WINDOW STRATEGIES IN THE SOUTHWEST

Choosing fenestration strategies matched to climate and facade can substantially improve a home's energy performance and the comfort of its occupants in all seasons.

BY LARRY KINNEY

LARRY KINNEY

Windows are wonderful devices; they enable us to see outside of our homes, provide natural light to the inside of the house, and can be opened to provide ventilation. Windows are also big business. In 2003, 66.7 million residential window units were sold—50% for replacements or remodels, and 44% for new housing. The remaining 6% went to manufactured housing and nonresidential structures. Despite their benefits, windows—particularly inefficient ones—are effectively holes in the insulated envelope through which a great deal of energy can flow. If a well-insulated wall (R-25) has 15% of its area glazed with conventional insulating glass windows (R-2), conductive losses through the windows are 2.2 times the conductive losses through the remainder of the wall. Furthermore, if the windows are not protected from direct-beam sunlight, summertime heat gain through windows can be large. In climates predominated by cooling energy needs, even fairly energy-efficient windows can account for 25% of total energy use for space conditioning—40% or more if clear glazing is unshaded.

That's the bad news. The good news is that modern window technology allows builders to choose from a wide variety of fenestration options that can turn liabilities into assets, even in quite severe climates.

Charles Lathrem is a Tucson-based custom builder whose homes have won awards for energy efficiency. He installs Andersen 400 series Fibrex composite wood-and-recycled PVC frame windows on almost all of his projects. They cost about twice as much as vinyl windows—roughly $25/ft^2—but Lathrem uses them for several good reasons. He and his clients find them more attractive; he can get larger windows with comparatively smaller frames (large vinyl windows require auxiliary mullions down the center to meet mechanical codes); and Fibrex frames tend to last longer in Tucson's intense sun. Furthermore, overall energy performance is excellent.

Unlike most production builders, Lathrem matches glazing characteristics to facades—and he uses shading devices. He uses Sun Low-E windows on all facades not protected by awnings. These windows have a U-factor of 0.32, a solar heat gain coefficient (SHGC) of 0.26, and a visual transmittance (Vt) of 0.32 (see "Window Technology," p. 56). Windows protected by awnings have a higher SHGC—0.36—because direct beam is blocked out in the cooling season by awnings, and they enjoy a higher Vt—0.59. The added diffuse daylighting allows homeowners to use less electric lighting during the day—and enhances the view.

TABLE 1. SIMULATION RESULTS OF A CLEAR 2-PANE UNIT

	North		East and West		South		Totals				
City	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Peak kW	Annual $	% of Total $
Albuquerque	251	6.71	1,219	2.35	465	-4.34	1,935	4.72	1.35	$192	37
Cheyenne	101	9.48	535	8.77	240	- 1.78	876	16.47	1.48	$214	26
Denver	168	7.10	910	6.50	431	-2.05	1,509	11.55	1.62	$225	36
Las Vegas	509	2.33	2,317	0.95	924	-2.81	3,750	0.47	2.55	$339	51
Phoenix	652	1.22	2,936	1.14	1,308	-0.82	4,896	1.54	2.88	$383	54
Salt Lake	245	6.39	1,214	7.18	502	-0.31	1,961	13.26	2.06	$262	37

Note: This table is provided for comparison purposes only. Clear glass is not recommended for use in either new or existing homes because high-performance low solar gain low-e glass is more cost-effective.

TABLE 2. SIMULATION RESULTS OF A LOW SOLAR GAIN LOW-E 2-PANE UNIT

	North		East and West		South		Totals				
City	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Peak kW	Annual $	% of Total $
Albuquerque	143	3.67	711	1.69	263	-2.86	1,117	2.50	1.00	$ 118	31
Cheyenne	49	6.68	259	6.43	113	-0.66	421	12.45	1.01	$144	22
Denver	100	5.21	493	4.75	221	- 1.21	814	8.75	1.14	$145	28
Las Vegas	309	1.80	1,382	-0.80	547	-2.71	2,238	-1.71	1.67	$183	37
Phoenix	400	0.94	1,760	0.71	774	-0.89	2,934	0.76	1.83	$227	42
Salt Lake	141	4.66	694	5.07	280	-0.18	1,115	9.55	1.42	$168	30


ROSS DEPAOLA

Replacing single-pane windows like the ones this house features with more efficient units can increase comfort and decrease energy costs.

Annual Performance in the Southwest

To compare window options in different southwestern climates, I used an hourly simulation program called RESFEN (short for residential fenestration). RESFEN is based on DOE-2.1E software and was developed at the Lawrence Berkeley National Laboratory. It is a tool for evaluating the energy consequences of various fenestration systems in a number of cities, using typical meteorological year weather data. I made a number of runs on homes in southwestern cities with RESFEN Version 3.1, using windows of various characteristics. In all cases, I assumed a single-story, frame, 2,000 ft^2 home with 300 ft^2 of fenestration distributed evenly on the four facades of the home. Homes in Albuquerque, Las Vegas, and Phoenix were assumed to have slab-on-grade construction; those in Cheyenne, Denver, and Salt Lake City had basements. The homes in Albuquerque, Cheyenne, Denver, and Salt Lake City had attics insulated to R-38 and walls insulated to R-19; attics in Las Vegas and Phoenix had R-30 insulation and walls of R-14 and R-11 respectively. Furnace seasonal efficiency was assumed to be 78% and cooling systems were 10-SEER. Duct leakage was set at 10% during both summer and winter. (The Southwest Energy Efficiency Project, where I work, counts as the Southwest Colorado, New Mexico, Arizona, Nevada, Utah, and Wyoming.)

I modeled six fenestration systems with the following characteristics:

1. A double-pane insulating-glass unit with clear glass and non-thermally-broken aluminum frame with an overall window system U-factor of 0.79 and a SHGC of 0.68 (clear two-pane).
2. A spectrally selective, double-pane insulating-glass unit with an overall window system U-factor of 0.5 and a SHGC of 0.4 (low solar gain low-e two-pane).
3. The same spectrally selective, double-pane insulating-glass unit with the addition of (1) interior shades resulting in a SHGC multiplier of 0.8 in summer, no shades in winter; (2) 2-ft exterior overhangs; and (3) exterior obstructions of the same height as the window 20 ft away that represent adjoining buildings or fences (shaded low solar gain low-e two-pane).
4. A spectrally selective double-pane insulating-glass unit with an overall window system U-factor of 0.34 and a SHGC of 0.34 (better low solar gain low-e two-pane).
5. A spectrally selective triple pane insulating-glass unit with an overall window system U-factor of 0.24 and a SHGC of 0.25 (high-performance three-pane).
6. The low solar gain low-e two-pane window with an exterior insulating shutter that brings the window

system to a U-factor of 0.1 when closed (low solar gain low-e two-pane with shutters). The shutter was assumed to be closed during the night in summer and winter and open during the day in winter, but selectively closed during the day in summer by an automated system that shields windows from direct-beam sunlight as the sun traverses the sky. It was assumed that the automated system was overridden by users 10% of the time. During periods in which direct beam would otherwise enter the glazing of a given facade, SHGC was assumed at 0.05. At all other times, SHGC was assumed at 0.4, the SHGC of the low solar gain low-e two-pane window.


BILL HAYS

In climates dominated by cooling energy needs, even fairly energy-efficient windows can account for 25% of the total energy used for space conditioning. Choose windows wisely.

The shutters analyzed for the final fenestration system are still in the prototype development stage and are not currently in production. However prototypes have been extensively tested during both summer and winter by a team from the Syracuse Research Corporation with funding from DOE. The system achieves good air seals and results in system insulating values of above R-10 (U-factor of 0.1). The aim is to produce units that are easily installed by the builder at a cost of under $30/ft^2. Current development

WINDOW TECHNOLOGY

Windows transfer energy by radiation, conduction, and convection. Under many conditions, radiation predominates. Our eyes see only a narrow range of that radiation, slightly less than half of the solar spectrum. Over the last several decades, manufacturers have developed the means to produce windows that selectively filter portions of the spectrum. The technique involves depositing very thin layers of metal on a surface of glass or a plastic substrate, typically using a sputtering process in a partial vacuum. First generation systems resulted in "low-e" coatings or films that are highly reflective of long wavelength radiation associated with room temperatures. Windows with these conventional low-e coatings let through most of the sun's radiation, but reflect back into the house radiation from interior sources. The result is good performance of the window system in the wintertime, since it lets in the whole spectrum of solar radiation yet keeps in radiation from objects that are indoors.

Newer window technology can be much more carefully tuned to filter just the wavelengths desired. For example, it is possible to filter only the infrared and ultraviolet portions of the spectrum while allowing most of the visible portions to be transmitted. This style of spectrally selective window keeps out a large portion of the radiation that would heat the interior of a home, while allowing unobstructed viewing and substantial daylighting. This type of window is ideal for the Southwest, as well as any areas where cooling concerns are primary.

Windows also lose energy by conduction and convection. Windows with high insulation values provide several benefits. During cold weather, they are significantly warmer on the inside surface than are windows with low insulation values, reducing the chances of moisture condensing on them. Occupant comfort is increased, thermostat setpoints can be lowered, and the home's heating system may be downsized. During the summer,

TABLE 3. SIMULATION RESULTS OF A SHADED LOW SOLAR GAIN LOW-E 2-PANE UNIT

	North		East and West		South		Totals				
City	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Peak kW	Annual $	% of Total $
Albuquerque	53	4.06	269	4.20	63	-1.57	385	6.69	0.66	$ 99	21
Cheyenne	10	7.44	46	10.17	11	1.34	67	18.95	0.65	$184	21
Denver	32	5.74	148	7.63	39	0.18	219	13.55	0.76	$142	24
Las Vegas	190	2.02	577	1.64	231	-2.26	998	1.40	1.10	$105	22
Phoenix	241	1.08	892	1.22	336	-0.97	1,469	1.33	1.12	$126	26
Salt Lake	63	5.19	283	7.32	72	1.02	418	13.53	0.88	$162	25

TABLE 4. SIMULATION RESULTS OF A BETTER LOW SOLAR GAIN LOW-E 2-PANE UNIT

	North		East and West		South		Totals				
City	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Peak kW	Annual $	% of Total $
Albuquerque	124	2.46	612	0.05	223	- 2.16	959	0.35	0.81	$ 83	19
Cheyenne	41	4.47	213	3.06	92	- 1.78	346	5.75	0.89	$ 76	11
Denver	83	3.52	410	2.11	181	-2.03	674	3.60	0.98	$ 86	17
Las Vegas	261	1.19	1,167	-0.59	463	-2.73	1,891	-2.13	1.36	$148	30
Phoenix	331	0.63	1,485	0.21	652	-0.98	2,468	-0.14	1.49	$181	36
Salt Lake	122	3.16	592	2.58	237	-1.04	951	4.7	1.20	$109	19

work includes automating shutter operation via wireless technology.

Using RESFEN, I was able to model energy gains and losses that are due to the window systems alone (see Tables 1–6, starting on p. 55). In particular, I examined the total heating and cooling energy flows and costs represented by windows alone. (Analyses are based on each city's local energy cost and weather data.) The last columns in the tables show the portion of total energy use for heating and cooling represented by the windows systems. Inefficient window systems (aluminum frames, clear glass, even if double-pane) can account for 26%–54% of energy use for space heating and cooling (see Table 1). These systems were shown to have annual costs of $192 (in Cheyenne) to $383 (in Phoenix) in a standard 2,000 ft^2 air-conditioned home. The use of better windows, with better frames and low SHGC, can cut energy use attributable to windows by an average of 58%. Excellent windows can save from 66% ($252 per year) in Phoenix to 77% ($164 per year) in Cheyenne (the difference between Tables 5 and 1). Finally, the use of automated insulating shutters along with low solar gain low-e results in

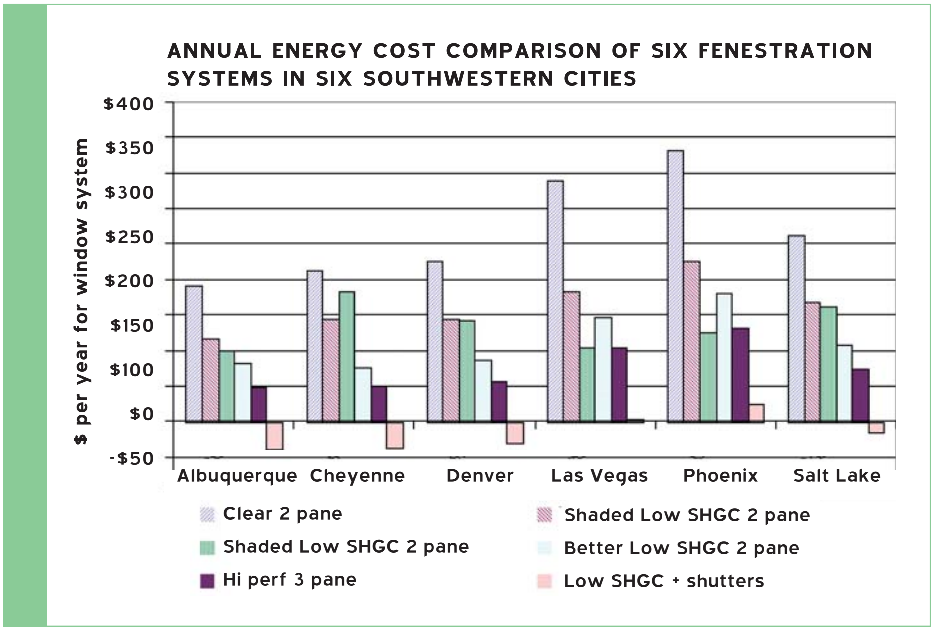
well-insulated windows (particularly those that also have low solar heat gain coefficients) are more comfortable, thereby allowing for higher thermostat set points and downsizing of the cooling system.

The National Fenestration Rating Council (NFRC) rates windows and doors on five measures related to energy performance. Sticky-backed NFRC labels should be prominently displayed on all doors and windows for sale in this country. The labels will include the following factors:

Solar heat gain coefficient (SHGC) is the fraction of solar heat transmitted through a window system (plus absorbed energy that ends up supplying heat inside) with respect to the amount of solar heat that would flow through an unimpeded opening of the same size. It is a dimensionless number that can range between 0 and 1. SHGC's of clear single and double-glazed window systems run from 0.7 to 0.9, whereas windows with spectrally selective glazing typically run from 0.2 to 0.5.

Visual transmittance (Vt) is the fraction of visible light transmitted through a window system with respect to the amount of visible light that would flow through an unimpeded opening of the same size. It is also a dimensionless number that can range between 0 and 1. Vt of clear single and double-glazed glass run from 0.8 to 0.9, while heavily tinted glass can have a Vt of 0.1 or even lower. The Vt of double-glazed spectrally selective glass typically runs from 0.4 to 0.7. A typical spectrally selective window system suitable for the Southwest might have a Vt of 0.55 and a SHGC of 0.35.

The U-factor represents the conductivity of a window system. The lower the U-factor, the better. The U-factor is the reciprocal of R-value and is the rate of heat loss through a window system (which counts its frame) measured in Btu per hour per square foot per degree Fahrenheit (Btu/hr•ft2•°F). U-value has the same units, but refers to the conductivity through the center of glass only. Unlike the ratings for insulation products, window U-factors and U-values include the effects of indoor and outdoor air films.



LARRY KINNEY

Figure 1. The annual energy cost associated with the windows is cut roughly in half by going from ordinary aluminum frame double pane windows to spectrally selective low solar gain low-e glass.

even lower energy use and cost in all parts of the region (see Table 6).

The use of very low SHGC windows (or fixed shading devices, for example) can further reduce energy use and cost in very hot climates, but not necessarily in colder climates (see Tables 3 and 4).

These results show that the type of window system makes a very big difference in the energy performance and cost to heat and cool dwellings in the Southwest. Note that cooling energy associated with the east and west facades is 1.5 to 2 times the cooling energy associated with the north and south facades, whether or not windows are equipped with shading devices. Differences in the annual cost of energy associated with each fenestration system in the six cities analyzed are shown graphically in Figure 1.

The annual energy cost associated with the windows is cut roughly in half by going from ordinary aluminum frame double pane windows (which are quite common throughout the Southwest) to spectrally selective low solar gain low-e glass. Also note that the better low solar gain low-e system (Table 4) achieves good performance in all of these Southwestern cities. In Las Vegas and Phoenix, the shaded system results in even better performance, however. In all climate areas, significant energy improvements result with the high-performance triple-glazed system, and the effect of insulating shutters is even more significant, producing net energy and positive dollar flow in all regions save for Phoenix and Las Vegas, where shading costs are quite small.

To better understand the effect of shading, it is useful to take a closer look at the circumstances shown in Tables 2 and 3. Both use exactly the same window system, a spectrally selective double-pane insulating-glass unit with an overall window system U-factor of 0.5 and a SHGC of 0.4 (low solar gain low-e two-pane). This window just meets IECC code requirements in hot climates. In the first case, there is no shading. In the second case, there are fixed, 2-ft exterior overhangs and exterior obstructions of the same height as the window 20 ft away that represent adjoining buildings or fences. Finally, the shaded case includes interior shades that diminish the SHGC by 20% in the summer, but which are not used in winter.


STEVEN J. BEAUCHER DESIGN

Modern window technology affords builders a wide variety of fenestration options.

In Phoenix, which is dominated by cooling loads, the same window system with overhangs and shading uses 50% less energy (and money) over the cooling season than does the unprotected window system, even though it meets the IECC code requirement of a SHGC of 0.4. In the winter, shading has a somewhat deleterious effect on passive-solar heating, so overall annual dollar savings due to shading savings in Phoenix are 45% ($101 per year). In Denver, shading results in a 73% savings in air conditioning energy and costs (as well as 0.38 kW of demand). However, since the summertime climate is much milder, these savings are almost completely negated by losses in passive solar during the substantially more severe

TABLE 5. SIMULATION RESULTS OF A HIGH-PERFORMANCE 3-PANE UNIT

	North		West		East and South		Totals				
City	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Peak kW	Annual $	% of Total $
Albuquerque	92	1.82	447	-0.24	162	-2.54	701	-0.96	0.61	$ 49	16
Cheyenne	28	3.28	133	-2.00	58	-1.46	219	3.82	0.78	$ 50	9
Denver	56	2.60	277	1.37	119	-1.66	452	2.31	0.82	$ 57	13
Las Vegas	195	0.89	863	-0.66	339	-2.24	1,397	-2.01	1.02	$104	24
Phoenix	251	0.48	1,103	0.07	474	-0.86	1,828	-0.31	1.12	$131	30
Salt Lake	87	2.33	415	1.72	168	-0.94	670	3.11	0.91	$ 75	17

TABLE 6. SIMULATION RESULTS OF A LOW SOLAR GAIN LOW-E 2-PANE UNIT WITH SHUTTERS

	North		East and West		South		Totals				
City	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Cool kWh	Heat MBtu	Peak kW	Annual $	% of Total $
Albuquerque	9	1.52	56	-2.15	26	-4.69	91	-5.32	0.22	-$39	-13%
Cheyenne	1	2.88	6	-0.62	2	-4.11	9	-1.85	0.25	-$38	- 6%
Denver	5	2.29	29	-0.60	12	-3.76	46	-2.07	0.27	-$31	-8%
Las Vegas	76	0.71	244	-1.51	104	-3.35	424	-4.15	0.49	$3	0%
Phoenix	97	0.39	307	-0.18	137	-1.11	541	-0.90	0.56	$25	7%
Salt Lake	18	2.03	74	0.17	30	-2.49	122	-0.29	0.38	-$17	-4%

winter. Accordingly, the annual dollar savings are effectively a wash—only $3 per year. This suggests that a strategy that uses awnings, shutters, or similar exterior shading devices that can be stowed when solar gain is desired would result in optimal energy performance.

The combination of high-quality glazing plus strategic shading and overhangs matched to the weather region is a winner in all climate areas. That is, using very low SHGC windows with devices that provide shading on east, south, and west facades in the cooling season is a good strategy in climates like Phoenix and Las Vegas. Higher SHGC windows on south facades in the other cities in the Southwest (particularly Cheyenne) are more appropriate because they have better solar gain in the winter. However, even in northern areas of the Southwest, modest fixed overhangs on the south and shading devices on the east and west used during the cooling season will produce the best energy performance.

Peak demand figures track overall savings, and are most significant in the hottest climates. Note that the shading option results in lower peak demand than does low solar gain windows alone in all climate areas; a belt and suspenders approach is optimal. Even in Denver and Salt Lake City, better low SHGC double-pane windows can cut peak cooling demand by 0.6–0.9 kW. This is highly important to overall demand on the electric grid, since the Southwest is growing quickly, and peak demand periods occur on hot, sunlit summer weekday afternoons. Peak demand drives the need for new power plants—and associated infrastructure.

In a new home, reduced demand owing to more efficient windows can also lead to downsized air conditioning units. A 1-ton equipment downsizing, which is possible with demand reductions of this size, translates to nearly $500 in first-cost savings. Thus, taking advantage of better windows can pay for a significant portion of the cost of the upgrade. As noted, in areas where cooling energy use predominates, shading combined with low solar gain windows can cut peak demand. However, even the use of better low solar gain low-e windows alone can cut peak demand by 1.2–1.4 kW in hot climates such as Phoenix and Las Vegas. To reduce peak demand, utilities may well want to consider providing incentives for high-quality fenestration with low SHGC glazing and tactical shading.

Reasonable Payback?

It is clear that substantial benefits are associated with more efficient glazing—increased comfort in all seasons, as well as savings in electricity, gas, and peak demand—but what are the economics associated with installing more efficient windows? It is difficult to get an accurate answer here, since window costs are a powerful function of frame type and associated hardware. Also, first cost depends on who is buying windows (builders, contractors, and consumers get different prices) and on the scale of the purchase. Non-thermally broken aluminum windows are at the lower end. Vinyl and thermally broken aluminum frames are more expensive, followed by high-quality wood, fiberglass, and composites. Since framing is more expensive than glazing, small windows tend to be more expensive on a square-foot basis than larger windows.

Nonetheless, to focus on the cost of energy saved, it is useful to look at the /ft^2 difference in cost between a standard insulating glass unit of, say, 10–16 ft^2 and a high-quality unit suitable for the Southwest. I examined the savings, incremental costs, and simple payback associated with the better low solar gain low-e two-pane window system (U-factor and SHGC both 0.34) versus the standard insulating glazing unit with non-thermally broken aluminum frames (U-factor 0.79, SHGC 0.68). (Energy performance of these systems is shown in Tables 1 and 4.) An expert on energy-efficient construction reports that the incremental cost for this upgrade ranges from \$2.00 to \$2.50/ft^2. Accordingly, in analyzing paybacks, we assumed \$2.25/ft^2. Note that this cost premium is for both the low-e coating and the better window frame. I found that it is cost-effective to upgrade to high-performance windows in all parts of the region (see Table 7). The simple payback period ranges from 3.3 years in Phoenix (mostly because of the improved SHGC) to 6.2 years in Albuquerque's milder climate.

TABLE 7. SAVINGS, INCREMENTAL COSTS, AND PAYBACKS OF UPGRADING FROM CLEAR 2-PANE UNIT TO BETTER LOW-E 2-PANE UNIT

City	Electric Savings (kWh/yr)	Gas Savings (MBtu/yr)	Demand Savings (kW/yr)	Savings (\$/yr)	Upgrade Cost (\$)	Simple payback (years)
Albuquerque	976	4.37	0.54	\$109	\$675	6.2
Cheyenne	530	10.72	0.59	\$138	\$675	4.9
Denver	835	7.95	0.64	\$139	\$675	4.9
Las Vegas	859	2.60	1.19	\$191	\$675	3.5
Phoenix	2,428	1.68	1.39	\$202	\$675	3.3
Salt Lake	1,010	13.26	0.86	\$143	\$675	4.7

ROSS DEPAOLA

An upgrade to a better-insulating window makes sense in a place like Denver where window condensation can create problems.

It is possible to reduce solar gain to even lower levels than those illustrated in the above examples. A new two-pane window system achieves a SHGC of 0.2 through a combination of improved coating and moderate tinting. These windows, which have a U-factor of 0.34, cost an extra \$1/ft^2 for the glass, bringing the assumed cost of the upgrade to \$3.25/ft^2.

In this case, the payback ranges from 4 to 11.8 years. Paybacks are marginal in Cheyenne and Albuquerque, owing to mild summers in Cheyenne and overall mild weather in Albuquerque. The best paybacks are in Phoenix (4 years) and Las Vegas (4.4 years), where cooling loads dominate and the very low SHGC is most effective.

This prompts the question of whether it is cost-effective to upgrade from the better two-pane window system ($U = 0.34$ and $SHGC = 0.34$) to the very best low SHGC window system ($U = 0.34$ and $SHGC = 0.2$) at an incremental cost of \$1/ft^2. For the homeowner, this is reasonable only in Phoenix and Las Vegas, where paybacks for this option are 7.5 years and 10 years respectively. In other cities, the additional heating cost exceeds the cooling benefit. But this analysis is from the consumer perspective. From the perspective of the electric utility, the peak demand and electricity savings are worth considerable money—on the order of \$75 to \$85 per year in Phoenix and Las Vegas. (Typical electric utility avoided costs in the Southwest region are \$115–\$135/kW/yr for peak demand and \$30–\$35/MWh for electricity.) Thus this upgrade is cost-effective from a societal perspective.

Market Trends

Unfortunately, many people consider double-pane clear glass windows to be energy efficient, and these windows are still in wide use. In 2003, clear glass represented 40% of the residential windows sold in the United States. (The same percentage was sold in the Mountain States region, which includes the Southwest.) Although this is down from 49% in 2001, there is still a great deal of clear glass being installed in housing—and plenty of it in existing residential housing stock. Low-e glass sold in 2003 represents 58% of the total of 5.7 million residential window units sold in the mountain states in 2003, but there are no statistics that show how many *low SHGC* low-e units were sold.

In 2003, vinyl frames amounted to 49% of the total residential market; 26% were aluminum-clad wood, 11% were vinyl-clad wood, 6% were aluminum without a thermal break, and

4% were aluminum with a thermal break. Both wood and aluminum (thermally broken and non-thermally broken) are losing market share at a high rate, primarily to vinyl. Recent advances in plastics technology have made vinyl windows more resilient to ultraviolet degradation, but their lifetime is nonetheless likely to be shorter than that of most composites, such as wood/plastic or wood/fiberglass extruded shapes.

High-performance, low solar heat gain windows can greatly reduce energy costs and peak electric demand in new and existing homes throughout the Southwest—and do so quite cost-effectively, particularly in the case of new homes where only incremental costs are considered and labor is not a consideration. (It's true that as an incremental cost in a new home, the economics of replacing windows are more attractive than with retrofits. However, a do-it-yourselfer can replace poorly performing windows with lots better windows for $\$10$–$\$12/\text{ft}^2$, realizing both better comfort and on the order of $300 annual savings in areas with severe summer weather.) Importantly, upgrading window systems would not entail changes to the building design or changes to homeowner behavior. In addition, employing well-designed shading devices can lead to even lower energy costs and peak demand, but with greater first costs and longer payback periods. Although it is not currently practiced in the building industry, the combination of low solar gain windows and automated insulating shutters could entirely eliminate the substantial energy cost associated with windows in all parts of the Southwest, but at significantly greater cost.

Larry Kinney has been involved in energy efficiency work for three decades. He is a senior researcher with the Southwest Energy Efficiency Project in Boulder, Colorado.

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FOR MORE INFORMATION:

Carmody, J., S. Selkowitz, and L. Heschong. *Residential Windows: A Guide to New Technologies and Energy Performance*. New York: W.W. Norton, 1996.

Efficient Windows Collaborative. Web site: www.efficientwindows.org. Contact: Alison Tribble, EWC program administrator, Alliance to Save Energy, 1200 18th St. NW, Ste. 900, Washington, DC 20036. Tel: (202)530-2231;E-mail: ewc@ase.org.

"Windows and Window Treatments" by Larry Kinney and "Policies and Programs for Expanding the Use of High Efficiency Fenestration Products in Homes in the Southwest" by Howard Geller are both downloadable at SWEEP's web site, www.swenergy.org.