RDH

Choosing Windows

Balancing U-Values, Solar Heat Gain, Comfort and Energy

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September 2012

RDH

Agenda

- About Window Thermal Performance
- Choosing Windows for Energy
- Choosing Windows for Thermal Comfort
- Multi-Unit Residential Buildings and Commercial/Institutional Buildings
- Conclusions

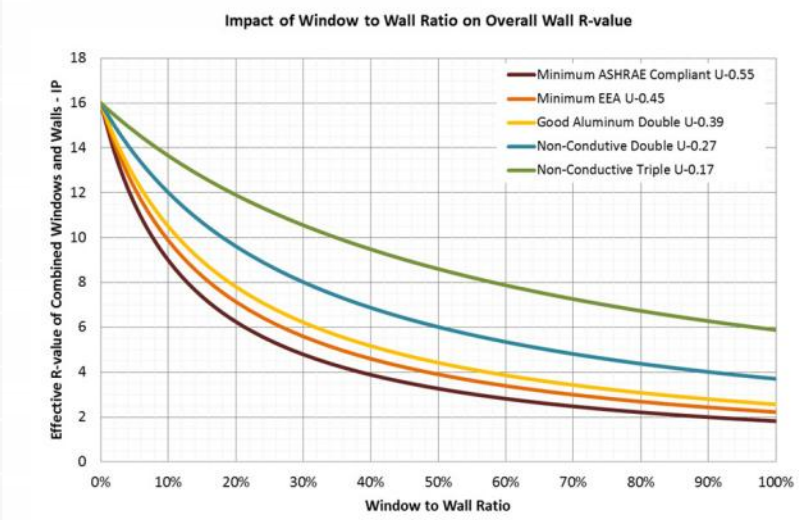
Background: Research Review of Window Energy Rating

- Canada-wide study of the Energy Rating (ER) for windows
  - Single rating for a window based on U-value, solar heat gain coefficient, and air leakage
- Research project goals: study the ER to determine how it rates windows
- **Not a report on the project** – rather, draw from research findings to present information on window selection
- Final research report to be out late fall

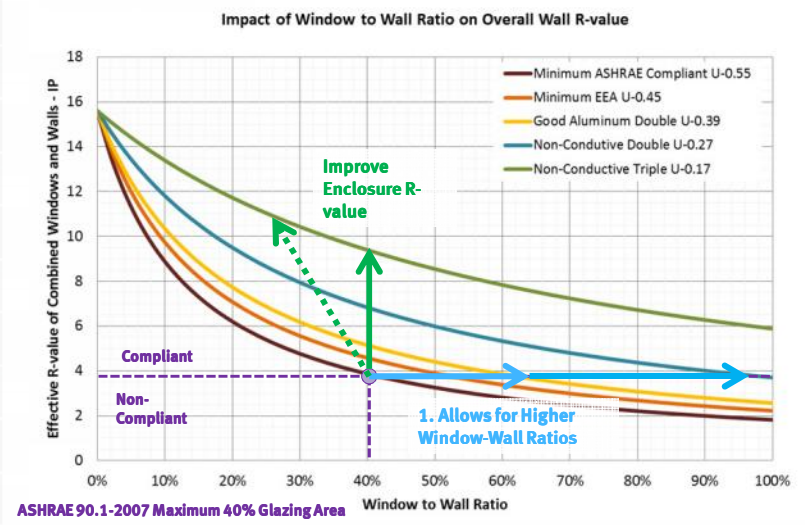
The Issues

- Windows account for significant portion of energy consumption in buildings – "weakest link"
- Windows impact heating and cooling energy
- Can have conflicting priorities
  - Cooling vs. Heating energy consumption
  - Lower energy consumption versus preventing overheating

Window to Wall Ratio Impacts



Value of High Performance Windows



Heat Flow Basics for Windows

- Conduction
  - Heat is lost or gained through window when there is a temperature difference between inside and outside
  - Measured in terms of **U-value,** Btu/hr-ft^2-F or W/m^2-K
- Solar Gain
  - Heat gained through direct or indirect solar radiation
  - Measured in terms of the Solar Heat Gain Coefficient (**SHGC**)
- Infiltration
  - Air leakage through cracks in fenestration



Window U-Values Simplified

Window U-value =

Frame U x %Frame Area

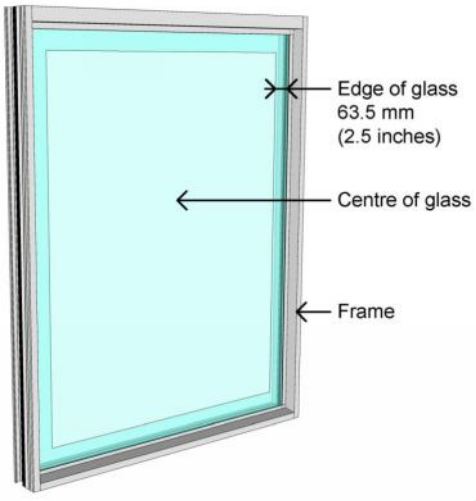
+

Center of Glass U x %Glass Area

+

Edge of Glass U x %Edge of Glass Area

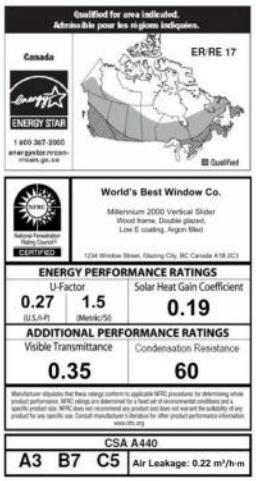
Overall R-value = 1/U-value



U-Value Requirements: BC Energy Efficiency Act

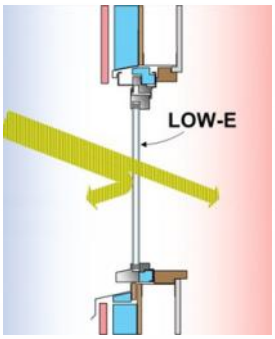
BC Energy Efficiency Act
Residential Requirements

4 Storeys or Less		5 Storeys or More	
Windows and Glazed Doors Frame Type	**Maximum U-factor** Btu/h•ft²•° F (W/m²•° K)	**Windows and Glazed Doors Frame Type**	**Maximum U-factor** Btu/h•ft²•° F (W/m²•° K)
Vinyl and Fibreglass	0.35 (2.0)		
Wood	0.35 (2.0)	Non-Metal	0.35 (2.0)
Metal	0.35 (2.0)	Metal	0.45 (2.57)
Skylights	0.55 (3.1)	**Skylights**	0.55 (3.1)
Exemptions		**Exemptions**	
•Decorative – stained glass, inserts and blinds inside the insulated glazing unit (IGU)		•Buildings compliant with ASHRAE 90.1 (2004, 2007 or 2010)	
•Products installed in designated heritage buildings and buildings included in local or provincial heritage registers		•Products installed in designated heritage buildings and buildings included in local or provincial heritage registers	
•IGU replacements in an existing sash and frame		•IGU replacements in an existing sash and frame	
•Products used in non-heated buildings		•Products used in non-heated buildings	
•Products exported from B.C.		•Products exported from B.C.	



Window Solar Heat Gain Coefficient

- Fraction of solar heat gain to the space
- 0 = totally opaque
- 1 = hole in the wall
- 0.87 = clear glass



Window Air Leakage Rates

- Air leakage ratings in CSA A440-00 and NAFS-08

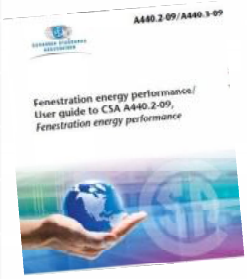
Window Rating	CSA A440-00		NAFS-08
	Max air leakage rate, $m^3/h/m$	Max air leakage rate, converted to $L/s/m^2$ (NFRC Standard Size Window)	Max air leakage rate for R Class, $L/s/m^2$
A1	2.79	1.86	n/a
A2	1.65	1.10	1.5
A3	0.55	0.37	0.5
Fixed	0.25	0.17	0.2

The ER Calculation

- Calculation given in CSA A440.2, for low-rise residential
- ER Equation:

$$ER = \frac{[SHGC_w \times F_\theta \times H_t \times R] - [(T_{bi} - T_{bo}) \times U_w] - [(T_{bi} - T_{bo}) \times (PF/20) \times L_{75} \times \rho C_p]}{DF} + SF$$

- Simplified Equation:



$$ER = (57.76 \times SHGC_w) - (21.90 \times U_w) + (1.97 \times L_{75}) + 40$$

Solar Heat Gain | Conduction | Air Leakage

$F_\theta \times H_t = 72.20\ W/m^2$

$(T_{bi} - T_{bo}) = 21.90\ K$

$PF = 1.5\ m^3/s/m^2$

U-Value Requirements: ENERGY STAR Windows

- Voluntary Program
- Two Compliance Paths: ER or U-Value

Windows

Zone	Heating Degree-Day Range	Compliance Paths: Energy Rating (ER) Minimum ER Max. U-Value 0.35 Btu/h-ft²-F (2.00 W/m²•K)	or	U-Value: Max. U-Value Btu/h-ft²-F (W/m²-K)	U-Value: Minimum ER
A	<= 3500	21	or	0.32 (1.80)	13
B	> 3500 to <= 5500	25	or	0.28 (1.60)	17
C	> 5500 to <= 8000	29	or	0.25 (1.40)	21
D	> 8000	34	or	0.21 (1.20)	25

2012 National Building Code Proposed Changes

- Includes U-Value OR ER path

	Zone 4	Zone 5	Zone 6	Zone 7a	Zone 7b	Zone 8
HDD	<3000	3000 to 3999	4000 to 4999	5000 to 5999	6000 to 6999	≥7000
Max U-Value, Btu/h-ft²-F (W/m²-K)	0.32 (1.8)	0.32 (1.8)	0.28 (1.6)	0.28 (1.6)	0.25 (1.4)	0.25 (1.4)
Minimum ER	21	21	25	25	29	29

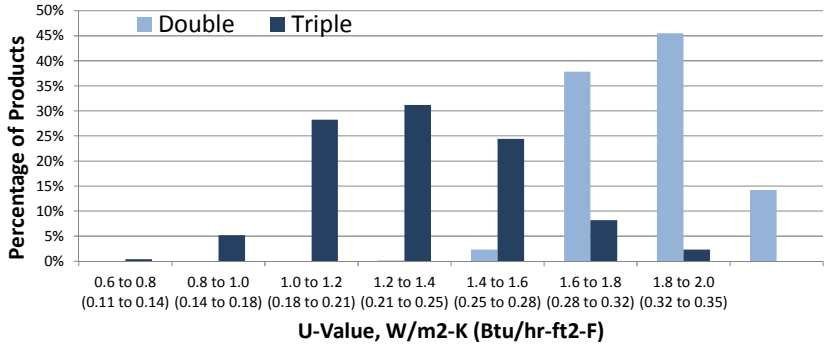
- Similar to ENERGY STAR:

Zone A <3500 Zone B <5500 Zone C <8000

Additional Zone D >8000

Window Products Available in Canada

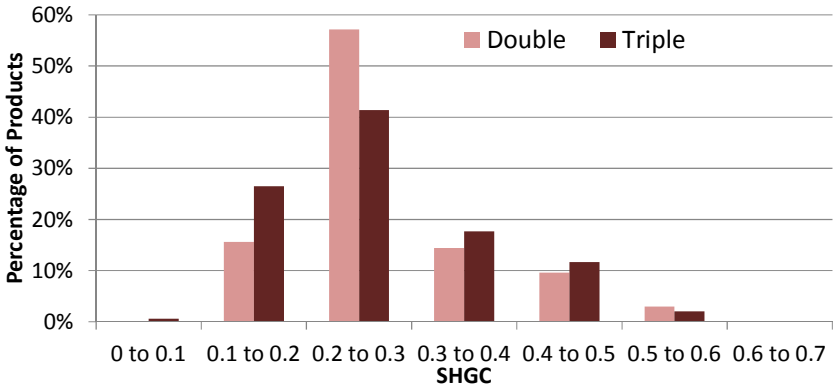
- Residential Windows in the ENERGY STAR database
- Distribution of U-Values



Averages: Double = U-0.29 (U_{SI}-1.65); Triple = U-0.23 (U_{SI}-1.32)

Window Products Available in Canada

- Residential Windows in the ENERGY STAR database
- Distribution of SHGC values



Average SHGCs: Double = 0.27; Triple = 0.27

Choosing Windows for Single Family Houses

Characteristics:

- Relatively low Window to Wall Ratios
  - Average = 18% WWR
  - Upper range (90th percentile) = 25%
  - Lower range = 7%
- Wood frame enclosure assemblies
  - 2x4 or 2x6 with batt insulation
  - Typically R10 to R16
- Typically vinyl or wood frame windows
  - Lower U-values are more easily achievable

Window Selection for Energy and Thermal Comfort

Winter Goals:

- Minimize heating energy
- Improve thermal comfort by reducing cold surfaces

Winter Window Selection Strategies:

- Low U-Value: Minimize heat loss
- High SHGC: Maximize solar heat gain

Window Selection for Energy and Thermal Comfort

Summer Goals:

- Minimize cooling energy
- Improve thermal comfort (prevent overheating)

Summer Window Selection Strategies:

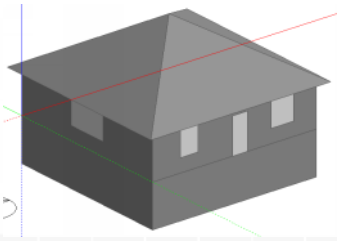
- U-Value not as important
- Low SHGC: Minimize solar heat gain

Conclusion:

- Low U-value is always good
- Higher SHGC in winter and lower SHGC in summer?

Whole Building Energy Simulations

- Hourly energy simulations performed using the program DesignBuilder (EnergyPlus engine)
- Several archetype houses – sizes, enclosures, etc.
- Climates across Canada – Vancouver presented here but trends in other cities are similar
- Various window types - investigate different combinations of U-values and SHGCs



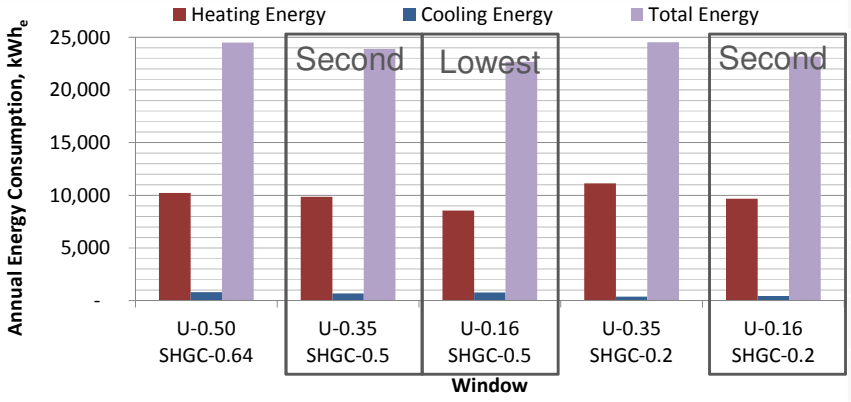
Typical Windows

- Actual study looked at 23 different windows
- Will focus on results for 5:

Representative Window	U-Value [Btu/hr-ft²-F]	SHGC
ASHRAE 90.1 Compliant, Aluminum Frame	0.50	0.64
High U-Value / High SHGC	0.35	0.50
Low U-Value / High SHGC	0.16	0.50
High U-Value / Low SHGC	0.35	0.20
Low U-Value / Low SHGC	0.16	0.20

Window Selection for Energy

- Heating, cooling and total energy in Vancouver
  - Cooling energy low relative to heating and total energy
  - Generally lower U-value & higher SHGC result in lower energy

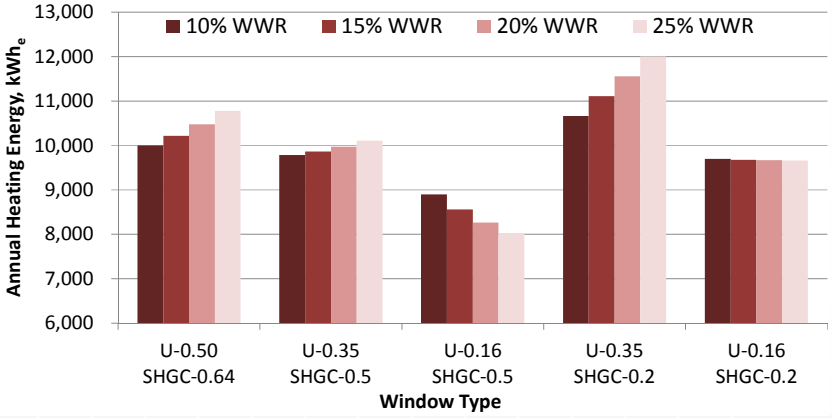


Window Selection for Energy

- Cooling energy for most houses in British Columbia and across Canada is much lower than heating energy
- When looking at annual energy consumption heating dominates, even in warmer climates like Kelowna and Toronto
- Whether or not a house has cooling, based on this, would select windows with a:
  - Low U-value
  - High SHGC

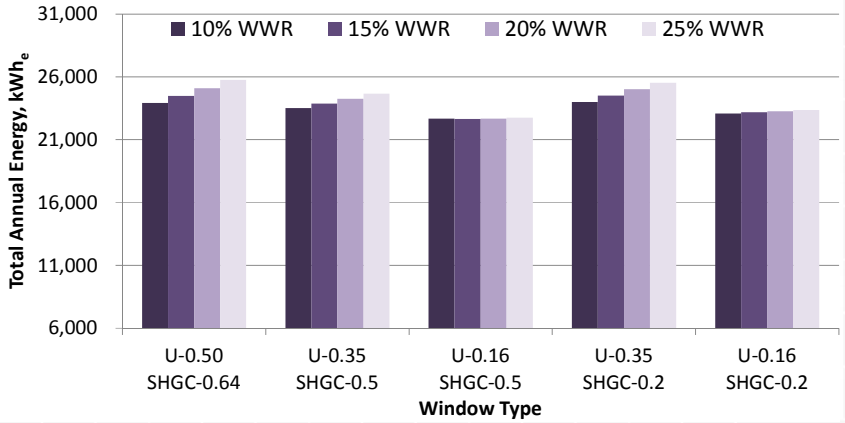
Window Selection for Energy: Higher WWRs

- Heating Energy
  - High U-Value: Energy increases for higher WWRs
  - Low U-Value, high SHGC: Energy decreases for higher WWRs



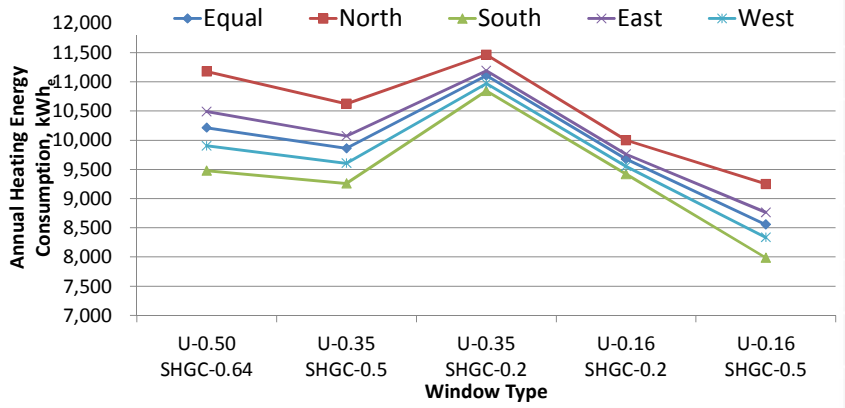
Window Selection for Energy: Higher WWRs

- Total Energy
  - Energy increases for higher WWRs in all cases due to greater impact of cooling energy at higher WWRs



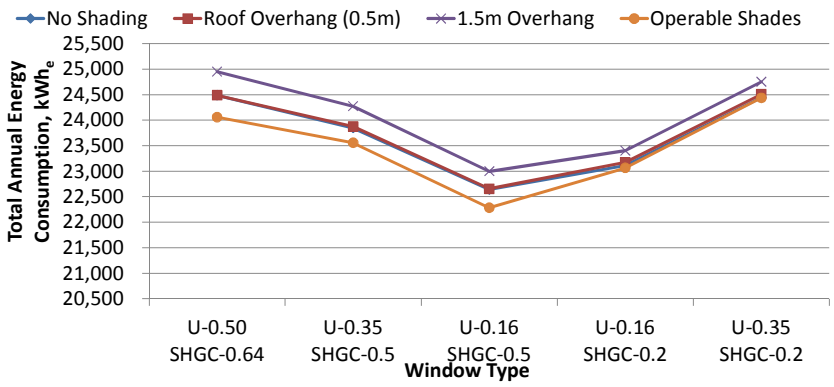
Window Selection for Energy: Orientation

- Heating Energy
  - High SHGC has less savings for North-facing windows



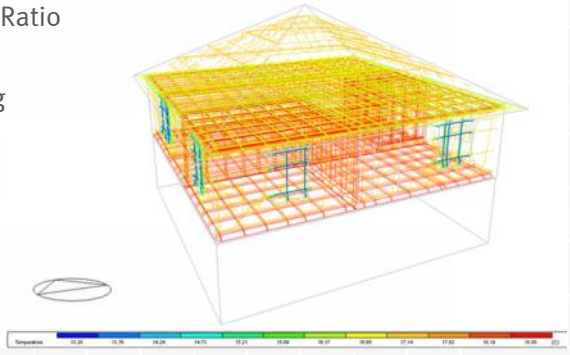
Window Selection for Energy: Exterior Shading

- Total Energy
  - High SHGC best for windows that are well-shaded in the summer



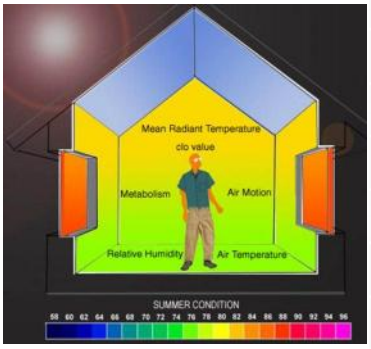
Window Selection for Energy

- Low U-value & high SHGC result in lowest energy consumption in most typical houses
  - Cooling is low relative to heating and total energy
- Important to consider the following factors
  - Window to Wall Ratio
  - Orientation
  - Exterior Shading



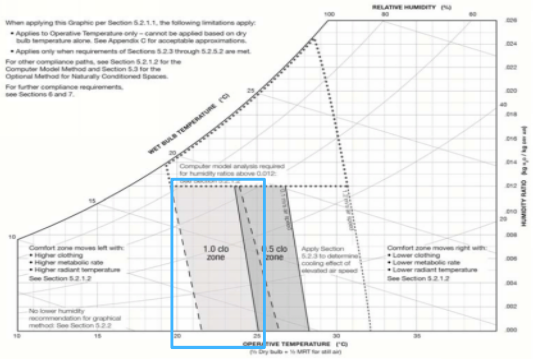
Window Selection for Thermal Comfort

- How to "measure" thermal comfort?
- *ASHRAE Standard 55: Thermal Comfort Conditions for Human Occupancy*
- 6 Primary factors that affect thermal comfort:
  - Air temperature
  - Radiant Surface Temperature
  - Humidity
  - Air Speed
  - Metabolic Rate
  - Clothing Insulation



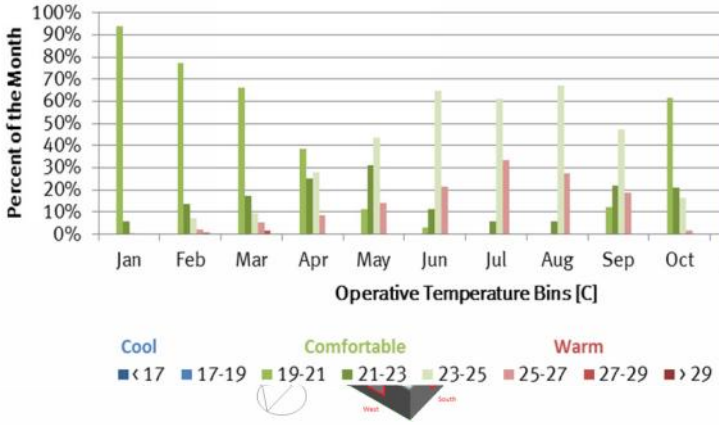
Window Selection for Thermal Comfort

- Operative Temperature: Balance of surface temperature and air temperature
- ASHRAE acceptable range of operative temperature based on research studies



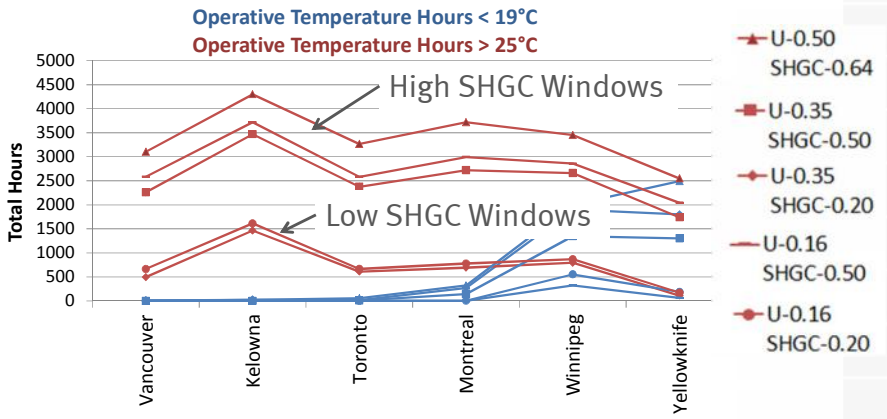
Window Selection for Thermal Comfort

- Hourly Energy Simulations – extract window surface temperature, air temperature, operative temperature



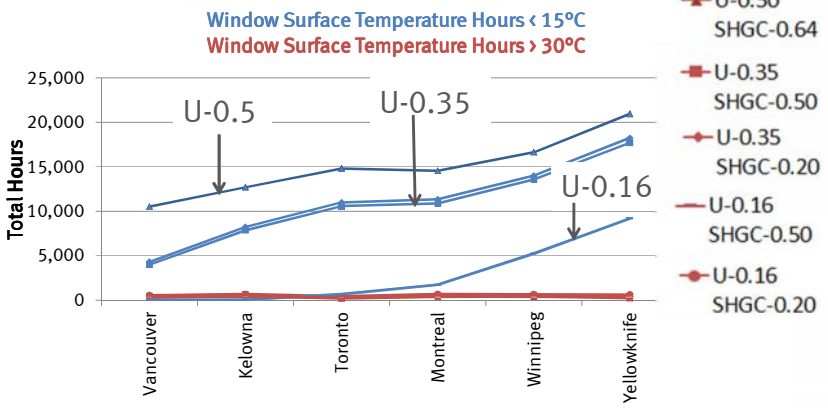
Operative Temperature: Too Cold and Too Warm

- "Warm" hours more significant
- SHGC important for overheating



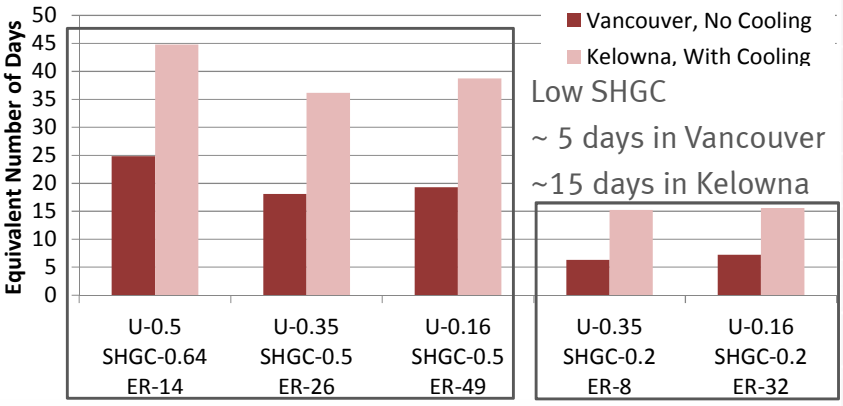
Surface Temperature: Too Cold and Too Warm

- "Cold" hours more significant
- U-value important for surface temperature



Overheating: Equivalent Number of Days

- Number of "warm hours" (›25°C) divided by 24
- Gives an idea of the impact of overheating

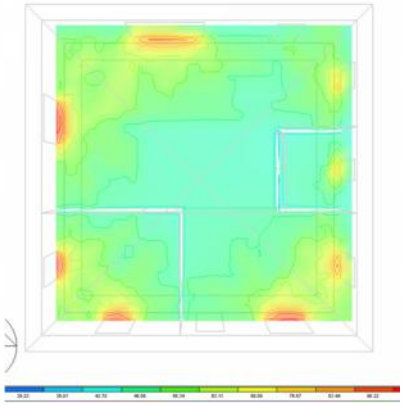


Low SHGC
~ 5 days in Vancouver
~15 days in Kelowna

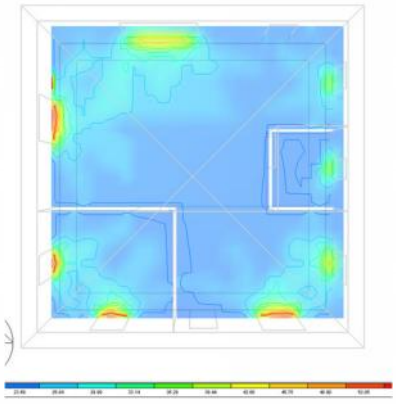
Computational Fluid Dynamics (CFD): Winter Conditions

- Percent People Dissatisfied (PPD) distribution in house
- Windows U-0.5, SHGC-0.64

Yellowknife



Vancouver



Choosing Windows for Thermal Comfort

- Low U-value improves surface temperature, particularly in the winter
- Low SHGC reduces overheating
  - Consider whether overheating is a concern
- Also consider project-specific conditions
  - Exterior shading
  - Orientation
  - Window to Wall Ratio

Overall Window Selection for Houses

- Always look for the lowest possible U-value
  - Double glazed, low conductivity frames generally in the range of U-0.27 to U-0.35
  - Triple glazed, low conductivity frames generally in the range of U-0.17 to U-0.22 or higher
- Wide range of glazing available means large selection of low/high SHGC products with good U-values
- Evaluate an appropriate SHGC based on project specific conditions
  - If overheating is not a concern, use a high SHGC window (e.g. if there is good exterior shading)
  - If overheating may be a concern, consider a low SHGC window

How Can the ER Help?

- Provides a single number to compare different windows
- Generally a higher ER results in lower energy consumption in Canada
- But, if overheating is a concern, look at U-value and SHGC separately
  - High ER windows may have a high SHGC, and therefore may be more susceptible to overheating
- Intended for houses only

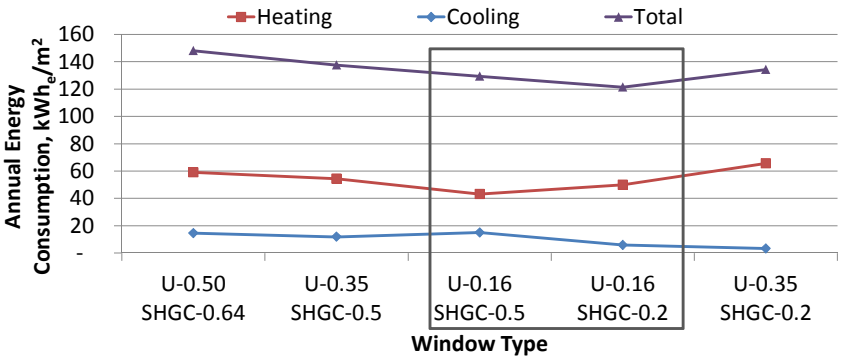
Choosing Windows for Multi-Unit Residential Buildings

Characteristics:

- Higher Window to Wall Ratios
  - Upwards of 90% can exist
  - Curtain wall, window wall most common
- Typically aluminum frames in high-rise, vinyl or wood frame windows in low-rise
- Higher density means more internal gains, less space heating needs
- But, also less insulated enclosures
- Often do not have air conditioning in BC

Window Selection for MURBs

- Heating, cooling and total energy for a 20-storey MURB in Vancouver, 60% WWR
  - Cooling energy is much more significant



Window Selection for MURBs

- With higher WWRs, solar heat gain becomes much more significant
- If the building has air conditioning, cooling energy becomes significant
- Whether the building has air conditioning or not, thermal comfort may be a concern
- Low SHGC may be preferable if the building has a high WWR and no exterior shading
- Check the model – even if energy savings suggests a high SHGC is best, consider whether overheating may occur

Windows for Commercial, Institutional and Other Buildings

- Best design depends on many building-specific factors
  - E.g. Office buildings typically have higher cooling needs due to heat from office equipment, therefore low SHGC windows may be preferable
- Should be simulated in most cases to meet ASHRAE 90.1
- But consider comfort
  - E.g. if simulation suggests high SHGC is best, consider thermal comfort implications

Windows for Commercial, Institutional and Other Buildings

- Many other factors to consider in these buildings
  - Visible light transmittance and Glare
  - Colour of glass and aesthetics
  - UV transmittance

Photo: Building Science Consulting, www.buildingscience.com

Conclusions

- Important to consider both energy and thermal comfort when selecting windows
- Low U-value is always good
- For SHGC, consider building-specific conditions:
  - Window to wall ratio: how high?
  - Window orientation: South and West have greatest chance of overheating, also East
  - Exterior shading: less chance of overheating if well shaded in summer
  - Location – Worse in hotter climates but still an issue in mild climates like Vancouver
- MURBs, commercial and institutional buildings tend to have higher WWRs – cooling energy and thermal comfort become more significant

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Questions?

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