



Building Science Bootcamp Key Window Concepts

Strategies Designed for Mountain West Climates



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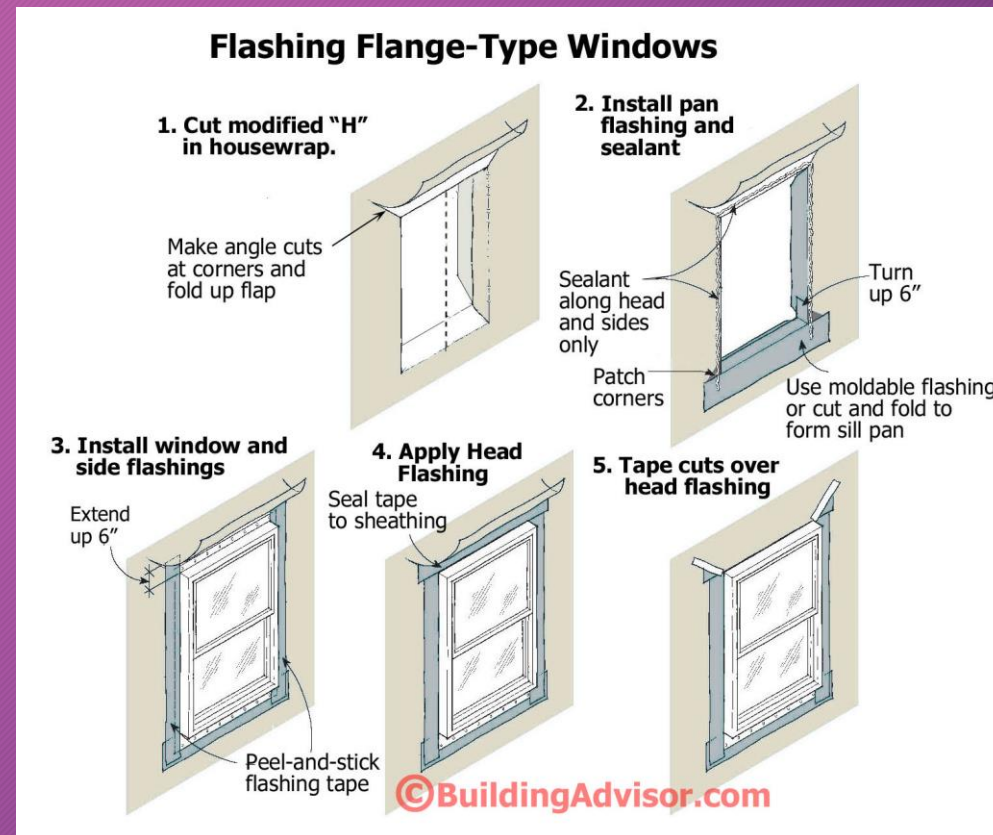
Key Window Concepts

Fenestration Detail Concerns

Back to Basics:

Air-and-Water Mitigation:

- Proper flashing details should be more consistent,
- Windows/doors not always integrated into house wrap,
- Errors & omissions more common when homeowners act as their own “General Contractor”.



Key Window Concepts Fenestration Detail Concerns

Requires Integration Between Trades/Subs:

- Sub-contractors who install windows and doors must complete house-wrap at the same time,
- Staging/timing is challenging... with gaps between stages of construction & crews.

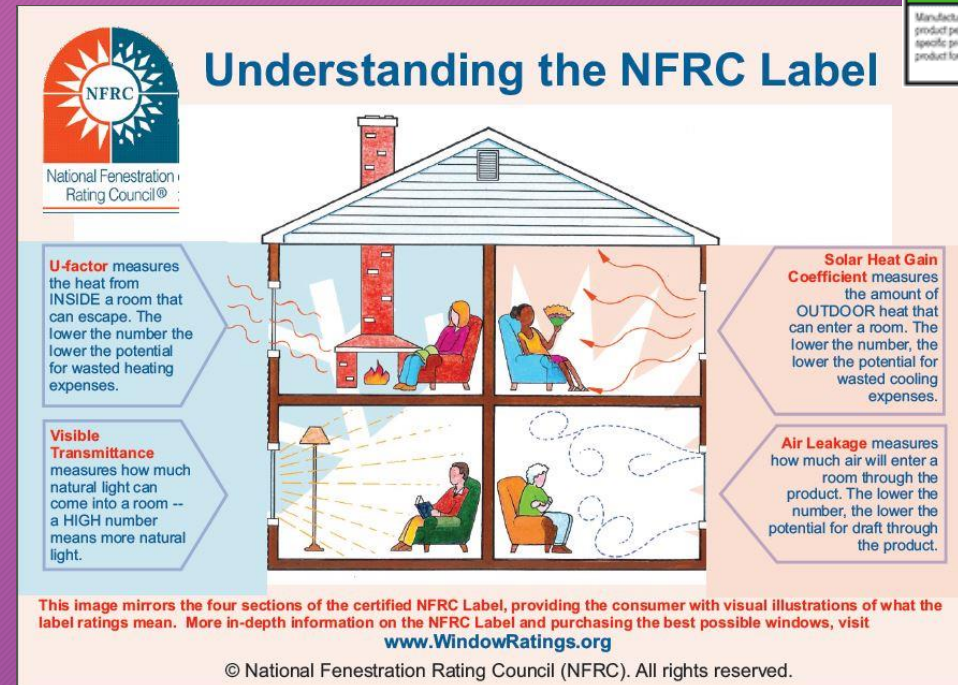


Above: Properly integrated & flashed

Key Window Concepts Energy Performance Ratings

NFRC Window Specs*:

- U-factor measures energy transfer as a percentage, and lower is better,
- U-factor is the *INVERSE* of the R-Value:
(i.e. $0.35 \text{ U-factor} (1/.35) = R\text{-value } 2.8$)
- Solar Heat Gain Coefficient (SHGC) measures the percentage of radiant energy that passes through the glass,
- Visible-light transmittance measures “brightness” of natural light,
- AIR-LEAKAGE measures the rate of air-infiltration in or out of the home.



 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 (U.S. / I-P) 0.35	Solar Heat Gain Coefficient 0.32
ADDITIONAL PERFORMANCE RATINGS	
Visible Transmittance 0.51	Air Leakage (U.S. / I-P) ≤ 0.3
<small>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</small>	

**Window Orientation, Overhangs, Shading, and Exposure to Wind have Significant Effects on Heating & Cooling*

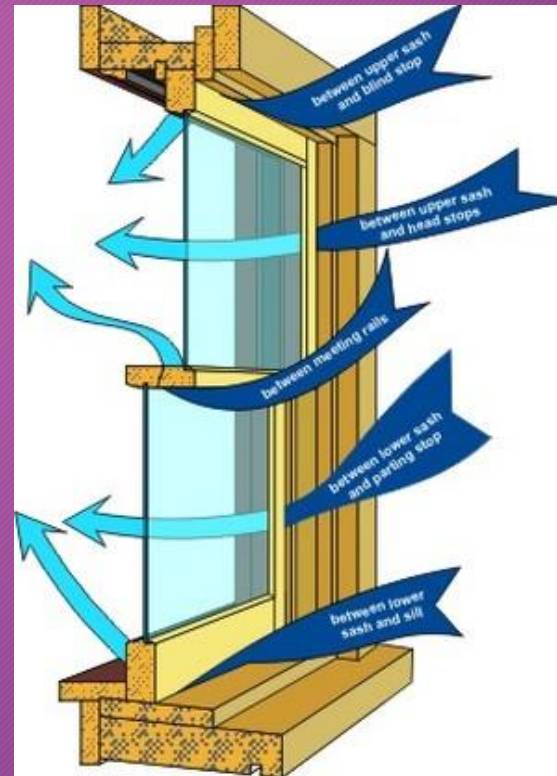
Key Window Concepts

Energy Performance - Air Leakage

How leaky (or tight) are the lowest-cost contractor-grade windows?

CFM per sq-ft of window = 0.3 cfm sf
0.3 cfm X 4'x4' slider = 5 cfm each,
20-windows x 5 cfm each = 100 cfm total,
100 cfm X 60 min = 6,000 c-ft per hr

A 1/3 of a building's allowable air-leakage budget can come from lowest-cost contractor-grade windows!



Series 9000, Single Slider, XO Operation, 59.5 x 71.5, 1" Setback Nail Fin, White Frame Color, 1/8" Low-E 366, 3/16, Clear, Argon Gas, WOOD, Screen and Service, U-Factor = 0.31, SHGC = 0.21, VT = 0.5, STC/OTC = 33/28 Overall Dimensions: 59.5" x 71.5" Rough Opening: 60" x 72"

ENERGY PERFORMANCE RATINGS	
U-Factor (U.S./I-P)	Solar Heat Gain Coefficient
0.31	0.21
ADDITIONAL PERFORMANCE RATINGS	
Visible Transmittance	Air Leakage (U.S./I-P)
0.5	0.3
Condensation Resistance	
53	-

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

Key Window Concepts

Energy Performance - Air Leakage



Worst: Tilt-to-clean

\$\$ Air-leakage: >0.3



Avg: Sliders/D-hung

\$ Air-leakage: 0.1 - 0.2



Best: Casement

\$\$\$ Air-leakage: 0.01- 0.05

Sliding windows and glass doors which operate either vertically or horizontally generally allow the most air exchange due to design trade-offs that allow the units to open and close using reasonable effort.

Key Window Concepts

Energy Performance - Durability

Tilt-to-Clean Windows are the leakiest and fail sooner than other window styles, especially in Colorado with our wide daily temp-swings and intense solar degradation.



Spring-loaded vinyl tracks warp and lose tension over time, and often fail before the end of the window's useful life.

Key Window Concepts

Energy Performance - Air Leakage

The Case for Casements and Tighter Windows:

Multiple latches compress seals,
Wind pressure actually make them
seal tighter during windy storms,

Examples;

Gerkin Windows: = 0.04 cfm per sf

Alpen windows: = 0.01 cfm per sf



Key Window Concepts

Energy Performance - Solar Heat Gain

Overlooked Opportunities:

- Orientation really changes the heating and cooling loads of buildings,
- Use overhangs (eaves, porches, etc.) to keep the glass out of the summer sun,
- Solar Gain can be customized to greatly improve comfort and efficiency,
- Floor to ceiling, and wall-to-wall = high window ratios makes for challenging climate control.



Window ratings for solar-heat-gain can be prescriptive depending on orientation. Green builders use high-solar-gain on south facing windows (w/ ample overhangs) for passive winter heating, and low-solar-gain on east and west facing windows for better summer cooling. No single window spec is best for every orientation.

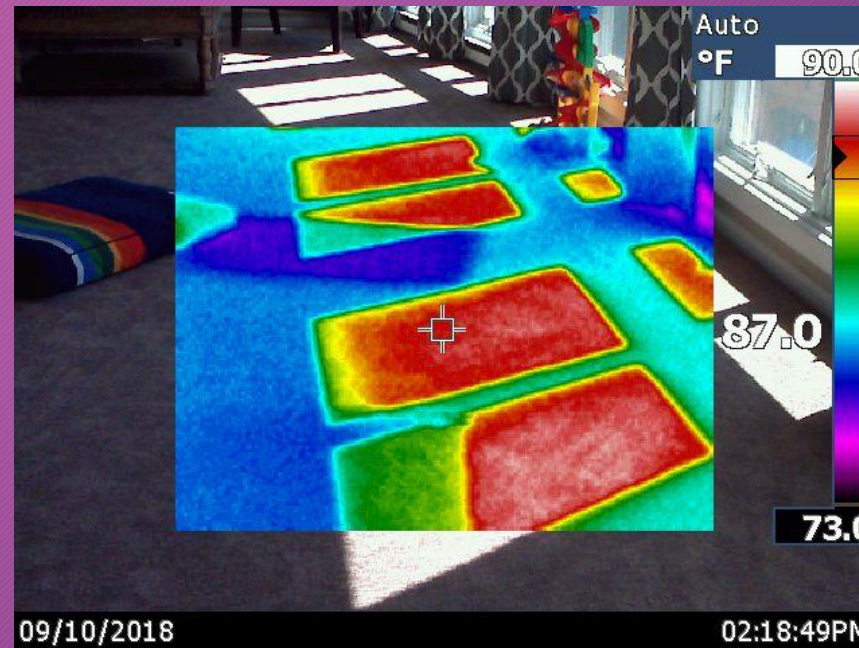
Key Window Concepts

Energy Performance - Solar Heat Gain

By 1988, about 20% of new windows had Low-E coatings, but...



Builders did not consistently install early Low-E windows until 2004:



High solar gain windows can be beneficial in winter, but must have southern orientation with adequate overhangs to avoid summer cooling problems.

Windows that Work Better

Five Versions of Low-E Glass

Glass Description:	U-factor air/argon	Solar-heat-gain	Visible-light
Best for East/West Facing			
Cardinal LoE ³ -366®	0.29 / 0.24	0.27	65%
Cardinal LoE ² -270®	0.30 / 0.25	0.37	70%
Best for South Facing (w/eaves)			
Cardinal LoE-180®	0.31 / 0.26	0.69	79%
Cardinal LoE-i89®	0.33 / 0.29	0.75	80%
North: Triple-Pane LoE-180®	0.19 / 0.15	0.56	70%

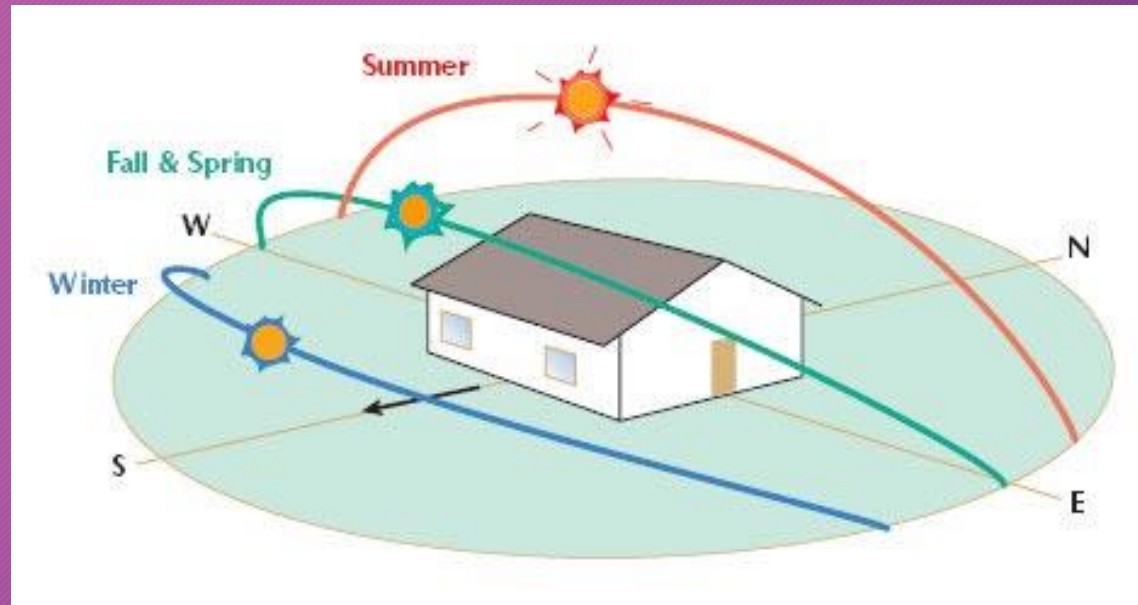
<https://www.cardinalcorp.com/technology/reference/technical-glass-guide/>

Key Window Concepts Orientation for Colorado



Advantages of Proper Orientation and Overhangs:

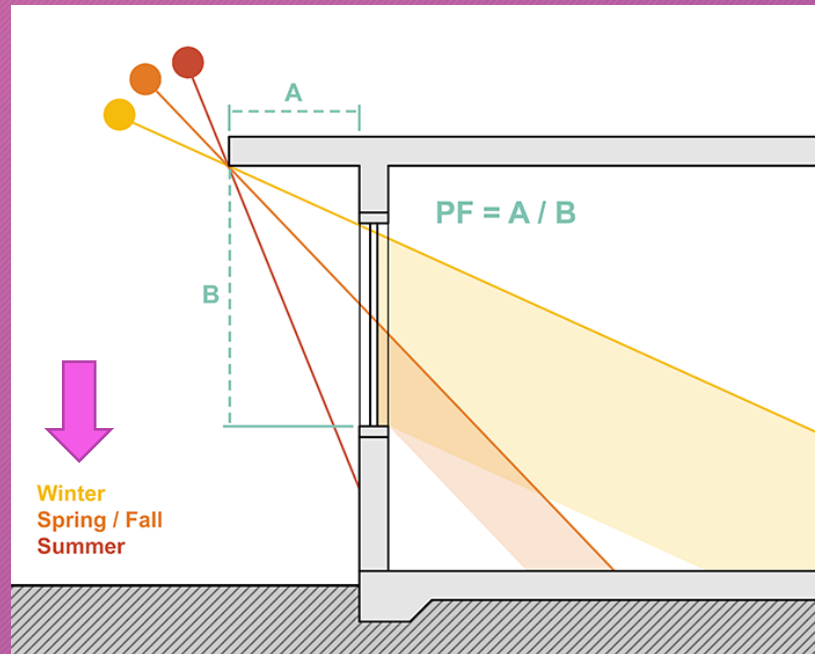
- Southern solar-gain in winter offers free daytime heating,
- Reduced east/west solar gain in summer lowers cooling costs and improves summer comfort,
- Minimize north-facing heat losses in winter with fewer windows,
- One-size-fits-all window specs missed opportunity in Colorado.



Key Window Concepts

Control Solar-Heat-Gain by Season

Projection Factor = A / B



Overhangs designed to reduce summer solar heat gain coefficient:

SHGC Multipliers for Permanent Projections

Adapted from Table 5.5.4.4.1 of ANSI/ASHRAE/IES Standard 90.1 (2007 through 2016 editions).

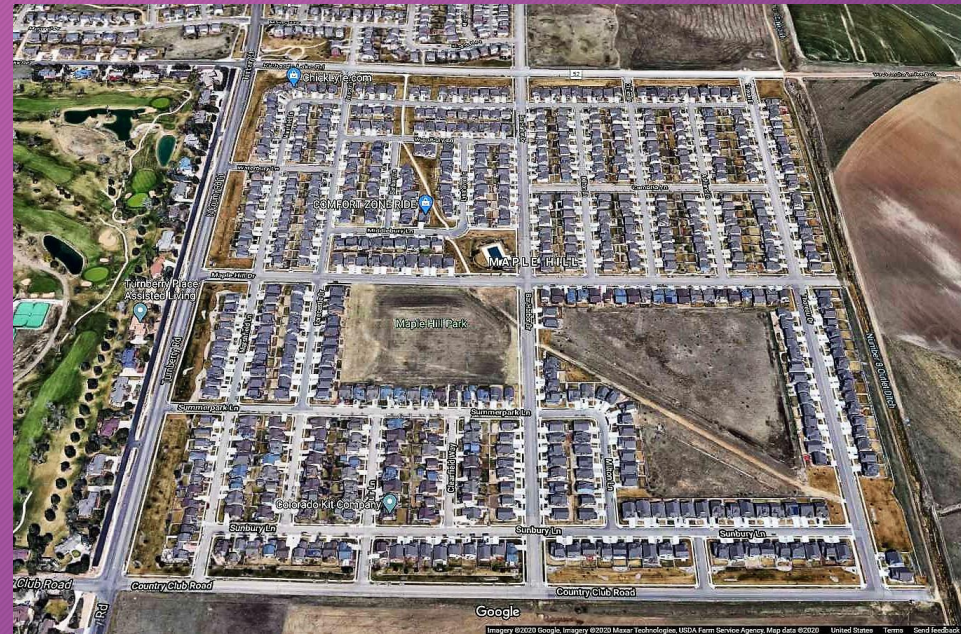
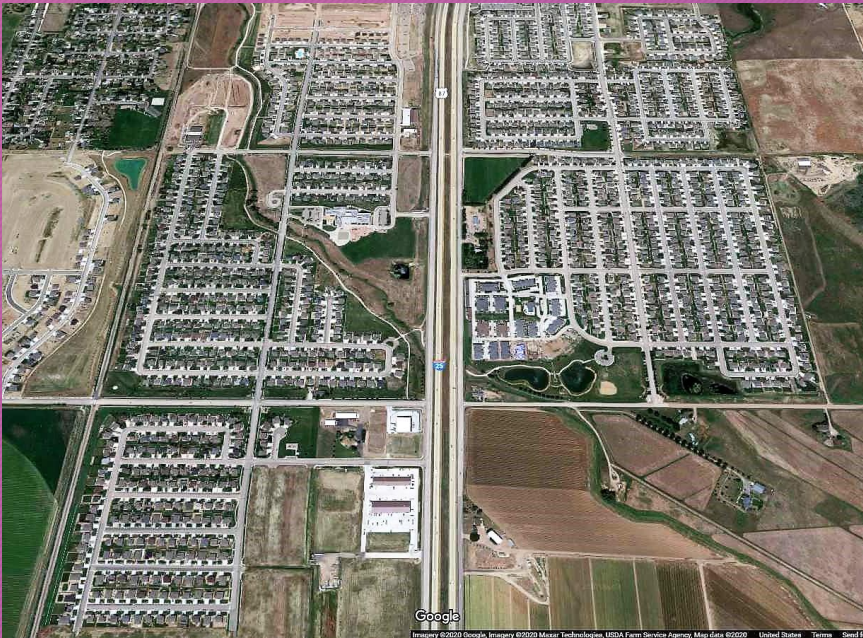
Projection Factor (PF)	SHGC Multiplier (South, East and West Orientations)	SHGC Multiplier (North-Orientations*)
0.00-0.10	1.00	1.00
>0.10-0.20	0.91	0.95
>0.20-0.30	0.82	0.91
>0.30-0.40	0.74	0.87
>0.40-0.50	0.67	0.84
>0.50-0.60	0.61	0.81
>0.60-0.70	0.56	0.78
>0.70-0.80	0.51	0.76
>0.80-0.90	0.47	0.75
>0.90-1.00	0.44	0.73

**North-orientation multiplier is omitted from the 2016 edition of ANSI/ASHRAE/IES Standard 90.1.*

A window with a 3-ft overhang has 15% less solar-gain than with a 2-ft overhang.

Key Window Concepts Orientation for Colorado

“It appeared that the power of the sun was not considered as houses were sited (oriented with regard to the sun’s path) or designed (window type, placement, sizing, shading). This resulted in temperature control problems, overheating and glare complaints, and helped drive the growth in air conditioning.” City of FC Building Code Study



Entire subdivisions with worst-case orientation for solar gain in summer, and absent desired solar gain in winter:

Key Window Concepts Orientation for Colorado

Worse-case orientation with an entire subdivision facing *SOUTHWEST*:



Large custom homes facing with high cooling costs facing *SOUTHWEST*:



Windows that Work Over-Glazing in New Construction

What happens when we have
too much glass facing the
wrong way...?



One house with FIVE
air-conditioning
systems!

Key Window Concepts

Over-glazing in New Construction

What's the Actual R-value?

What's the weighted average R-value of typical residential wall?

$U\text{-avg} = ((U1 \times A1) + (U2 \times A2)) / \text{Total Area}$

Let's do the math for area circled in red:

Wall Cavities = R20 x 140 sq ft

Wood Framing = R7 x 35 sq ft

Windows = R3 x 40 sq ft

Weighted Avg: = R7.8

Heat-Flow Losses = 13%*

**replace 100% energy lost every 8 hrs.*

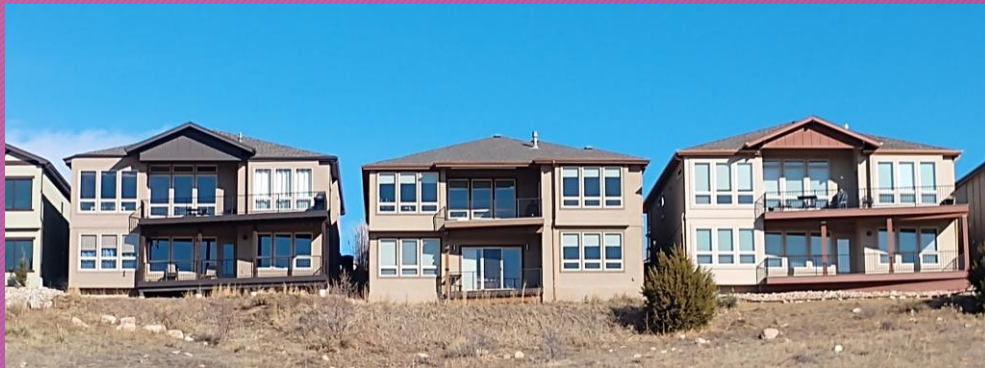


To the right of the circled area = R3.5, and also
NORTH facing = 29% heat loss per hour.

Key Window Concepts Over-glazing in New Construction

These walls and windows have a Weighted Average R-value of R-5, and Heat Flow Resistance of 80% (so 20% escapes):

Therefore...100% of the energy produced for heating / cooling escapes every 5 hours, and must be replaced nearly 5 times daily!



Key Window Concepts Over-glazing in New Construction

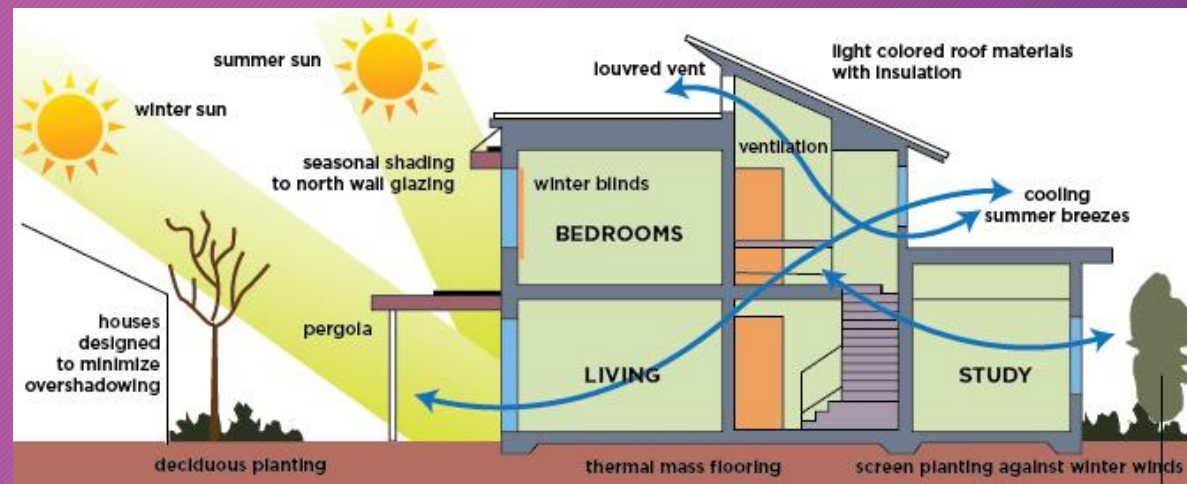
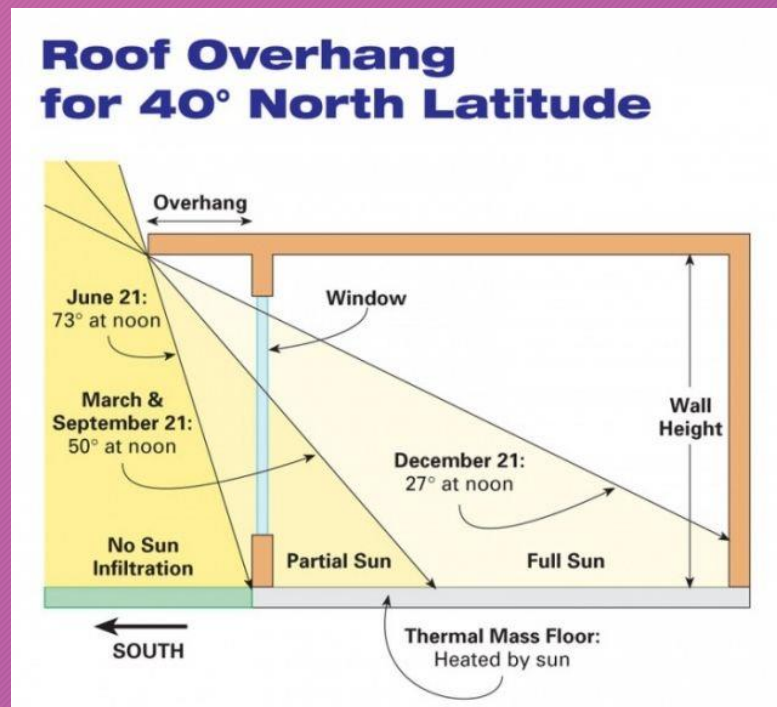


Builder used 30-barrels of closed-cell spray-foam to meet ResCheck, and still needed two large AC units.



Windows that Work Better Control Solar Heat Gain by Season

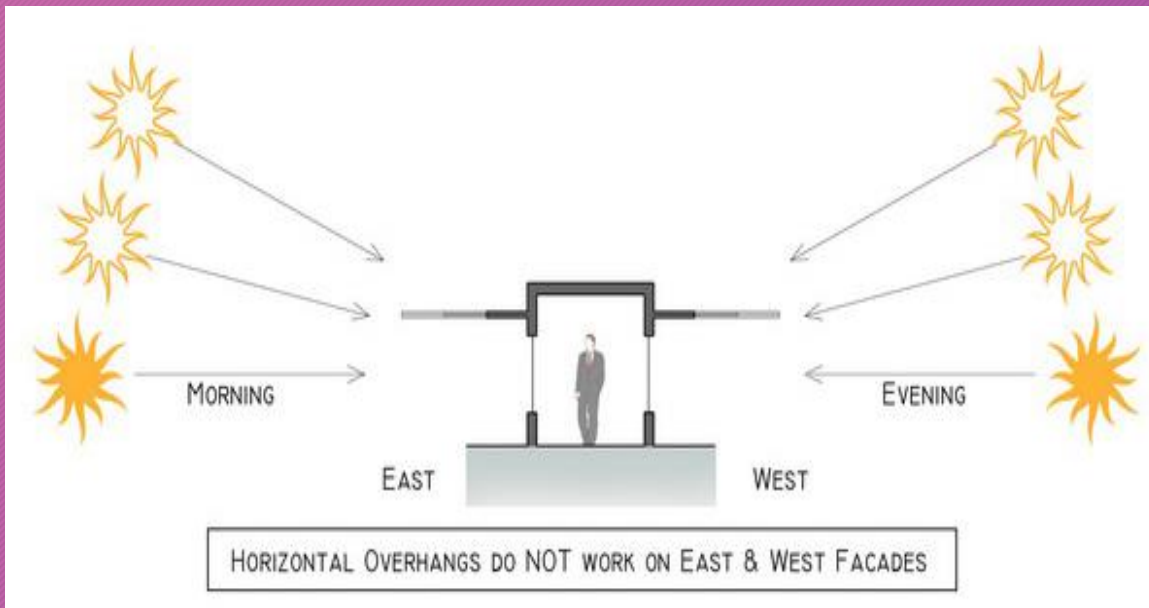
Rocky Mountain West: Ideal sunny winter weather for passive-solar heating...



They had a few things figured out in the 1970's...

Windows that Work Better Orientation for Colorado

Keep the glass out of the sun whenever possible, with fewer, smaller east/west facing windows, and use lowest solar-gain windows available for those windows.



Windows that Work Better Orientation for Colorado

Wide East/West facing *SLOT* windows, provide panoramic views while high on the wall, and shaded by eaves:



Windows that Work Better

Examples of Passive Solar Homes



Building Science Bootcamp

Key Window Concepts

To Learn More about Energy Codes or Green Building, please contact:

Community Development

<https://www.larimer.org/building>

Building: 970-498-7700 or

Planning: 970-498-7683



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