calculation Methods in North America's Eight Climate Zones

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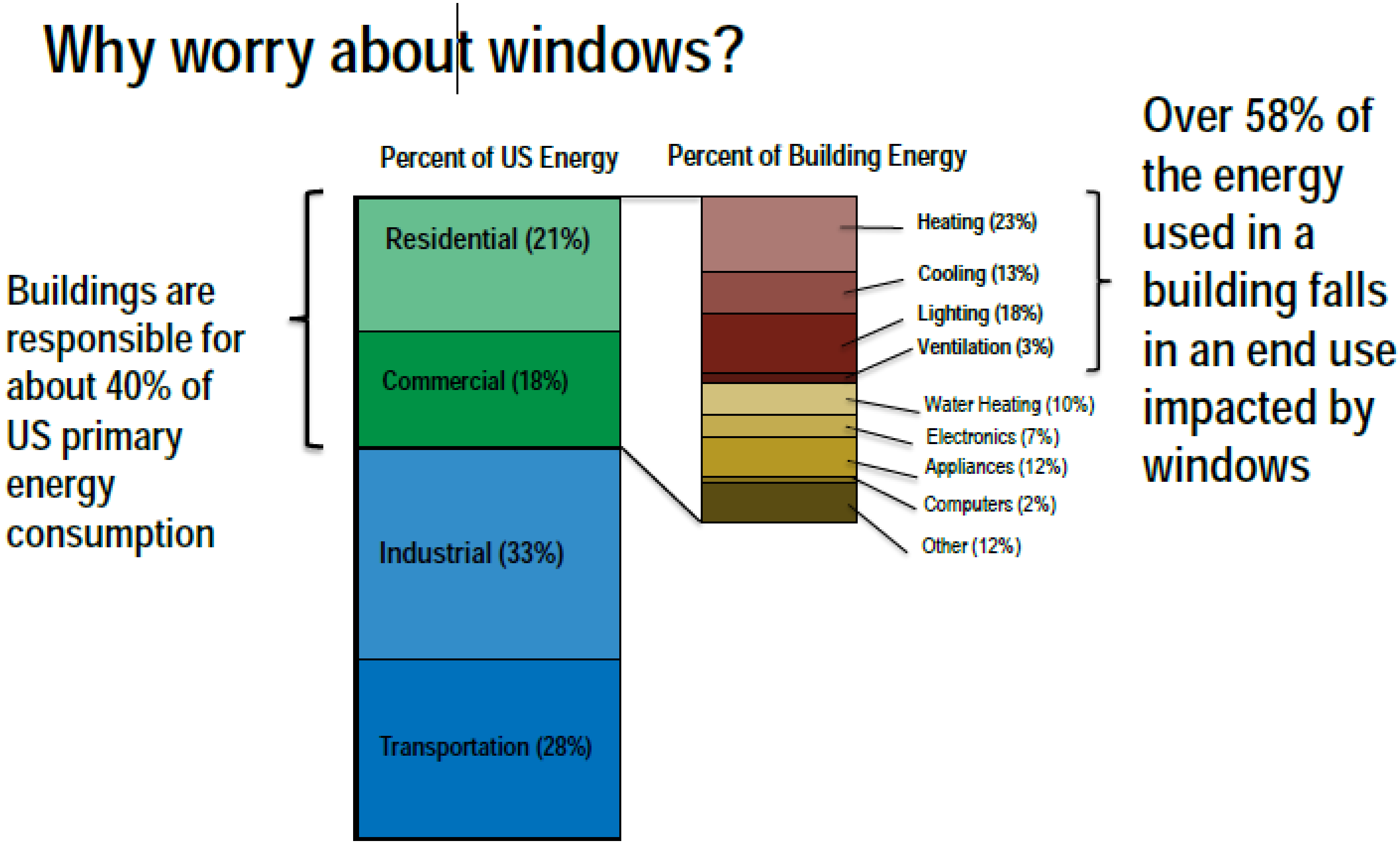
Introduction

- Residential sector, 3rd largest consumer of energy in Canada, consuming 17% of the total energy used and producing 15% of total GHGs (NRC, 2009)
- In a typical home, 30–50% of the energy used is transmitted through the windows (Gustavsen, Grynninga, Arasteh, Petter Jelle, & Goudey, 2011)
- Window frames account for 20 to 30% of the whole window area yet can be responsible for more than 30% of the rate of heat transfer (Gustavsen, Arasteh, Petter Jelle, & Curcija, 2008)

Energy Consumption of Windows in the U.S., 2011



Canadian and American Window Ratings (National Fenestration Rating Council (NFRC))

ENERGY STAR
HIGH EFFICIENCY
HAUTE EFFICACITÉ

Windows					
		Compliance Paths			
		Energy Rating (ER)	or	U-Factor	
Zone	Heating Degree-Day Range	Minimum ER (unitless) Maximum U-Factor 2.00 $W/m^2 \bullet K$ (0.35 $Btu/h \bullet ft.^2 \bullet °F$)		Maximum U-Factor $W/m^2 \bullet K$ ($Btu/h \bullet ft.^2 \bullet °F$)	Minimum ER (unitless)
A	≤ 3500	21	or	1.80 (0.32)	13
B	> 3500 to ≤ 5500	25	or	1.60 (0.28)	17
C	> 5500 to ≤ 8000	29	or	1.40 (0.25)	21
D	> 8000	34	or	1.20 (0.21)	25

NFRC
National Fenestration Rating Council®
CERTIFIED

World's Best Window Co.
Series "2000"
Casement
Vinyl Clad Wood Frame
Double Glazing•Argon Fill•Low E
ABC-X-1-00001-00001

ENERGY PERFORMANCE RATINGS

U-Factor		Solar Heat Gain Coefficient
0.35 (U.S./I-P)	**1.99** (Metric/SI)	**0.32**

ADDITIONAL PERFORMANCE RATINGS

Visible Transmittance	Air Leakage	
0.51	**0.2** (U.S./I-P)	**1.0** (Metric/SI)
Condensation Resistance		
51	**—**	

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

$$U_t = \frac{[\sum(U_f A_f) + \sum(U_e A_e) + \sum(U_c A_c)]}{A_{pf}}$$

European Committee for Standardization (CEN)

Certificate

valid until 31.12.2011

Passivhaus Institut
Dr. Wolfgang Feist
Rheinstraße 44/46
D-64283 Darmstadt

PHI

Component suitable for Passive Houses: **Window Frame**

Manufacturer: **Vale Passive Window Partnership Ltd.**
Pembrokeshire SA41 3TH

Name of product: **The Vale Passive Window**

The following criteria were checked to award the certificate:

The criteria are valid for the cool temperate climate.

Passive House comfort criterion:

Under standard conditions (use of glazing with $U_g = 0.7$ W/(m²K), width of window 1.23 m, height of window 1.48 m) the U-Value of the window fulfils the following condition:

$$U_w = 0.79 \leq 0.80 \text{ W/(m}^2\text{K)}$$

Thermal data of the window frame:

Frame	jamb	parapet
U_f [W/(m²K)]	0.77	0.80
Width [mm]	128	128

Spacer	Swisspacer V
Ψ_g [W/(mK)]	0.028

Conditions specific for Passive Houses:

The suitability for Passive Houses was checked only with the spacer denoted above; thermally worse spacers, especially those made of aluminium, lead to significantly higher thermal losses.

Installing the window suitable for Passive House:

Including all thermal bridge effects, the window fulfils the condition

$$U_{w,installed} \leq 0{,}85 \text{ W/(m}^2\text{K)},$$

if the window is installed into wall constructions suitable for Passive Houses (brick wall with thermal insulation, light weigth wooden construction and form work for concrete of polysterene) according to the drawings of details given in the appendix.

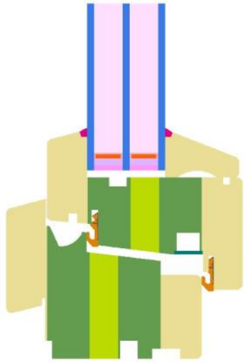
The certificate has to be used as follows:

Component suitable for Passive Houses Dr. Wolfgang Feist

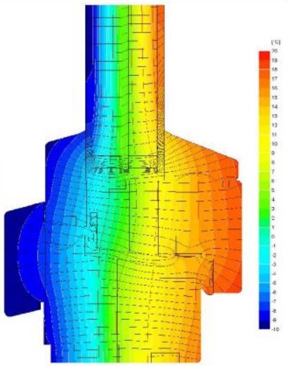
Window frame:
U_f = 0.77 / 0.80 W/(m²K)
Ψ_g = 0.028 W/(mK)
Width = 128 / 128 mm

Datenblatt zum Zertifikat

Passivhaus geeignete Komponente Dr. Wolfgang Feist



Rahmenschnitt 'unten'



Isothermen- und Wärmestrombild

Vale Passive Window Partnership 'The Vale Passive Window'

Fensterrahmen aus gedämmten Holzprofilen; Holzanteile des Rahmens aus Lärche mit einer Rohdichte $\rho \approx 600$ kg/m³ und $\lambda = 0{,}15$ W/(mK); Dämmung aus Polyurethan-Hartschaum mit $\lambda = 0{,}048$ W/(mK) und Polyurethan-Recyclingmaterial mit $\lambda = 0{,}09$ W/(mK)

Verglasung [1] 44 mm (4/16/4/16/4)

		seitl./oben	unten
Rahmenkennwerte	U_f [W/(m²K)]	0,77	0,80
	Ansichtsbreite [mm]	128	128
Abstandhalter: 'Swisspacer V'	Ψ_g [W/(mK)]	0,028	
Temperaturfaktor am Glasrand	$f_{Rsi=0,20\,m^2K/W}$ [-]	0,79	
Fenster-U-Wert [1] (1,23 x 1,48 m)	U_w [W/(m²K)]	0,79 [1]	

Hersteller: Vale Passive Window Partnership Ltd.
c/o Thomas Joinery Bancyffynnon, Brynberian, Crymych,
Pembrokeshire SA41 3TH

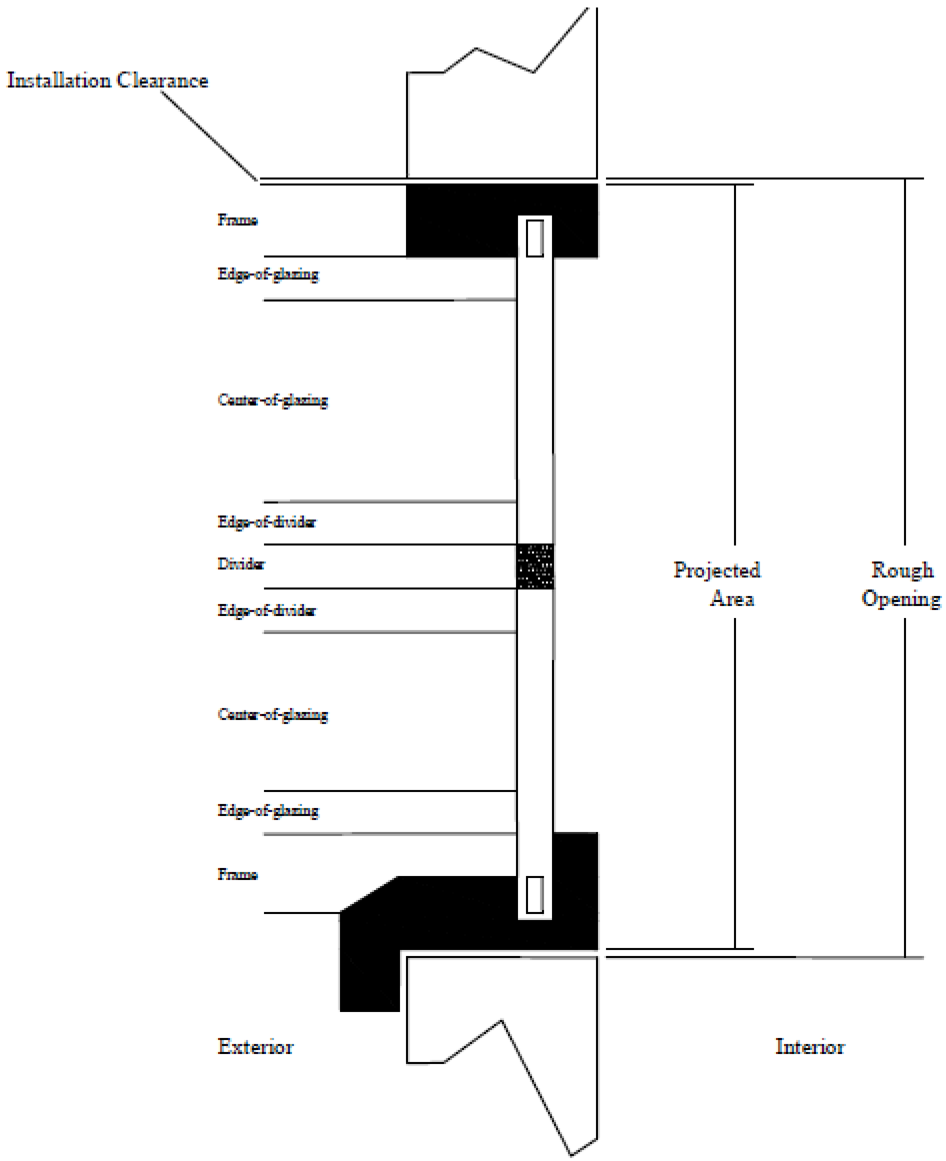
Berechnung: Passivhaus Institut 2010

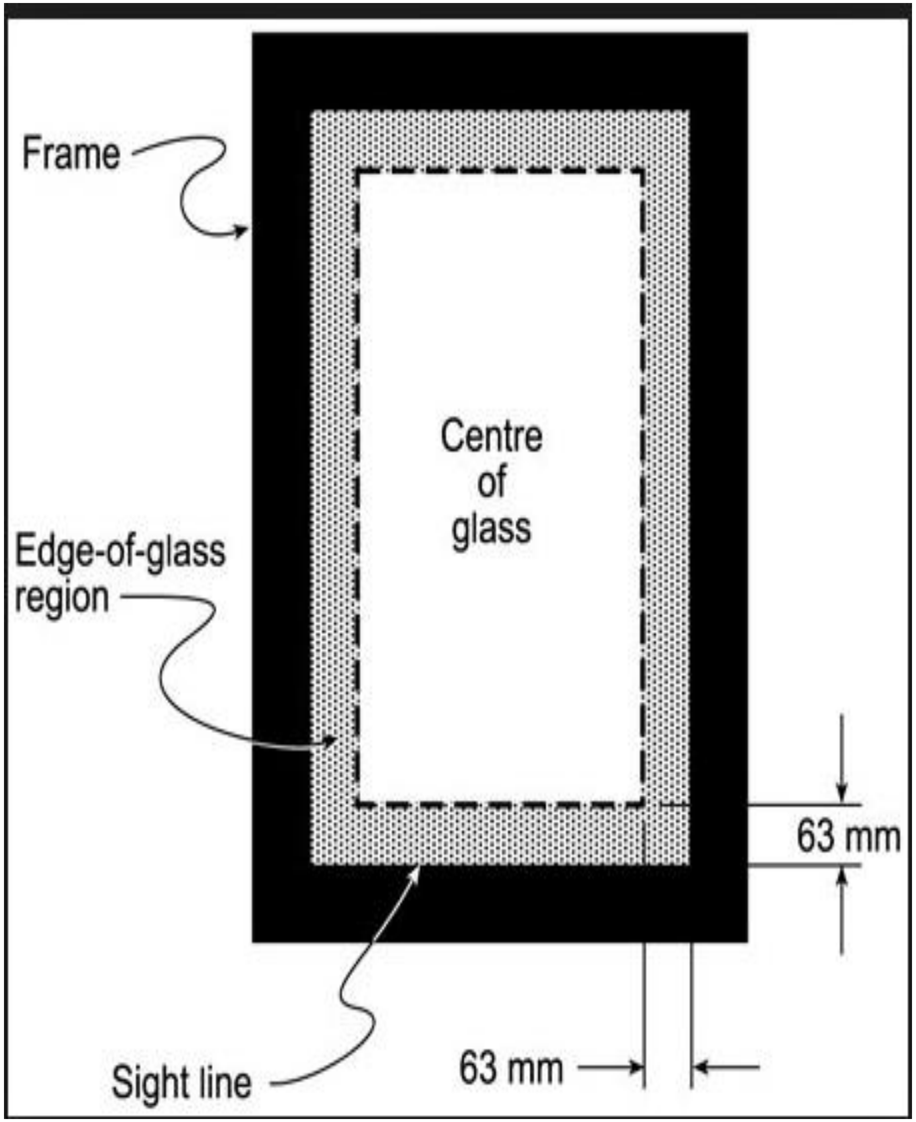
[1] Bei der Ermittlung des Fenster-U-Wertes (b = 1,23 m; h = 1,48 m) wurde ein Glas-U-Wert U_g = 0,70 W/(m²K) angesetzt.

$$Uw = \frac{\sum AgUg + \sum AfUf + \sum lg\Psi g}{\sum Ag + \sum Af}$$

North American (NFRC) and European (CEN) Window Energy Performance Standards

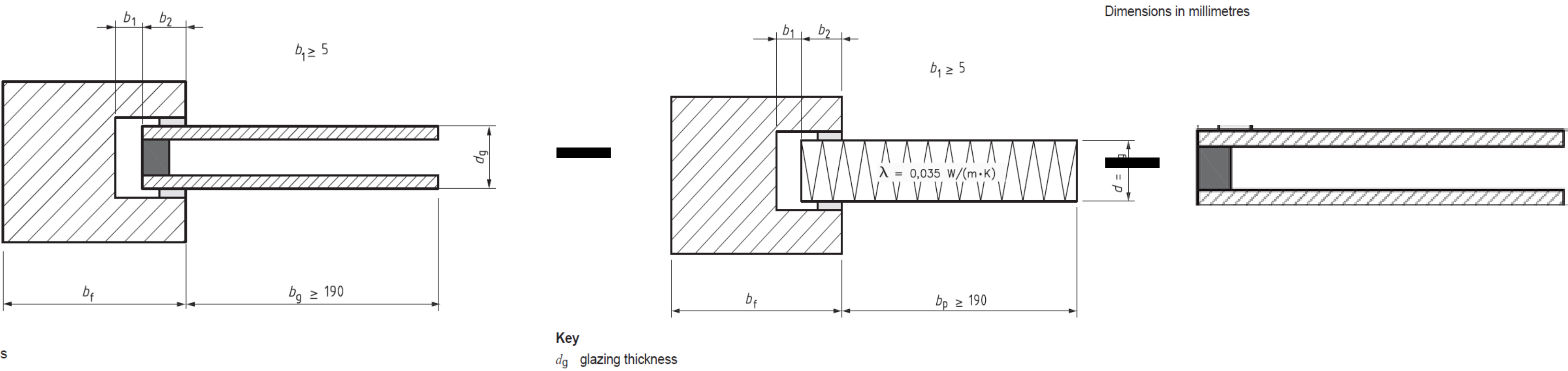
- Long disagreement between both methods; +/- 10% difference (Blanusa, 2001 and Weitzmann et al., 2000)
  - Calculation methods
  - Interior and exterior temperatures
  - Surface film coefficients
  - Wind velocities
  - Edge effects


Installation Clearance
Frame
Edge-of-glazing
Center-of-glazing
Edge-of-divider
Divider
Edge-of-divider
Center-of-glazing
Edge-of-glazing
Frame
Projected Area
Rough Opening
Exterior
Interior


Frame
Centre of glass
Edge-of-glass region
63 mm
Sight line
63 mm

(NFRC, 2010)

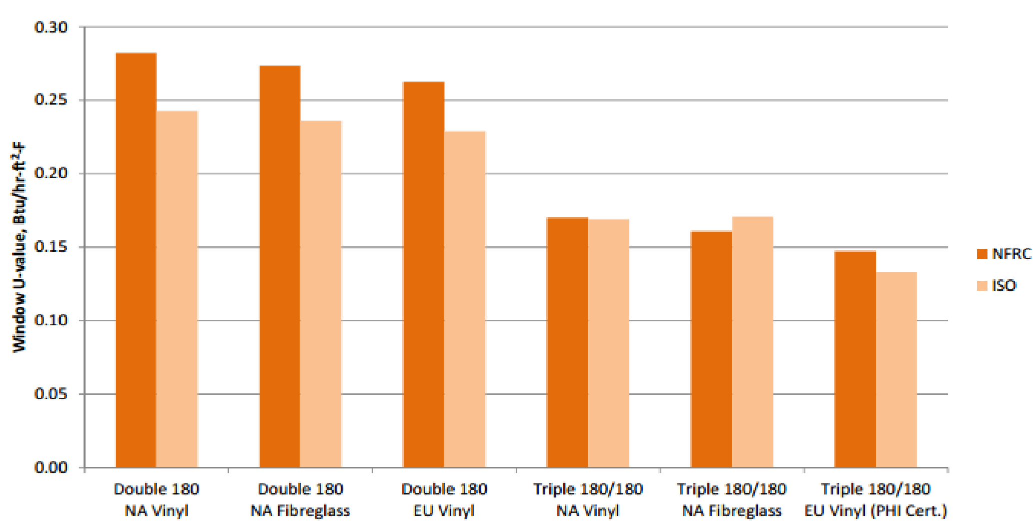
Ψ–Value (CEN)



$$\Psi = L_{\Psi}^{2D} - Ufbf - Ugbg$$

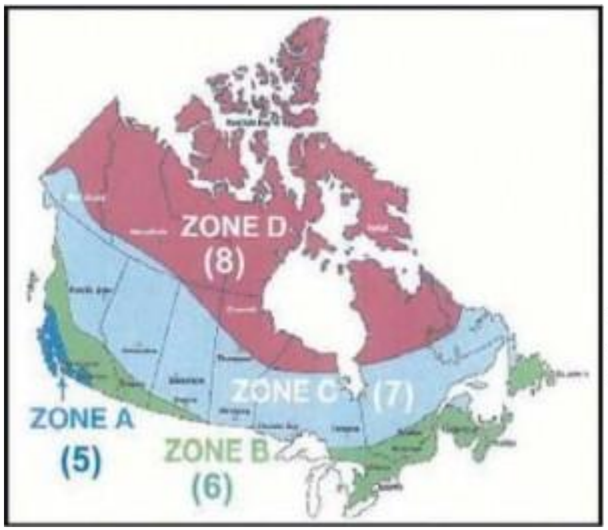
U_{window}: NFRC VS CEN

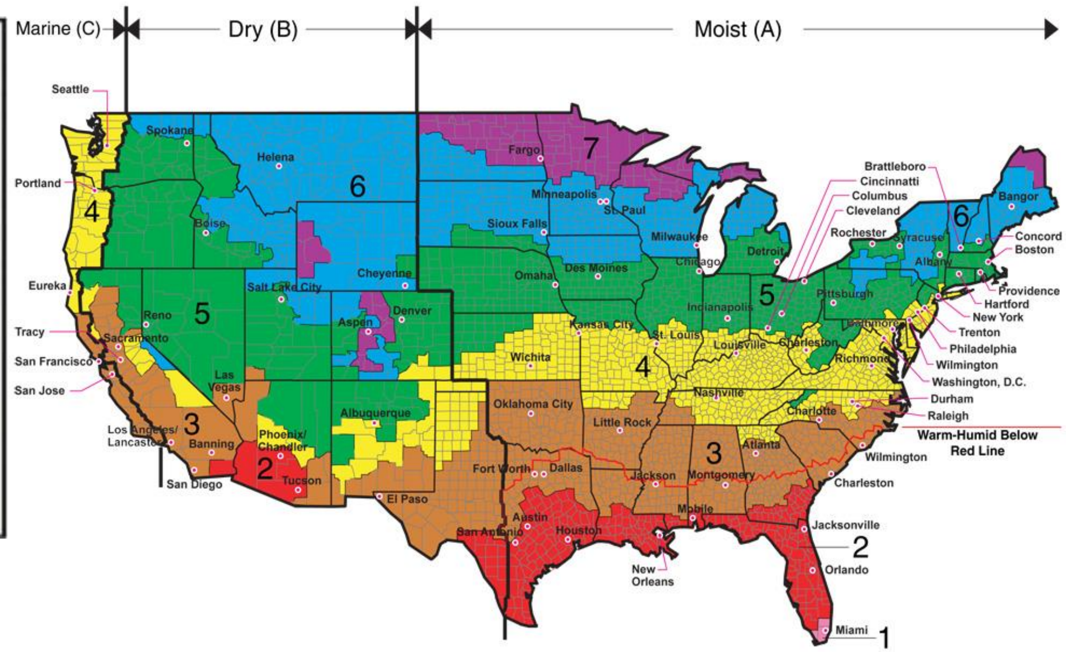
- NFRC center-of-glass U-values: up to 23% higher than CEN values
- NFRC frame U-values: 5% lower to 24% higher than CEN values
- NFRC whole window U-values: 14% lower to 18% higher than CEN values



(RDH Building Engineering Ltd., 2014)

North America's 8 Climate Zones
(IECC/ASHRAE)





All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

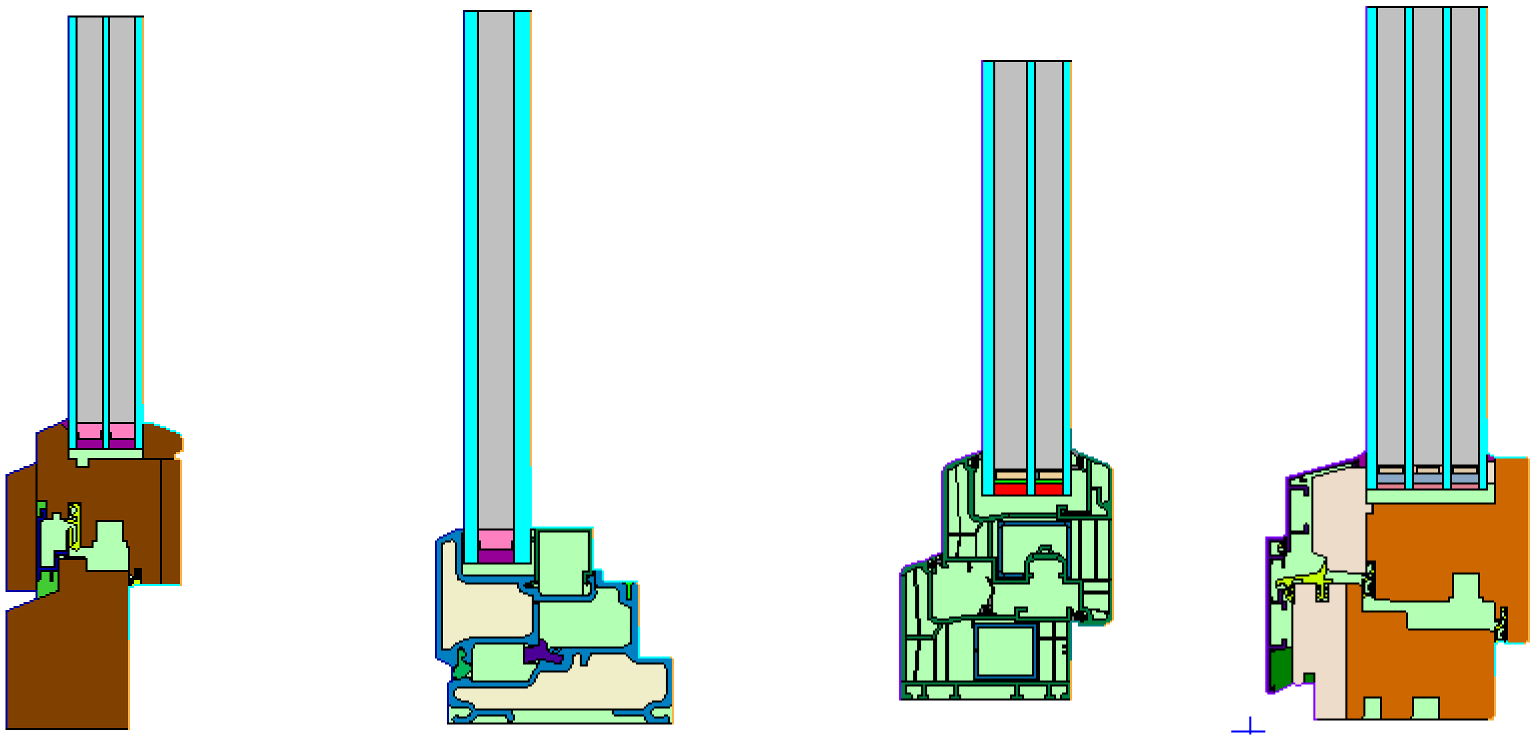
Research Questions

1. What are the differences between the NFRC and CEN calculation methods for determining the U-value for window products?

2. What parameters can be harmonized between the two U-value calculation methods?

3. How are these parameters affected by the different boundary conditions in North America's eight climate zones?

Methodology



Simulation Matrix

Exterior Temp.	Frame Material	Glazing Combination	Spacer	Material Thermal Conductivity	Frame Cavity Method	Wind Speed	Surface Film Coefficients	SHGC Methods
NA 8 climate zones	Insulated fiberglass	Double IGU; high and low SHGC	A	NFRC 101	NFRC	Inland	NFRC	NFRC
	Solid wood	Triple IGU; high and low SHGC	B	CEN (ISO 10077-2)	CEN	Coastal	CEN	CEN
	TBSW	Quad IGU; high SHGC	C					
	U-PVC							

NFRC and CEN Winter Boundary Conditions

	North America (NFRC)	Europe (CEN)
ISO Standard Used	ISO 15099	ISO 10077
Interior Temperature	21°C	20°C
Exterior Temperature	-18°C	0°C
Exterior Wind Velocity	5.5 m/s	4 m/s
Exterior Radiant Mean Temperature	$T_{r,m} = T_{exterior}$	$T_{r,m} = T_{exterior}$
Interior Radiant Mean Temperature	$T_{r,m} = T_{interior}$	$T_{r,m} = T_{interior}$

NFRC and CEN Summer Boundary Conditions

	NFRC	CEN
Standard	NFRC 200-2010	ISO 15099
Interior temperature	24°C	25°C
Exterior temperature	32°C	30°C
Interior convective surface heat transfer coefficient, hcv,int	7.7 W/(m2K) (NFRC 102 hc int and ASTM E1423)	2.5 W/(m2K)
Exterior convective surface heat transfer coefficient, hcv, ext	15 W/(m2K)	8 W/(m2K)
Radiant Mean Temperature, Tr,m	Tex	Tex
Solar irradiance, Is	783 W/m2	500 W/m2
Wind Velocity	2.75 m/s	4 m/s

(Chen and Wittkopf, 2011)

NA’s Climate Zone Boundary Conditions

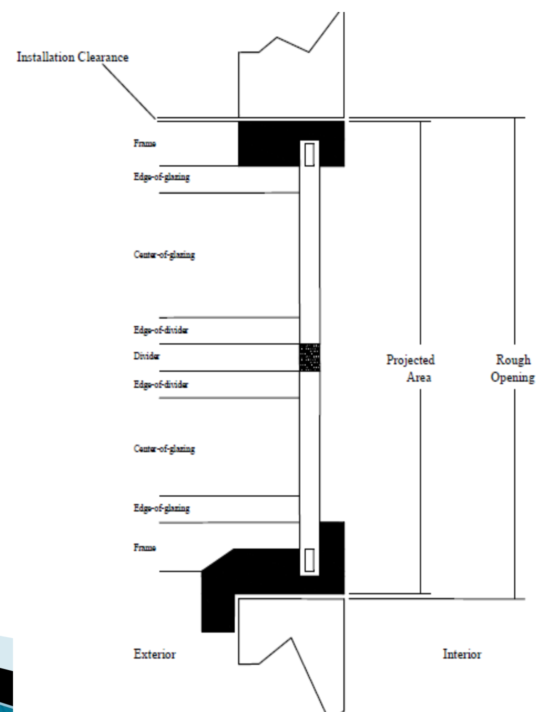
(ASHRAE, 2009)

Climate Zones (inland)	Winter Design Temp. (°C)	Summer Design Temp. (°C)	Annual Low Average Temp. (°C)	Annual Average Temp (°C)	Annual High Average Temp. (°C)	Wind Velocity (m/s)
1 **						
2 Austin, TX	-1	37	14.4	20.3	26.2	7.6
3 Atlanta, GA	-4	33	11.8	17.0	22.2	7.7
4 Albuquerque, NM	-6	34	7.5	14.0	20.4	9.3
5 Indianapolis, IN	-14	32	6.6	11.8	16.9	8.4
6 Toronto, ON	-16	29	5.6	9.2	12.7	9.1
7 Winnipeg, MB	-30	29	-3.1	2.6	8.3	9.8
8 Yellowknife, NT	-40	24	-9	-4.6	-0.2	7.7

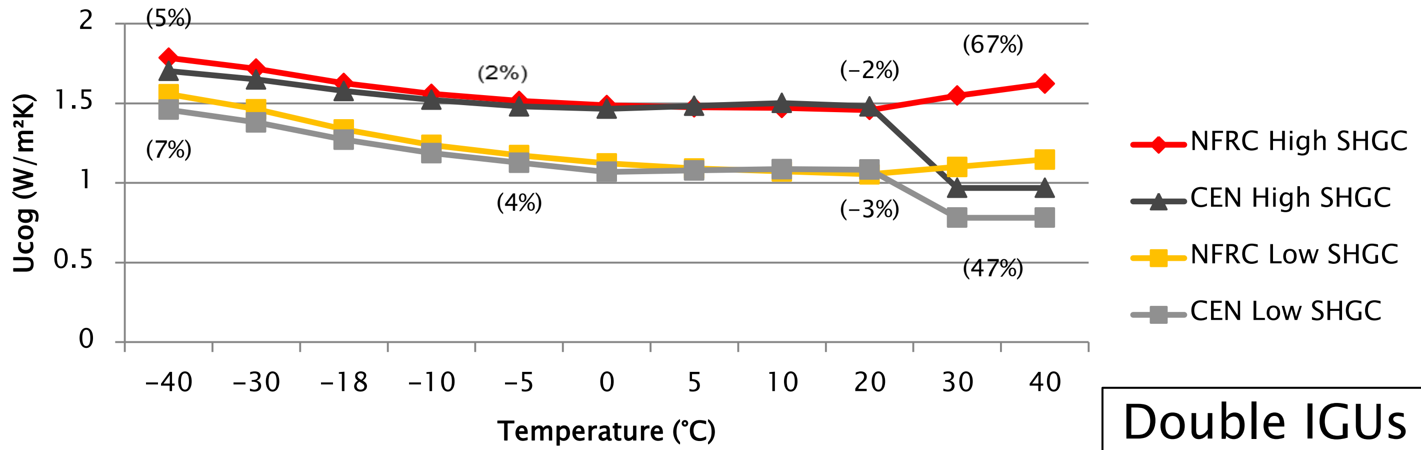
Climate Zones (coastal)	Winter Design Temp. (°C)	Summer Design Temp. (°C)	Annual Low Average Temp. (°C)	Annual Average Temp. (°C)	Annual High Average Temp. (°C)	Wind Velocity (m/s)
1 Miami, FL	11	33	21.2	25.1	29.1	7.7
2 Jacksonville, FL	0	34	14.3	20.3	26.3	7.3
3 San Francisco, CA	5	26	10.6	14.1	17.6	10.6
4 New York City, NY (JFK airport)	-8	30	8.3	12.3	16.2	9.6
5 Vancouver, BC	-4	24	6.5	10.1	13.7	7.6
6 St. John’s, NFLD	-14	23	0.6	4.7	8.7	12.3
7 Whitehorse, YT	-35	23	-5.9	-0.7	4.5	8.4
8 Iqaluit, NU	-38	14	-13.6	-9.8	-6.0	11.1

RESULTS: Solar Heat Gain Coefficient (SHGC)

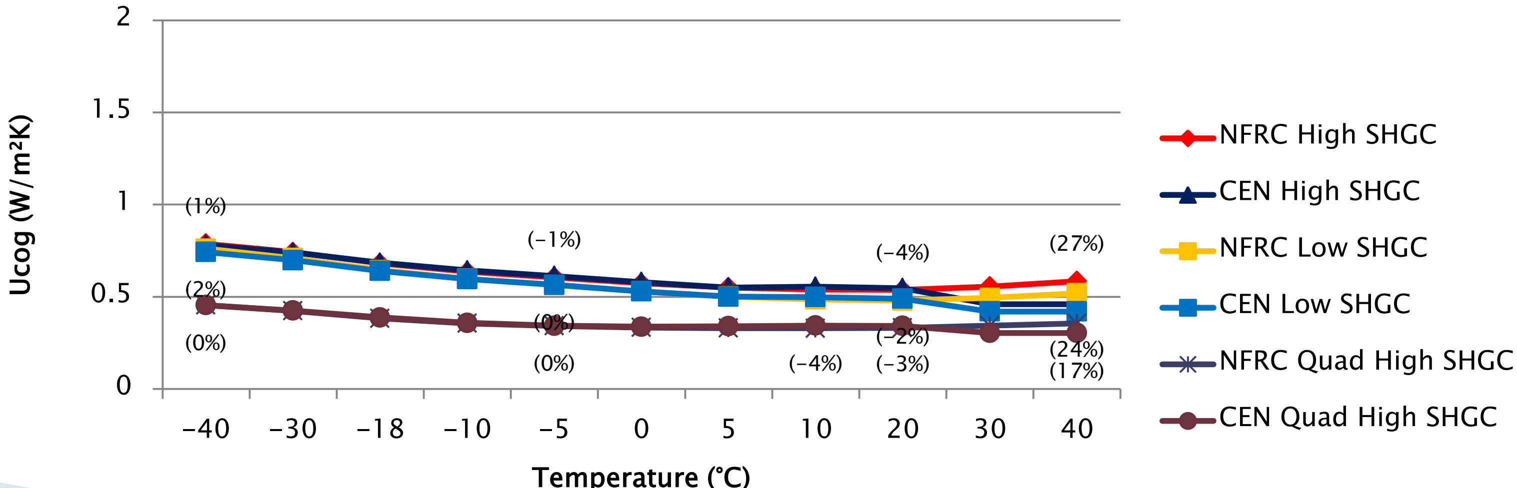
- The NFRC SHGC values were 24– 46% lower than CEN values (standard methods)
- NFRC SHGC values were 2–5% higher than CEN values for the triple and quad IGUs (IGU only)



Center-of-Glazing U-values (U_{cog})

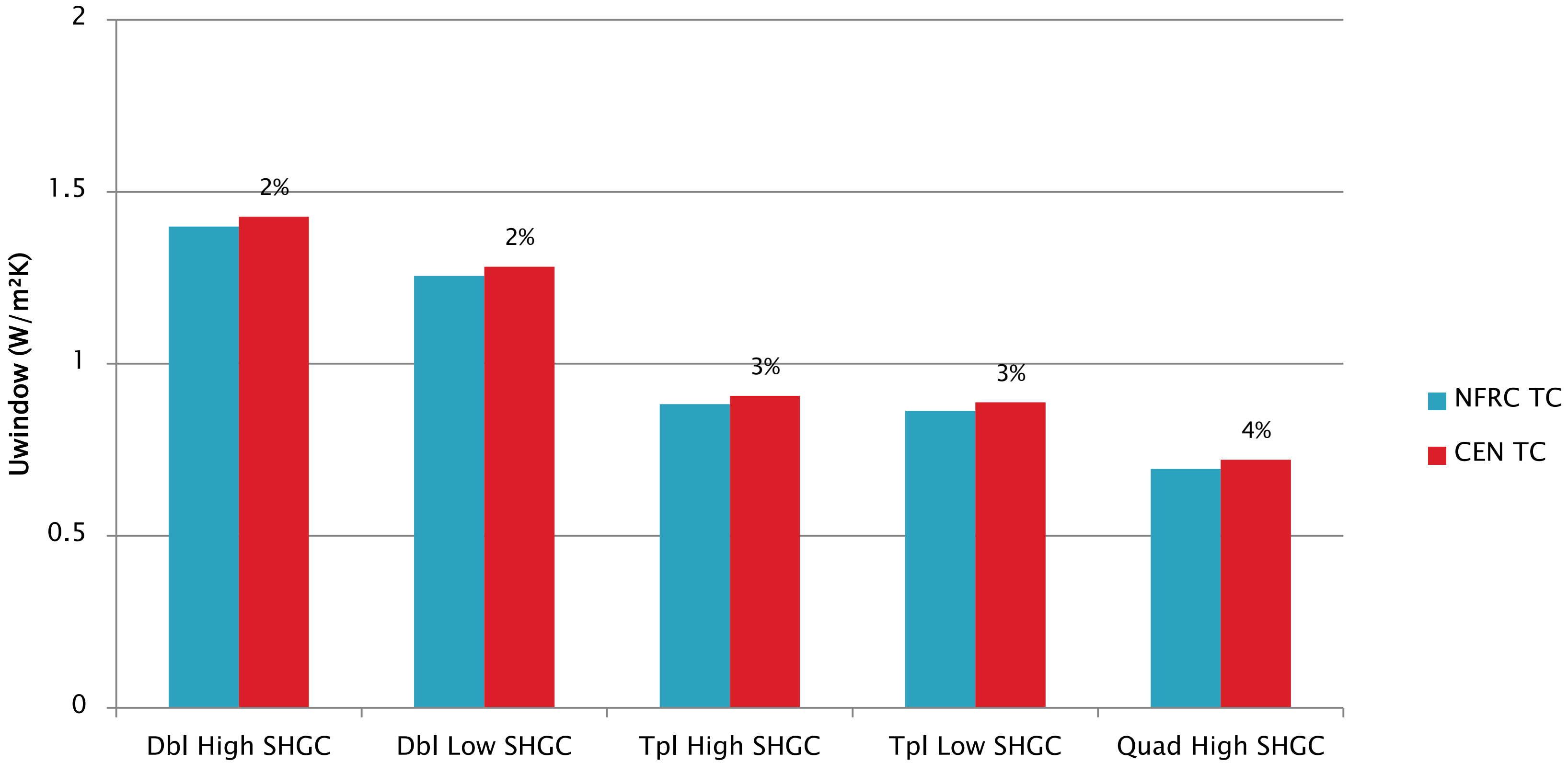


Double IGUs

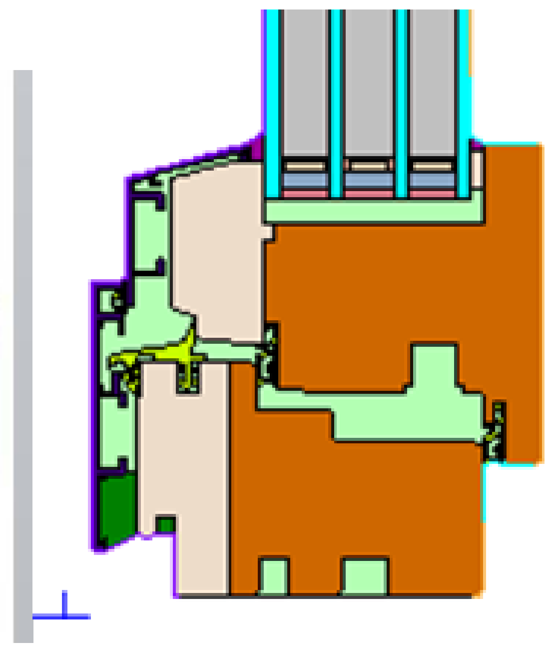


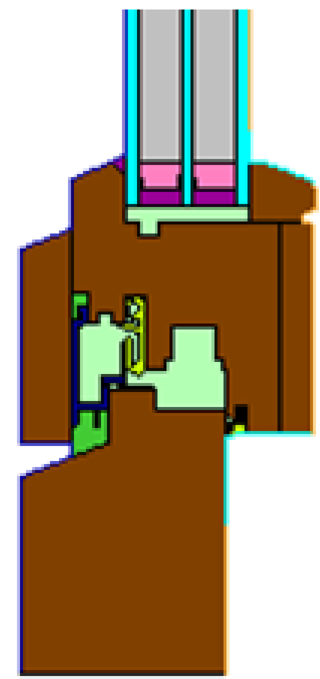
Triple and Quad IGUs

Material Thermal Conductivities (TBSW)

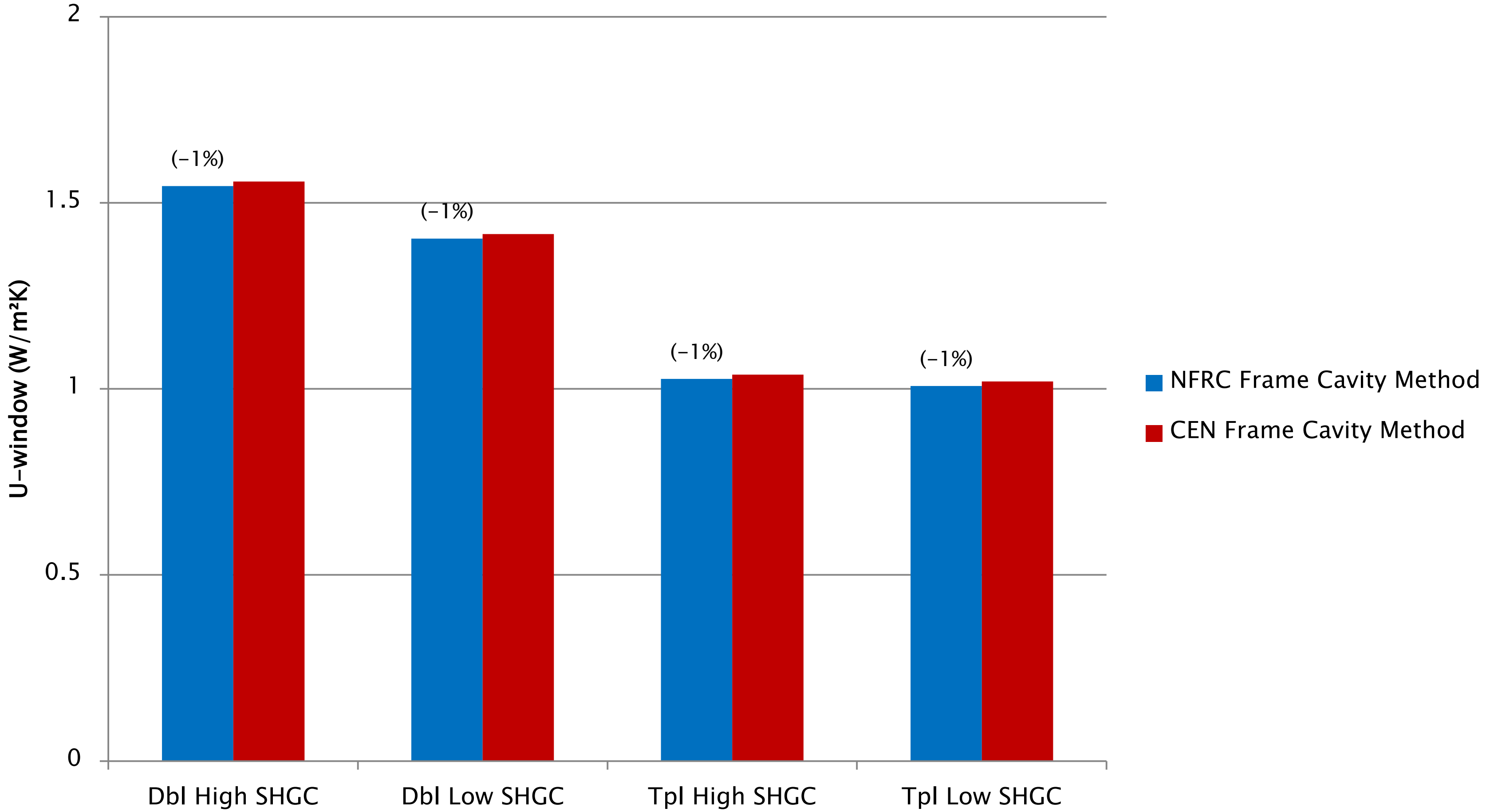


TBSW vs Solid Wood Windows





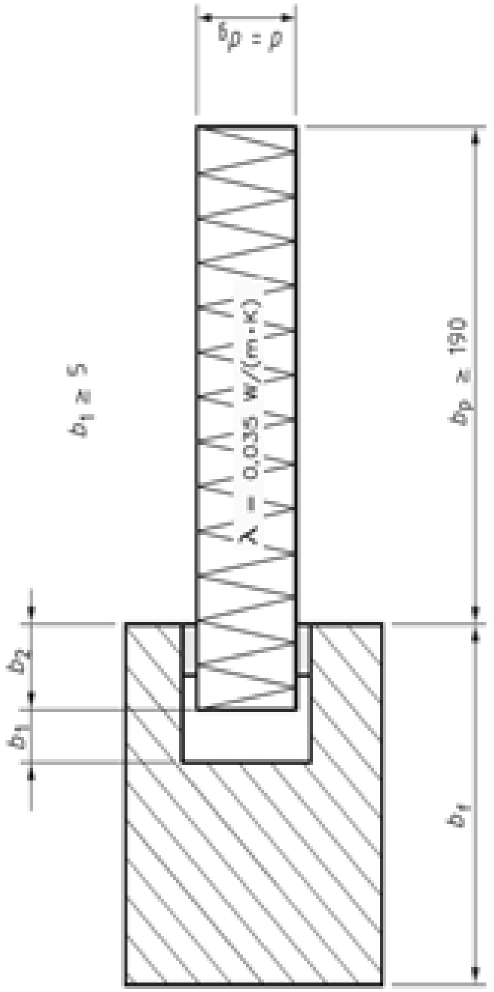
Frame Cavity Methods (Uwindow-NFRC)

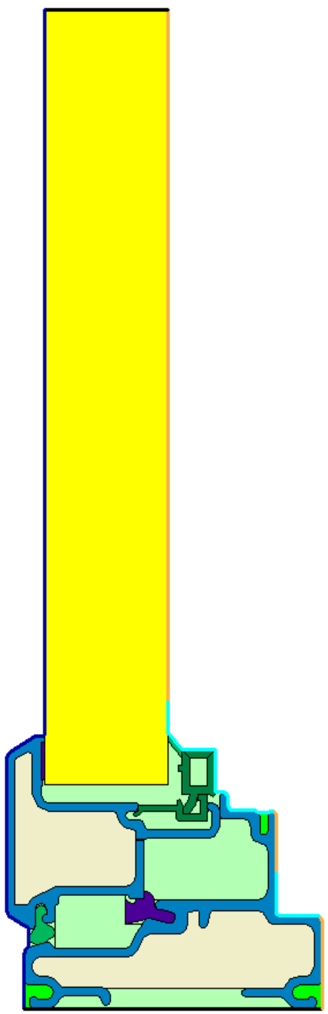


Surface Film Coefficients

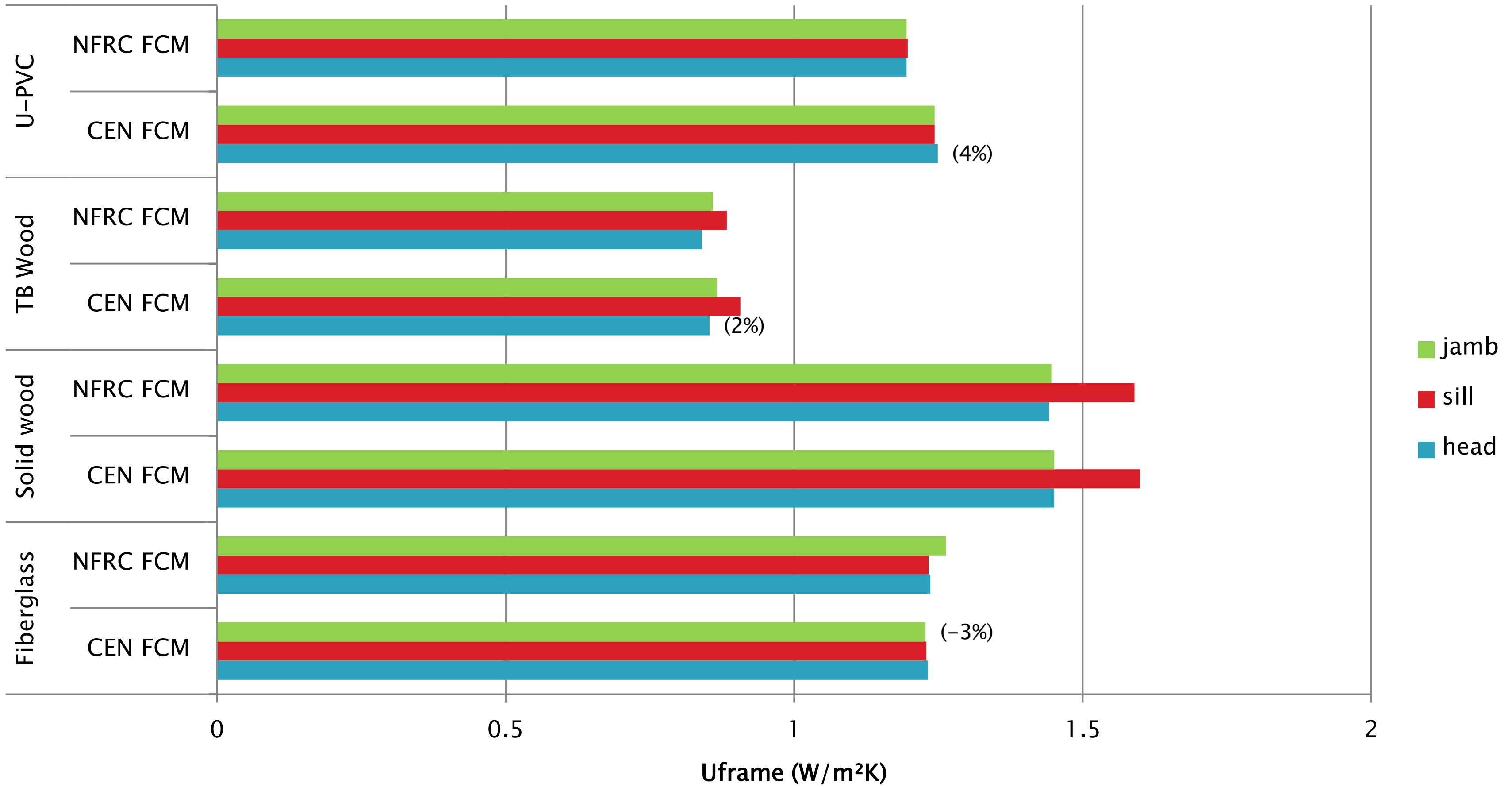
- Radiation coefficient: cannot be interchanged due to temperature dependent variable
- Convective coefficient: no significant difference
- Higher surface film coefficients contribute to higher U_{window} values
- Inland and coastal locations: no significant difference

$U_{frame-CEN}$ with Calibration Panel (ISO 10077-2)





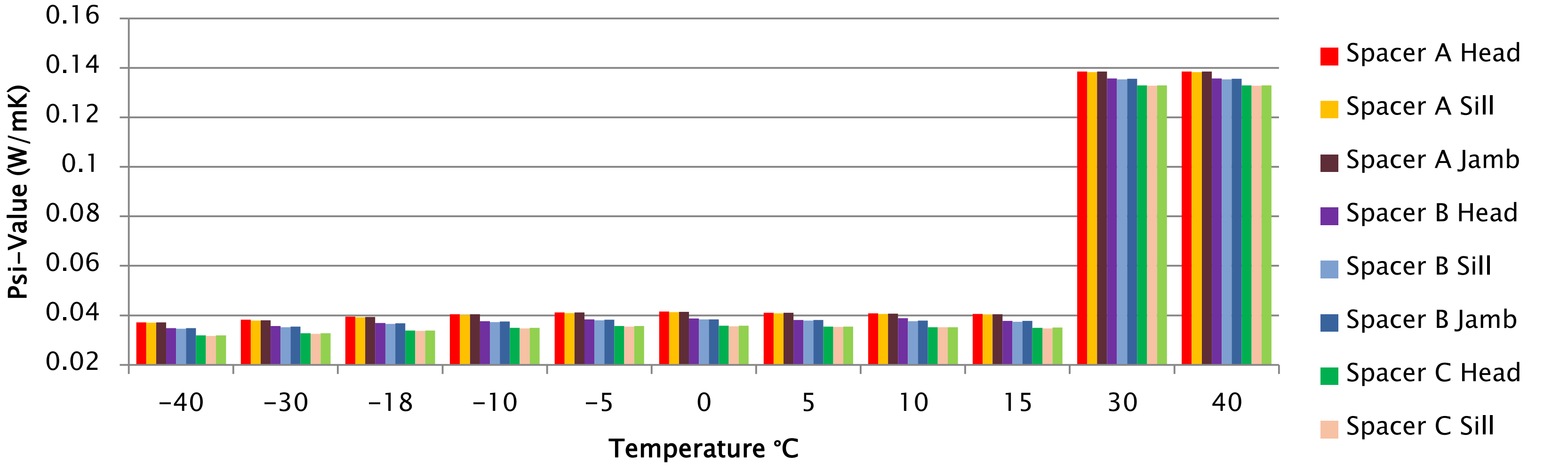
$U_{frame-CEN}$

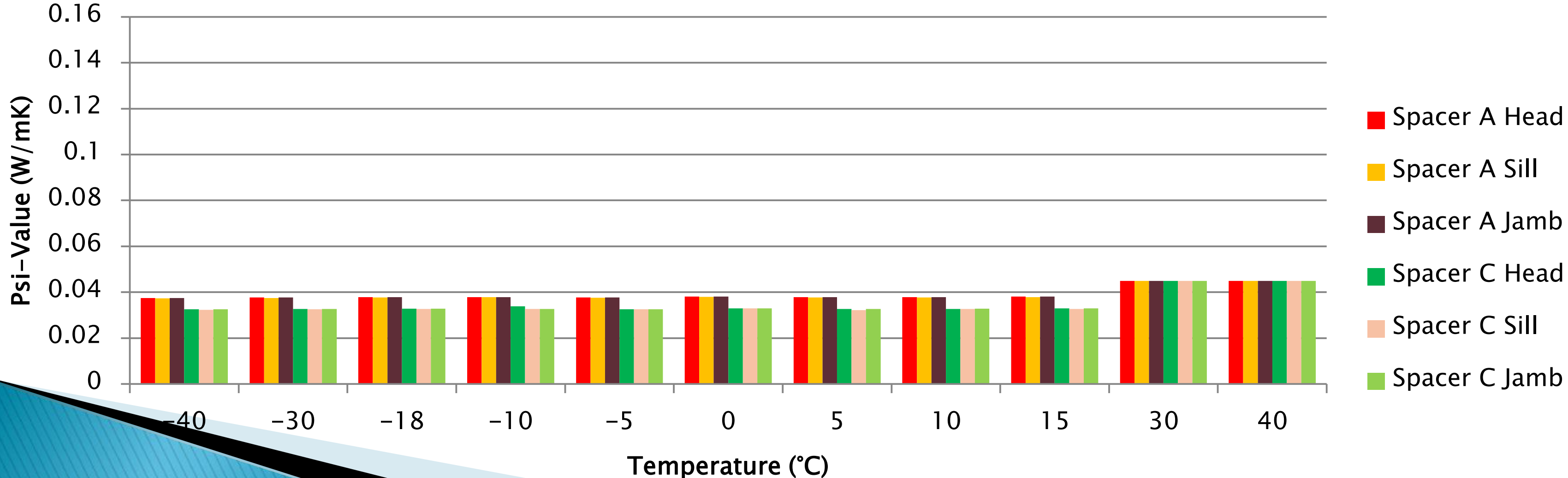


U-PVC
TB Wood
Solid wood
Fiberglass
NFRC FCM
CEN FCM
(4%)
(2%)
(-3%)
0
0.5
1
1.5
2
Uframe (W/m²K)
jamb
sill
head

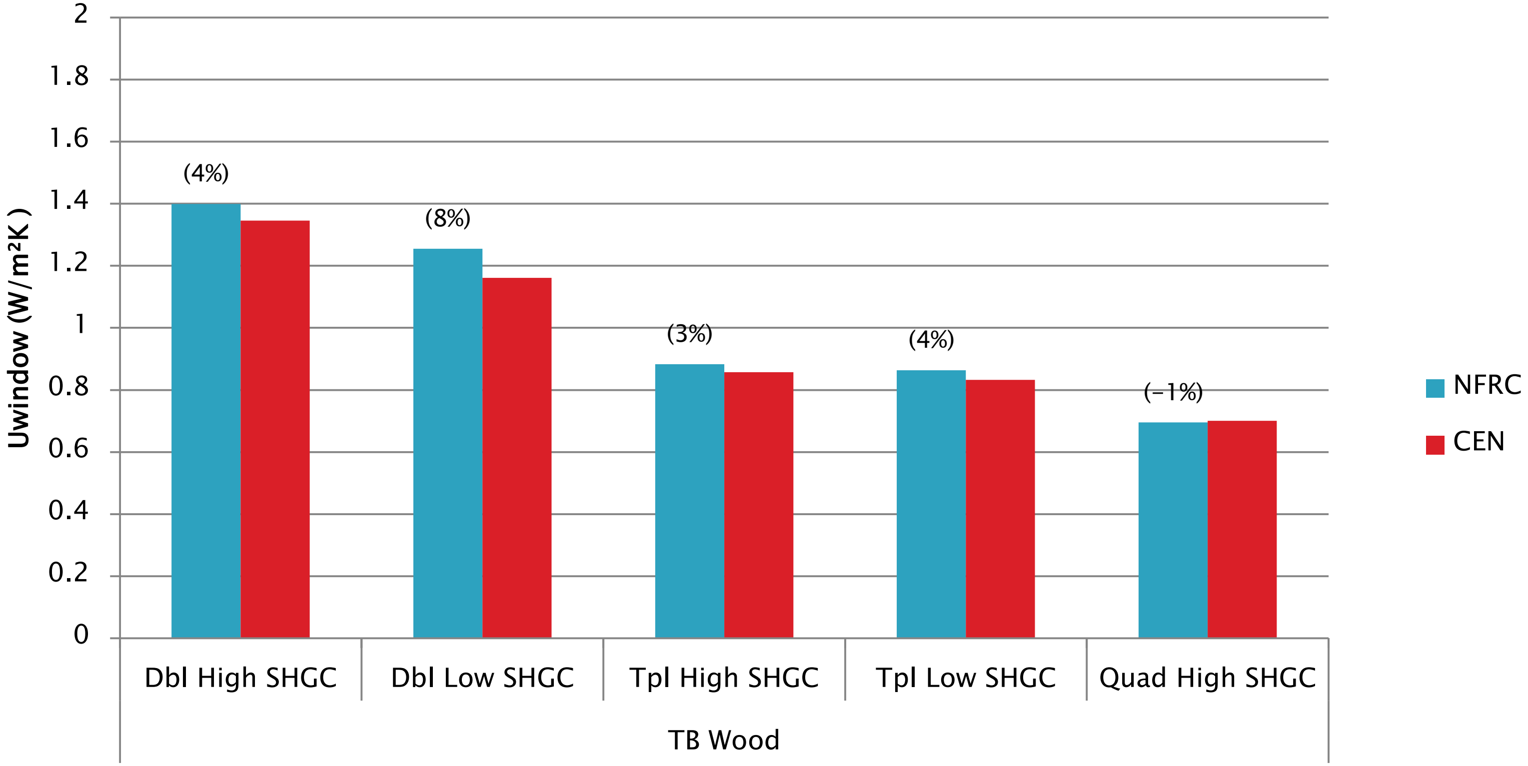
Ψ-Values

TBSW Frame: Double and Quad IGUs



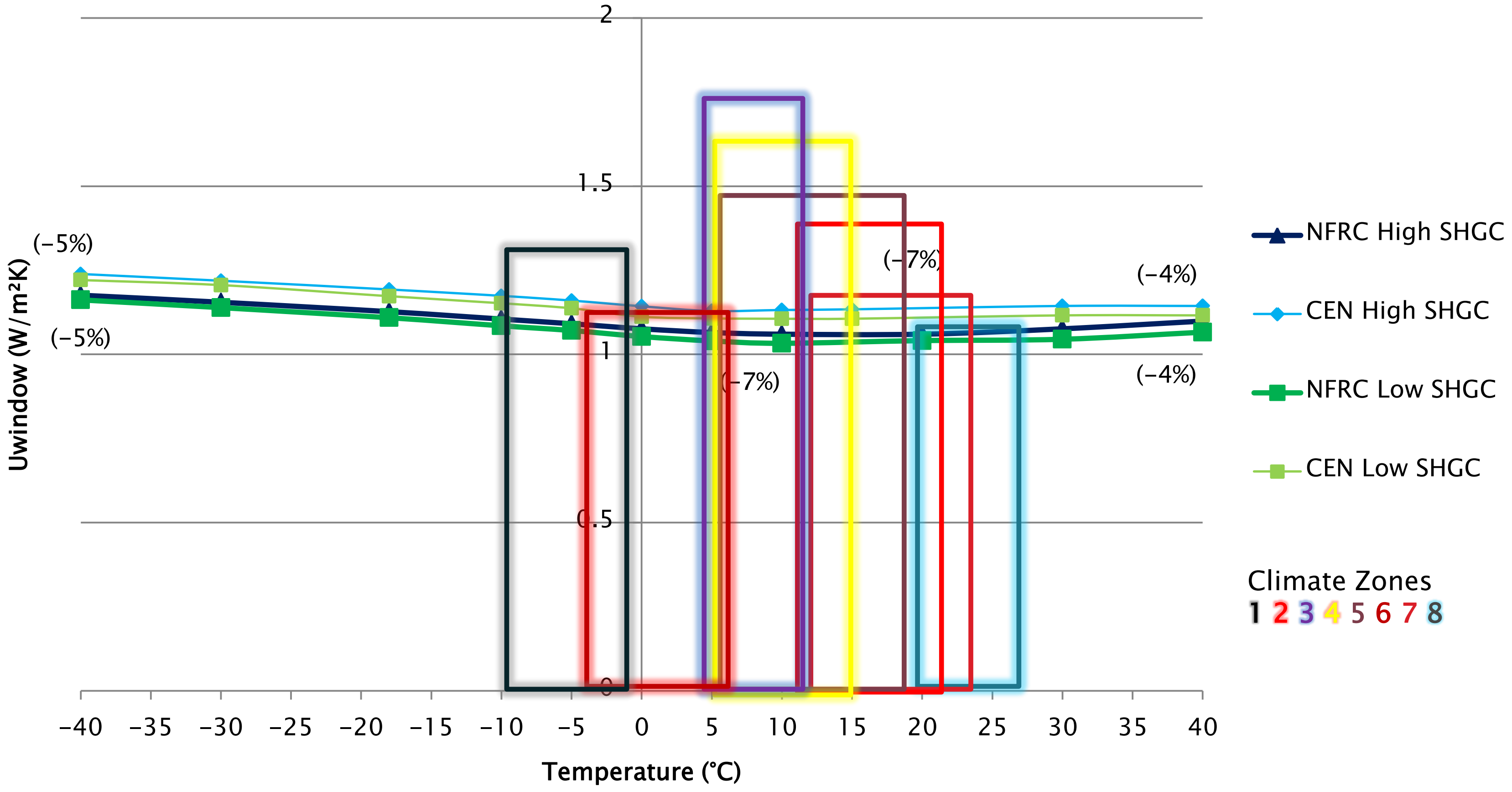


U_{window} Standard Values



TBSW Frame

U_{window} in the 8 Climate Zones



Solid Wood, Triple IGU

Harmonization of Both Methods

- Exterior temperature symmetry
- Frame cavity method
- Material thermal conductivity
- U_{frame} method

Areas that Need Improvement

- SHGC (with and without the frame)
- Ucog method
- Climate specific U-values
- Single International Calculation Method
  ($U_{W-ITN'L}$)

Questions? Comments?

(Miller, 2010)