Selecting the Right Glass for Solar Shading

Keeping cool in summer, warm in winter, comfortable all the time,... and saving energy too

Back to Basics: Specifying the Right Windows for Your Job
ASHRAE Seminar
Sunday, June 27 10:15 a.m. to 12:15 p.m.

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Background

- **I teach a half-day short course on Energy Smart Windows for residences**
- **Short Course Outline:**
  - **Fundamentals of heat transfer**
  - **Dealing with the sun – orientation and shading**
  - **Solar spectrum fundamentals –**
  - **Spectral selectivity for hot and cold climates**
  - **Intro to daylighting & glare**
  - **Interior, exterior, and glazing shading options**
  - **Hourly energy performance**
  - **Web sites for energy ratings and hourly performance estimation**
  - **Advice on selecting the right windows for your residence**
- **This presentation:**
  - **Material I present dealing with glazing systems**
  - **Emphasis is on reducing solar heat gain**
  - **while admitting adequate daylight illumination**

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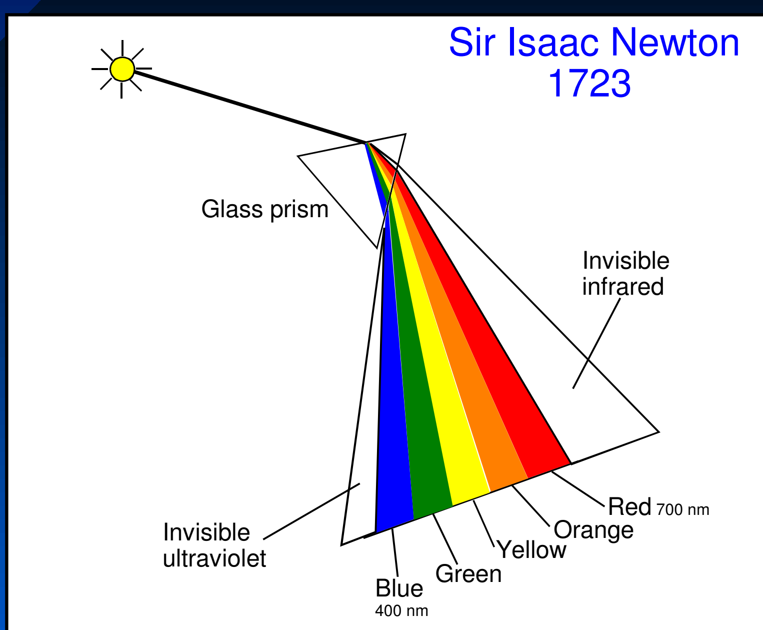
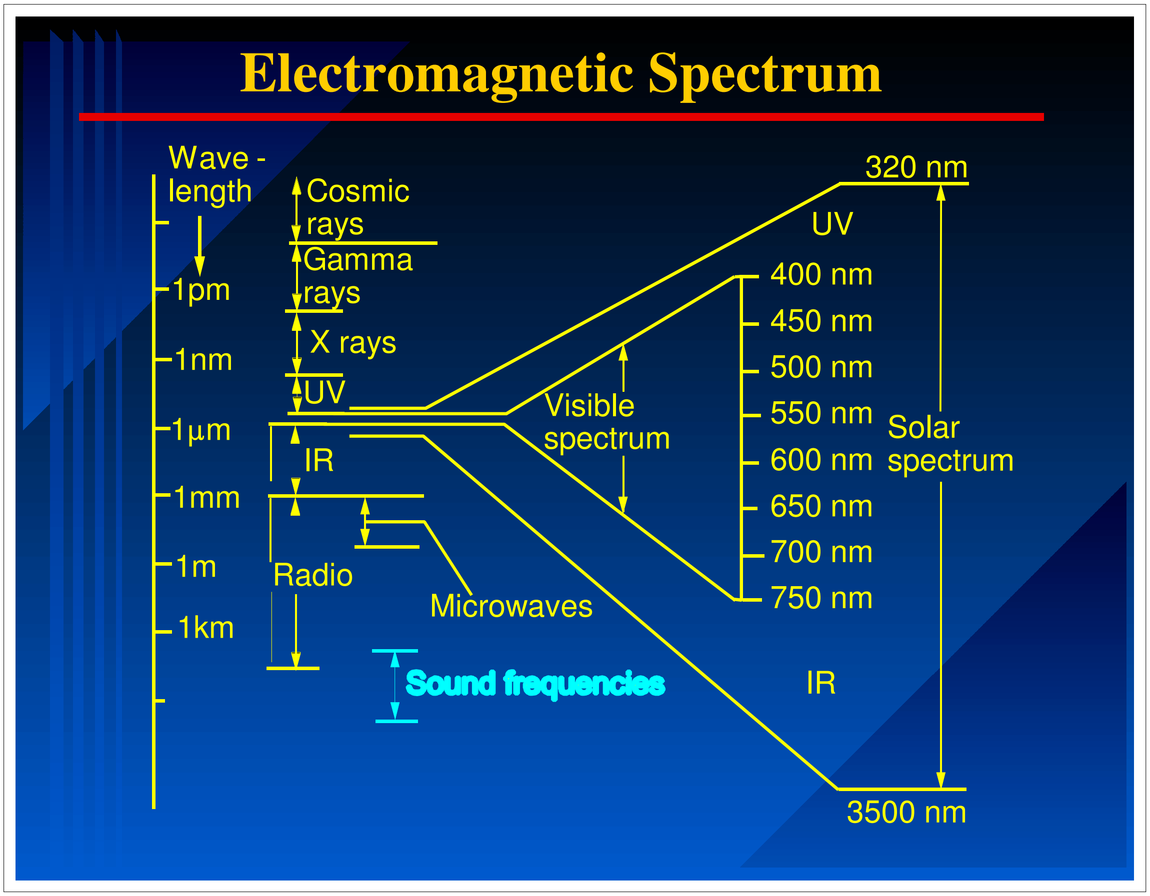
Solar Spectrum Fundamentals

- Solar radiation covers a range of colors and wavelengths
- Important for the design and performance of windows in different climates.
- Solar radiation physics
- Needed to fully understand the variety of window products now on the market.
- We begin with the electromagnetic spectrum.

Breaking sunlight into its various colors




Electromagnetic Spectrum
Wave - length
1pm
1nm
1µm
1mm
1m
1km
Cosmic rays
Gamma rays
X rays
UV
IR
Radio
Microwaves
Sound frequencies
Visible spectrum
320 nm
UV
400 nm
450 nm
500 nm
550 nm
600 nm
650 nm
700 nm
750 nm
Solar spectrum
IR
3500 nm

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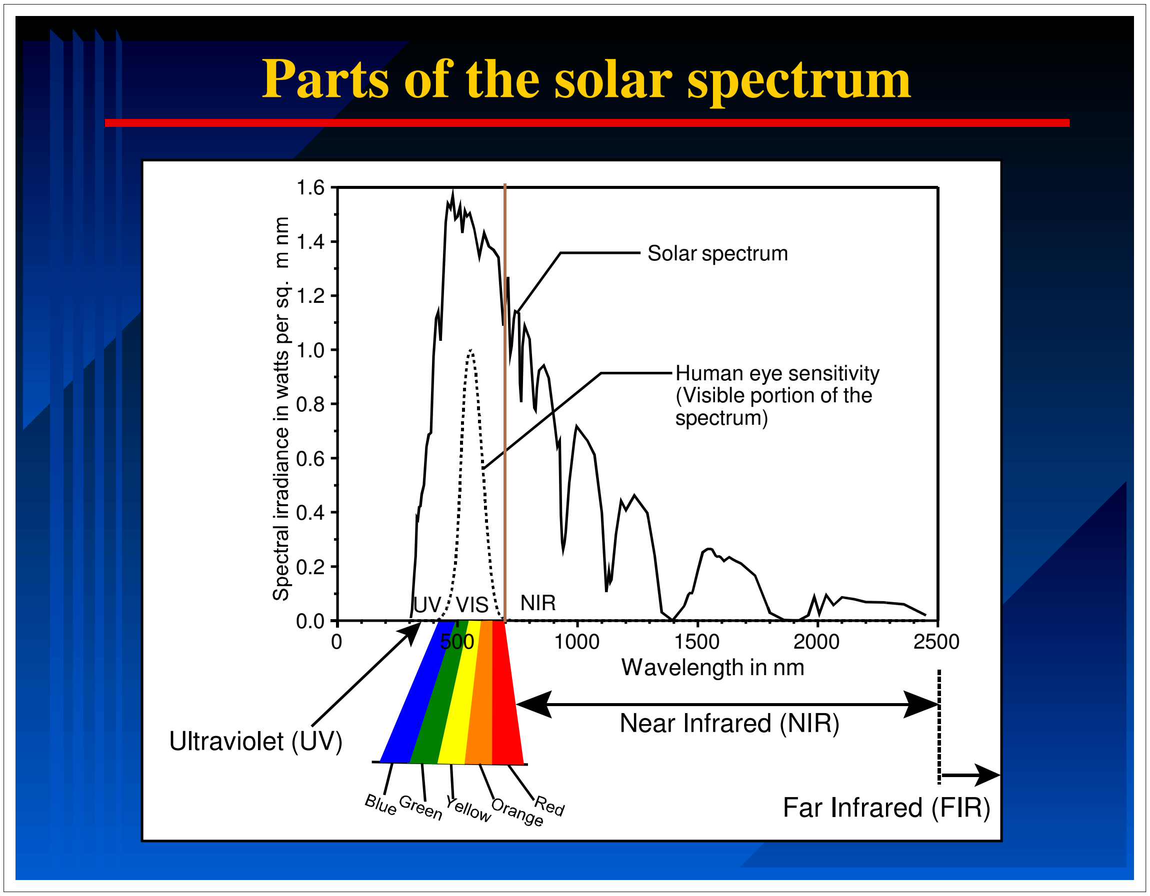
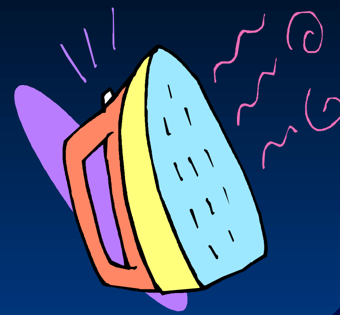
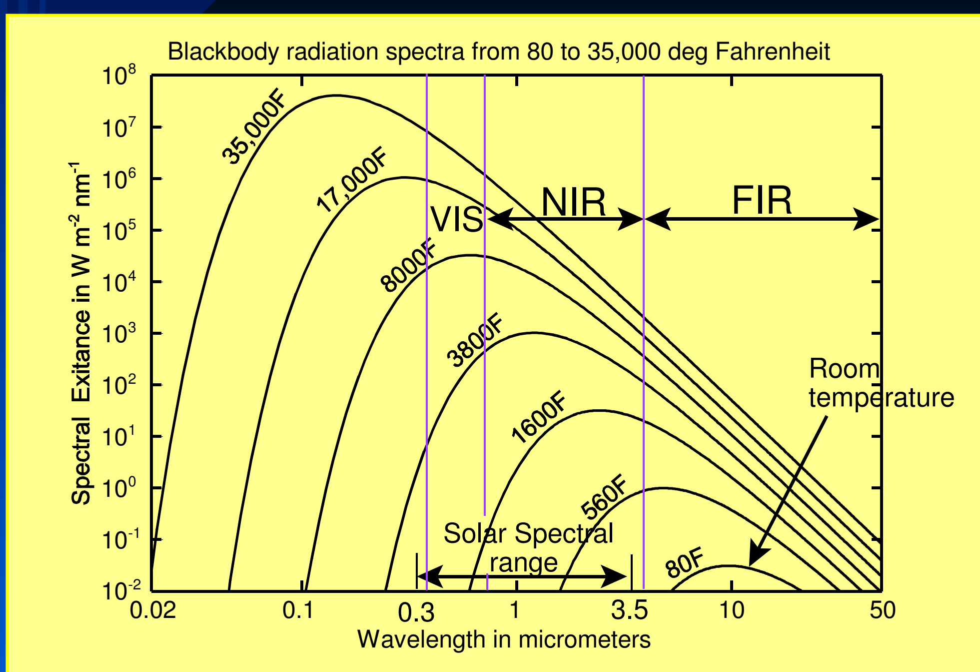

Parts of the solar spectrum
Spectral irradiance in watts per sq. m nm
Solar spectrum
Human eye sensitivity (Visible portion of the spectrum)
UV
VIS
NIR
Wavelength in nm
Ultraviolet (UV)
Near Infrared (NIR)
Far Infrared (FIR)
Blue
Green
Yellow
Orange
Red

Emission of Heat Radiation

- Warm objects emit radiation
- The hotter they are, the more they emit
- As their temperature increases, the spectral distribution shifts as well, as shown on the next slide

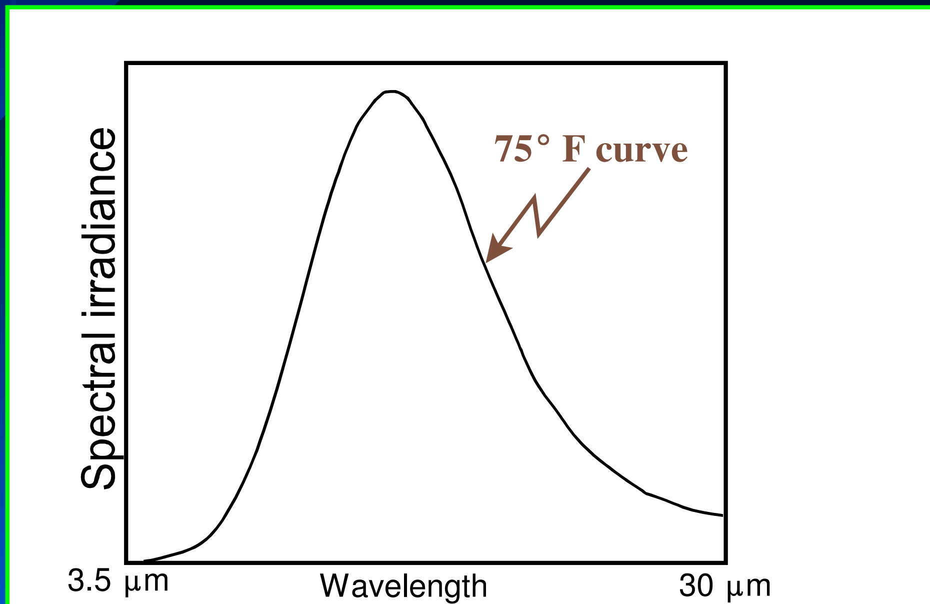


Warm Objects Emit Radiation

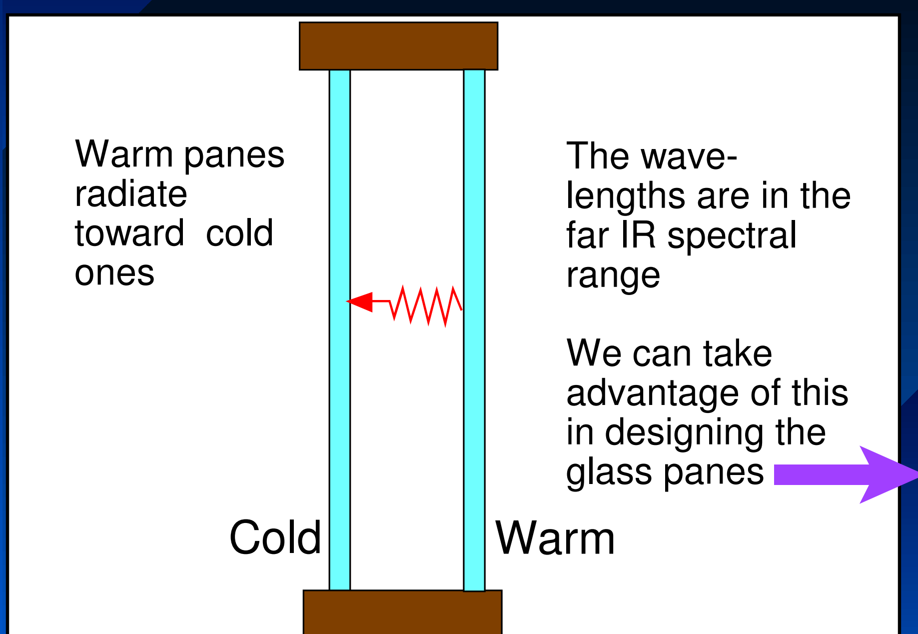


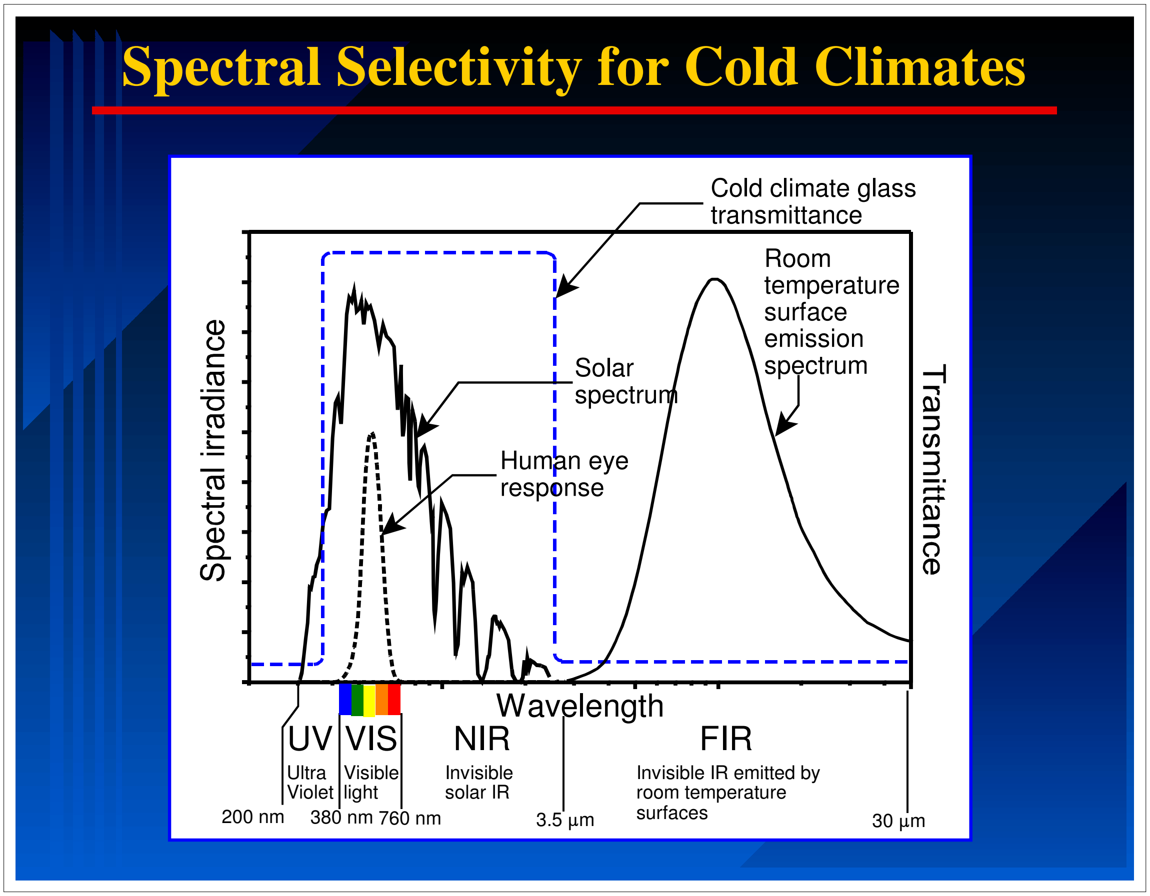
Blackbody Radiation

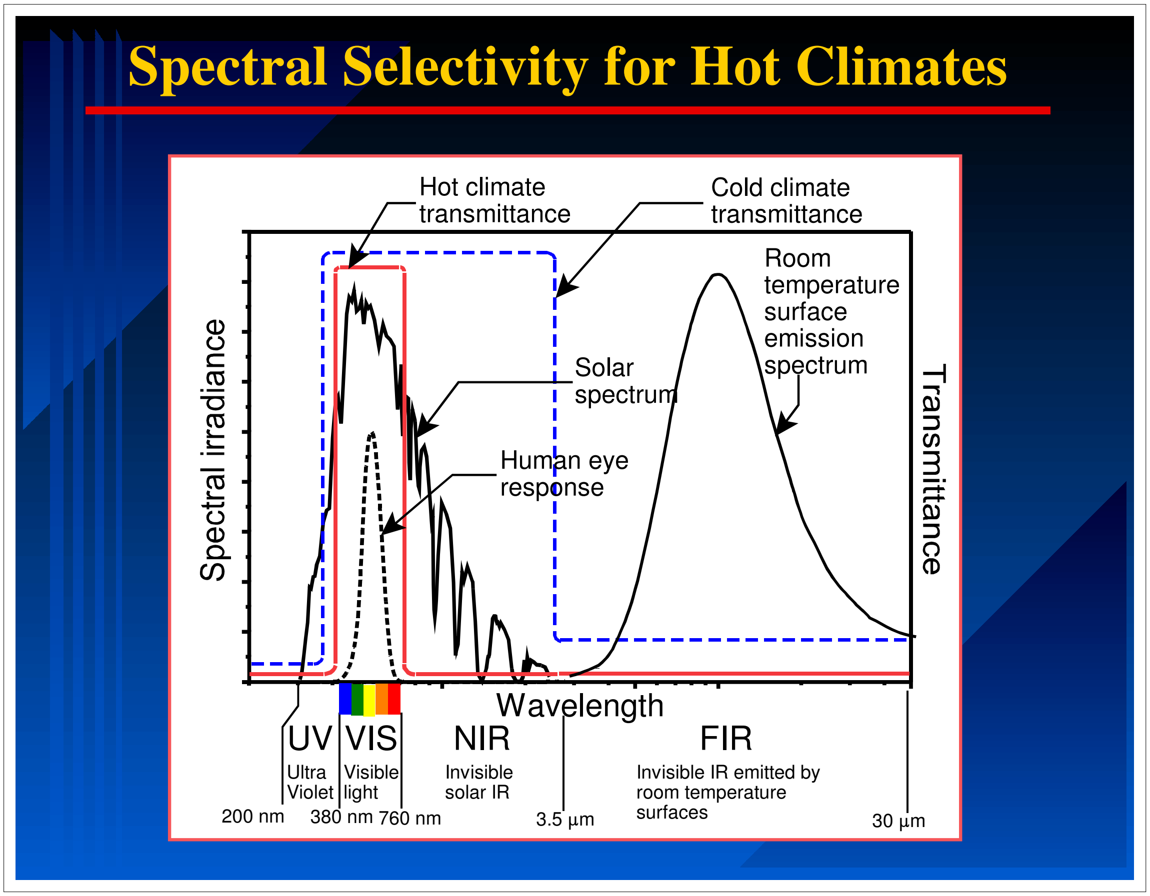
Previous slide was on a log scale. This is on a linear one.



Why black body radiation is important




Spectral Selectivity for Cold Climates
Cold climate glass transmittance
Room temperature surface emission spectrum
Solar spectrum
Human eye response
Spectral irradiance
Transmittance
Wavelength
UV
Ultra Violet
VIS
Visible light
NIR
Invisible solar IR
FIR
Invisible IR emitted by room temperature surfaces
200 nm
380 nm 760 nm
3.5 µm
30 µm


Spectral Selectivity for Hot Climates
Hot climate transmittance
Cold climate transmittance
Room temperature surface emission spectrum
Solar spectrum
Human eye response
Spectral irradiance
Transmittance
Wavelength
UV
Ultra Violet
VIS
Visible light
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200 nm
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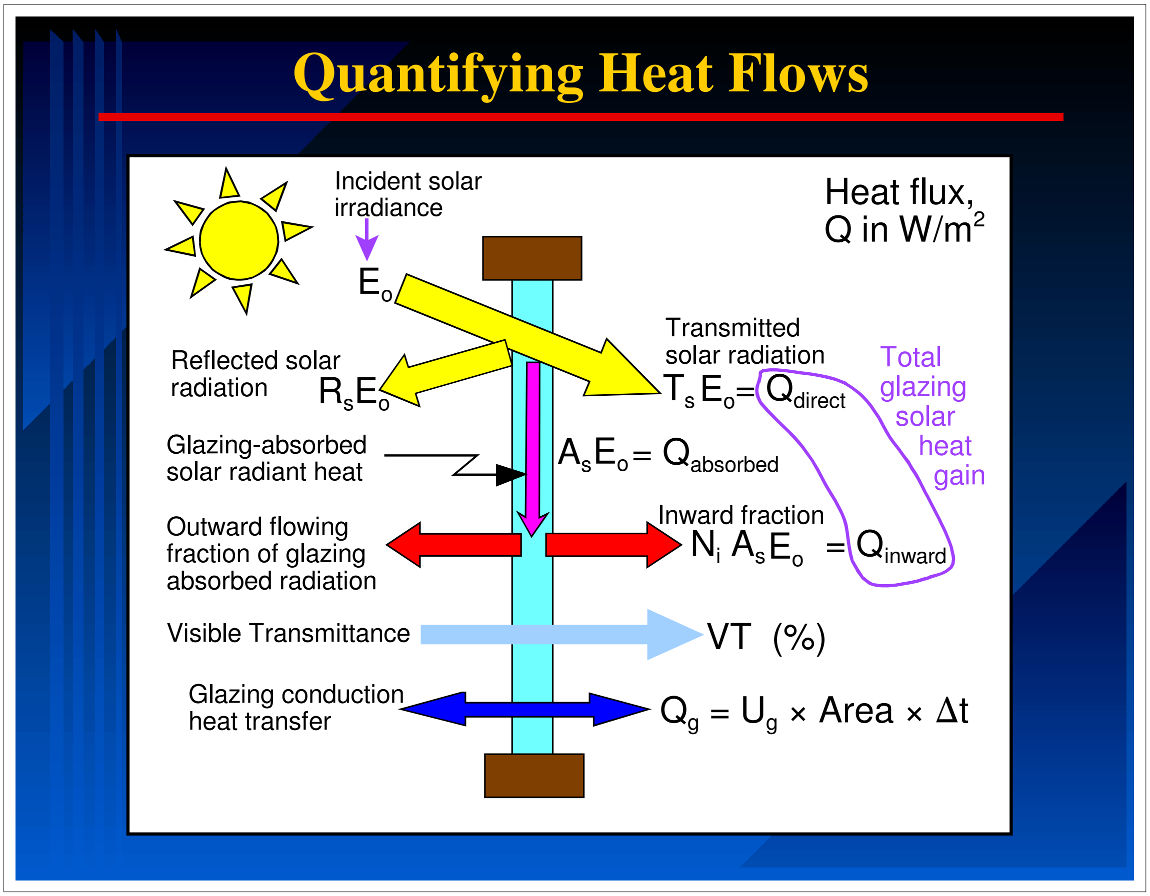
Quantifying Heat Flows
Incident solar irradiance
Heat flux, Q in W/m²
E_o
Transmitted solar radiation
$T_s E_o = Q_{direct}$
Total glazing solar heat gain
Reflected solar radiation
$R_s E_o$
Glazing-absorbed solar radiant heat
$A_s E_o = Q_{absorbed}$
Outward flowing fraction of glazing absorbed radiation
Inward fraction
$N_i A_s E_o = Q_{inward}$
Visible Transmittance
VT (%)
Glazing conduction heat transfer
$Q_g = U_g \times Area \times \Delta t$

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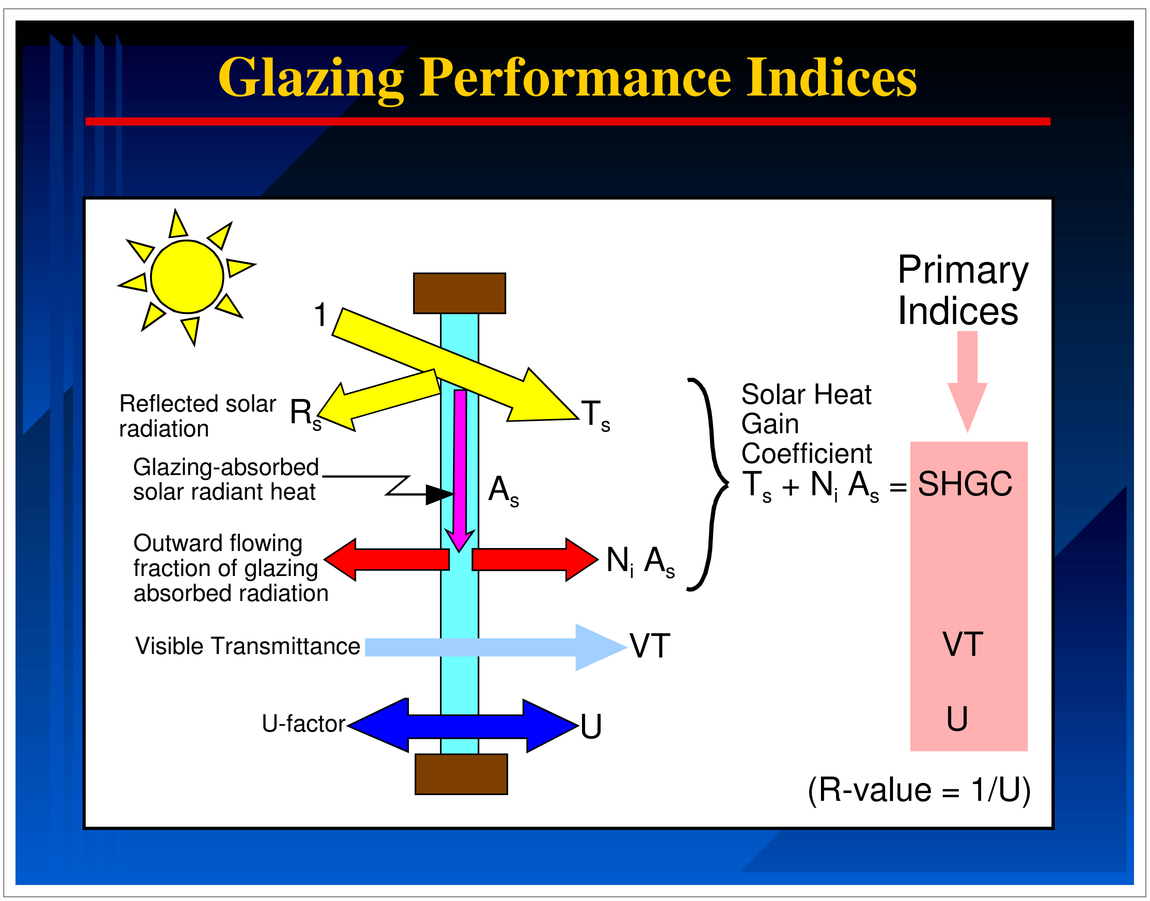
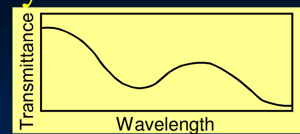

Glazing Performance Indices
Primary Indices
1
Reflected solar radiation
R_s
T_s
Glazing-absorbed solar radiant heat
A_s
Solar Heat Gain Coefficient
$T_s + N_i A_s =$ SHGC
Outward flowing fraction of glazing absorbed radiation
$N_i A_s$
Visible Transmittance
VT
VT
U-factor
U
U
(R-value = 1/U)

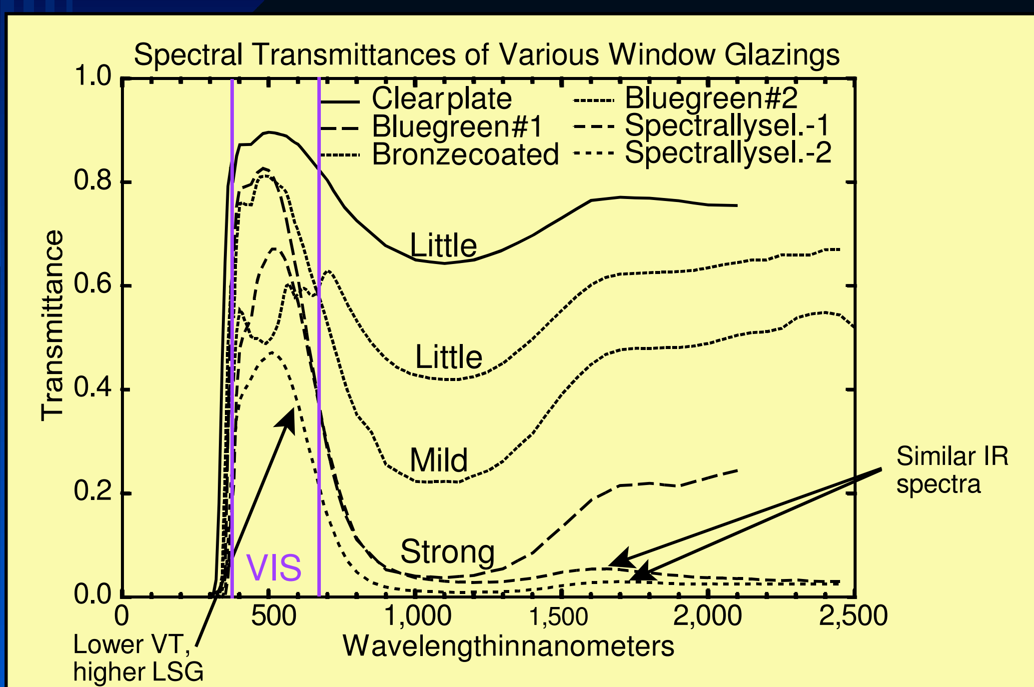
Quantifying Spectral Selectivity

- Spectral selectivity: Optical properties vary with wavelength



- Not needed in northern Alaska
- Can be very helpful in hot and warm climates
- Useful in cold climates when buildings are internal load dominated and have trouble losing heat
- In these cases we need low solar heat gain
  - So Just lower the solar transmittance
  - But this also lowers visible transmittance
- Spectral selectivity allows dropping solar gain without dropping visible transmittance as much

Spectral Selectivity of Real Glazings



Light to Solar Gain ratio - A measure of spectral selectivity

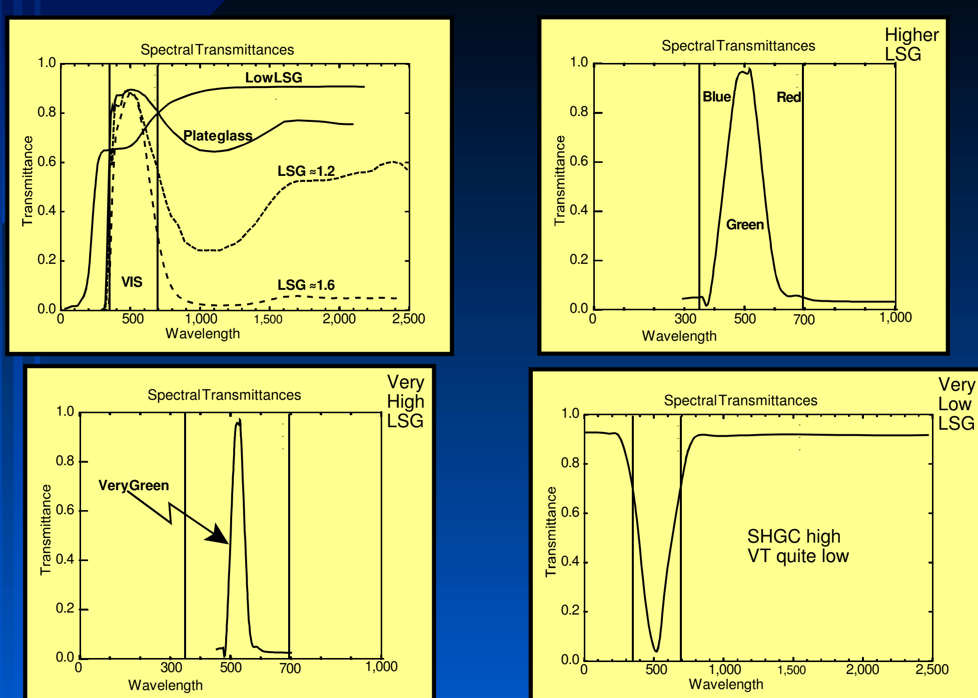
VT Visibletransmittance:
Fraction of incident light transmitted

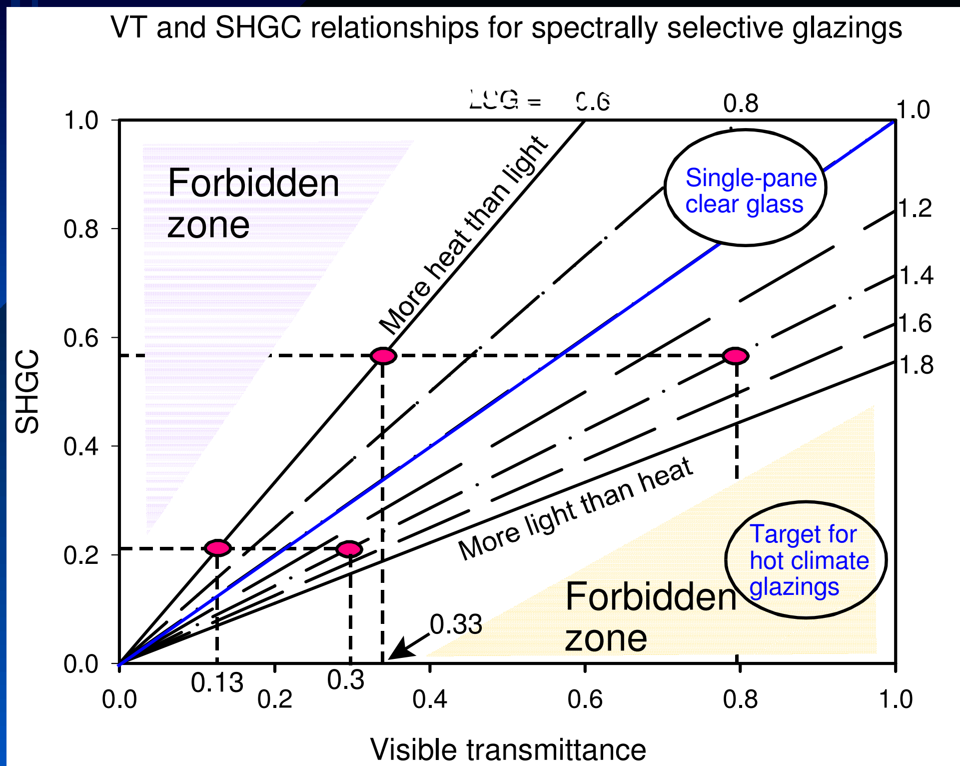
SHGC Solar heat gain coefficient:
Fraction of incident solar radiation admitted as heat gain

LSG Light-to-Solar Gain ratio:
Ratio of visible transmittance to solar heat gain coefficient

$$LSG = \frac{VT}{SHGC}$$

Color Limits

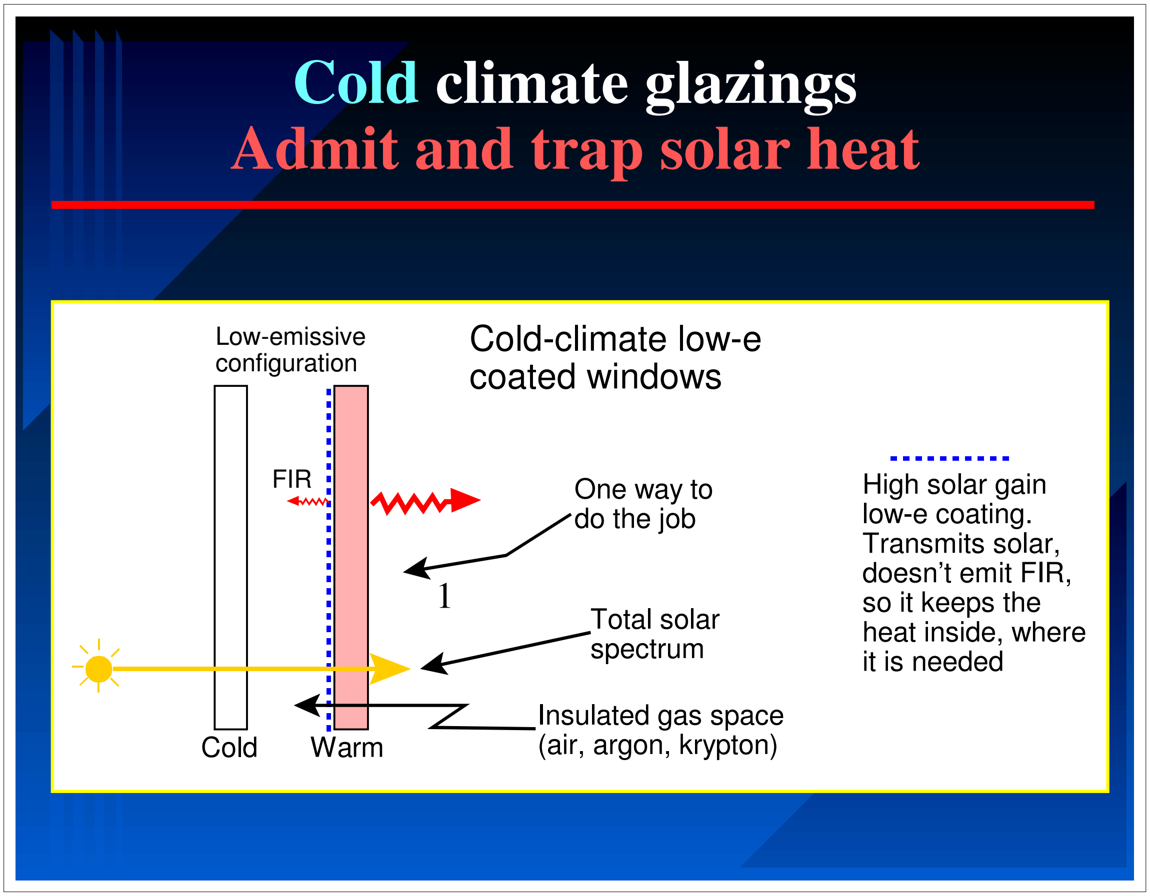




Coatings and Tints

One can use

- High solar gain low-e coatings for cold climates
- Low solar gain low-e coatings for hot climates
- IR-absorbing glass for hot climates
- A variety of ways to coat and tint glass
- Here’s a detailed rundown on the options


Cold climate glazings
Admit and trap solar heat
Low-emissive configuration
Cold-climate low-e coated windows
FIR
One way to do the job
1
Total solar spectrum
Insulated gas space (air, argon, krypton)
Cold
Warm
High solar gain low-e coating. Transmits solar, doesn't emit FIR, so it keeps the heat inside, where it is needed

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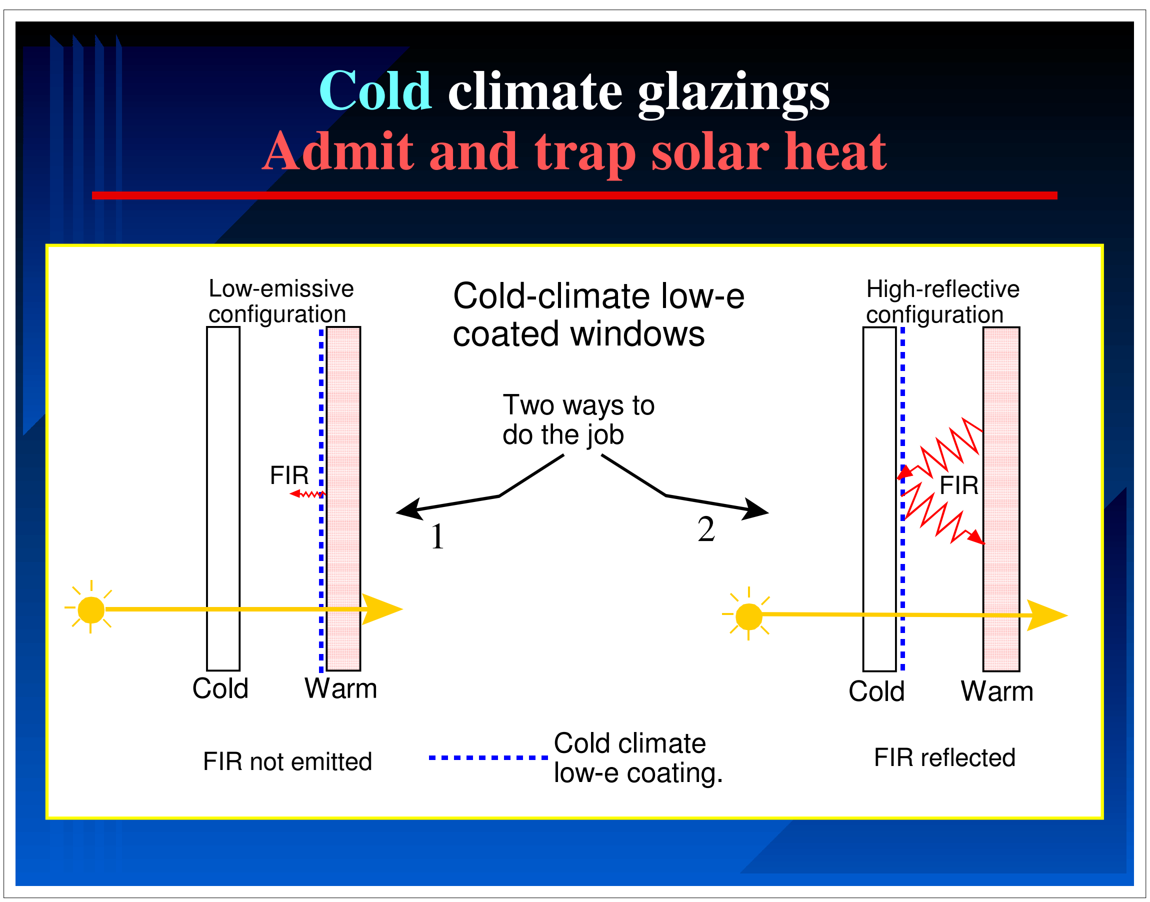
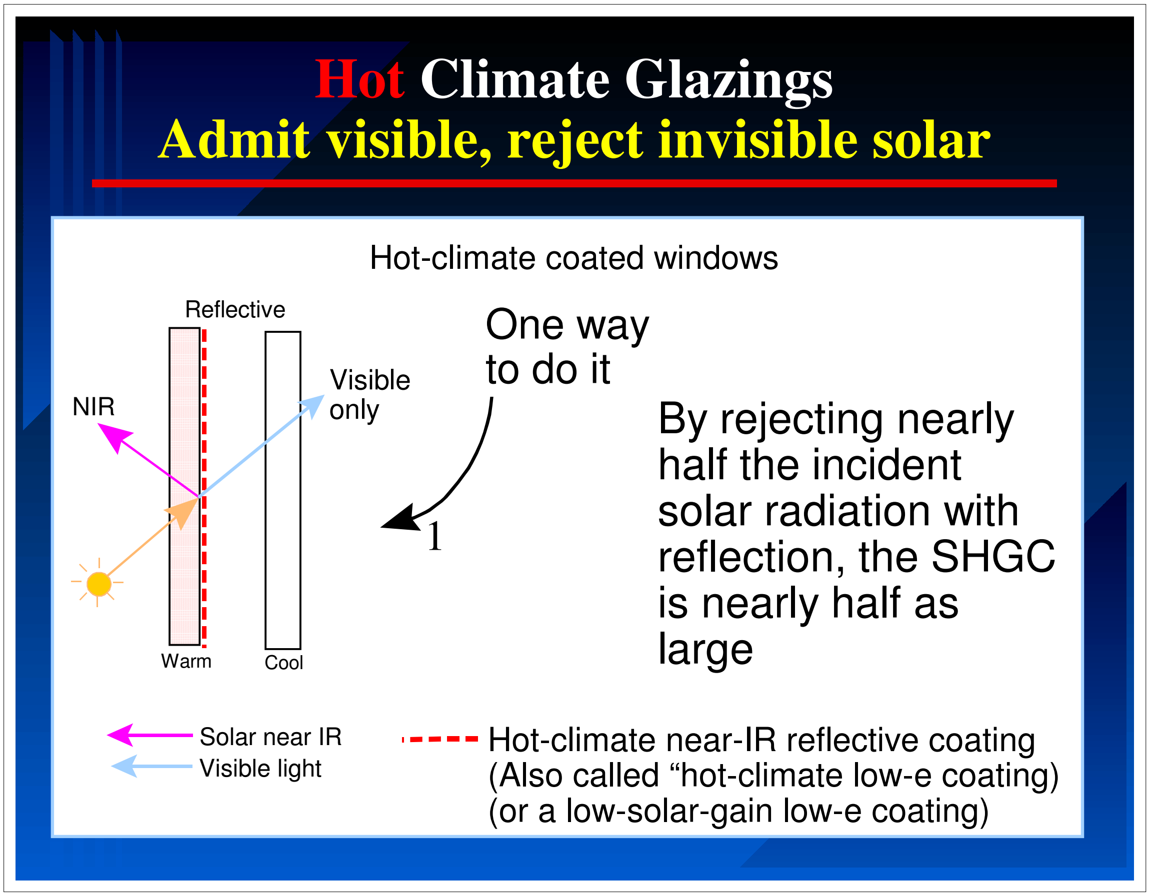
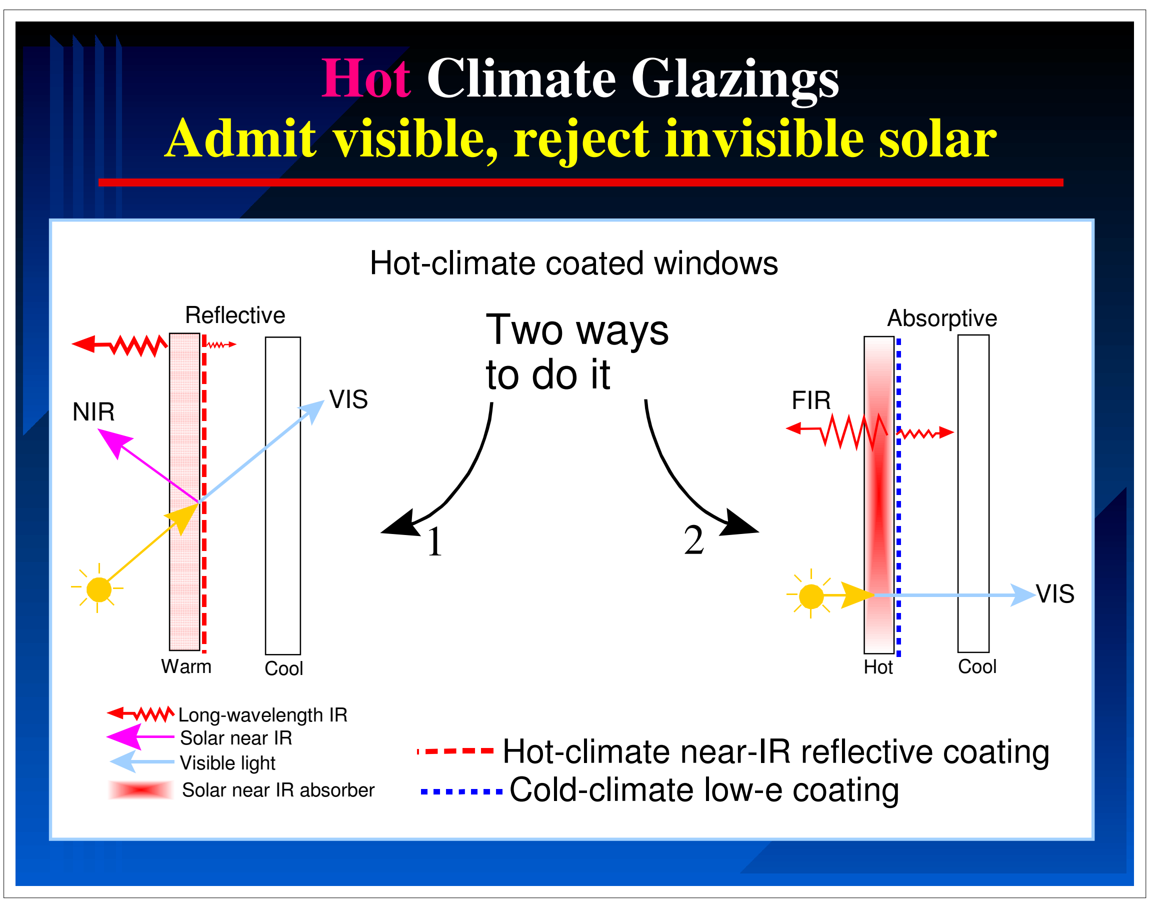
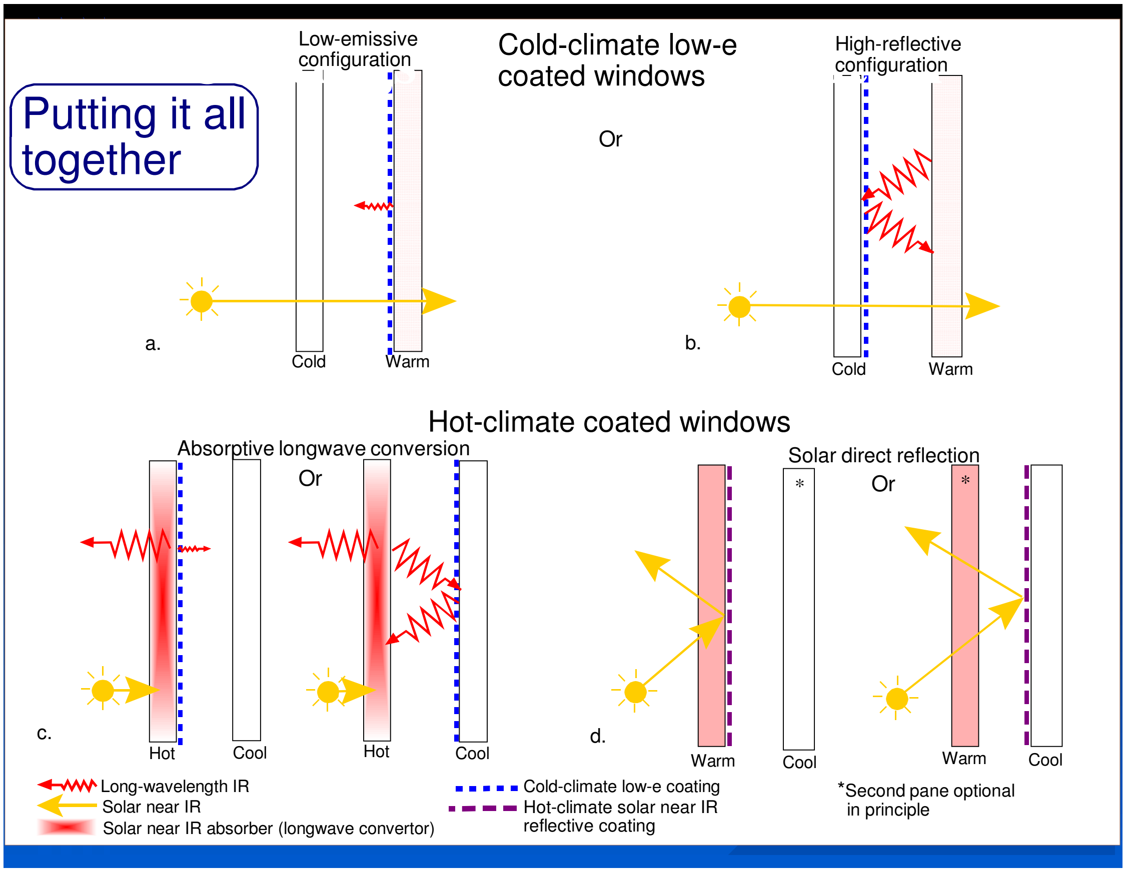

Cold climate glazings
Admit and trap solar heat
Low-emissive configuration
Cold-climate low-e coated windows
High-reflective configuration
Two ways to do the job
FIR
1
2
FIR
Cold
Warm
Cold
Warm
FIR not emitted
Cold climate low-e coating.
FIR reflected


Hot Climate Glazings
Admit visible, reject invisible solar
Hot-climate coated windows
Reflective
NIR
Visible only
Warm
Cool
One way to do it
1
By rejecting nearly half the incident solar radiation with reflection, the SHGC is nearly half as large
Solar near IR
Visible light
Hot-climate near-IR reflective coating
(Also called “hot-climate low-e coating)
(or a low-solar-gain low-e coating)


Hot Climate Glazings
Admit visible, reject invisible solar
Hot-climate coated windows
Reflective
NIR
VIS
Warm
Cool
Two ways to do it
1
2
Absorptive
FIR
VIS
Hot
Cool
Long-wavelength IR
Solar near IR
Visible light
Solar near IR absorber
Hot-climate near-IR reflective coating
Cold-climate low-e coating



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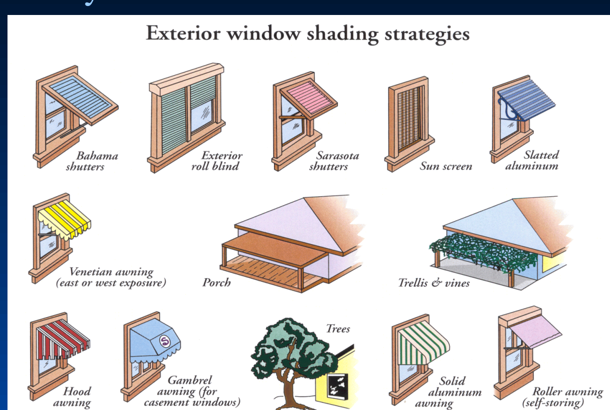
Exterior Shading

Though we're talking about glazing systems, I can't fail to mention the value of exterior shading.
It is generally better to block the sun before it strikes the glass



- But we cannot always do this, due to
  - Subdivision restrictions
  - Aesthetic considerations
  - Multi-story building
  - Desire not to block an important scene

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When exterior shading is neither permitted, nor desired, nor possible

Use High-Performance Glazing Systems

- To minimize solar heat gain, use **low solar gain low-e coated** glazings with **high LSG** ratio
- Choose VT to fit the situation
  - **VT high** for north-facing, and exposures already shaded fairly well
  - **VT low** for east- and west-facing exposures inadequately shaded
- To reduce peak load, enhance comfort and allow smaller air conditioners, use **double pane** windows
  - **Impact resistant** for coastal zone
  - **Insulated frames** to reduce condensation and improve comfort further

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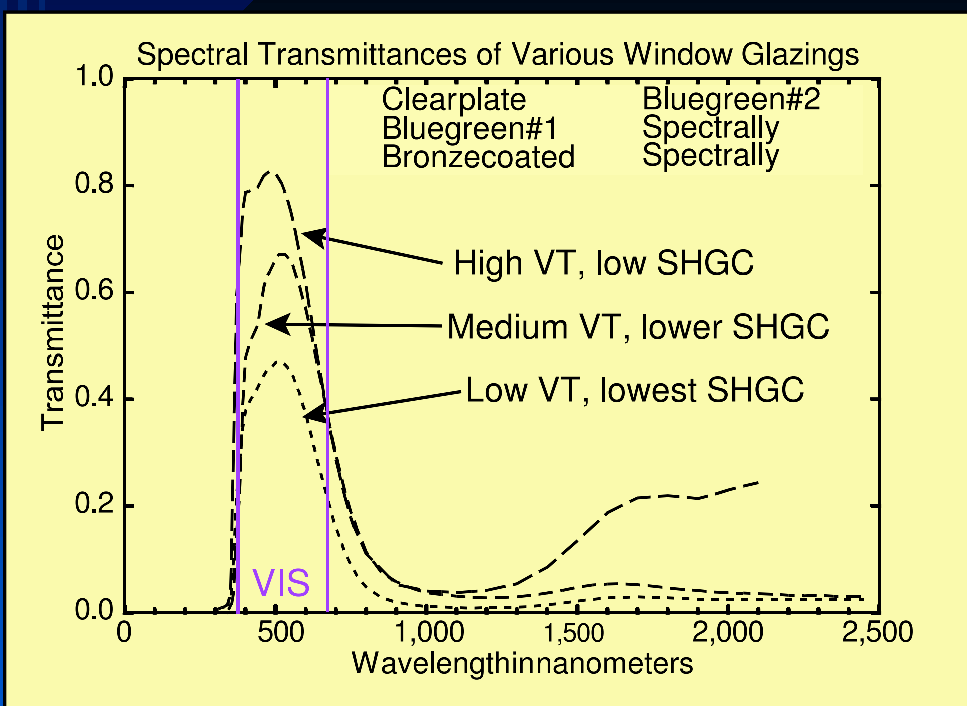
Glass Spectral Choices



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Window Recommendations in Summary

- **All windows:** Insist on high-LSG glazings and double-pane, insulated windows throughout the building—for energy savings, comfort, reduced peak load, and smaller A/C capacity (and cost).
- **North-facing**: Use a side-wall, or a deep window reveal to block low rising and setting sun on hot summer days
- **South-facing**:
  - Use a modest overhang if you like winter sun
  - Use a wide overhang to avoid sun year round
  - High-LSG glazings are especially important if shading's inadequate
- **East- and West-facing**, a menu of choices:
  For hot climates:
  - Dense tree shading where possible Awning shade
    Exterior shade screen Exterior roller shutters
    Highest-LSG glazing system, VT between 0.2 and 0.4
    Interior reflective operable shade

  For cold climates:
  - Well-insulated multiple pane windows with insulated frames
- Laminated glass for impact resistance if exterior shade is not enough for this

Proper Glazing Choices Promote

- Good energy efficiency
- Protection against future energy price shocks
- Protection against peak demand charges from utilities
- Reduced global warming
- Lower energy costs
- Visual and acoustic comfort
- Thermal comfort
- Higher building values
- More productive employees