Window Options

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

Ross McCluney, Ph.D., Principal Research Scientist
Florida Solar Energy Center

- Many factors affect the design and choice of windows for the Florida home.
- After some background information, we’ll take a tour through the options.
Are windows just “holes in the insulation?”

Some are, but . . . “it ain’t necessarily so!”

- Good windows can out-perform opaque insulated walls, energy-wise.
- Windows provide much more than energy savings!
- A building is there to provide comfort and protection from the elements, not just to save energy.
- If energy can be saved too, that’s even better.

- We’ll start with some basics
- Then we’ll cover energy and economics
- And finish with a summary of window option recommendations
Finding the Right Window

- It is more than just choosing a pretty window.
- We must also deal with the heat and the cold, as well as the glare and overheating of direct sunlight
  - The heat and cold: insulation and shading
  - The glare and overheating of direct sunlight: orientation and shading
- Other issues
  - Choice of window frame and glazing
  - To insulate or not?
  - Impact resistance?
  - Acoustic isolation?
  - Utility concerns
Dealing with the Sun

- **The Good**: Big windows provide a bright and open room with great views and good daylight illumination
- **The Bad**: Overheating, fading of furnishings, blocked views
- **The Ugly**: Killer glare from the sun, big energy bills, thermal discomfort

**Three strategies for dealing with the sun**
- Know where the sun is
- Shape and orient the building properly relative to the sun
- Shade the windows and walls properly
Heat Transfer

The three modes of heat transfer

Radiation

Conduction

Convection
Heat Flows Through Windows

- Absorbed solar radiation conducted through the frame
- Directly transmitted solar radiation through the glazings (includes both light & heat)
- Reflected solar radiation
- Glazing-absorbed solar radiant heat
- Inward flowing fraction of glazing absorbed radiation
- Outward flowing fraction of glazing absorbed radiation
Heat Flows Through Windows

Absorbed solar radiation conducted through the frame

Directly transmitted solar radiation through the glazings (includes both light & heat)

Inward flowing fraction of glazing absorbed radiation

Heat conducted through the glass

Heat conducted through the frame

Reflected solar radiation

Glazing-absorbed solar radiant heat

Outward flowing fraction of glazing absorbed radiation
Insulated windows reduce conduction, convection, and radiation

- Heat conducted through the glazing system
- Coatings reduce radiation transfer
- Insulating gas reduces conduction
- Proper spacing minimizes convection
- Insulation reduces heat conduction through the frame

During Winter, cold air moves upward, while during Summer, hot air moves downward. The insulation in the window helps to reduce heat transfer.
Knowing Where the Sun is

- Radiation from the sun is generally much stronger than that from the sky, except on hazy and partially overcast days.
- The sun moves through the sky in a known way each day.
- Radiation coming directly from the sun’s “disk” is called “direct beam radiation.”
- Orienting the building and its windows is important to maximize the benefits and minimize the problems produced by direct beam solar radiation.
- First we look at a generic drawing of the sun’s path through the sky on the summer and winter solstices.
- Then we consider how to orient a house properly relative to the sun’s positions in the sky.
**SUMMER**

Sun rises north of due east, sets north of due west, and is high in the sky at noon.

Shade:
overhang for noon east to northeast morning west to northwest afternoon

**WINTER**

Sun rises south of due east, sets south of due west, and is low in the sky at noon.

Shade: southwest to west to protect west window on warm winter days
Orientation and shading

- Minimize east and west exposure
- Shade the facade

Wide overhangs

Fence

Garage

Buffer East and West Exposures

Closet

Utility room
Exterior window shading strategies

- Bahama shutters
- Exterior roll blind
- Sarasota shutters
- Sun screen
- Slatted aluminum
- Venetian awning (east or west exposure)
- Porch
- Trellis & vines
- Hood awning
- Gambrel awning (for casement windows)
- Trees
- Solid aluminum awning
- Roller awning (self-storing)
Solar Spectrum Fundamentals

- The sun’s radiation covers a range of colors, and beyond.
- This electromagnetic radiation has important features for the design and performance of windows in different climates.
- We need to know a little more about the physics of solar radiation to fully understand the variety of window products now on the market.
- We begin with the electromagnetic spectrum.
Breaking sunlight into its various colors

Glass prism

Sir Isaac Newton 1723

Red 700 nm
Orange
Yellow
Green
Blue 400 nm

Invisible ultraviolet

Invisible infrared

Red 700 nm
Orange
Yellow
Green
Blue 400 nm

Invisible ultraviolet
Parts of the solar spectrum

- Ultraviolet (UV)
- Visible (VIS)
- Near Infrared (NIR)
- Far Infrared (FIR)

Human eye sensitivity (Visible portion of the spectrum)
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 spectra from 80 to 35,000 deg Fahrenheit

- 35,000F
- 17,000F
- 8000F
- 3800F
- 1600F
- 560F
- 80F

Spectral Exitance in W m⁻² nm⁻¹

Wavelength in micrometers

Room temperature

VIS

NIR

FIR

Solar Spectral range
Why black body radiation is important

Warm panes radiate toward cold ones.

The wavelengths are in the far IR spectral range.

We can take advantage of this in designing the glass panes.

Cold  Warm
Spectral Selectivity for Cold Climates

Cold climate glass transmittance

Room temperature surface emission spectrum

Solar spectrum

Human eye response

Visible light

Invisible solar IR

Invisible IR emitted by room temperature surfaces

200 nm 380 nm 760 nm 3.5 μm 30 μm

UV VIS NIR FIR

Ultra Violet Visible light Invisible solar IR Invisible IR emitted by room temperature surfaces
Spectral Selectivity for Hot Climates

Hot climate transmittance

Cold climate transmittance

Room temperature surface emission spectrum

Solar spectrum

Human eye response

Visible light (VIS)

Invisible solar IR

Ultra Violet (UV)

Invisible IR emitted by room temperature surfaces

Wavelength

Spectral irradiance

Transmittance

200 nm

380 nm

760 nm

3.5 µm

30 µm
Quantifying Heat Flows

Heat flux, \( Q \) in W/m\(^2\)

- Incident solar irradiance: \( E_0 \)
- Reflected solar radiation: \( R_s E_0 \)
- Glazing-absorbed solar radiant heat: \( A_s E_0 = Q_{\text{absorbed}} \)
- Transmitted solar radiation:
  - \( T_s E_0 = Q_{\text{direct}} \)
- Inward fraction:
  - \( N_i A_s E_0 = Q_{\text{inward}} \)
- Total glazing solar heat gain
- Visible Transmittance: \( V_T \) (%)

- Glazing conduction heat transfer
- Frame conduction heat transfer

- Heat flux equations:
  - \( Q_g = U_g \times \text{Area} \times \Delta t \)
  - \( Q_f = U_f \times \text{Area} \times \Delta t \)
Performance Indices

Reflected solar radiation: $R_s$
Glazing-absorbed solar radiant heat: $T_s$
Outward flowing fraction of glazing absorbed radiation: $N_i A_s$
Visible Transmittance: $VT$
U-factor: $U$

Solar Heat Gain Coefficient: $T_s + N_i A_s = \text{SHGC}$

(R-value = $1/U$)
### Light to Solar Gain ratio

- **A measure of spectral selectivity**

<table>
<thead>
<tr>
<th>VT</th>
<th>Visible transmittance:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fraction of incident light transmitted</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SHGC</th>
<th>Solar heat gain coefficient:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fraction of incident solar radiation admitted as heat gain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSG</th>
<th>Light-to-Solar Gain ratio:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ratio of visible transmittance to solar heat gain coefficient</td>
</tr>
</tbody>
</table>

\[
LSG = \frac{VT}{SHGC}
\]
Spectral Selectivity of Real Glazings

Spectral Transmittances of Various Window Glazings

- Clearplate
- Bluegreen#1
- Bluegreen#2
- Bronze
- Spectrally

Spectral selectivity:
- Little
- Mild
- Strong

Lower VT, higher LSG

Similar IR spectra
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
Cold-climate low-e coated windows

Low-emissive configuration

Cold-climate low-e coated windows

One way to do the job

High solar gain low-e coating. Transmits solar, doesn’t emit FIR, so it keeps the heat inside where it is needed

Total solar spectrum

Insulated gas space (air, argon, krypton)

FIR

Cold Warm

Admit and trap solar heat

Cold climate glazings
Cold climate glazings
Admit and trap solar heat

Two ways to do the job

1. Low-emissive configuration
   - Cold climate low-e coating.
   - FIR not emitted

2. High-reflective configuration
   - FIR reflected
Hot Climate Glazings
Admit visible, reject invisible solar

Hot-climate coated windows

Reflective

Visible only

NIR

Warm

Cool

By rejecting nearly half the incident solar radiation with reflection, the SHGC is nearly half as large

One way to do it

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

Two ways to do it

1. Hot-climate near-IR reflective coating
2. Absorptive coating

Long-wavelength IR
Solar near IR
Visible light
Solar near IR absorber

Hot-climate near-IR reflective coating
Cold-climate low-e coating
Putting it all together

Cold-climate low-e coated windows

- Low-emissive configuration

- Absorptive longwave conversion

- Solar near IR absorber (longwave converter)

- High-reflective configuration

- Hot-climate solar near IR reflective coating

- Second pane optional in principle

Putting it all together

- Cold Warm Cold Warm
- Hot Cool Warm Cool Warm Cool

- Solar near IR absorber (longwave converter)

Or

- Cold Warm Cold Warm

Or

- Solar direct reflection

Or

- Second pane optional in principle
Direct Beam Solar Radiation

Can produce discomforting glare and localized overheating, as well as add to the air conditioning bill.
Avoiding Direct Beam
Orientation & Shading Strategies

Minimize East and West Exposures

Wide overhangs

Buffer East and West Exposures

Fence

Garage

Closet

Utility room
Window Shading

Outdoors

Between the panes

Indoors
Exterior window shading strategies
Block solar gain before it reaches the window

- Bahama shutters
- Exterior roll blind
- Sarasota shutters
- Sun screen
- Slatted aluminum
- Venetian awning (east or west exposure)
- Porch
- Trellis & vines
- Hood awning
- Gambrel awning (for casement windows)
- Trees
- Solid aluminum awning
- Roller awning (self-storing)
When exterior shading is not permitted, desired, or possible

Use High-Performance Glazing Systems

- To minimize solar heat gain, use **hot-climate 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, enhancing comfort and allowing smaller air conditioners, use **double pane** windows
  - **Impact resistant** for coastal zone
  - **Insulated frames** to reduce condensation and improve comfort further
Spectral Transmittances of Various Window Glazings

- Clearplate
- Bluegreen #1
- Bluegreen #2
- Spectrally Bronzecoated

- High VT, low SHGC
- Medium VT, lower SHGC
- Low VT, lowest SHGC

Wavelength in nanometers
Window Energy Performance

- **Instantaneous versus long term hourly** performance
- For instantaneous perf., get the NFRC label information:
  - U-factor
  - SHGC
  - VT
- But how do you know what are good values of these for your application?
- You need something to tell you about the long-term energy (and peak load) consequences of a given choice
- And you need a way to convert energy efficiency into economic information.
- Next comes some background information on energy computer programs and economic indicators
Hourly Building Energy Simulations

Building thermal properties
- Thermal mass & location
- Wall, roof, & floor insulation
- Infiltration models
- Window SHGC & U-factors
- HVAC efficiency data

Assumed internal heat loads
- Equipment
- Humans & animals
- Occupancy

Weather data for each hour
- Air temperature & humidity
- Wind speed
- Direct beam solar
- Global horizontal solar

Loads on HVAC system
- Conduction through envelope
- Internal loads
- Fenestration Solar Gain

Energy use by energy type
- Electric energy
- Electric demand
- Gas energy
- Fuel oil

Costs of energy-efficiency
- Building envelope
- HVAC system
- Other features

Dollar costs to operate the building each hour and for a year
- Annual energy
- Demand charges
- Economic performance indicators

Other energy consumed
- Equipment
- Electric lighting
Window Energy Software

- **DOE-2** — Large & complex. Needs engineer to run it. Energy Plus is the next generation.
- **RESFEN** — Easier to run, and based on DOE-2, but you must be somewhat computer savvy to run it.
- **EnergyGauge USA** — Requires licensing and training.
- **EnergyGauge FlaRes** — Used mainly for code compliance.
- **Energy performance for a typical house can be determined at** www.efficientwindows.org but this treats shading only minimally.
What Can You Do to Get Energy Performance Information?

- Use Building Code energy provisions — Minimal
- Insist on NFRC ratings — Instantaneous values only, but still important to know that the numbers are correct
- Obtain Green Home Certification — Great environmentally, but modest incentive for window energy
- Use only Energy Star windows — Good but not best
- Information customized for your home, use RESFEN: http://windows.lbl.gov/software/resfen/resfen.html
Where to find these resources
National Fenestration Rating Council

NFRC.org
How to Select an Energy Efficient Window

1. **Look for the Energy Star**
   Look for a product that qualifies for the Energy Star in the Northern, Central, or Southern Climate Zone. To distinguish between Energy Star products, go to Step 2.

2. **Look for Energy Efficient Window Properties on the NFRC Label**
   The key window properties are U-factor, Solar Heat Gain Coefficient (SHGC), and Visible Transmittance (VT). The NFRC label provides the only reliable way to determine the window properties and to compare products. For typical cost savings from efficient windows in specific locations, go to Step 3.

3. **Compare Annual Energy Costs for a Typical House**
   Compare the annual energy use for different window options for a typical 2000-square-foot house in your state or region.
Energy Star

http://www.energystar.gov/products/windows/

**Energy Star Homes**
must meet a performance standard:
Have a HERS energy rating of 86 or above

**Energy Star Windows**
must meet a prescriptive standard:
In the hot climate zone:

<table>
<thead>
<tr>
<th></th>
<th>Windows &amp; Doors</th>
<th>Skylights</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U-Factor</strong></td>
<td>0.75 or below</td>
<td>0.75 or below</td>
</tr>
<tr>
<td><strong>Maximum Solar Heat Gain Coefficient</strong></td>
<td>0.40 or below</td>
<td>0.40 or below</td>
</tr>
</tbody>
</table>
None of the previous web sites offers much guidance on selecting window shading. The next one at least gives credit for tree shading.
Florida Green Home Certification

Florida Green Building Coalition, Inc., www.floridagreenbuilding.org

- Green Home Standard Certification based on a points rating
- “Green Home Designation Standard Checklist” publication
- Checklist includes points for Energy, Water, Site, Health, Materials, Disaster Mitigation, and a General category
- For new homes each category has a minimum number of points. The sum of the minimums (default case) is 160.
- Total points requirement is 200.
- More points are required if the minimum cannot be met in a category
- Window points are given for daylighting, east and west tree shading, and exceeding the Florida Energy Code HERS rating of 80
Window Selection Advice
To Double-pane or not?

- For energy savings only, double pane is generally not needed in hot climates.
- In this case it is more important to put your money into preventing solar gain —
  
  On the other hand:

- The highest LSG glass is only available in double pane.
- Double pane is more comfortable.
- Double pane allows smaller A/C, saving dollars.
- Double pane gives better acoustic isolation.
- The electric utility might pay you to use double pane (if you ask them nicely).
- Double pane is important for cold climates.
- Double pane will protect you from future demand charges.
Guidance for the Average Building Owner

- **Purchase the best window you can afford for your situation, considering:**
  - Direction the window faces
  - Degree of existing shading of that window

- **Shade east- and west-facing windows from direct sunlight**
  - Trees
  - Trellis vines
  - Shrubs and plants
  - Awnings and shade screens
  - Shutters

- **Use double-pane glass and insulated frames to**
  - Maintain thermal comfort
  - Reduce peak A/C size required
  - Save energy and electricity costs
  - Protect against possible future peak demand charges
Window Recommendations in Summary

- **All windows**: Insist on high-LSG glazings and double-pane, insulated windows throughout the house—for energy savings, comfort, reduced peak load, and smaller A/C capacity (and lowered equipment 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
Additional Information & Resources

- For more information continue exploring our windows web site: http://www.fsec.ucf.edu/en/consumer/buildings/window_basics/index.htm

- It has much information about windows and guidance in selecting windows.

- It has links to many other web sites with additional information.