

GPG Outbrief 25

# Lightweight Quad-Pane Windows

Emerging Building Technologies, GPG Program | U.S. General Services Administration | January 27, 2022

The logo for the U.S. General Services Administration (GSA), consisting of the letters "GSA" in white on a dark blue square background.

GSA

# GPG-048 Lightweight Quad-Pane Windows @ gsa.gov/gpg

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

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Home > Governmentwide Initiatives > Climate Action and Sustainability > Emerging Building Technologies > Published Findings > Building Envelope > Quad-Pane Windows

## Emerging Building Technologies

Overview

About Green Proving Ground (GPG)

### Published Findings

- Building Envelope
- Chromogenic Windows
- Dual-Zone Indoor Shades
- EC Windows for LPOE
- EC Windows for Office Space
- Hi-R Window System
- Low-E Window Film
- Quad-Pane Windows**
- Solar Control Films
- Vacuum Insulated Panels
- Energy Management
- HVAC
- Lighting
- On-Site Power & Renewables

## Lightweight Quad-Pane Windows

Advances in film and thin-glass technology have made lightweight quad-pane windows a cost-effective alternative to typical double-pane windows.

Researchers from the National Renewable Energy Laboratory found 24% average HVAC savings compared to high-performing double-pane windows. [View full-size infographic.](#) [PDF - 296 KB]

### 4-PAGE REPORT SUMMARY

[PDF - 584 KB]

### FULL REPORT—NOV 2021

[PDF - 3 MB]

**048** LIGHTWEIGHT QUAD-PANE WINDOWS

NOVEMBER 2021

### OPPORTUNITY

Windows are responsible for how much energy use?

**34%** OF COMMERCIAL BUILDING HVAC ENERGY IS LOST THROUGH WINDOWS<sup>1</sup>

An improved building envelope minimizes HVAC loads and contributes to Net-Zero goals

### TECHNOLOGY

How are Lightweight Quad-Pane Windows made?

**4 PANES IN INSULATED FIBERGLASS FRAME WITH WARM-EDGE SPACERS & KRYPTON GAS**

**R-8 RATED FULL-FRAME INSULATING VALUE**

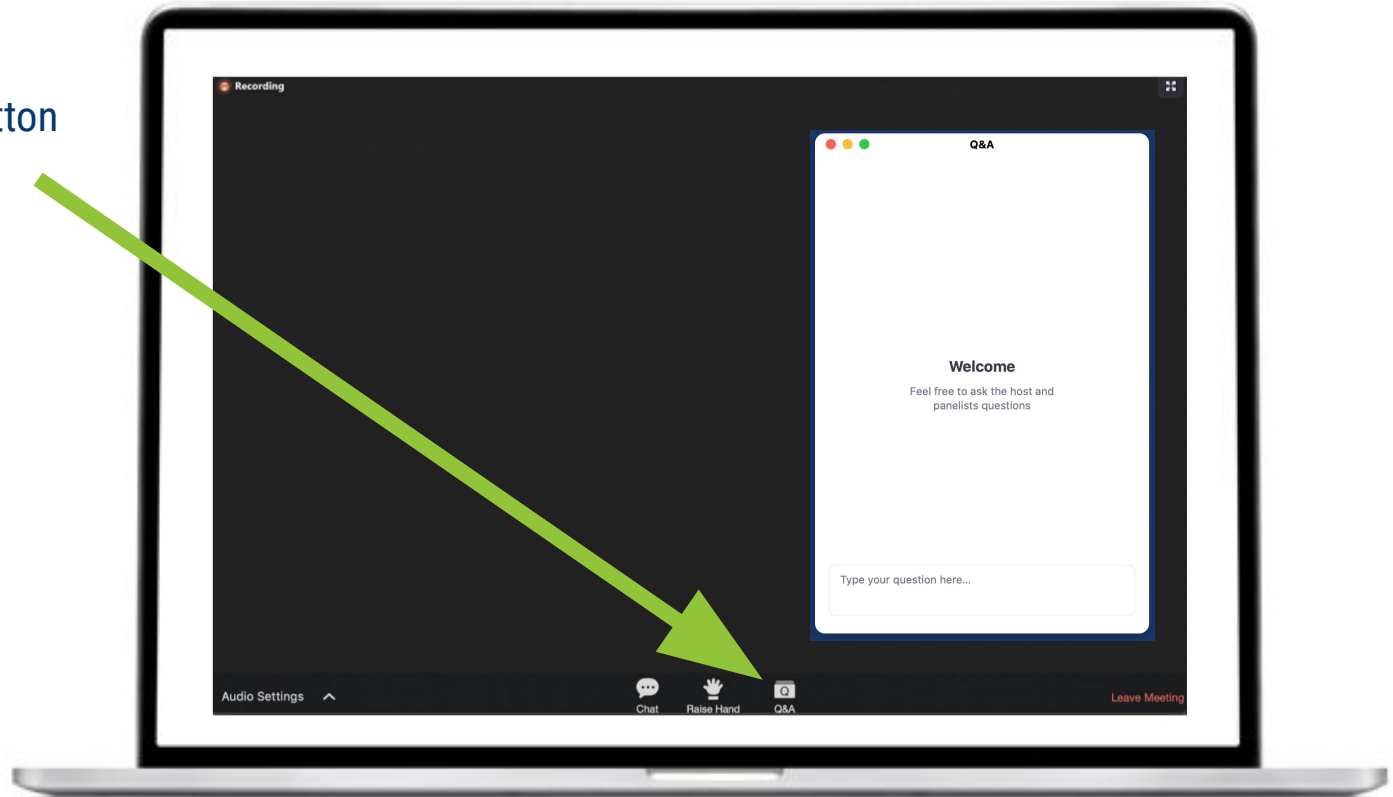
2 configurations: 2 outer panes of low-e glass containing either 2 panes of thin glass or 2 layers of suspended film

**M&V**

# How to Ask Questions

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Click the Q&A button to ask questions.



# Webinar Recording and Slides Available on gsa.gov/gpg

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Home > Governmentwide Initiatives > Climate Action and Sustainability > Emerging Building Technologies > GPG Webinars

## Emerging Building Technologies

- Overview
- About Green Proving Ground (GPG)
- Published Findings
- Ongoing Assessments
- Request for Information
- About Pilot to Portfolio (P2P)
- GPG Webinars**
- GPG-Proven Technologies with GSA Deployment Potential
- Newsletters
- GSA Technology Deployment Maps

## GPG Webinars

GPG webinars present results from real-world evaluations and feedback from facility managers at test-bed locations. Following each presentation, researchers and other GSA subject-matter experts answer questions.

### Upcoming webinars

**Lightweight Quad-Pane Windows**  
Thursday, January 27th, 2022, at 1 p.m. ET

[Register](#)

**Lightweight Secondary Windows**  
Thursday, March 3rd, 2022, at 12 p.m. ET

[Register](#)

### On-demand technology webinars

| Category          | Topic                                   | Date    | Video |
|-------------------|-----------------------------------------|---------|-------|
| Building Envelope | Electrochromic Windows for Office Space | 2018-04 |       |

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# Webinar Agenda

- ❑ Introduction (5 minutes)

Kevin Powell, Director, Center for Emerging Building Technologies

- ❑ Lightweight Quad-Pane Windows (25 minutes)

Kosol Kiatreungwattana, National Renewable Energy Laboratory

- ❑ On-the-Ground Feedback (10 minutes)

Tyler Cooper, Supervisory Energy Project Manager, GSA Region 8

- ❑ Q&A (20 minutes)

## Opportunity

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**34%** **OF COMMERCIAL BUILDING HVAC ENERGY IS LOST THROUGH WINDOWS**

An improved building envelope minimizes HVAC loads and contributes to Net-Zero goals



General Services Administration  
Public Buildings Service

GPG-048 | NOVEMBER 2021

## LIGHTWEIGHT QUAD-PANE WINDOWS



### Same Thickness as Double-Pane but with 24% more Energy Savings

Double-pane windows have been the industry standard for decades. They represent a vast improvement over single-pane windows but the potential for even greater energy savings with more highly insulating windows has been elusive. Recent price reductions in the thin glass used in both smartphones and flat-screen TVs, as well as in the krypton gas used in halogen lights, however, have made it possible to build lighter, high-efficiency quad-pane windows at a lower cost. Researchers from the National Renewable Energy Laboratory evaluated two configurations of quad-pane windows at an office building at the Denver Federal Center. Both configurations have the same thickness and a comparable weight as a standard commercial double-pane window—one model uses two layers of film suspended between two panes of standard glass, the other replaces the film with two panes of ultra-thin glass. Researchers found that on average, quad-pane windows saved 24% heating and cooling energy compared with a high-performing double-pane window. For new construction and window replacements, the quad-pane windows have payback between one and six years, depending on climate zone and utility rates, and are recommended throughout the GSA portfolio.

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

GPG-048

# Lightweight Quad-Pane Windows

# Measurement & Verification

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**Kosol Kiatreungwattana**

Research Engineer

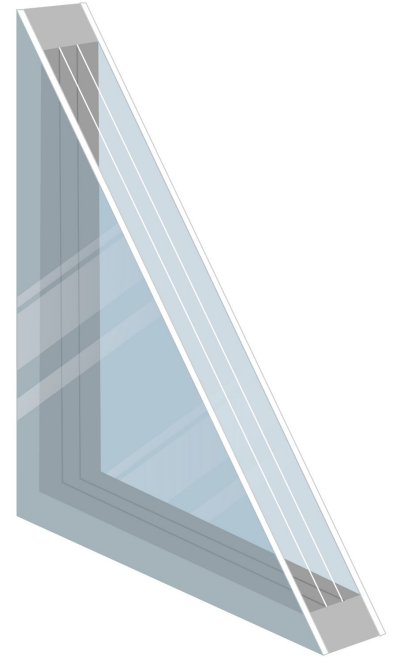
National Renewable Energy Laboratory



# Lightweight Quad-Pane Windows (provided by Alpen High Performance Products)

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- 4 panes in insulated fiberglass frame with krypton gas fill
  - 2 outer panes of low-e glass with
    - 2 inner panes of thin glass & warm-edge spacers
    - 2 layers of suspended film & stainless steel spacers
- R-8 full frame insulating value (Energy star windows are rated R-3)
- Same installation, identical profile and similar weight to double-pane windows; 50% lighter than standard triple-pane



# Lighter High-Efficiency Windows at a Lower Cost

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- Price of thin glass has dropped with increased manufacturing for smartphones and flat-screen TVs
- Krypton gas is a better insulator than more commonly used argon gas. With the market switching from halogen lighting to LED, krypton availability has increased and the price has dropped. (Krypton is 6 times denser than argon, 12 times denser than air.)
- Thin glass is also available without the frame for curtain-wall applications
- Units with thin glass can be made blast resistant



# Rated Insulating Value of Double- Triple- & Quad-Pane

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|          | <b>High-Performance Double-Pane</b> | <b>Triple-Pane*</b> | <b>Quad-Pane—Thin Glass &amp; Suspended Film</b> |
|----------|-------------------------------------|---------------------|--------------------------------------------------|
| U-Factor | 0.32                                | 0.15                | 0.12                                             |
| R-Value  | 3.1                                 | 6.7                 | 8.3                                              |

\*Incremental cost difference between Alpen Triple and Quad-Pane ~5% to 7%

# Thin Glass vs. Suspended Film

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|                         | Thin Glass                                                  | Suspended Film                                                                                    |
|-------------------------|-------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Cost                    | \$35/ft <sup>2</sup>                                        | \$37/ft <sup>2</sup>                                                                              |
| Weight                  | 6 lbs/ft <sup>2</sup><br><i>same as typical double-pane</i> | 5 lbs/ft <sup>2</sup>                                                                             |
| Condensation Resistance | 80<br><i>warm-edge spacers increase CR</i>                  | 65<br><i>uses stainless-steel spacers</i>                                                         |
| Customization           | SHGC                                                        | SHGC as well as additional customization with inner low-e film, meets tempered glass requirements |

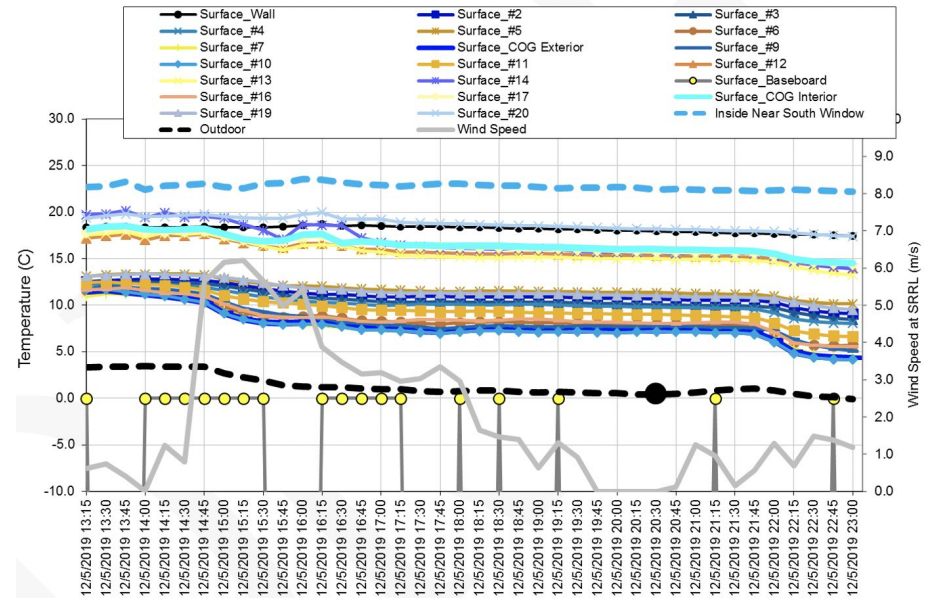
# Lightweight Quad-Pane Windows



# M&V Design

## Five thin-glass and five suspended film windows installed on western façade

- Measured glass, frame surfaces, space conditions, and outdoor 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-office building
- Calculated HVAC capacity, energy savings, and economics



# Modeling Results

|                                | U-Value               |                            | Solar Heat Gain Coefficient | Visible Transmittance | Condensation Rating |
|--------------------------------|-----------------------|----------------------------|-----------------------------|-----------------------|---------------------|
|                                | (W/m <sup>2</sup> ·K) | Btu/(h·ft <sup>2</sup> ·F) |                             |                       |                     |
| Quad-pane with suspended films | 0.832                 | 0.147                      | 0.20                        | 0.44                  | 65                  |
| Quad-pane with thin glass      | 0.953                 | 0.168                      | 0.20                        | 0.47                  | 67                  |

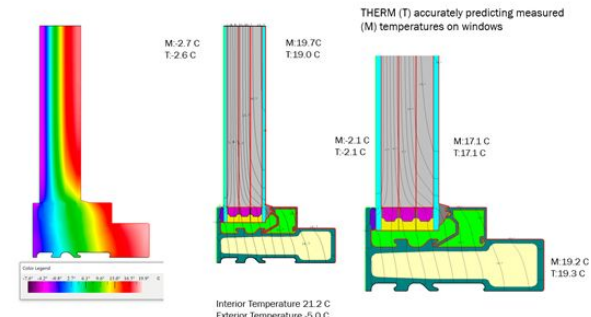
## Simulated results included

**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

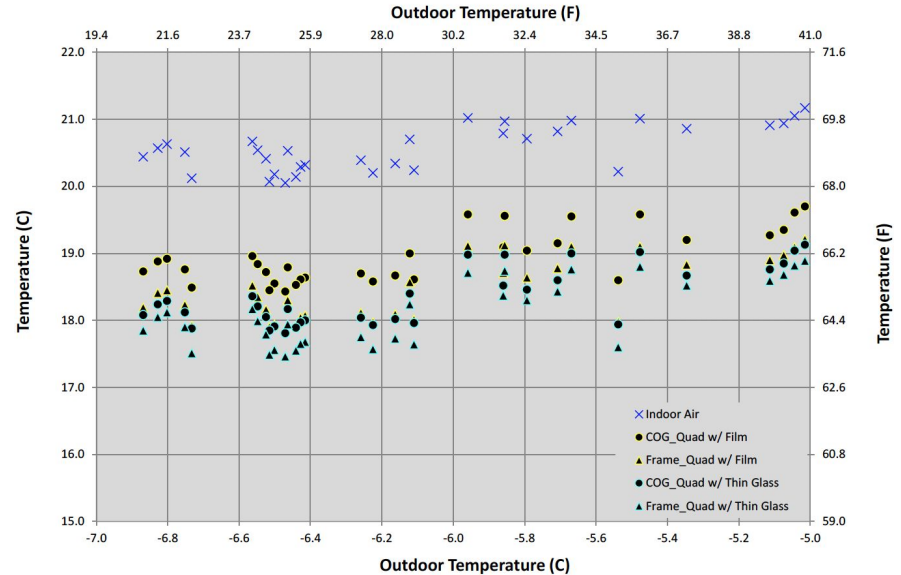
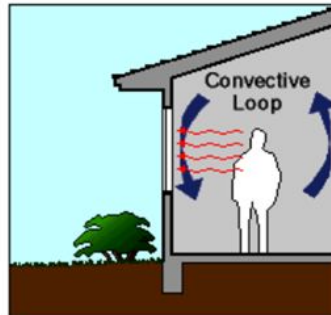
**Visible Light Transmission** the amount of light that passes through the window

**Condensation Resistance** indicates how well a window resists interior condensation



# Increased Thermal Comfort

- When the outdoor temperature was 21.6°F
  - Center of glass (COG) temperature was 66.2°F for quad-pane with film
  - COG was 65.2°F for the thin glass configuration
- Majority of the conditions were within the comfort boundary
- Reduced convective & radiative heat transfer effects





# Reduced HVAC Capacity Requirements

- Installing higher-performing windows can reduce HVAC capacity requirements.
- In the modeling for a large office building (498K ft<sup>2</sup>)
  - Required HVAC capacity reduced ~8% for heating and ~18% for cooling
  - Reduced capital costs of HVAC equipment by ~\$120K

| Performance Metric                                     | High Performance Double-Pane Baseline | Quad With Film | Quad With Thin Glass |
|--------------------------------------------------------|---------------------------------------|----------------|----------------------|
| Heating Capacity (kBtu/hr)                             | 11,321                                | 10,443         | 10,549               |
| Cooling Capacity (kBtu/hr)                             | 12,048                                | 9,933          | 9,908                |
| Reduction in Heating Capacity (%)                      | N/A                                   | 8%             | 7%                   |
| Reduction in Cooling Capacity (%)                      | N/A                                   | 18%            | 18%                  |
| Estimated total HVAC capacity savings (\$)             | N/A                                   | \$121,481      | \$118,200            |
| Annualized HVAC capacity savings over 20 years (\$/yr) | n/a                                   | 6,074          | 5,910                |

# Condensation

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- Condensation Rating (CR) indicates how well a window resists forming condensation on the inside surface (0-100)
- CR above 50 is recommended for cold climates
- Quad-pane with thin glass CR: 67
  - Testbed used steel spacers instead of warm-edge spacers and Alpen estimates that warm edge spacers would increase thin glass CR to 80
- Quad-pane with film CR: 65
  - Film version uses stainless steel spacers and can not use warm-edge spacers



# Quad-Pane Window Performance

**24%**  
average HVAC  
savings\*

\*compared to high-performance double-pane window; suspended film saved 1% more on average than thin glass

New construction payback < 3 years at average GSA utility rates\*\*

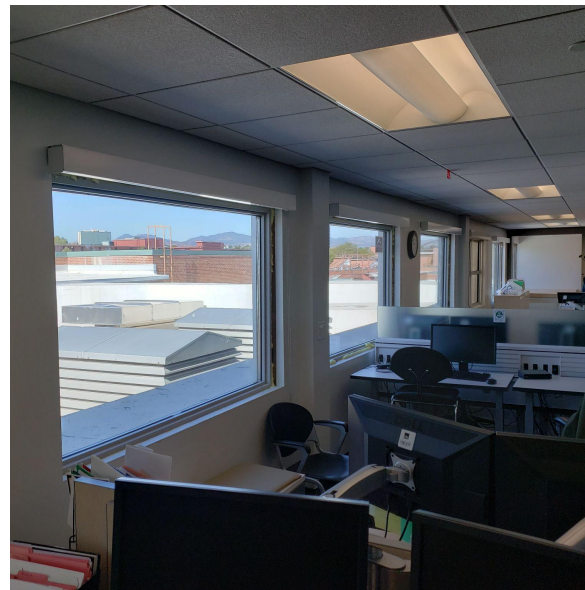
| Location               |                   | Savings from High-Performance Double-Pane to Quad-Pane Thin Glass* |                        |                    |            |                  |                           |
|------------------------|-------------------|--------------------------------------------------------------------|------------------------|--------------------|------------|------------------|---------------------------|
| CLIMATE ZONE           | CITY              | HEATING<br>kBtu/ft2/yr                                             | COOLING<br>kBtu/ft2/yr | FAN<br>kBtu/ft2/yr | TOTAL<br>% | PAYBACK**<br>YRS | SIR<br>positive ROI if >1 |
| 1A                     | Miami, FL         | 0.64                                                               | 2.29                   | 1.61               | 19%        | 1.7              | 12.1                      |
| 2A                     | Dallas, TX        | 1.09                                                               | 2.36                   | 1.59               | 20%        | 1.5              | 12.9                      |
| 2B                     | Phoenix, AZ       | 1.13                                                               | 2.16                   | 2.00               | 25%        | 1.5              | 13.3                      |
| 3A                     | Atlanta, GA       | 1.97                                                               | 2.31                   | 1.65               | 24%        | 1.4              | 14                        |
| 3B                     | Las Vegas, NV     | 1.54                                                               | 1.82                   | 2.08               | 27%        | 1.6              | 12.7                      |
| 3C                     | San Francisco, CA | 1.95                                                               | 2.00                   | 1.78               | 33%        | 1.5              | 13.1                      |
| 4A                     | Washington, D.C.  | 3.25                                                               | 2.48                   | 1.66               | 28%        | 1.3              | 15.5                      |
| 5A                     | Chicago, IL       | 4.40                                                               | 0.56                   | 1.21               | 23%        | 2.5              | 7.9                       |
| 5B                     | Ogden, UT         | 3.62                                                               | 0.68                   | 1.43               | 23%        | 2.4              | 8.3                       |
| 6A                     | Minneapolis, MN   | 4.96                                                               | 0.55                   | 1.17               | 20%        | 2.5              | 8.1                       |
| <b>AVERAGE SAVINGS</b> |                   | <b>2.46</b>                                                        | <b>1.72</b>            | <b>1.62</b>        | <b>24%</b> | <b>1.8</b>       | <b>11.8</b>               |

\*\*\$32.38/ft<sup>2</sup> double-pane    \$34.87/ft<sup>2</sup> quad-pane with thin glass    \$36.87/ft<sup>2</sup> for quad-pane with film

# Summary

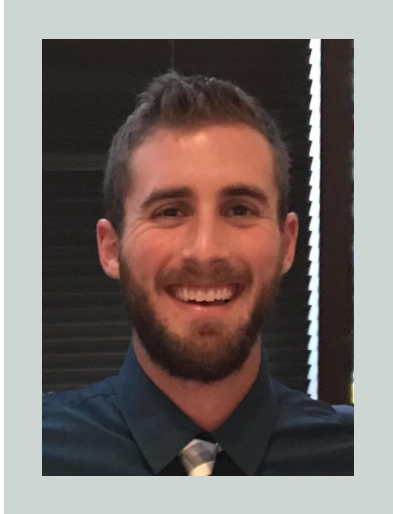
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- Modeled savings across climate zones were between 19% and 34% compared to a high-performance double-pane window
- Reduced HVAC capacity requirements
- Same thickness and comparable weight to double-pane windows
- Improved occupant comfort by reducing radiative and convective heat transfer effects
- Incremental cost difference of  $\sim \$2.50/\text{ft}^2$  for thin-glass and  $\sim \$4.50/\text{ft}^2$  for suspended film compared to a high-performance window
- Payback between 1 and 6 years



# GSA Feedback—Denver Federal Center

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**Tyler Cooper**  
Supervisory Energy PM  
GSA Region 8

# Identical Installation

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- Replacement and installation of a quad-pane window is the same as for a typical double-pane window.
- The weight of the quad-pane is similar to a double-pane window and 50% lighter than a triple-pane window made with standard glass.
- **Uses:** Fixed, Ribbon/Strip, Large “Punched” Openings and Window Walls
- **Applications:** New Construction, Retrofit, Residential, Commercial, Industrial & High Performance Buildings



# Occupant Satisfaction

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- 4 out of 5 occupants recommended window retrofit
- More visually appealing
- Baseline windows were older electrochromic and thermochromic windows, and window shades were disabled, so some occupants reported glare in comparison with electrochromic window
- Some thermal discomfort was reported but this already existed and may be caused by HVAC operation



# Best Practices

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- Higher-efficiency windows can reduce HVAC capacity requirements and should be calculated in the economics of any new construction or major renovation projects.
- 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

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## New Construction and End-of-Life Replacement

- Supports net-zero carbon emission goals
- At current pricing, the thin-glass configuration is more cost-effective
- The suspended film version offers more versatility in low-e coatings, provides better UV protection, and is a better option when tempered glass is a requirement.
- The film version is also lighter, about 1 lb per square foot lighter when compared to thin glass.
- For windows that have not yet reached end-of-life, consider thin glass secondary window inserts or low-e film



Q & A


# Survey and Continuing Education Credit

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### GPG Outbrief 25: Lightweight Quad-Pane Windows

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AIA Number

Your answer

First and Last Name

Your answer

The information presented in the Outbrief webinar was helpful.

1 2 3 4 5

Strongly Disagree      Strongly Agree

I am interested in installing lightweight quad-pane windows.

Yes, in the next 2 years.

Yes, in the next 5 years.

# Upcoming Webinar

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March 3    Lightweight Secondary Windows

## Webinar Recordings

Access all webinars on [GSA.gov](https://www.gsa.gov)

[GSA.gov/GPG](https://www.gsa.gov/GPG)

Thank you



For more information: [gsa.gov/GPG](https://gsa.gov/GPG)

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