



U.S. Department of Energy
Energy Efficiency and Renewable Energy

Fenestration

Charles Eley
Eley Associates



Energy Performance Characteristics of Windows

Heat transfer mechanisms:

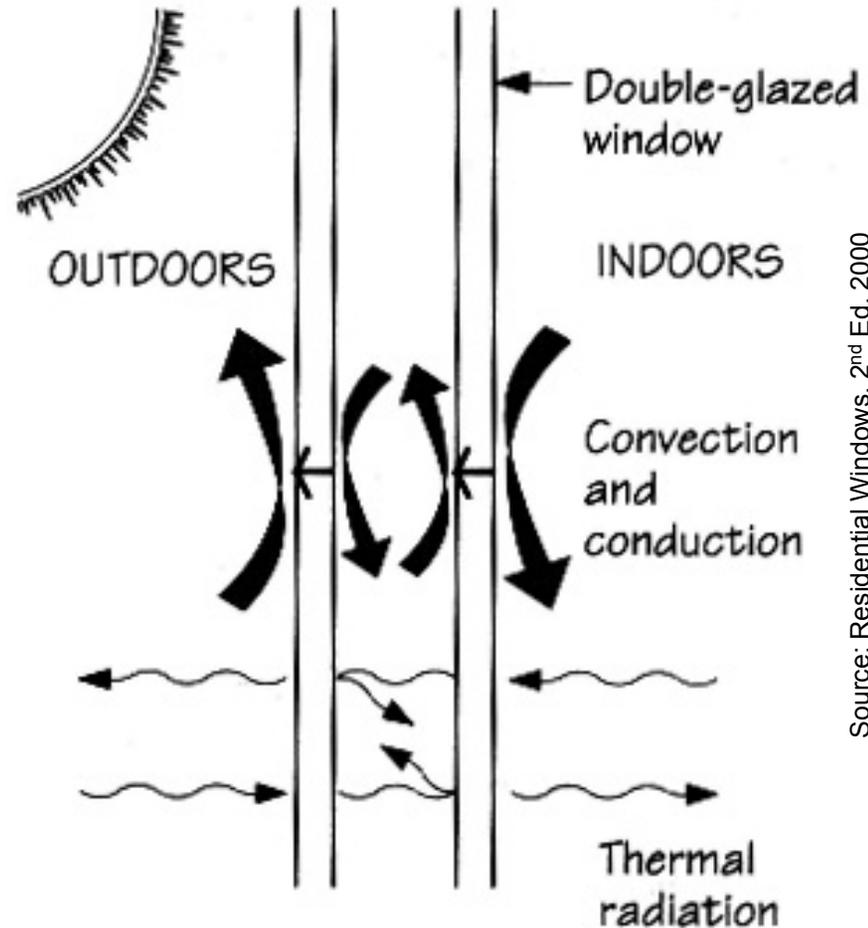
- Insulating value
- Solar radiation control
- Visible transmission
- Air leakage





Insulating Value (U-factor)

Components of heat transfer are related to insulating value.



Source: Residential Windows, 2nd Ed. 2000



Window A

Clear, Single Glazing

U-Factor=0.90 (window), 1.11 (center of glass)

Window B

Single Glazing, Bronze or Gray Tint

U-Factor=0.90 (window), 1.11 (center of glass)

Window C

Clear, Double Glazing

U-Factor=0.49 (window), 0.49 (center of glass)

Window D

Double Glazing, Bronze or Gray Tint

U-Factor=0.49 (window), 0.49 (center of glass)

Window E

Double Glazing, High-Performance Tint

U-Factor=0.49 (window), 0.49 (center of glass)

Window F

Double Glazing, High-Solar-Gain Low-E

U-Factor=0.36 (window), 0.30 (center of glass)

Window G

Double Glazing, Moderate-Solar-Gain Low-E

U-Factor=0.33 (window), 0.26 (center of glass)

Window H

Double Glazing, Low-Solar-Gain Low-E

U-Factor=0.32 (window), 0.25 (center of glass)

Window I

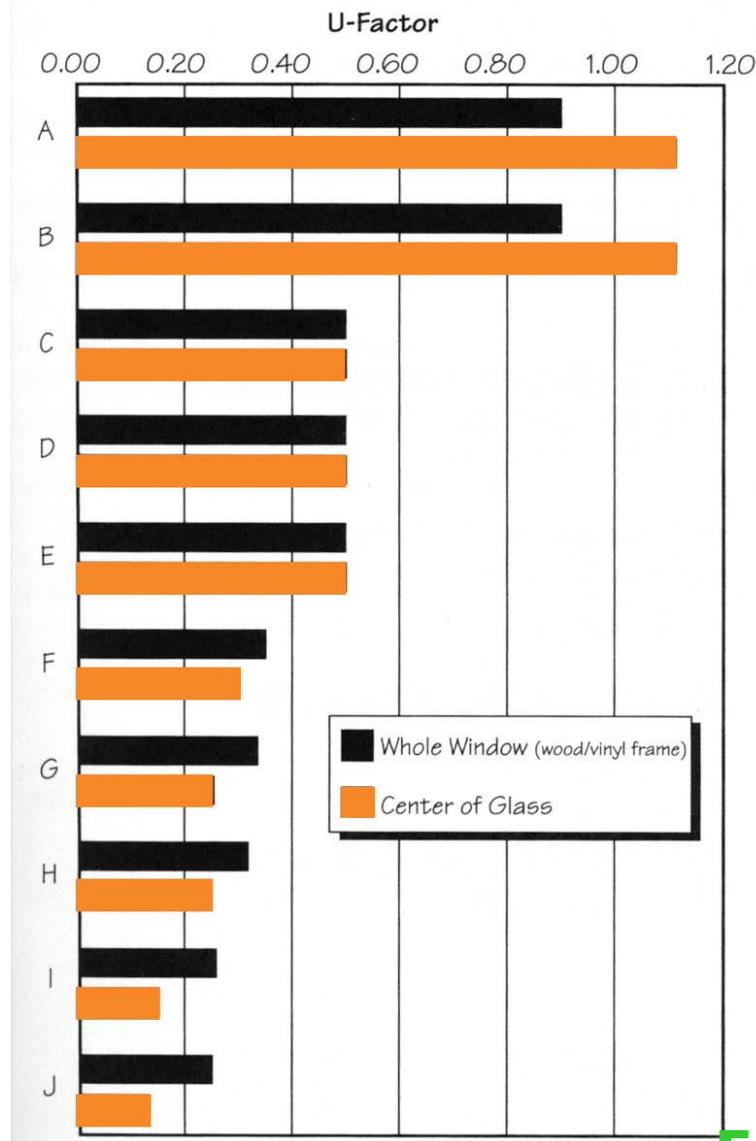
Triple Glazing, Moderate-Solar-Gain Low-E

U-Factor=0.26 (window), 0.15 (center of glass)

Window J

Triple Glazing, Low-Solar-Gain Low-E

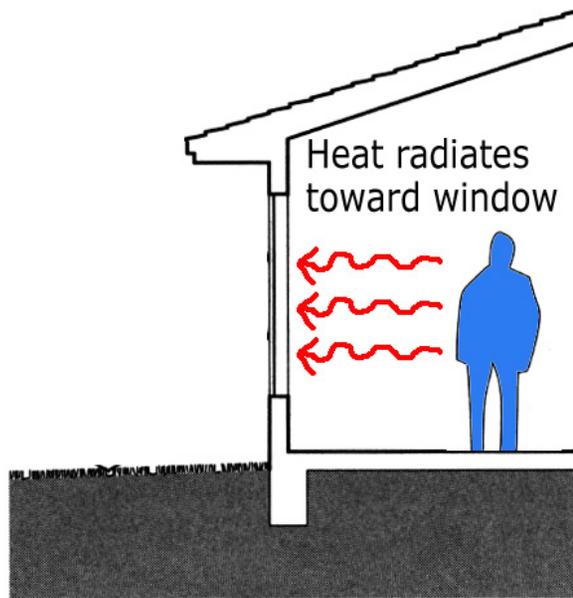
U-Factor=0.24 (window), 0.13 (center of glass)



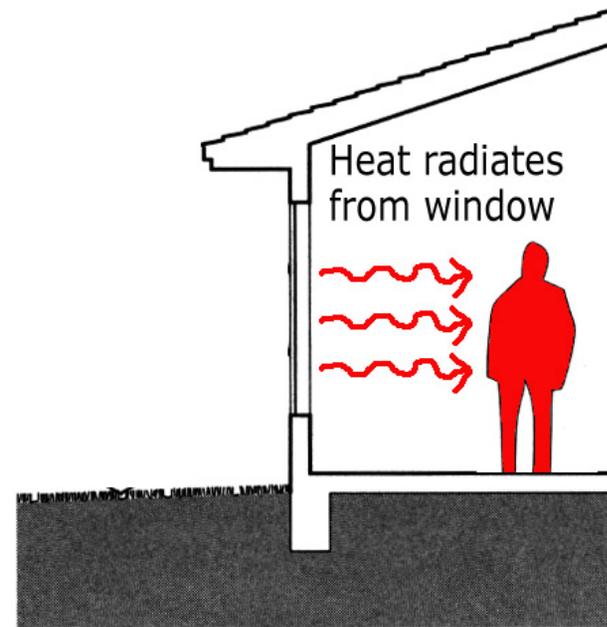
Source: Residential Windows, 2nd Ed. 2000



Mean Radiant Temperature and Thermal Comfort



Cold Window



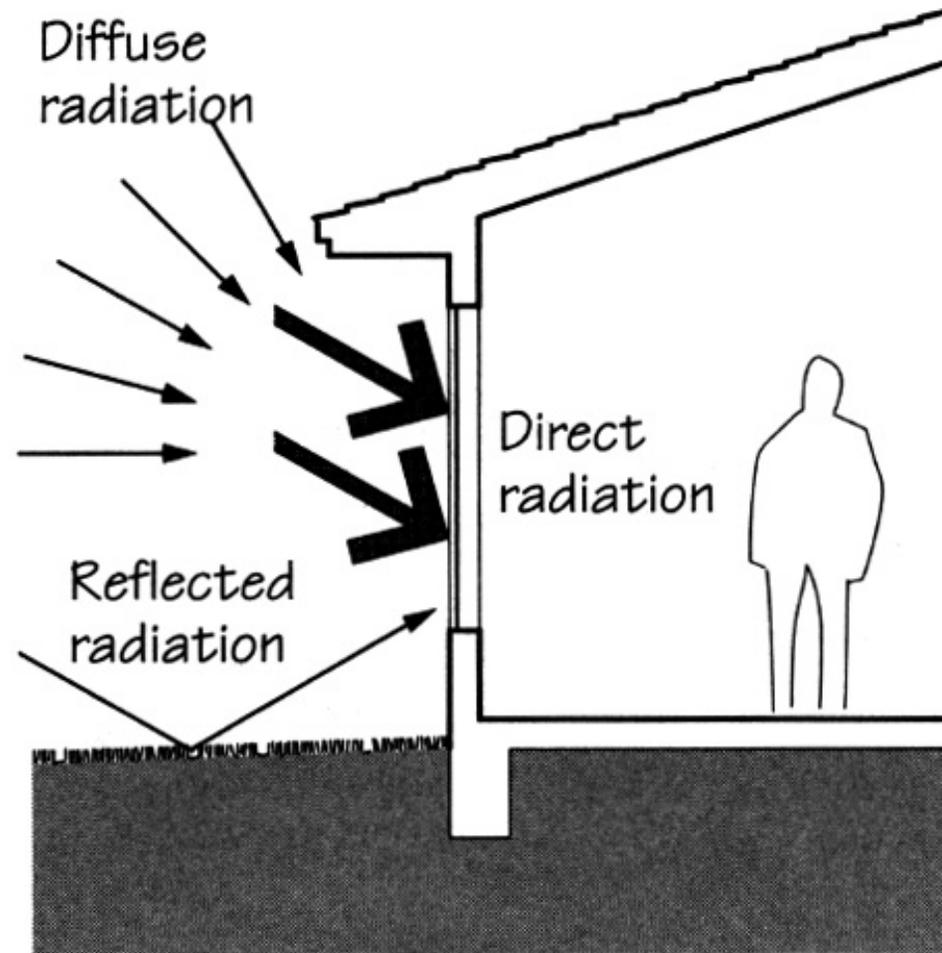
Hot Window



Solar Radiation Control (SHGC)

Solar heat gain:

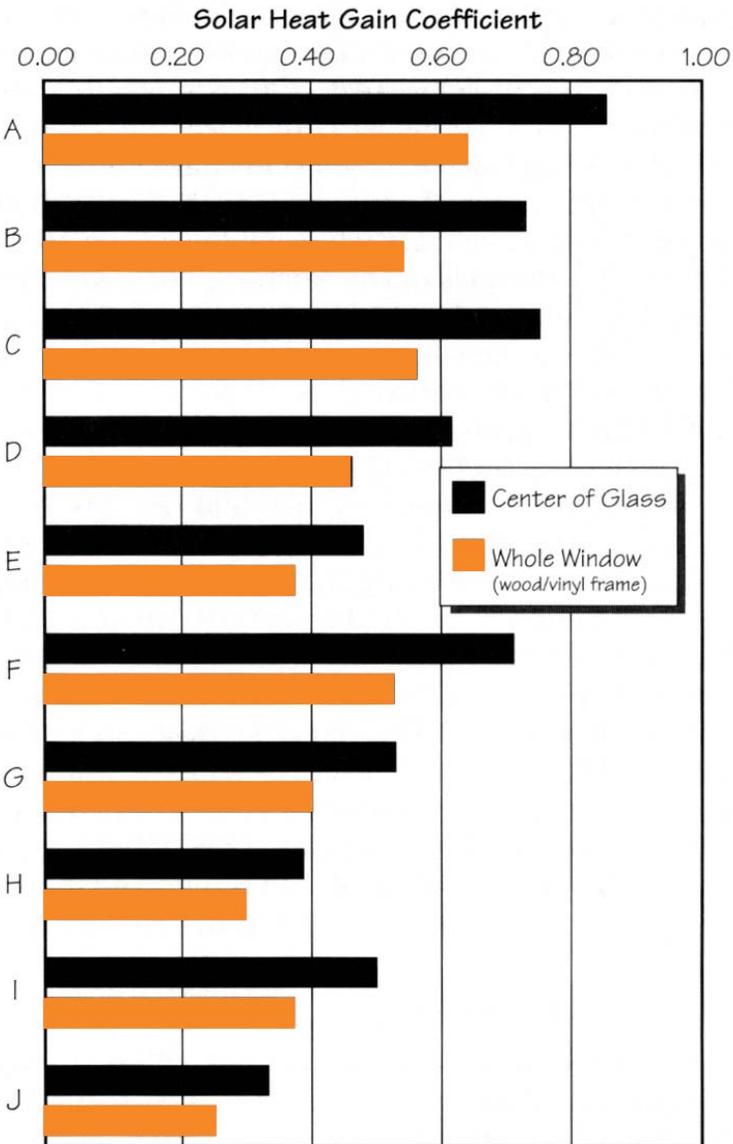
- Direct radiation
- Reflected radiation
- Diffuse radiation



Source: Residential Windows, 2nd Ed. 2000



- Window A**
Clear, Single Glazing
SHGC=0.86 (center of glass), 0.63 (window)
- Window B**
Single Glazing, Bronze or Gray Tint
SHGC=0.73 (center of glass), 0.54 (window)
- Window C**
Clear, Double Glazing
SHGC=0.76 (center of glass), 0.56 (window)
- Window D**
Double Glazing, Bronze or Gray Tint
SHGC=0.62 (center of glass), 0.46 (window)
- Window E**
Double Glazing, High-Performance Tint
SHGC=0.48 (center of glass), 0.37 (window)
- Window F**
Double Glazing, High-Solar-Gain Low-E
SHGC=0.71 (center of glass), 0.52 (window)
- Window G**
Double Glazing, Moderate-Solar-Gain Low-E
SHGC=0.53 (center of glass), 0.40 (window)
- Window H**
Double Glazing, Low-Solar-Gain Low-E
SHGC=0.39 (center of glass), 0.30 (window)
- Window I**
Triple Glazing, Moderate-Solar-Gain Low-E
SHGC=0.50 (center of glass), 0.38 (window)
- Window J**
Triple Glazing, Low-Solar-Gain Low-E
SHGC=0.33 (center of glass), 0.25 (window)

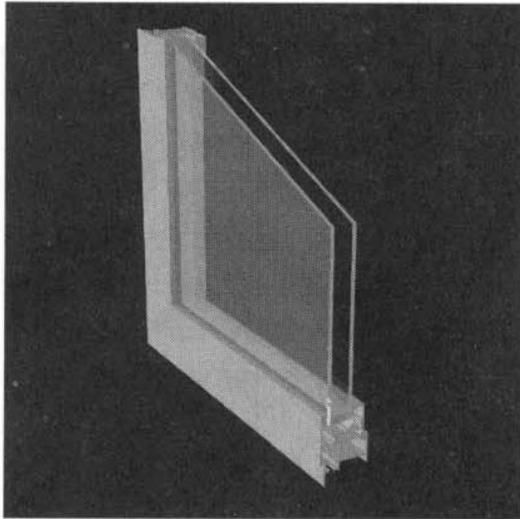


Source: Residential Windows, 2nd Ed. 2000

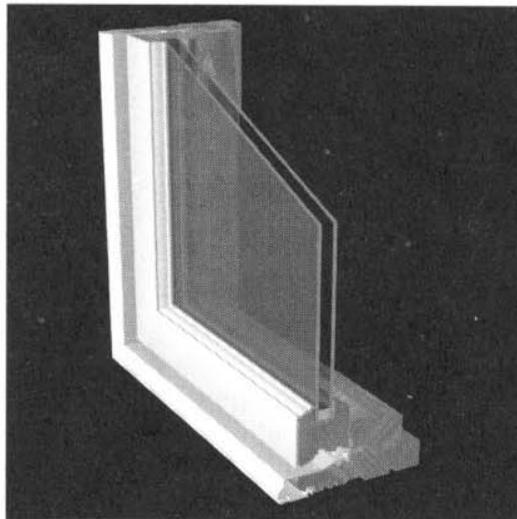


The Window Assembly

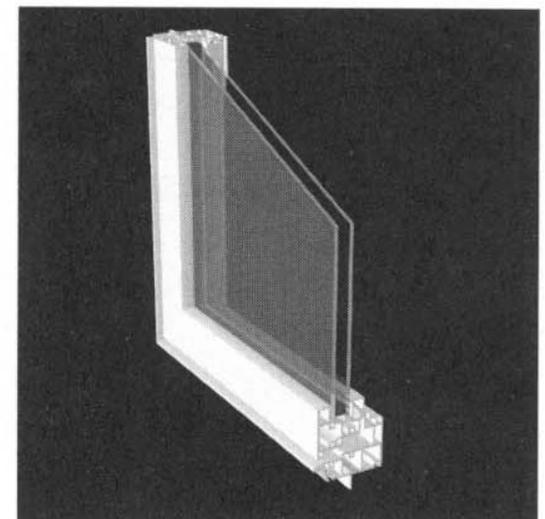
Source: Residential Windows, 2nd Ed. 2000



Aluminum frame



Wood frame with cladding

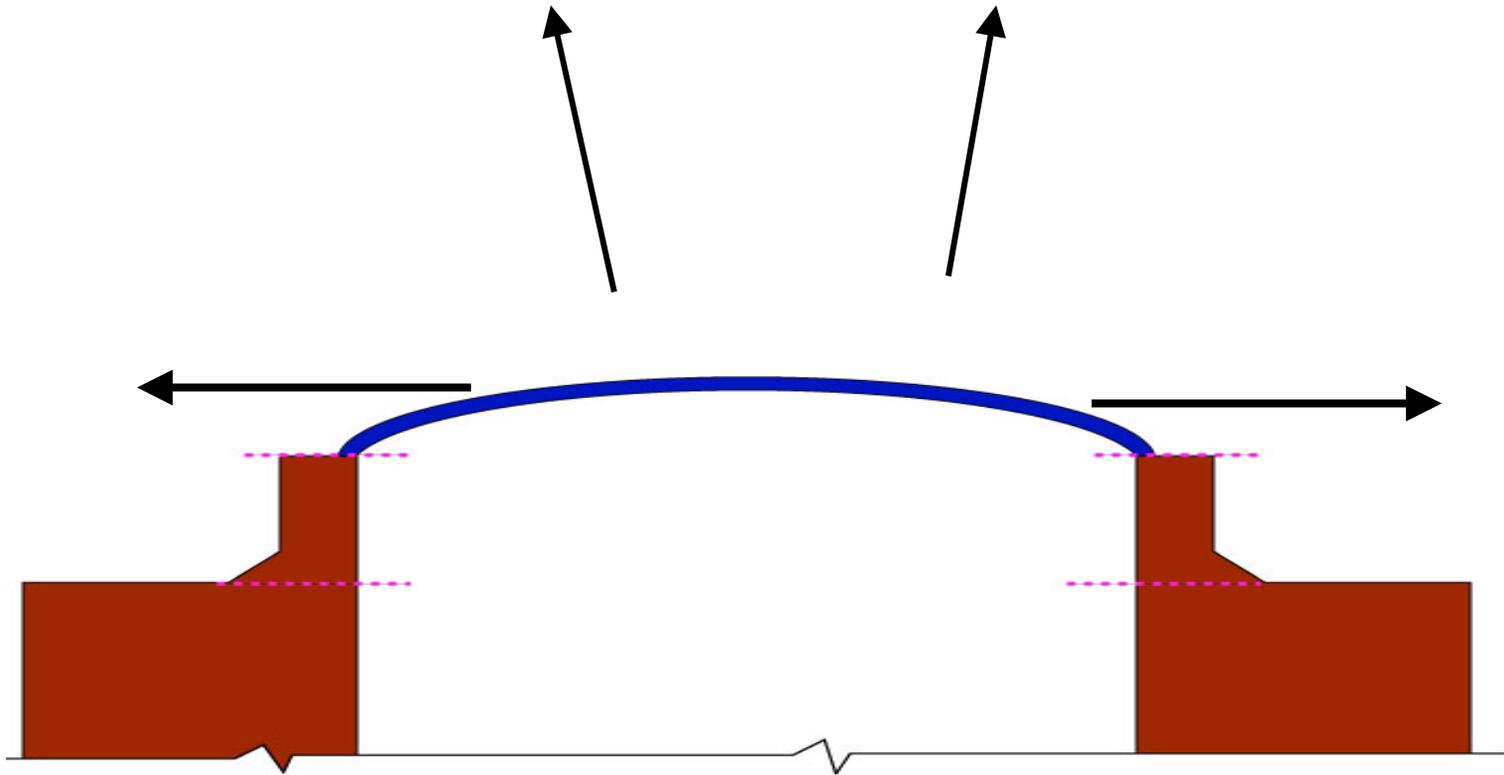


Vinyl frame

Window frame materials can have a substantial impact on energy performance as well as on appearance.



The Skylight Assembly



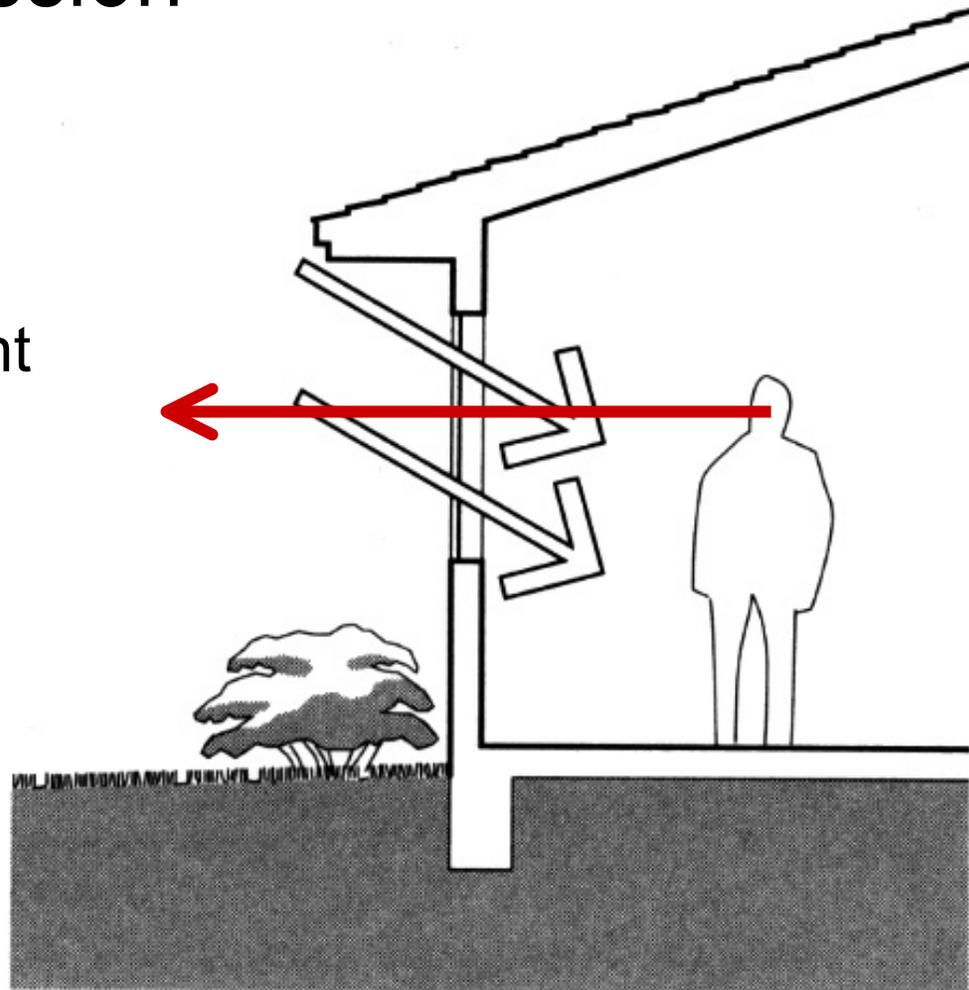
Heat loss occurs through glass *and* assembly



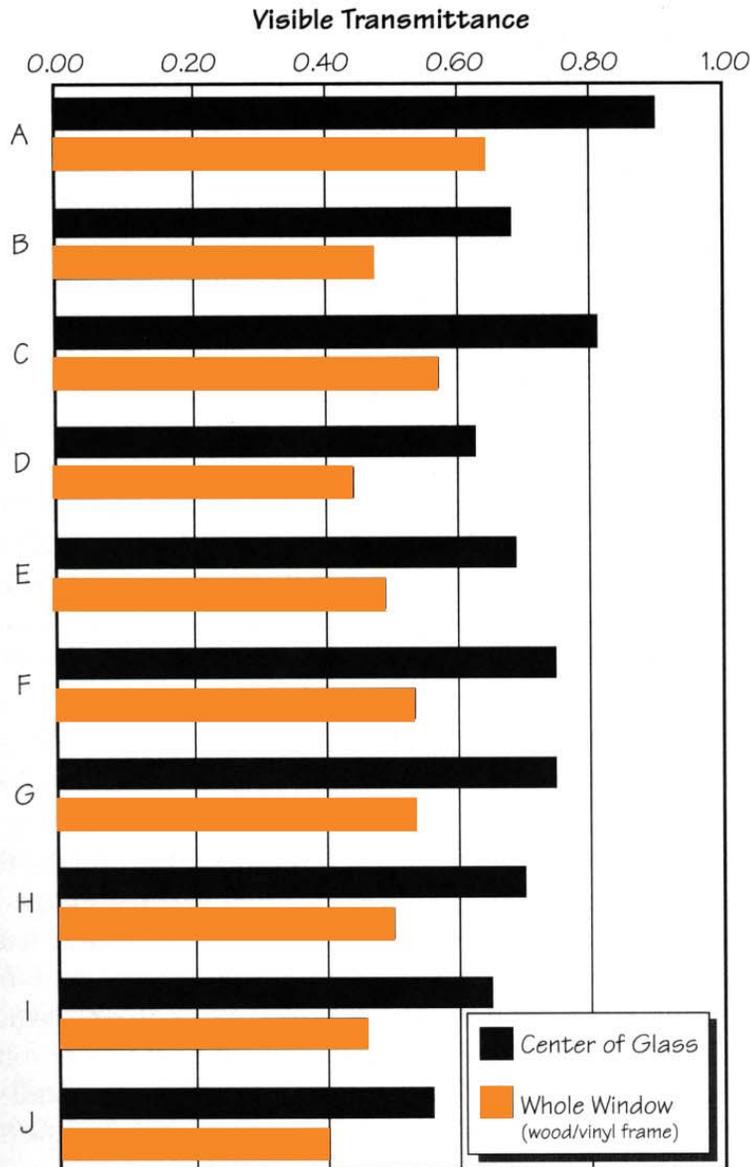
Visible Transmission

Visible transmittance:

Measures visible light that passes through glazing.



Source: Residential Windows, 2nd Ed. 2000



Window A

Clear, Single Glazing
VT=0.90 (center of glass), 0.64 (window)

Window B

Single Glazing, Bronze or Gray Tint
VT=0.68 (center of glass), 0.48 (window)

Window C

Clear, Double Glazing
VT=0.81 (center of glass), 0.58 (window)

Window D

Double Glazing, Bronze or Gray Tint
VT=0.62 (center of glass), 0.44 (window)

Window E

Double Glazing, High-Performance Tint
VT=0.69 (center of glass), 0.49 (window)

Window F

Double Glazing, High-Solar-Gain Low-E
VT=0.75 (center of glass), 0.53 (window)

Window G

Double Glazing, Moderate-Solar-Gain Low-E
VT=0.75 (center of glass), 0.53 (window)

Window H

Double Glazing, Low-Solar-Gain Low-E
VT=0.70 (center of glass), 0.50 (window)

Window I

Triple Glazing, Moderate-Solar-Gain Low-E
VT=0.65 (center of glass), 0.46 (window)

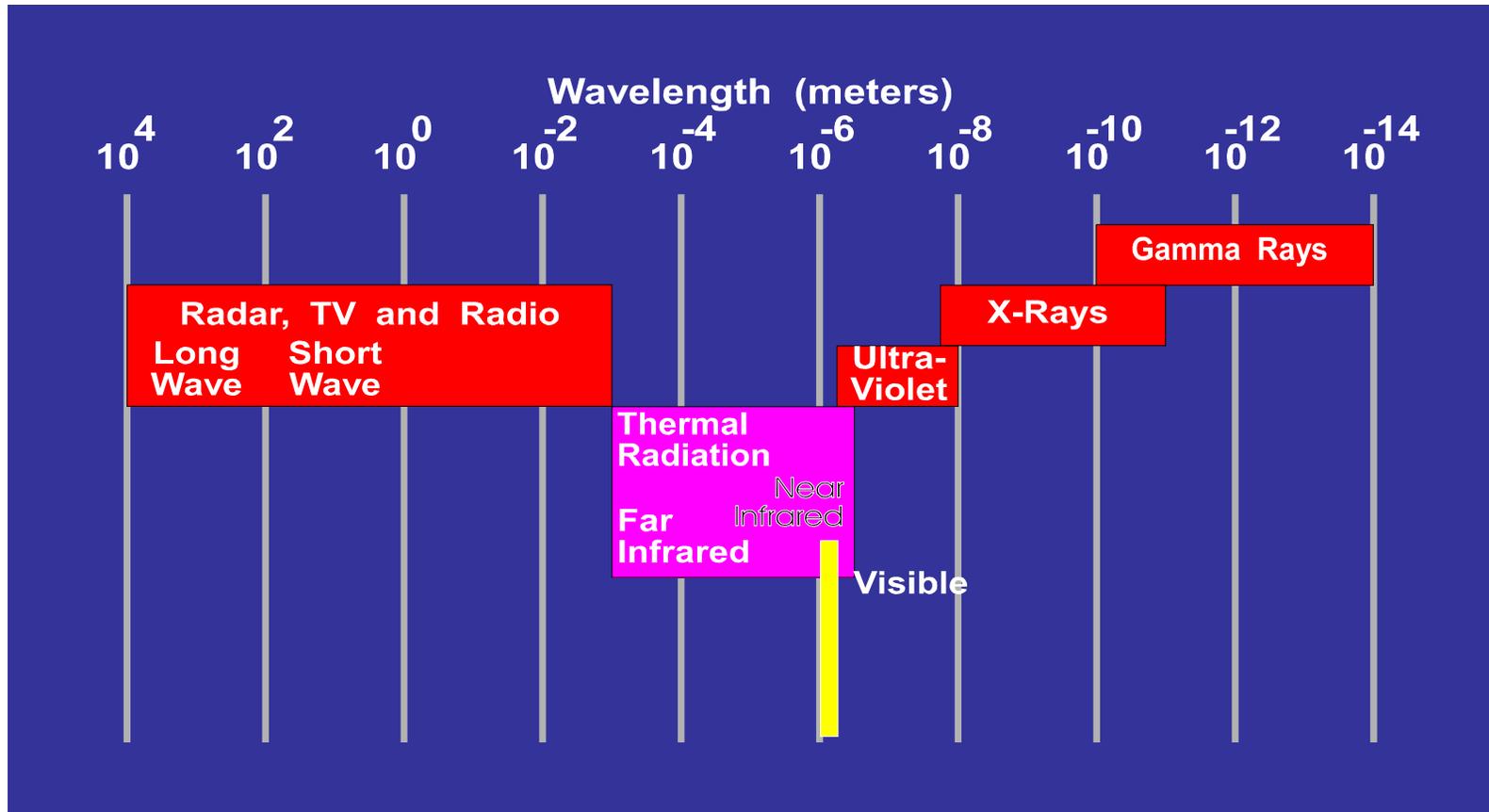
Window J

Triple Glazing, Low-Solar-Gain Low-E
VT=0.56 (center of glass), 0.40 (window)

Source: Residential Windows, 2nd Ed. 2000

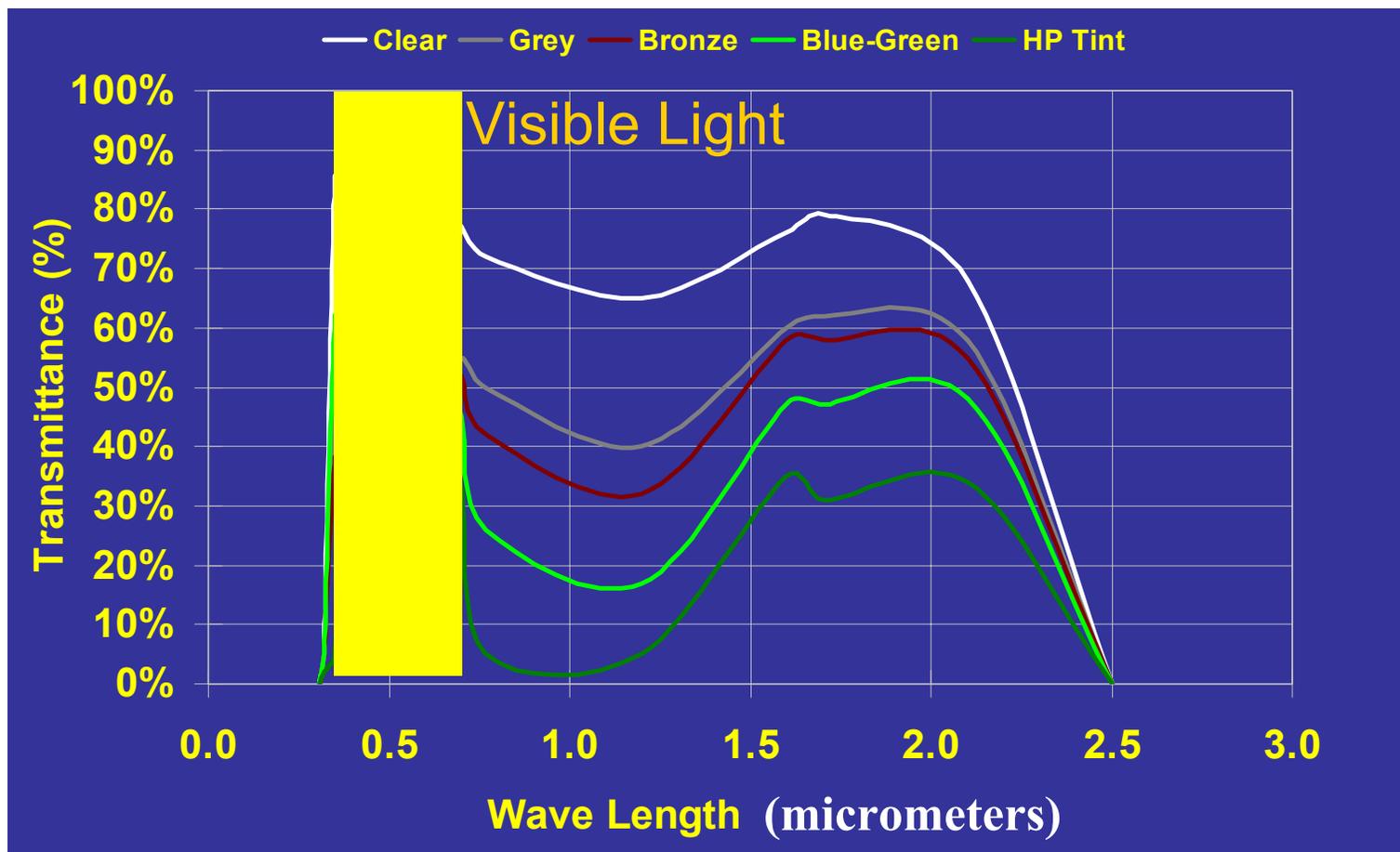


Electromagnetic Spectrum





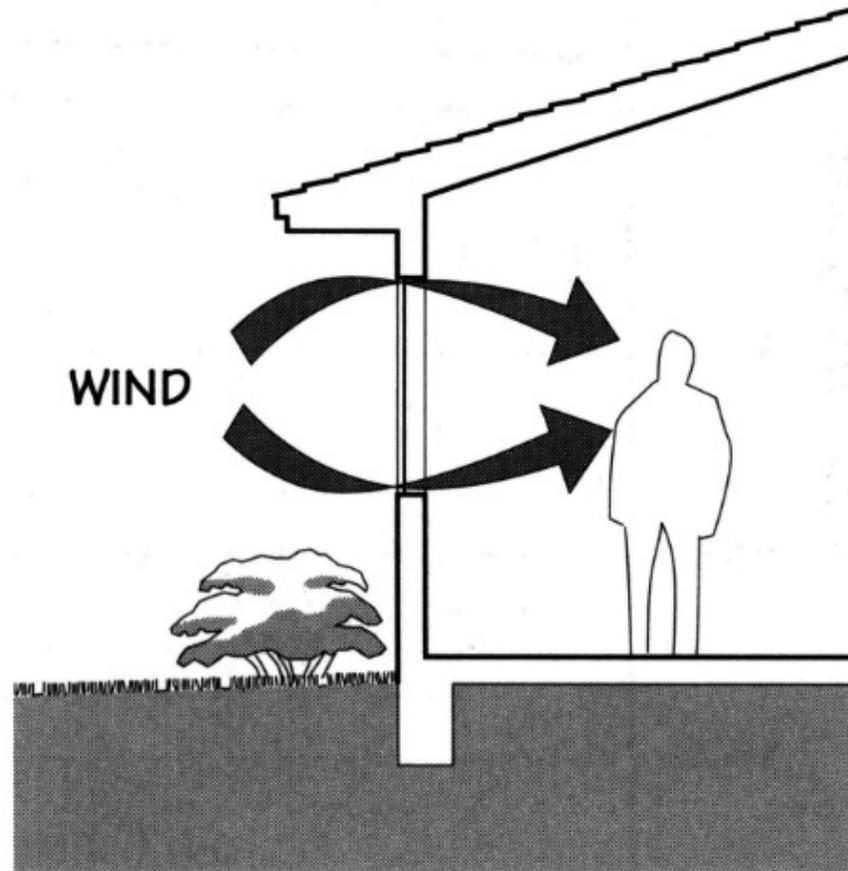
Transmission of Glazing Materials





Air Leakage

- Pressure difference created by wind is a major influence on air leakage through cracks in the window assembly.
- Wind exposure is determined by house location and site design.



Source: Residential Windows, 2nd Ed. 2000



National Fenestration Council Ratings





Glazing Materials

Glass	Plastic
Extremely durable and maintenance free	Less brittle than glass; does not shatter
Can tolerate higher or lower environmental temperatures	Lighter weight than glass, reducing structural requirements for frames
Non flammable but may shatter in a fire	May melt in a fire and give off toxic fumes
Can be coated easily	Can screen out virtually all ultraviolet radiation
Impermeable to gases and moisture	

Source: Residential Windows, 2nd Ed. 2000