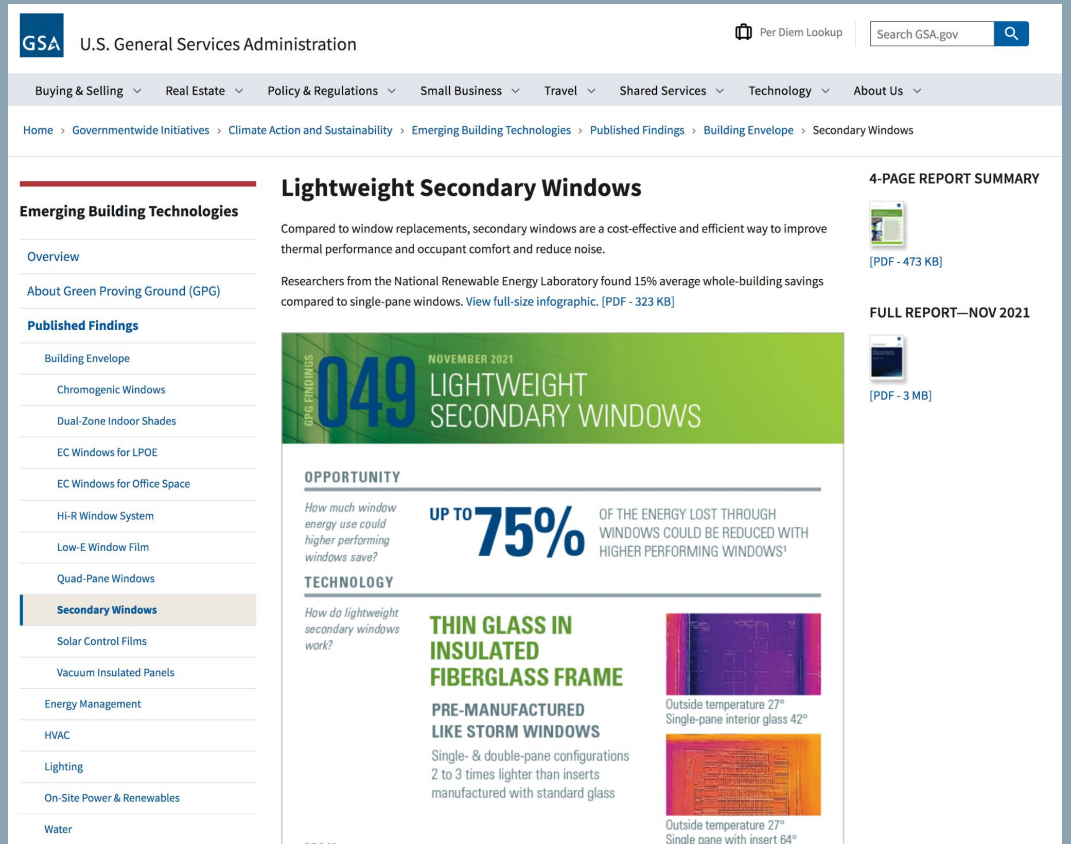
GPG Outbrief 26

Lightweight Secondary Windows

Emerging Building Technologies, GPG Program | U.S. General Services Administration | March 3, 2022

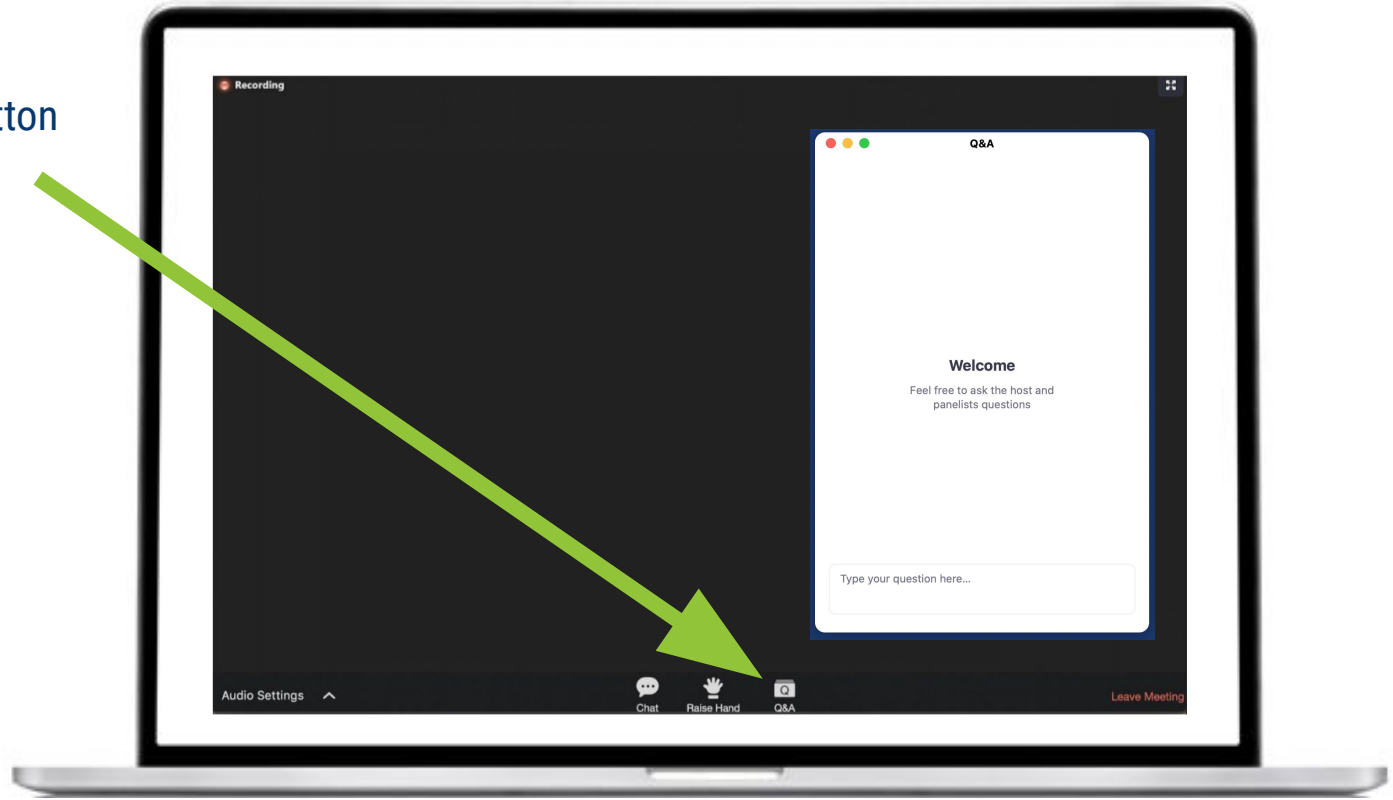
GPG-049 Lightweight Secondary Windows @ gsa.gov/gpg

- Infographic
- 4-page Findings
- Full Report
- Additional Resources

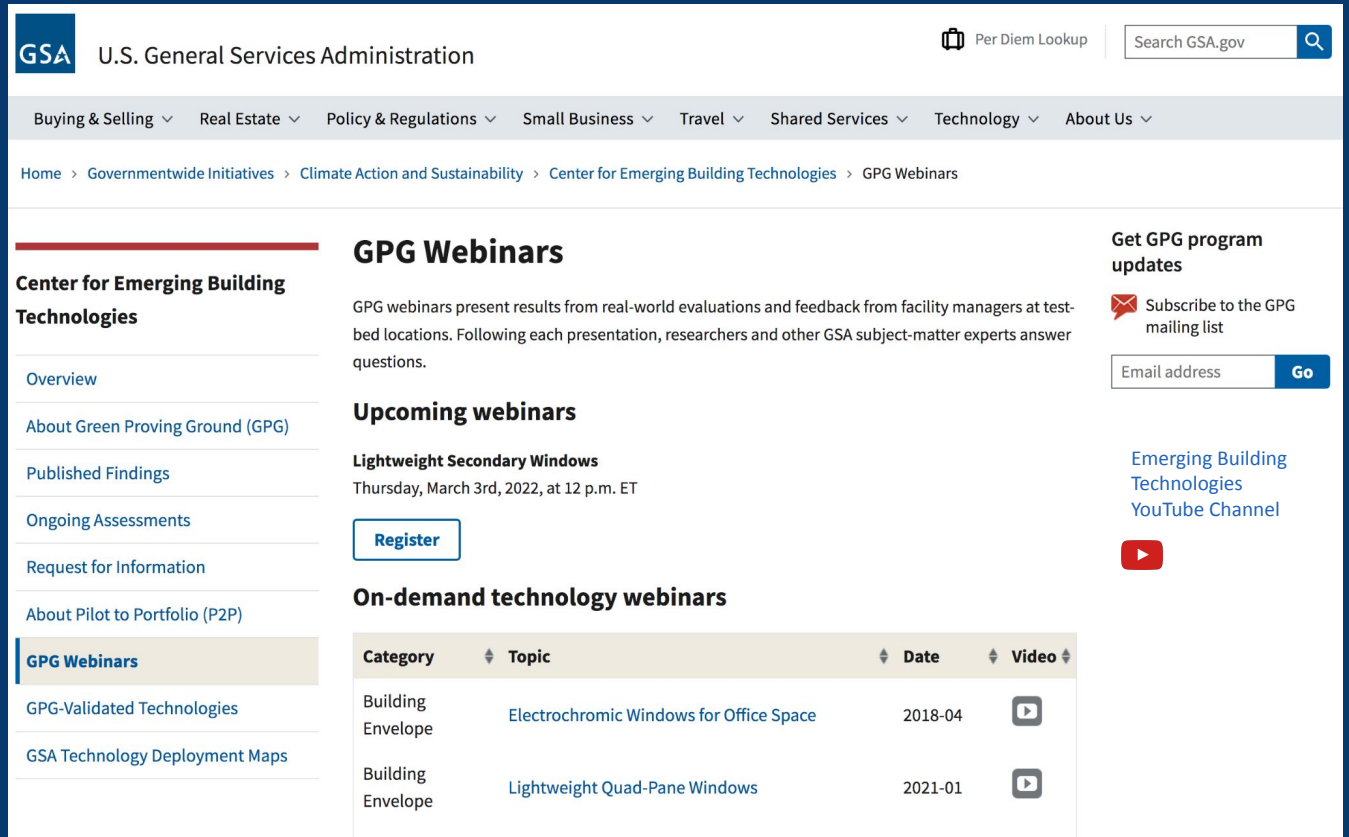


How to Ask Questions

Click the Q&A button to ask questions.



Webinar Recording and Slides Available on gsa.gov/gpg



Webinar Agenda

- Introduction (5 minutes)
  Kevin Powell, Director, Center for Emerging Building Technologies
- Lightweight Secondary Windows (30 minutes)
  Kosol Kiatreungwattana, National Renewable Energy Laboratory
- On-the-Ground Feedback (10 minutes)
  Tyler Cooper, Mechanical Engineer, GSA Region 8
- Q&A (15 minutes)

Opportunity

UP TO 75% OF THE ENERGY LOST THROUGH WINDOWS COULD BE REDUCED WITH HIGHER PERFORMING WINDOWS

GPG-049

Lightweight Secondary Windows

General Services Administration
Public Buildings Service

GSA

GPG-049 | NOVEMBER 2021

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/ft²), 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.

Measurement & Verification

Kosol Kiatreungwattana
Research Engineer
National Renewable Energy Laboratory

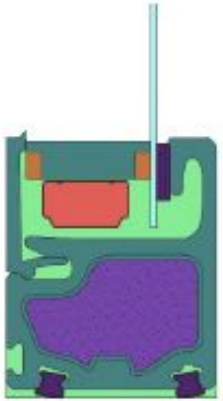
Lightweight Secondary Windows (provided by Alpen High Performance Products)

Retrofit/Add-on secondary window to improve performance of older windows

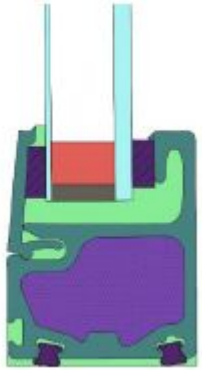
- Pre-manufactured like interior storm windows
- Easy to install:
  - Thin glass (1.3 mm thick) is 2 to 3 times lighter than inserts manufactured with standard glass
  - No drilling or permanent devices
- Works well with historic buildings where aesthetic changes to exterior windows are not allowed

Single- and Double-Pane Configurations

Fiberglass frame with thin glass in two configurations



Single-pane insert combines thin glass laminated to customized window film



Double-Pane Insert adds a pane of low-e coated glass with krypton gas fill

Images courtesy of Alpen High Performance Products

Rated Insulating Value with Single Pane Window

Double-pane is more than twice as insulating as single-pane*

	Single-Pane Clear Baseline	Baseline + Single-Pane Secondary	Baseline + Double-Pane Secondary
U-Factor	1.20	0.53	0.23
R-Value	0.83	1.9	4.3

*Incremental cost difference between single-pane and double-pane $5/ft^2

Single-Pane vs. Double-Pane

	Single-Pane Secondary	Double-Pane Secondary
Cost	$17/ft^2	$22/ft^2
Weight*	~1 lbs/ft^2	~3 lbs/ft^2
Condensation Resistance	44 CR *with baseline single-pane CR of 12*	46 CR *with baseline single-pane CR of 12*
Air Leakage**	0.06 cfm/ft^2 *single-pane baseline = 2.0 cfm/ft^2*	0.06 cfm/ft^2 *single-pane baseline = 2.0 cfm/ft^2*

*insert made with standard glass ~3 lbs/ft^2 single; ~6 lbs/ft^2 double

** AERC Testing by Quast Consulting & Testing, Sept. 2, 2021

Lightweight Secondary Windows

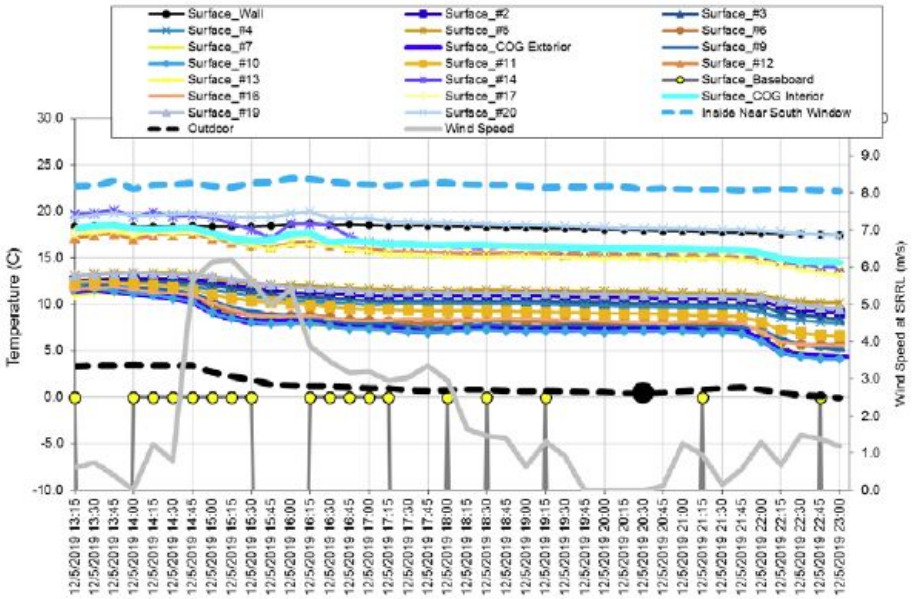
Technology for M&V provided by Alpen High Performance Products

M&V Denver Federal Center, Building 53

M&V Design

Retrofitted 10 single-pane windows, 5 in closed-office and 5 in open-office

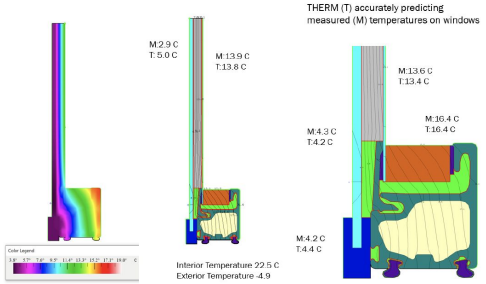
- Measured glass, frame surfaces, space conditions
- Used DOE WINDOW and THERM software to calculate window thermal performance indices, calibrated with measured data
- Used EnergyPlus for whole building energy simulation analysis of a large-and medium-office building
- Calculated HVAC capacity, energy savings, and economics



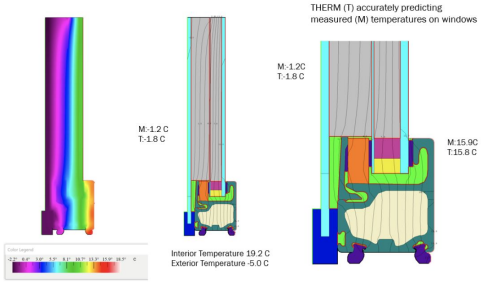
Simulated Model Results

	Effective U-value	Solar Heat Gain Coefficient	Visible Transmittance	Condensation Rating
Existing single-pane window	1.197	0.81	0.84	12
Single-pane secondary window with baseline single-pane window	0.532	0.70	0.73	44
Double-pane secondary window with baseline single-pane window	0.232	0.42	0.58	46

U-factor windows capacity to insulate, the smaller the U-factor, the better the insulation
Solar Heat Gain fraction of solar radiation that flows through the window from sunlight
Visible Light Transmission the amount of light that passes through the window
Condensation Resistance indicates how well a window resists interior condensation



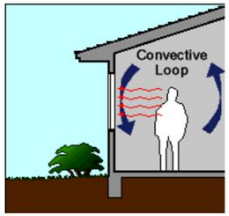
THERM model for single-pane secondary window



THERM model for double-pane secondary window

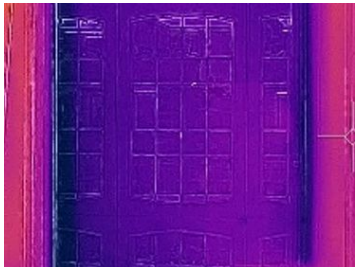
Increased Thermal Comfort

- When the outdoor temperature was 27°F
  - Single-pane interior glass 42°F
  - With double-pane insert 64°F
- Majority of the conditions were within the ASHRAE 55 thermal comfort boundary
- Reduced convective & radiative heat transfer effects

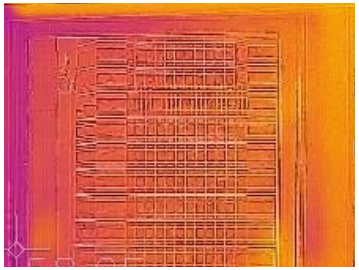


	Center of Glass	Frame
Baselined Single-Pane Window	48.0°F	50.9°F
Single-Pane Secondary Window	56.7°F	62.2°F
Double-Pane Secondary Window	68.2°F	64.8°F

Mean outdoor temperature 21.0° F Mean indoor temperature 73.2° F



Outside temperature 27°
Single-pane interior glass 42°



Outside temperature 27°
Single-pane with insert 64°

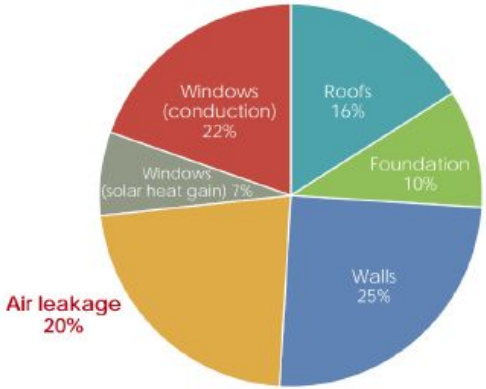
Reduces Interior Window Condensation

- Significantly improves condensation resistance
  - 12 CR – Single-pane
  - 44 CR – With single-pane secondary
  - 46 CR – With double-pane secondary

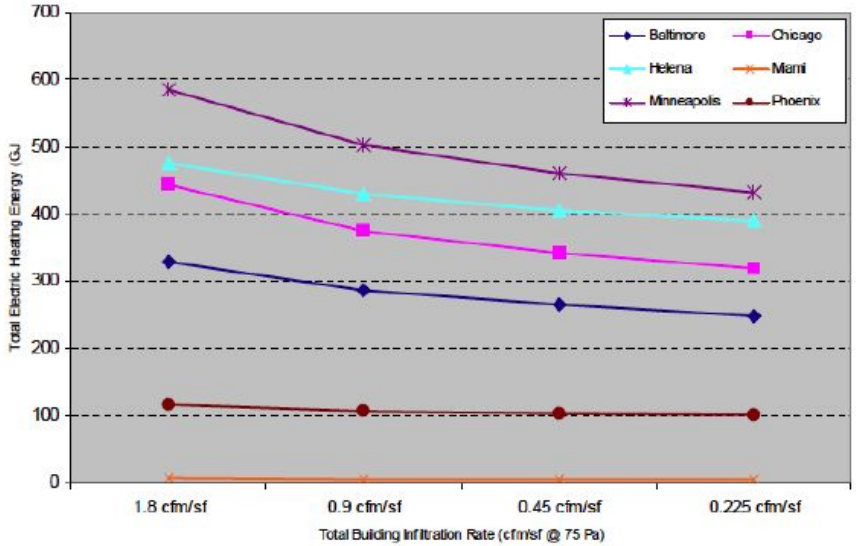
Sensor locations on a window, Kosol Kiatreungwattana

Impact of Air Infiltration

- DOE estimates that air leakage accounts for 20% of building energy use
- Energy loss due to infiltration is greater in cold climates
- Many older windows suffer from poor air tightness
- Reduced air infiltration will save additional energy



BUILDING ENVELOPE ENERGY USE

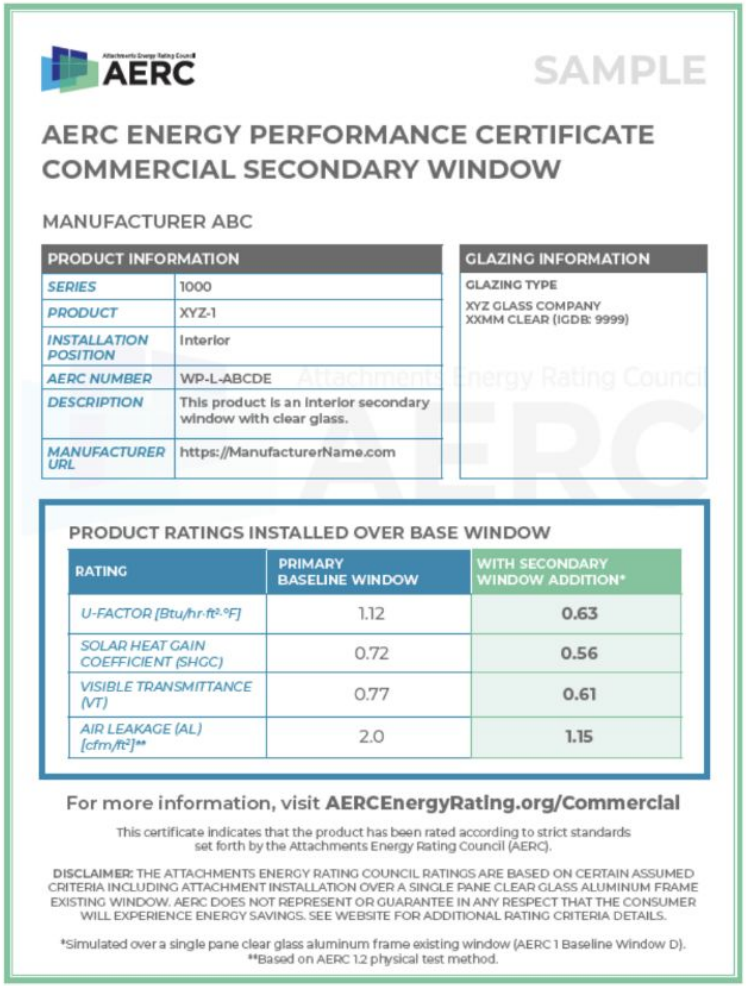


IMPACT OF INFILTRATION ON TOTAL ELECTRIC HEATING ENERGY

Gowri, K., D. Winiarski, and R. Jarnagin. 2009. "Infiltration Modeling Guidelines for Commercial Building Energy Analysis." Bothell, WA: Pacific Northwest National Laboratory

97% Reduced Air Infiltration

- Attachments Energy Ratings Council (AERC) is establishing a standard for secondary windows which will include air leakage
- AERC estimates average air-infiltration for single-pane window is 2.0/cfm/ft^2
- Third-party measurement* found both single and double-pane reduced air-infiltration to 0.06 cfm/ft^2
- To achieve an ENERGY STAR rating interior storm windows must have leakage < 0.5 cfm/ft^2



AERC

SAMPLE

AERC ENERGY PERFORMANCE CERTIFICATE
COMMERCIAL SECONDARY WINDOW

MANUFACTURER ABC

PRODUCT INFORMATION	
SERIES	1000
PRODUCT	XYZ-1
INSTALLATION POSITION	Interior
AERC NUMBER	WP-L-ABCDE
DESCRIPTION	This product is an interior secondary window with clear glass.
MANUFACTURER URL	https://ManufacturerName.com

GLAZING INFORMATION
GLAZING TYPE
XYZ GLASS COMPANY XXMM CLEAR (IGDB: 9999)

PRODUCT RATINGS INSTALLED OVER BASE WINDOW

RATING	PRIMARY BASELINE WINDOW	WITH SECONDARY WINDOW ADDITION*
U-FACTOR [Btu/hr·ft²·°F]	1.12	0.63
SOLAR HEAT GAIN COEFFICIENT (SHGC)	0.72	0.56
VISIBLE TRANSMITTANCE (VT)	0.77	0.61
AIR LEAKAGE (AL) [cfm/ft²]**	2.0	1.15

For more information, visit **AERCEnergyRating.org/Commercial**

This certificate indicates that the product has been rated according to strict standards set forth by the Attachments Energy Rating Council (AERC).

DISCLAIMER: THE ATTACHMENTS ENERGY RATING COUNCIL RATINGS ARE BASED ON CERTAIN ASSUMED CRITERIA INCLUDING ATTACHMENT INSTALLATION OVER A SINGLE PANE CLEAR GLASS ALUMINUM FRAME EXISTING WINDOW. AERC DOES NOT REPRESENT OR GUARANTEE IN ANY RESPECT THAT THE CONSUMER WILL EXPERIENCE ENERGY SAVINGS. SEE WEBSITE FOR ADDITIONAL RATING CRITERIA DETAILS.

*Simulated over a single pane clear glass aluminum frame existing window (AERC 1 Baseline Window D).
**Based on AERC 1.2 physical test method.

*AERC Testing by Quast Consulting & Testing, Sept. 2, 2021

Reduced HVAC Capacity Requirements

- Installing higher-performing windows can reduce HVAC capacity requirements.
- In the modeling for a medium office building (54K ft^2)
  - Double-pane secondary reduced required HVAC capacity by 19% for heating and 13% for cooling
  - Reduced capital costs of HVAC equipment by ~$8,500/yr over 20 years

	Baseline	Single-Pane Secondary	Double-Pane Secondary
Heating Capacity (kBtu/hr)	13,285	12,016	10,774
Cooling Capacity (kBtu/hr)	12,974	11,904	11,258
Reduction in Heating Capacity (%)	n/a	10%	19%
Reduction in Cooling Capacity (%)	n/a	8%	13%
Estimated total HVAC capacity savings ($)	n/a	94,862	171,515
Annualized HVAC capacity savings ($/yr)	n/a	4,743	8,576

Secondary Window Performance

15%

average HVAC savings

for double-pane insert with a baseline single-pane window

Cost-Effective Across Climate Zones

Location		Savings with Double-Pane Insert (Single-Pane Window Baseline)					
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 (53K sf).
Does not include savings from reduced air infiltration and HVAC capacity reduction.
A low SHGC-0.20 is more cost-effective in warm climates, with estimated payback < 10 years.
Double-pane insert $22/ft² Single-pane insert $17/ft² Installation $1.15/ft²

Use Single-Pane Inserts in Warm Climates

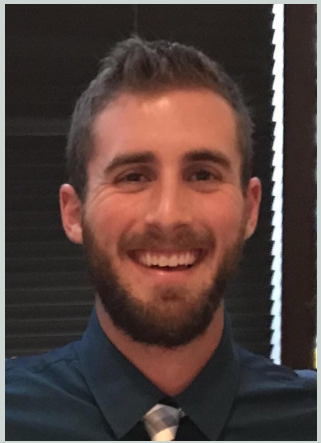
Warmer climates don't benefit from increased insulation

	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**

Summary

- 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 sf).
- Reduces air infiltration benefits which will save additional energy in cold climates.
- Improves thermal comfort. Winter interior window surface temperatures increased 20°.
- Improves window condensation resistance.
- Cost-effective with payback between 6 and 11 years.
- Payback and performance is highly dependent on building conditions including climate, existing window types, interior space configuration, and building form.

GSA Feedback—Denver Federal Center



Tyler Cooper
Supervisory Energy PM
GSA Region 8

Easy Installation

- 1 minute for 1 person for 1 window
- No drilled holes or permanent devices
- ~$1.15/ft^2 installation cost is a conservative estimate and assumes 15-minute per window

Installation Challenges at Building 53

- Building 53: concrete and brick walls, built in 1940s and had experienced settling so windows weren't square
- Gasketing: had to replace gaskets to improve seal because windows were not a complete square
- Safety fasteners: precautionary because windows weren't perfectly square

O&M Cleaning

- Suction cup facilitates removal and cleaning
- Cleaning frequency depends on condition of existing window

Occupant Satisfaction

- Five surveys received; 3/5 were positive and recommended the retrofit. 2/5 did not have opinion on the retrofit.
- Thermal discomfort existed and may be caused by HVAC rather than windows.
- Secondary window appearance was noticeable but acceptable.

Sensor locations on a window, Kosol Kiatreungwattana

Best Practices

- Higher-efficiency windows can reduce HVAC capacity requirements and should be calculated when HVAC equipment needs to be replaced.
- Window configuration should be customized for different climates, particularly the solar heat gain coefficient (SHGC).
- Windows with a high SHGC collect solar heat more effectively and are more broadly recommended for heating-dominated climates.
- Windows with a low SHGC block heat gain more effectively and are better suited to cooling-dominated climates.

Deployment Recommendation

Retrofit Single-Pane Windows

- In cold climates, double-pane secondary windows with high solar heat gain will be more cost-effective.
- In warm climates, the single-pane insert with a low solar heat gain has a better return on investment.
- Well suited for historic structures where changes to the facade are limited.
- Site-specific evaluation is essential to gauging the potential success of secondary window retrofits.

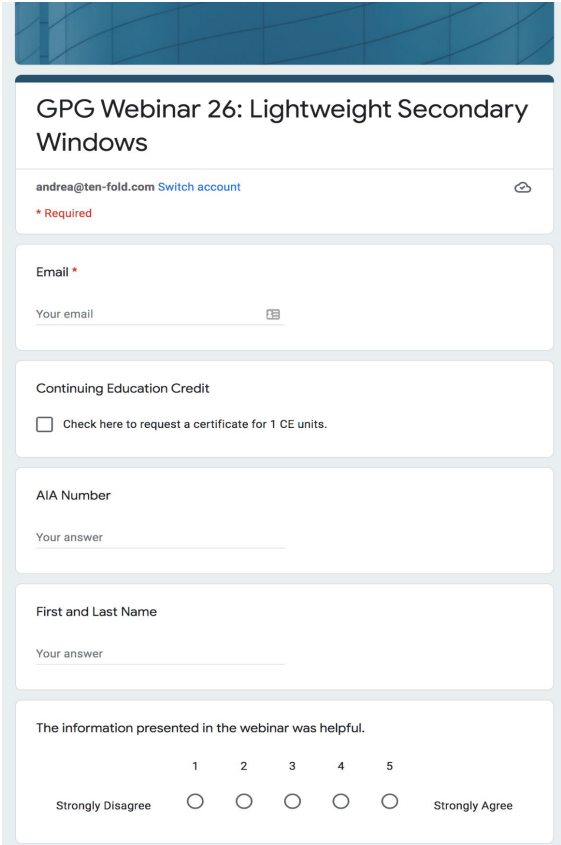
Q & A

Survey and Continuing Education Credit

GPG webinars offer 1 Continuing Education Learning Unit through the American Institute of Architects. GSA attendees are eligible for 1 Continuous Learning Point (CLP).

To receive credit:

Complete the post-webinar email survey.



Thank you

For more information: gsa.gov/GPG

Tyler Cooper, Supervisory Engineer tyler.cooper@gsa.gov 303-335-7548
Kevin Powell, Program Manager kevin.powell@gsa.gov 510.423.3384