General Services Administration
Public Buildings Service

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LIGHTWEIGHT SECONDARY WINDOWS

Thin Glass Simplifies Installation

Windows, especially, single-pane windows are the weakest energy efficiency link in a building envelope. They account for approximately 39% of the annual U.S. energy used to heat commercial buildings and 28% of the energy used to cool buildings[1]. Higher performing windows could reduce the annual U.S. energy use due to windows by up to 75%[2], but replacement can be costly; even more so in older buildings where lead paint and/or asbestos must be remediated as part of a window replacement. Secondary windows are pre-manufactured units designed to improve the insulating power of low-performing windows without the expense of replacing windows. These new secondary windows are manufactured with ultra-lightweight thin glass, making them easy to install and suitable for structures that cannot handle extra weight. Researchers from the National Renewable Energy Laboratory evaluated two configurations of secondary windows—single-pane and double-pane—at an office building at the Denver Federal Center. Researchers found that in cold climates the double-pane configuration saved twice as much heating and cooling energy as the single-pane secondary configuration. With a small incremental cost difference over the single-pane configuration ($5/ft^2), double-pane secondary windows are recommended for cold climates. In warm climates, the single-pane insert will be more cost-effective. With 35% of the GSA-owned portfolio designated as historic[3], secondary windows are particularly suitable for GSA because they do not require external changes to a building's facade.

The GPG program enables GSA to make sound investment decisions in next-generation building technologies based on their real-world performance.

INTRODUCTION

"These thin glass secondary windows improved window performance and installation was fast and achieved with minimal disruption."

–Tyler Cooper
Mechanical Engineer
Denver Federal Center
U.S. General Services Administration

PERFORMANCE SPECIFICATIONS
Whole-Window Properties

SINGLE-PANE CLEAR BASELINE

U-Factor	1.20
R-Value	0.83
SHGC	0.81
VT	0.84
CR	12
AL*	2.0

BASELINE + SINGLE-PANE SECONDARY

U-Factor	0.53
R-Value	1.9
SHGC	0.20
VT	0.73
CR	44
AL**	0.06

BASELINE + DOUBLE-PANE SECONDARY

U-Factor	0.23
R-Value	4.3
SHGC	0.42
VT	0.58
CR	46
AL**	0.06

SHCH = solar heat gain coefficient
VT = visible light transmission
CR = condensation resistance

*AL = air leakage. AERC estimates single-pane window AL is 2.0 cfm/ft²

**AERC testing by Quast Consulting & Testing. To achieve an Energy-Star rating, interior storm windows must have air leakage <0.5 cfm/ft²

Use single-pane inserts in warm climates
Single pane secondary windows with a low SHGC are more cost-effective for warm climates

	Single-Pane Secondary Climate zone 1 SHGC .20	Double-Pane Secondary Climate zone 1 SHGC .20
Annual energy savings (kBtu)	498,012	498,665
Energy cost savings ($)	16,449	16,472
Payback (yr)	7.7	9.8
SIR (Savings-to-Investment Ratio)	2.6	2.0

What Is This Technology

INTERIOR WINDOW INSERT WITH THIN GLASS AND INSULATED FIBERGLASS FRAME

Light-weight, high-performance secondary windows use ultra-thin glass in an insulated low-profile fiberglass frame. These inserts are two to three times lighter than secondary windows made with standard glass. Warm-edge spacer technology extends the high-insulation glass performance across the frame, minimizing the condensation risk between the secondary and primary window by eliminating cold spots. The secondary windows are installed on the room side of existing windows and are available in single- and double-pane configurations. The single-pane version combines an ultra-lightweight piece of thin glass (typically 1.3 mm for larger assemblies) laminated to a customized window film. The double-pane version adds a pane of customized low-emissivity coated glass and either argon or krypton gas fill. Both configurations offer customizable solar heat gain coefficient levels. The secondary windows for this evaluation were provided by Alpen High Performance Products and are made in America.

What We Did

MEASURED DATA COMPARED TO MODELED PERFORMANCE

In September 2019, GSA retrofitted ten single-pane windows at Building 53, a 388,000 ft² two-story office building, at the Denver Federal Center. Five double-pane secondary windows were installed in a closed office, and five single-pane secondary windows were installed in an open office. Researchers measured glass and frame surfaces to compare and calibrate measurements with models created using Department of Energy (DOE) WINDOW and THERM software. Simulated results included U-factor, solar heat gain coefficient (SHGC), visible light transmission (VT), and condensation resistance (CR). The U-factor of glazing is related to the resistance of heat transfer between the interior and exterior of windows; the smaller the U-factor, the better the insulation. The SHGC references the fraction of solar radiation that flows through the window from direct sunlight. VT refers to the amount of light that passes through a window. CR measures how well a window resists condensation on its interior surface. The higher the number, the better a window resists condensation. AL represents air infiltration and measures the amount of air entering the window. In addition to window measurements and modeling, researchers assessed occupant comfort, ease of installation, and overall cost-effectiveness.

FINDINGS

15% AVERAGE WHOLE-BUILDING ENERGY SAVINGS Modeling for the double-pane secondary windows compared to a single-pane clear window demonstrated whole-building energy savings between 11% to 18% for a medium-sized office building (53K). Modeled savings did not include the impact of reduced air infiltration which will generate additional energy savings, particularly in cold climates.

WINTER INTERIOR WINDOW SURFACE TEMPERATURES INCREASED 20° When the outdoor temperature was 21°F, the double-pane center of glass temperature was 68.2°F, compared to 48°F with the single-pane glass baseline.

REDUCES INTERIOR WINDOW CONDENSATION CR indicates how well a window resists condensation on its interior surface. The higher the CR number, the better a window resists condensation. The double-pane secondary window CR was 46 as compared to 12 for a baseline single-pane window.

10-MINUTE INSTALLATION One installer installed the secondary window in less than 10 minutes. The inserts are installed without drilled holes or permanent devices and are 2 to 3 times lighter than inserts made with standard glass so they can be easily removed for cleaning or maintenance.

REDUCED AIR INFILTRATION WILL SAVE ADDITIONAL ENERGY IN COLD CLIMATES Reducing air infiltration can result in additional energy savings and accelerated payback, particularly in cold climates. The Attachments Energy Ratings Council (AERC) estimates air infiltration for single-pane windows at 2.0 cfm/sf.[4] According to third-party testing, both the single- and double-pane secondary windows reduced infiltration to 0.06 cfm/sf, a 97% savings.[5]

RECOMMENDED RETROFIT FOR SINGLE-PANE WINDOWS Retrofitting single-pane windows with lightweight, high-performance windows is recommended throughout the portfolio. In cold climates, double-pane secondary windows will be more cost-effective. In warm climates, the single-pane insert has a better return on investment. The retrofit technology is particularly well suited for historic structures where changes to the facade are limited.

Cost-Effective Across Climate Zones[6]

Positive return on investment at average GSA utility rates, $0.11/kWh and $7.43/mmBtu

Location		Savings from Single-Pane to Double-Pane Insert					
CLIMATE ZONE	CITY	WHOLE BUILDING ENERGY SAVINGS kBtu/ft²/yr	ENERGY COST SAVINGS $/ft²/yr	ANNUAL SAVINGS $/yr	SAVINGS %	PAYBACK* YRS	SIR positive ROI if >1
1A	Miami, FL	8.1	$0.27	$14,480	11%	11.2	1.59
2A	Houston, TX	9.1	$0.30	$16,088	12%	10.1	1.76
2B	Phoenix, AZ	10.7	$0.35	$18,770	14%	8.7	2.05
3A	Atlanta, GA	10.3	$0.35	$18,770	14%	8.7	2.05
3B	Las Vegas, NV	10.8	$0.36	$19,306	15%	8.4	2.11
3C	San Francisco, CA	8.3	$0.28	$15,016	13%	10.8	1.64
4A	Baltimore, MD	12.6	$0.43	$23,060	16%	7.1	2.52
5A	Chicago, IL	13.5	$0.46	$24,669	17%	6.6	2.70
5B	Boulder, CO	13.9	$0.47	$25,205	18%	6.5	2.76
6A	Minneapolis, MN	15.6	$0.54	$28,959	17%	5.6	3.17
AVERAGE SAVINGS		**11.3**	**$0.38**	**$20,432**	**15%**	**8.4**	**2.2**

*Modeling for high SHGC-0.42 in a medium-sized office building.
A low SHGC-0.20 will be more cost-effective in warm climates, with estimated payback < 10 years.
Does not include savings from reduced air infiltration.
Double-pane insert $22/ft² Single-pane insert $17/ft² Installation $1.15/ft²

CONCLUSIONS

These Findings are based on the report, "Demonstration and Evaluation of Lightweight High Performance Secondary Windows," which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

What We Concluded

IMPROVES OCCUPANT COMFORT AND SAVES ENERGY

Compared to window replacements, secondary windows are a cost-effective and efficient way to improve thermal performance and occupant comfort and reduce noise. They have lower heat loss, less air leakage, and warmer window surfaces that improve occupants' comfort and minimize condensation. By allowing occupants to sit comfortably near windows, they could help GSA increase occupant density in buildings. And by reducing cooling and heating requirements, high-performance windows can save money by reducing capacity needs for HVAC equipment. The secondary windows assessed at the Denver Federal Center are light and easy to install. In addition to improving the insulating value of the windows, they form a tight seal reducing air infiltration.

Secondary windows will be most effective in buildings with low-performing windows. In colder climates, double-pane inserts with a high solar heat gain will be most cost-effective. In warm climates, single-pane inserts with a low solar heat gain will be more cost-effective. However, the impact of windows on energy demand is extremely context-specific. The payback and performance of secondary windows is highly dependent on building conditions including climate, existing window types, interior space configuration, and building form. For major renovation projects or new construction, quad-pane windows are a better option. See GPG-048 for an evaluation of lightweight high-performance quad-pane windows offered by the same manufacturer.

Lessons Learned and Best Practices

- Site-specific evaluation is essential to gauging the potential success of secondary window retrofits. Though modeled savings were demonstrated for all building types and climates, performance is highly site-specific.
- AERC is establishing standards and labeling for secondary windows that include measurements for air infiltration. Both the single-and double-pane inserts reduced infiltration from 2.0 cfm/ft^2 for a single-pane window to 0.06 cfm/ft^2. This will result in additional energy savings and accelerated payback, particularly in cold climates. Payback numbers in this study do not reflect savings from reduced air infiltration.
- Economics improve if you can add secondary windows and upgrade HVAC equipment at the same time. Modeling for the double-pane inserts showed the capital costs for HVAC equipment in a large office building (498Ksf) reduced by $171k through related load-capacity reduction.
- Window configuration should be customized for different climates, particularly the SHGC. Windows with a high SHGC collect solar heat more effectively and are more broadly recommended for cold climates. Windows with a low SHGC block heat gain more effectively and are better suited to warm climates.
- For cold climates, the double-pane secondary window outperformed the single-pane insert and is broadly recommended. For warm climates, a single-pane secondary window with a low SGCH could be more cost-effective.

Footnotes

[1] Apte, J., Arasteh, D. (2006), Window-Related Energy Consumption in the US Residential and Commercial Building Stock. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL) report, LBNL-60146

[2] Highly Insulating Window Panel Attachment Retrofit. Charlie Curcija, Howdy Goudey, Robin Mitchell, Erin Dickerhoff (LBNL), December 2013, p.3

[3] 551 buildings designated as historic out of 1574 GSA-owned buildings

[4] Attachments Energy Ratings Council (AERC), AERC Energy Performance Certificate, https://aercenergyrating.org/reading-the-commercial-label/, accessed 08-30-2021

[5] AERC Testing by Quast Consulting & Testing, Sept. 2, 2021

[6] Demonstration and Evaluation of Lightweight High-Performance Secondary Windows. Kosol Kiatreungwattana, Lin Simpson (NREL), November 2021, p.66

Technology for testbed measurement and verification provided by Alpen High Performance Products.