Comparative Analysis of Retrofit Window Film to Replacement with High Performance Windows

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Abstract

Energy saving films are increasingly being used worldwide to lower building energy costs by reducing excessive solar heat gain through windows.

This paper will highlight the comparative cost savings per dollar invested for retrofit of existing windows with energy saving window film compared to window replacement with new solar-control low-e windows.

Introduction

Since the early 1960's energy saving films have been used as a means to reduce building energy costs. Energy saving window film typically consists of a thin (0.025mm, 0.001 inch) polyester film substrate that has a micro-thin, transparent metal coating applied to one side. This metal coating is applied using vacuum-based technologies such as vapor deposition or sputtering. A second layer of polyester film is laminated over the metal coating to protect the metal. A scratch resistant (SR) coating is applied onto the side of this laminated composite that faces the building interior to protect the film during normal window cleaning. An adhesive layer is applied onto the film side that faces the glass and is protected by a removable release liner until just before the film is applied to the glazing system. UV absorbers are added to the polyester film layers, the adhesive layer, or both to protect from UV degradation.

The appearance of film including color, the level of visible light transmission and degree of reflectivity are determined by the metal coating(s) used. Typical all-metal energy films can be silver-reflective, gray, silver-gray, bronze or light green in color. Visible light transmissions (VLT) can vary from very dark (10%) to very light (70%), and the visible reflectance can vary from the same reflectance as clear glass (8%) to highly reflective (60%). The ability of a glazing system to reduce solar heat gain is measured by its solar heat gain coefficient (SHGC). As expected from the variety of films available, the SHGC for window films can vary significantly, from 0.17 to 0.71, as measured on 3mm (1/8 inch) clear glass.

The Study

Due to variations that affect a building's energy consumption such as: weather changes, changes in occupancy, additions of energy consuming equipment such as computers, among other factors, it is difficult to directly (through means of metering data) and precisely measure energy cost savings following window film installation. To more accurately determine the cost benefits of energy saving window film, a comparative study was conducted, using eQUEST DOE-2 (see www.doe2.com) energy simulations, to evaluate four buildings in each of four climate zones, for a total of sixteen buildings with film and sixteen buildings with new window systems. Climate zones across the United States were selected, corresponding to the Northern, North/Central, South/Central, and Southern Climate Zones from the ENERGY STAR® Climate Map shown in Figure 1.

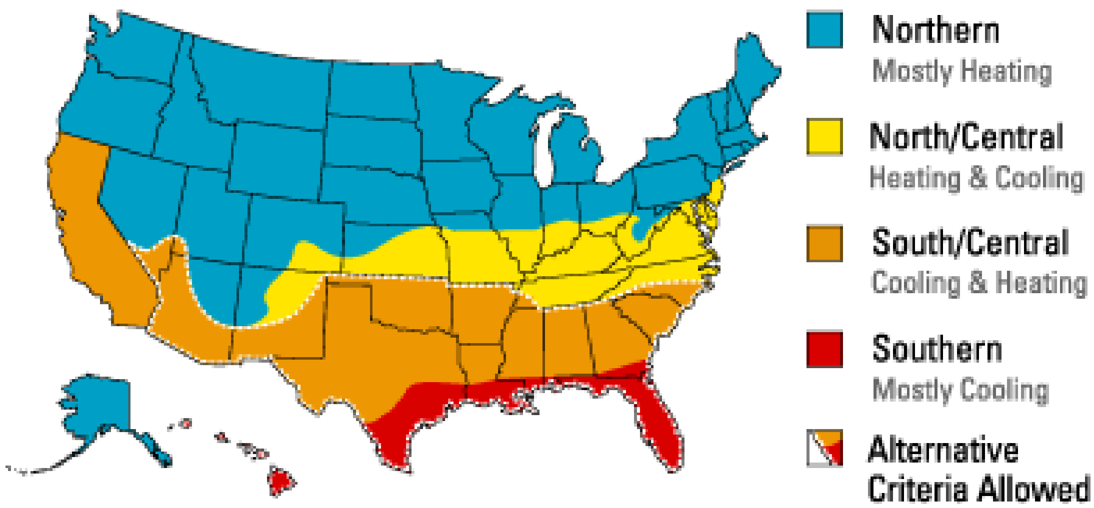

Figure 1 – ENERGY STAR® Climate Zone Map

The four buildings in each climate zone were identical, except for the existing window type. The four different window types used for the existing buildings were: single-pane clear and single-pane gray (indicative of buildings built prior to 1980), and dual-pane clear and dual-pane gray (indicative of post-1980 construction).

With regard to a building's windows, incident solar energy is either transmitted into the building space, reflected away by the glass surface and kept out of the building interior, or absorbed into the glass. A large percentage of the absorbed solar energy is transferred to the outdoors by convection (due to wind) and radiation. Single-pane clear glass provides virtually no protection from solar heat gain by rejecting only 19% of the sun's heat. Single pane clear glass has very low solar absorption and solar reflection, and therefore, offers little in the way of solar protection.

Tinted glass provides better solar energy rejection than clear glass, but at best is classified as a medium-performance glazing. While tinted glass is better performing than clear glass, it typically only rejects 35-45% of the sun's heat. Energy-saving films reject solar heat effectively by reflecting a greater portion of the sun's heat than tinted or heat absorbing glass, rejecting up to 84% of solar heat gain.

While window film are often valued in warm climates for their quick payback, in 3 years or less in many cases, payback is often affected just as much by electricity costs as climate. Therefore, use of energy saving window films should be considered in any climate with above average electricity rates, as air conditioning systems are taxed in office buildings even during cooler weather due to the high solar load through large expanses of windows.

LLumar R20, a 20% VLT silver reflective film, was selected for the study because it is one of the highest performing films in terms of solar heat rejection (81% on 3mm thick single pane clear glass), and is one of the lowest cost films available at this performance level.

Low-E^3 (low-E cubed) windows were selected for this study as it is expected that they will be considered the "standard" to meet most energy codes in commercial construction for warm and moderate climates. Low-E^2 (low-E squared) windows block less solar heat than Low- E^3 windows and are often found in North Central and Northern climate zones, since they allow more free solar heat for climates with larger heating requirements.

Conclusion

Across all climate zones, energy saving window films offer a better return on investment than low-E window replacement due to the combination of solar performance and significantly lower material and installation costs ($3.00 per square foot for window films versus $40 or more per square foot for new windows). Over all four U.S. climate zones (which are indicative of most climate zones globally), for each dollar available for window retrofit or replacement, window film provided 6.6 times greater energy cost savings than total window replacement with new low-E windows. As expected, this ratio is best in the Southern climate zone (10.2 times greater savings with film compared to new low-E windows for each dollar spent) and South/Central zone (7.40 times). Window film even provides impressive results for the North/Central (5.5 times) and Northern zones (4.3 times). See Figures 2 and 3 in the Appendix for details.

While total window replacement with solar-control low-E windows provides for good energy savings (average savings of nearly 10% of total building energy costs), it provides poor simple payback due to high installation costs. Retrofitting existing windows with energy saving window films provide total building energy cost savings averaging 4.8%, but range as high as 9.9% in the Southern climate zone.

It should also be noted that energy cost savings generated by the window film used in this study pays for itself on average 3 times during the expected 20-year service life of the film (average Savings to Investment Ratio of greater than 3), while it is entirely doubtful that the energy savings generated from low-E window installation would be able to pay for itself during its expected service life, as the average payback period for replacement with low-E windows in the study was just over 40 years.

With these factors in mind, application of energy saving window films should be strongly considered in lieu of window replacement if existing windows are functionally sound (no or few failed seals, limited air leakage, frames in good condition), while replacement with new low-E windows would make more sense where windows are suffering from one or more of these failing conditions and window replacement is needed to maintain building integrity.

About the Author:

By Steve DeBusk, Global Energy Solutions Manager, CPFilms®. With more than 25 years in the energy-efficiency industry, DeBusk developed energy programs for the State of Virginia and Hercules Aerospace prior to joining CPFilms in 1995 as the Technical Marketing Manager for Commercial and Residential Films. Since 2003, DeBusk has developed CPFilms' Energy Solutions Program globally and has worked with Energy Service Companies (ESCOs), Performance Contractors, property management companies, energy management companies, and energy efficiency consultants to promote and implement the energy savings benefits of window film. DeBusk is a Certified Energy Manager and Certified Measurement and Verification Professional through the Association of Energy Engineers.

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Appendix

All Climate Zones

DOE Energy Star Climate Zone	Existing Glass Type	Existing Total Annual Energy $ (1)	Type of Upgrade	Total Annual Energy $ with Upgrade	Annual Energy $ Savings with Upgrade	Estimated Cost of Upgrade (2)	Estimated Simple Payback of Upgrade, yrs	Percent Savings in Annual Energy $ (1)
Southern	Single Clear	$135,215	add Silver20 Film	$122,991	$12,224	$36,768	3.01	9.9%
South/Central	Single Clear	$132,487	add Silver20 Film	$121,822	$10,665	$36,768	3.45	8.8%
North/Central	Single Clear	$135,940	add Silver20 Film	$127,862	$8,078	$36,768	4.55	6.3%
Northern	Single Clear	$142,397	add Silver20 Film	$134,776	$7,621	$36,768	4.82	5.7%
Southern	Single Gray	$130,407	add Silver20 Film	$124,633	$5,774	$36,768	6.37	4.6%
South/Central	Single Gray	$128,699	add Silver20 Film	$123,367	$5,332	$36,768	6.90	4.3%
North/Central	Single Gray	$132,787	add Silver20 Film	$128,806	$3,980	$36,768	9.24	3.1%
Northern	Single Gray	$140,278	add Silver20 Film	$136,397	$3,880	$36,768	9.48	2.8%
Southern	Dual Clear	$129,870	add Silver20 Film	$121,984	$7,886	$36,768	4.66	6.5%
South/Central	Dual Clear	$124,264	add Silver20 Film	$117,084	$7,181	$36,768	5.12	6.1%
North/Central	Dual Clear	$123,853	add Silver20 Film	$118,372	$5,480	$36,768	6.71	4.6%
Northern	Dual Clear	$127,276	add Silver20 Film	$122,491	$4,785	$36,768	7.68	3.9%
Southern	Dual Gray	$124,589	add Silver20 Film	$120,792	$3,797	$36,768	9.68	3.1%
South/Central	Dual Gray	$119,582	add Silver20 Film	$116,153	$3,429	$36,768	10.72	3.0%
North/Central	Dual Gray	$120,231	add Silver20 Film	$117,896	$2,335	$36,768	15.75	2.0%
Northern	Dual Gray	$124,695	add Silver20 Film	$122,530	$2,165	$36,768	16.98	1.8%
All 16 Bldg Models		**$2,072,568**		**$1,977,956**	**$94,612**	**$588,288**	**6.22**	**4.8%**
Southern	Single Clear	$135,215	Low-e3 366	$120,624	$14,591	$490,240	33.60	12.1%
South/Central	Single Clear	$132,487	Low-e3 366	$115,060	$17,427	$490,240	28.13	15.1%
North/Central	Single Clear	$135,940	Low-e2 272	$117,605	$18,335	$490,240	26.74	15.6%
Northern	Single Clear	$142,397	Low-e2 272	$121,308	$21,089	$490,240	23.25	17.4%
Southern	Single Gray	$130,407	Low-e3 366	$120,624	$9,783	$490,240	50.11	8.1%
South/Central	Single Gray	$128,699	Low-e3 366	$115,060	$13,639	$490,240	35.94	11.9%
North/Central	Single Gray	$132,787	Low-e2 272	$117,605	$15,182	$490,240	32.29	12.9%
Northern	Single Gray	$140,278	Low-e2 272	$121,308	$18,969	$490,240	25.84	15.6%
Southern	Dual Clear	$129,870	Low-e3 366	$119,935	$9,935	$490,240	49.35	8.3%
South/Central	Dual Clear	$124,264	Low-e3 366	$113,474	$10,791	$490,240	45.43	9.5%
North/Central	Dual Clear	$123,853	Low-e2 272	$114,763	$9,090	$490,240	53.93	7.9%
Northern	Dual Clear	$127,276	Low-e2 272	$117,408	$9,868	$490,240	49.68	8.4%
Southern	Dual Gray	$124,589	Low-e3 366	$119,935	$4,654	$490,240	105.34	3.9%
South/Central	Dual Gray	$119,582	Low-e3 366	$113,474	$6,108	$490,240	80.26	5.4%
North/Central	Dual Gray	$120,231	Low-e2 272	$114,763	$5,468	$490,240	89.65	4.8%
Northern	Dual Gray	$124,695	Low-e2 272	$117,408	$7,287	$490,240	67.28	6.2%
All 16 Bldg Models		**$2,072,568**		**$1,880,353**	**$192,215**	**$7,843,840**	**40.81**	**10.2%**

Figure 2 – Energy Savings Comparison, Window Film vs. New Low-E Windows

Notes:

(1) Annual Energy Costs include electricity and natural gas using eQUEST DOE2.2.
See Figure 4 for details of eQUEST models.

(2) Installed costs include all materials and labor, and include new frames for new low-e windows.
In simulations, all windows were either replaced with new low-e windows or had window film added.

Installed cost of window film ($/sqft):	$3.00	from window film industry estimates
Installed cost of new low-e windows ($/sqft):	$40.00	from window industry estimates

Breakdown by Climate Zone

		Annual Savings with Upgrade	Cost of Upgrade	Savings per $ Invested	Ratio Savings per $ Invested Film vs Windows
Southern	add Silver20 Film	$29,681	$147,072	$0.202	**10.16**
South/Central	add Silver20 Film	$26,606	$147,072	$0.181	**7.40**
North/Central	add Silver20 Film	$19,874	$147,072	$0.135	**5.51**
Northern	add Silver20 Film	$18,451	$147,072	$0.125	**4.30**
All Climate Zones	**add Silver20 Film**	**$94,612**	**$588,288**	**$0.161**	**6.56**
Southern	Low-e3 366	$38,962	$1,960,960	$0.020	
South/Central	Low-e3 366	$47,965	$1,960,960	$0.024	
North/Central	Low-e2 272	$48,075	$1,960,960	$0.025	
Northern	Low-e2 272	$57,213	$1,960,960	$0.029	
All Climate Zones	**New Low-e Windows**	**$192,215**	**$7,843,840**	**$0.025**	

Figure 3 – Energy Savings Comparison, By Climate Zone

Software	**eQUEST 3.55 build 4500 used in all building energy simulations in this study.** **Window Performance data used in eQUEST was taken from the Window 5.2a v5.2.17a Program from Lawrence Berkeley National Labs**
Building	Mid-size office building, 125,000 sqft 4 story bldg Square Bldg, all exposures same size, true N/S orientation 33% Window to Wall Ratio, all 4 exposures, 3,064 sqft windows on each exposure Windows, punched openings, with 3" overhang/side fins from frame on all sides Light-color horizontal blinds in use, 50% of the time Building occupancy primarily from 8am to 6pm M-F and 9am-2pm Sat, but some limited (10%) occupancy from 7am-8am, and 6pm-10pm M-F Lighting levels 1.25 w/sqft general offices, 1.50 w/sqft executive offices, 0.60 w/sqft hallways Average equipment loads 0.75 w/sqft
Windows & Film	Existing Bldgs all have aluminum frames with no thermal break Windows with film upgrades do not change out frame, still aluminum frames with no thermal break Upgrades to new low-e glass includes new aluminum frames with thermal breaks Existing Dual pane windows air filled New Low-e windows argon gas filled
HVAC System	Variable Air Volume system with hot water reheat Variable speed drives on HVAC fan motors Air-side economizer, based on outside air temperature Supply air temperature reset based on outside air temperature Hot water reset based on outside air temperature Cooling Temp 74 deg F occupied hrs (8am-6pm M-F), 82 deg F unoccupied Heating Temp 70 deg F occupied hrs (8am-6pm, M-F), 64 deg F unoccupied Reciprocating Chillers, 0.75 kw/ton Natural Gas hot water boilers, 80% efficiency HVAC System fans operate 7am to 6pm M-F, 8am-3pm Sat
Energy Rates	Electricity rates $0.10 per kwhr, no demand charges (same for all locations as model for a given zone represents avg climate for zone and electricity rate avg for all cities in zone) Natural Gas rate, $1.20 per therm
Climate Zones Used	Study was for representative city from each of the Energy Star Climate Zones Evaluated weather data for cities within each zone and chose a representative city in each zone

Zone	No. of locations in zone w/weather data available	For cities in zone Avg HDD	For cities in zone Avg CDD	Degree Days for Representative City HDD	Degree Days for Representative City CDD	Representative City	2009 IECC Zone
Southern	53	1339	6899	1369	6728	New Orleans, LA	2
South/Central	40	2871	4988	3013	4792	Atlanta, GA	3
North/Central	56	4795	3578	4725	3719	Baltimore, MD	4
North	115	6790	2448	6790	2556	Albany, NY	5

Figure 4 – Energy Modeling Assumptions

Window Film and Window Properties

Cardinal Low-e3 366 (#2 surface) Dual Pane Glass with Argon fill used for Zones 2 and 3. Window size used 42" x 48".
Window 5.2 Program ID# 2157 E366-6.CIG
Cardinal Low-e2 272 (#2 surface) Dual Pane Glass with Argon fill used for Zone 4 and 5. Window size used 42" x 48".
Window 5.2 Program ID# 2014 EE272-6.CIG
LLumar R20 SR CDF window film used for the window film in this study.

Window 5.2 performance data files used in eQUEST models for all windows and windows with film.

Window Performance Properties Used in Film vs. New Low-e Window Study

All windows are 42" wide x 48" tall
Existing windows have aluminum frame with no thermal break.
Existing dual-pane windows are assumed to be air-filled.
Windows retrofitted with window film would have the same frames and air-fill (if dual pane) as existing windows.
New solar-control low-e windows would have aluminum frames with a thermal break for improved insulating performance.
New solar-control low-e windows would also have argon gas fill for improved insulating performance.

Properties below are "whole-window" values including effects of frame, not center-of-glass values

	U-Value (BTU/hr/sqft/deg F)	Solar Heat Gain Coefficient (SHGC)
Single Clear	1.178	0.749
Single Gray	1.178	0.554
Dual Clear	0.763	0.656
Dual Gray	0.764	0.455
Single Clear with R20 Film	1.119	0.279
Single Gray with R20 Film	1.119	0.315
Dual Clear with R20 Film	0.749	0.347
Dual Gray with R20 Film	0.749	0.291
Low-E^3 windows (1)	0.420	0.265
Low-E^2 windows (2)	0.426	0.368

(1) Southern and South/Central Climate Zones, lower SHGC for improved solar control
(2) Northern and North/Central Climate Zones, higher SHGC for less solar control (more free solar heat)

Figure 5 – Window Specification Details