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ULTRALIGHT INSULATING PANELS FOR OPERABLE WINDOWS

Improves Window Performance While Maintaining Operability

Windows are responsible for 34% of all commercial space conditioning energy use, equivalent to roughly 1.5% of the total U.S. energy consumption.[1] Windows typically have a long life (25 to 35 years), but as double- and triple-pane windows age, the seals can start to fail, causing the gas between the glass panes to escape, reducing the thermal insulating properties of the window. Furthermore, because window replacement is costly, particularly in older buildings where lead paint and asbestos must be remediated, windows often remain in place for more than 50 years. Ultralight window insulation panels snap on the interior glass surface, simplifying retrofit installation. The panels create an air gap between the glass and plastic panel to minimize conductive and convective heat loss, and the windows remain operable, which can be important for climate control, compliance with local building codes, and egress. GSA collaborated with the Pacific Northwest National Laboratory (PNNL) to evaluate the performance of window insulation panels at a federal building and courthouse in Eau Claire, Wisconsin. Researchers found that the technology improved the window's insulating performance by 52%. The window insulation panels also increased the interior winter surface temperature by 7°F on average. Modeled whole building savings ranged between 2% and 7% for cold climates and 4% and 7% for warm climates, based on a single- or double-pane baseline. At current GSA utility rates ($0.13/kWh for electricity and $9.10/MMBtu for gas), warm climates had the best return on investment.

INTRODUCTION

Positive return on investment possible at scale. More cost-effective in warm climates.

	Savings from Single-Pane with Non-Metal Frame					
	Electricity Savings kW/ft²/yr	Gas Savings kbtu/ft²/yr	Annual Savings $/ft²/yr	Whole-Building Savings %	Payback* yrs	SIR positive ROI if >1
WARM CLIMATE AVERAGE	1.4	0.1	$0.18	6%	13	1.2
MODERATE CLIMATE AVERAGE	0.3	0.9	$0.05	3%	58	0.3
COLD CLIMATE AVERAGE	0.5	2.9	$0.09	6%	21	1.0

*Assuming a 54K ft² building with < 10 uniquely-sized fixed ribbon windows; average GSA utility rates of $0.13/kWh for electricity and $9.10/MMBtu for gas; installation cost of $1.6/ft²; and material cost of $16/ft² for the panel with SHGC coating in warm and moderate climates and $9/ft² for the panel without coating in cold climates.

"Secondary windows can improve the insulation of the building envelope and can be an effective strategy for supporting our net zero goals."

– Erin Lannon
Program Manager
Applied Innovation Learning Lab
U.S. General Services Administration

PERFORMANCE SPECIFICATIONS

Ultralight Window Insulation Panel

HIGH-PERFORMANCE PANEL: COLD CLIMATES

U-Factor (rated)	**0.8**
U-Factor (measured)	**0.6**
R-Value (rated)	**1.2**
R-Value (measured)	**1.7**
% Solar Heat Gain Reduction	**10%**
VT	**0.9**

HIGH-PERFORMANCE PANEL: WARM CLIMATES

U-Factor (rated)	**0.7**
R-Value (rated)	**1.4**
% Solar Heat Gain Reduction	**35-50%***
VT	**0.4**

*35% solar heat gain reduction on clear double-pane window and 50% reduction on clear single-pane.

U-Factor/R-Value = capacity to insulate
VT = visible light transmission

What Is This Technology

TRANSPARENT SNAP-ON PANELS MOUNT ONTO EXISTING WINDOWS

The window insulation panels mount to the interior glass surface of an existing window via small translucent snap-together connectors placed at the four corners of the glass surface. Clear silicone sealant is applied to each corner to further secure the fasteners. The existing window remains operable, which can be important for climate control and egress. The technology is made from thin (20 mil), ultra-lightweight (0.17 lbs/ft²), copolyester plastic which reduces stress on slider and hinged windows, keeps shipping weight low, and reduces the embodied carbon footprint compared to products made from glass or thicker acrylic. There are two options for the panel: one designed for shaded facades/cold climates that improves the U-value of the window without reducing its solar heat gain coefficient (SHGC) and one for sunny facades/warm climates that includes a solar coating that can be customized. There are also two profiles of the insulation panels. The default high-profile design (0.6") creates a 0.5" gap of air space between the panel and the window, which maximizes the insulating value. The low-profile design (0.33") is 2-3% less insulating. This evaluation considered only the high-profile design. The panels can be recycled, and in the future, the vendor anticipates that 99% of their product will be made from recycled content. The window insulation panels for this evaluation were provided by WexEnergy and are 100% made in America.

What We Did

MEASURED DATA COMPARED TO MODELED PERFORMANCE

In October 2022, GSA retrofitted 75 window insulation panels at the 37,000 ft² Eau Claire Federal Building and U.S. Courthouse in Eau Claire, Wisconsin (75 windows had 57 different-sized insulation panels). The Eau Claire Courthouse was built in 1909, and the building's windows were last replaced in 1981, so many double-pane window seals had failed, leading to single-pane performance. Researchers measured glass surfaces to compare and calibrate measurements with models created using Department of Energy (DOE) WINDOW and EnergyPlus software. In addition to window measurements and modeling, researchers assessed occupant comfort, ease of installation, and cost-effectiveness.

FINDINGS

IMPROVED INSULATION AND REDUCED HEAT FLUX The window insulation panels improved the insulation by 52%, from a U-Factor of 1.15 to 0.55. The panels also slowed the room's natural cooldown due to heat loss by 31% during cold winter months.

WHOLE-BUILDING ENERGY SAVINGS BETWEEN 2% AND 7% Modeled whole-building savings ranged between 2% and 7% for cold climates and between 4% and 7% for warm climates, based on a single-or double-pane baseline. The highest savings are for single-pane windows with non-metal or thermally broken aluminum frames. Modeling for Climate Zone 6A in Minneapolis, Minnesota, estimated 7% whole building energy savings for non-metal framed single-pane windows versus 6% for metal-framed single-pane windows.

IMPROVED INTERIOR GLAZING SURFACE TEMPERATURE When the outdoor air temperature was 0°F, the average interior glazing surface temperature improved by 7°F. During a particularly cold period in Eau Claire, Wisconsin, when the outdoor air temperature averaged -5.2°F, the interior glazing surface temperature improved by 8.25°F.

ULTRALIGHT PANELS SIMPLIFY INSTALLATION Installation involves few tools and no skilled labor. The panels at Eau Claire were installed by GSA staff and took ~10 minutes per panel. O&M staff stated that because the panels are ultralight (0.17 lbs/ft^2), the installation was easier than other retrofits, particularly if the large panel had to be moved around furniture. Multiple panels, typically 10, are shipped in a box that can be moved by one or two people.

MIXED OCCUPANT FEEDBACK, BUT PRE-PRODUCTION VERSION TESTED Occupant feedback from 15 surveys was mixed, but there were many factors besides the technology that may have impacted these results. The tested panels included pre-production milky white spacers for panes greater than 3 feet and white 3D-printed cutouts around window locks. In addition, the site was under construction, so many of the window panels retained their blue protective film. The vendor now offers versions with clear spacers and cut-outs.

POSITIVE FACILITY FEEDBACK On-site O&M staff recommended this technology for other GSA facilities with operable windows, provided that the payback was less than 10 years. They noted that "People want to be able to open windows. Even if they don't do it very often, they like having the option."

POSITIVE ROI POSSIBLE AT SCALE Based on the current product pricing of $21/ft^2, installation of $1.6 ft^2, and average GSA utility rates ($0.13/kWh and $9/MMBtu), payback for single-pane windows in cold climates averaged 33 years. The vendor estimates that scaled production with fewer unique panel sizes (< 10-panel sizes for a 54K ft^2 building) reduces costs to $9/ft^2 for cold climates and $16/ft^2 for warm climates.

Based on scaled pricing, panels in cold climates on single-pane windows require an average electricity rate of $0.23/kWh and a gas rate of $22/MMBtu to be cost-effective. Panels in warm climates require an average electricity rate of $0.13/kWh and a gas rate of $12/MMBtu to be cost-effective. To achieve a positive return on investment at current GSA energy rates, the average panel cost needs to be less than $8/ft^2 for cold climates and less than $17/ft^2 for warm climates.

CONSIDER WHEN MAINTAINING WINDOW OPERABILITY IS DESIRED This technology is best suited to single-pane or older double-pane operable windows with non-metal or thermally broken aluminum frames that do not have condensation issues. Also consider for large windows that are comprised of smaller glass panes. The maximum window pane size is 4 ft x 6 ft. The panels are appropriate for historic buildings because they do not impact the façade's appearance.

CONCLUSIONS

These Findings are based on the report, "Window Retrofits: Ultralight Window Insulating Panels," 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

CONSIDER FOR WHEN IT IS IMPORTANT TO KEEP WINDOWS OPERABLE

Better insulated envelopes play a crucial role in reducing reliance on high-energy heating and cooling systems and facilitating the shift to electrified buildings. Enhanced envelope efficiency also strengthens resilience during power outages. Secondary windows offer a cost-effective and efficient way to improve building envelope performance without window replacement. The window insulation panels evaluated here are currently the only retrofit technology on the market that attaches directly to the glazing, thereby preserving window operability. They can be a good option for large windows comprised of multiple glass lites due to their smaller and lighter design compared to framed secondary windows. However, because they don't seal the frame or provide additional air sealing, they provide about half the insulating value of framed secondary windows.[3] In cold climates, an option that provides more insulation and reduces air infiltration will result in additional energy savings and may be the better choice. This technology could be an ideal fit for residential use where occupants desire operational windows and can install the panels themselves.

Lessons Learned and Best Practices

- The panel implementation for warm climates is more cost-effective.
- Improving building envelopes in moderate climates can be difficult to achieve cost-effectively.
- Site-specific evaluation is essential to gauging the potential success of secondary window retrofits.
- Maintaining a window's operability may require using the low-profile version of this technology, which has a 2-3% energy savings reduction relative to the high-profile version of this technology.
- Have the vendor take field measurements of the windows to ensure the panel sizing is correct.
- Clean interior glass panes before installation and factor this into installation costs and processes.
- Aftermarket film applied to the glass may make it more difficult to apply the fasteners.
- If air infiltration or noise are issues with the existing windows, consider alternative retrofit technologies that are mounted in a frame.

Footnotes

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

[2] Ayyagari S., Gartman M., and Corvidae J. 2020. Hours of Safety in Cold Weather – A Framework for Considering Resilience in Building Envelope Design and Construction. Rocky Mountain Institute.

[3] GPG-049. 2021. Lightweight Secondary Windows.

Technology for testbed measurement and verification provided by WexEnergy.