December 07, 2023

GPG Outbrief 30
Automated Building Envelope Sealing

Green Proving Ground | U.S. General Services Administration

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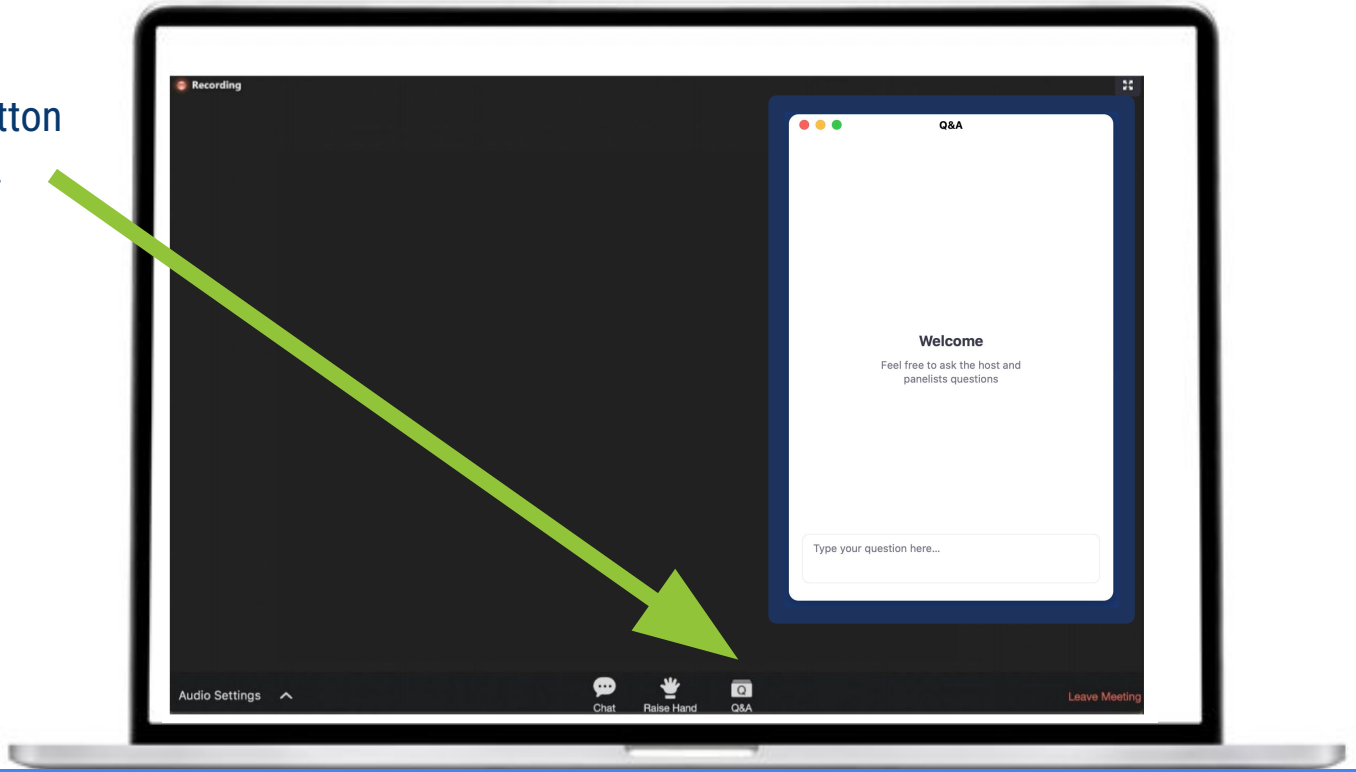

Webinar Recording and Slides

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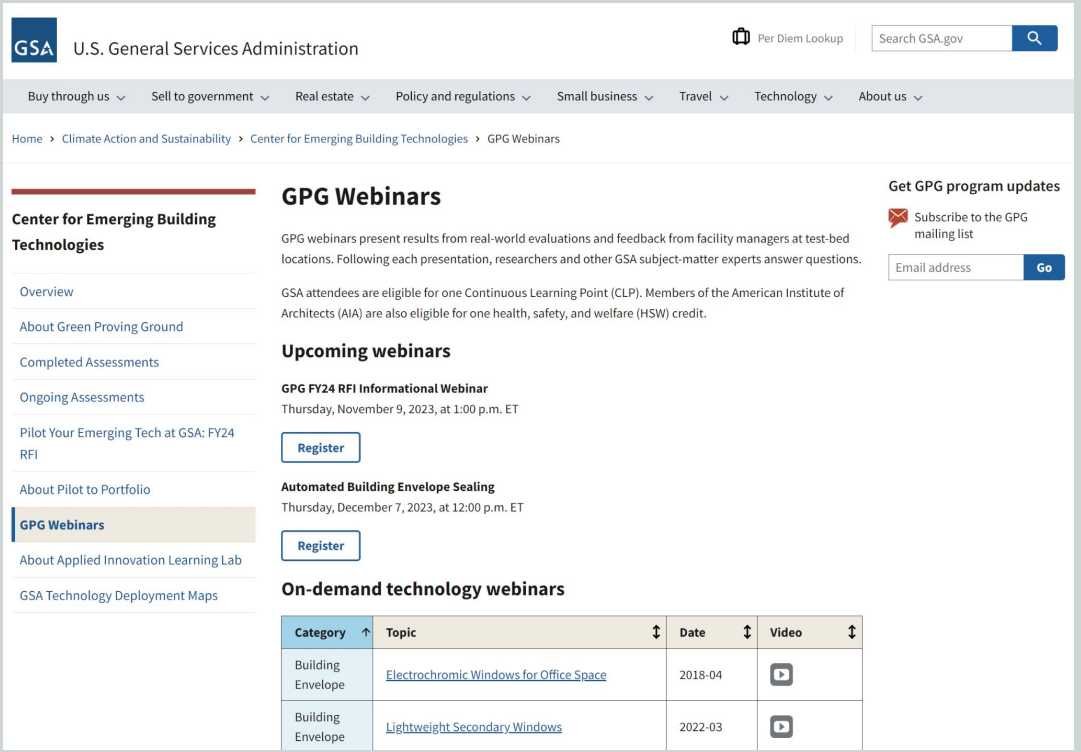
The webinar is being recorded.

The recording and slides will be shared by email and posted to gsa.gov.



GPG-053 Automated Building Envelope Sealing

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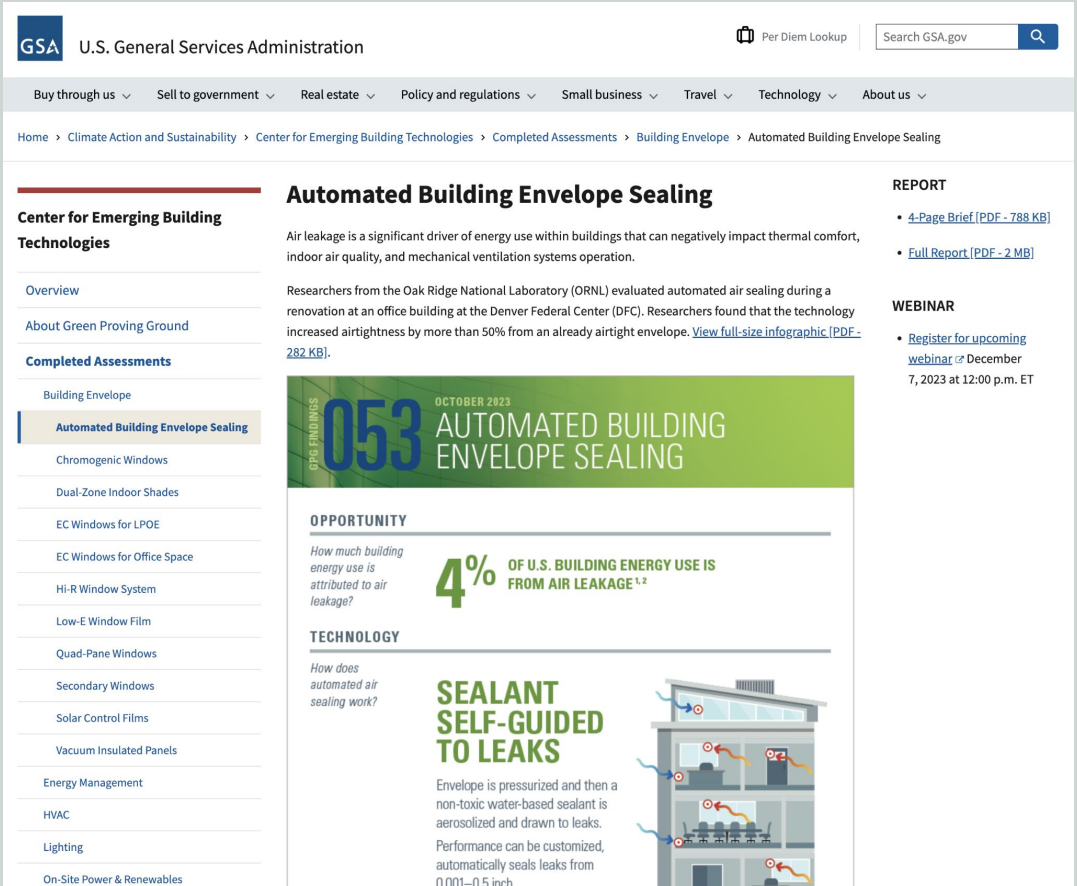
- Infographic
- 4-Page Brief
- Full Report



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Center for Emerging Building Technologies

- Overview
- About Green Proving Ground
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  - Building Envelope
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    - Chromogenic Windows
    - Dual-Zone Indoor Shades
    - EC Windows for LPOE
    - EC Windows for Office Space
    - Hi-R Window System
    - Low-E Window Film
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    - Solar Control Films
    - Vacuum Insulated Panels
  - Energy Management
  - HVAC
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  - On-Site Power & Renewables

Automated Building Envelope Sealing

Air leakage is a significant driver of energy use within buildings that can negatively impact thermal comfort, indoor air quality, and mechanical ventilation systems operation.

Researchers from the Oak Ridge National Laboratory (ORNL) evaluated automated air sealing during a renovation at an office building at the Denver Federal Center (DFC). Researchers found that the technology increased airtightness by more than 50% from an already airtight envelope. View full-size infographic [PDF - 282 KB].

GPG FINDINGS 053 OCTOBER 2023 AUTOMATED BUILDING ENVELOPE SEALING

OPPORTUNITY

How much building energy use is attributed to air leakage?

4% OF U.S. BUILDING ENERGY USE IS FROM AIR LEAKAGE[1,2]

TECHNOLOGY

How does automated air sealing work?

SEALANT SELF-GUIDED TO LEAKS

Envelope is pressurized and then a non-toxic water-based sealant is aerosolized and drawn to leaks.

Performance can be customized, automatically seals leaks from 0.001–0.5 inch

REPORT

- 4-Page Brief [PDF - 788 KB]
- Full Report [PDF - 2 MB]

WEBINAR

- Register for upcoming webinar December 7, 2023 at 12:00 p.m. ET

Webinar Agenda

Introduction (5 minutes)
Erin Lannon, Program Manager, Applied Innovation Learning Lab

Evaluation of Automated Building Envelope Sealing (20 minutes)
Emishaw Iffa, Researcher, Oak Ridge National Laboratory

On-the-Ground Feedback (10 minutes)
Tyler Cooper, Mechanical Engineer, GPG Technical Committee, Region 8

Q&A (20 minutes)

Opportunity

4% OF U.S. BUILDING ENERGY USE IS FROM AIR LEAKAGE

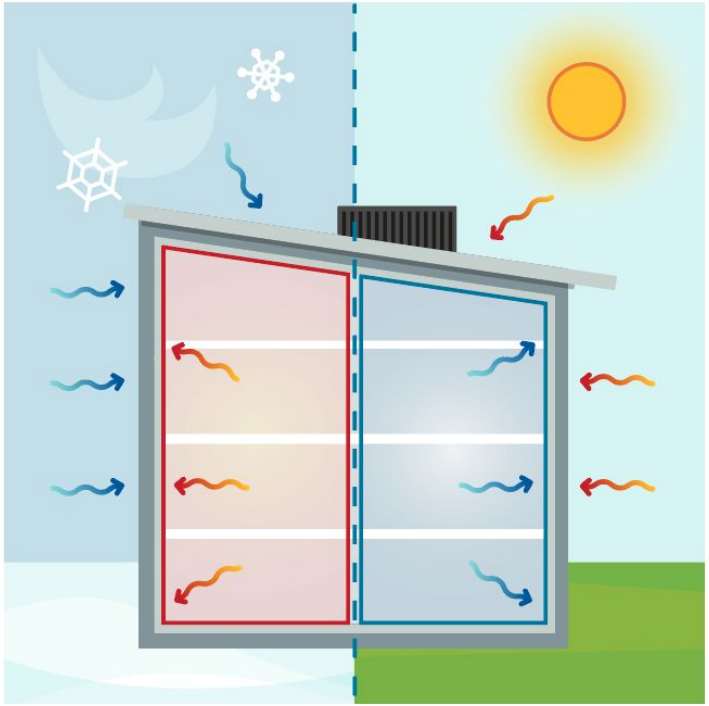
Supports GSA's Climate Goals

High-performing envelopes are the most effective way to reduce a building's heating and cooling demand and support building electrification.

They will be key to meeting GSA's ambitious goals:

2030
65% reduction of operational GHG (2008 baseline)

2045
Net Zero Carbon Operations across building portfolio



Measurement & Verification

Emishaw Iffa
Researcher
Oak Ridge National Laboratory

GPG-053

Automated Building Envelope Sealing

Emishaw Iffa, Niraj Kunwar, Mikael Salonvaara
Oak Ridge National Laboratory

General Services Administration
Public Buildings Service

GSA

GPG-053 | OCTOBER 2023

AUTOMATED BUILDING ENVELOPE SEALING

Increases Airtightness and Reduces Overall Heating and Cooling Demand

Air leakage is a significant driver of energy use within buildings. The U.S. Department of Energy estimates that it accounts for approximately 4% of building energy use in the United States. [1,2] Air leakage also negatively impacts thermal comfort, indoor air quality, and mechanical ventilation systems operation. Typical manual air sealing with spray foam and weather stripping can increase airtightness between 6% and 17%.[3]

Automated envelope sealing is automatically drawn to leaks, removing human error and reaching inaccessible areas. Researchers from the Oak Ridge National Laboratory (ORNL) evaluated automated air sealing during a renovation at an office building at the Denver Federal Center (DFC). Researchers found that the technology increased airtightness by more than 50% from an already airtight envelope.

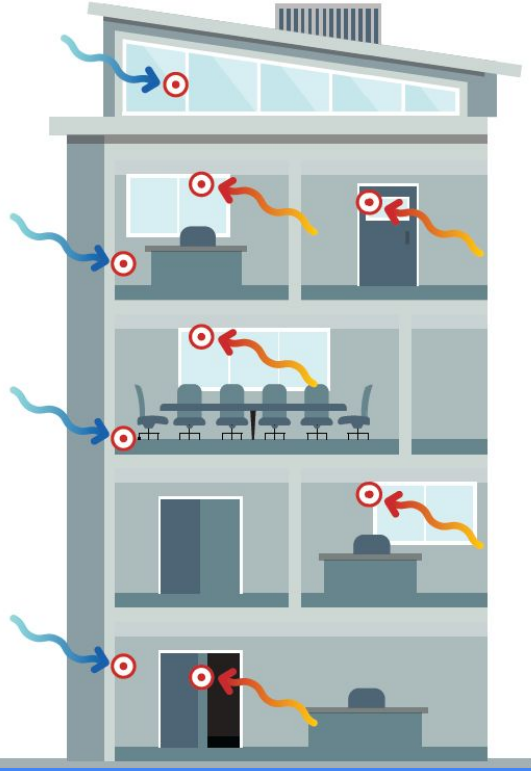
The largest potential for cost savings is when heating, ventilation, and air conditioning (HVAC) equipment is downsized along with envelope tightening. Researchers estimated that HVAC equipment costs could drop by 70% when tightening a leaky envelope. A sealed building envelope reduces overall heating and cooling demand, supporting GSA's climate goals and enabling low-cost building electrification. It should be considered for all new construction and major renovation projects in GSA's portfolio.

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

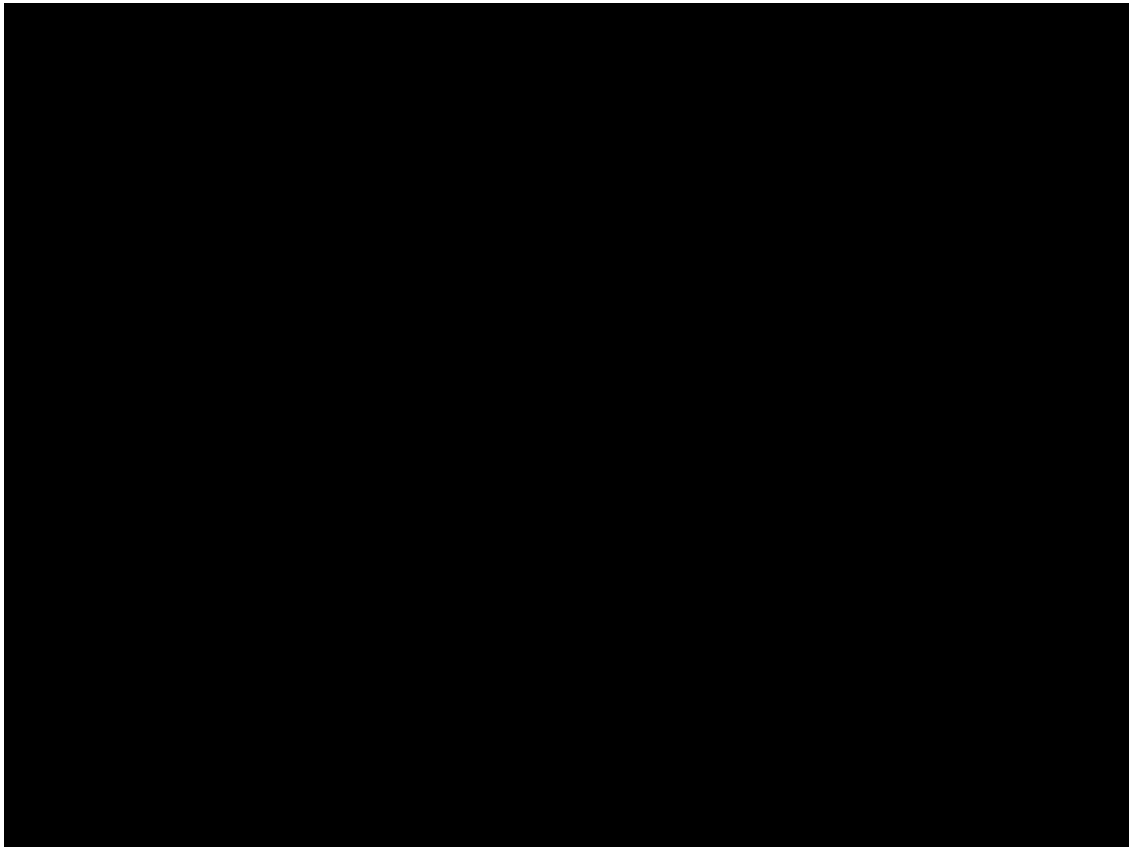
How Does Automated Building Envelope Sealing Work?

Sealant self-guided to leaks

- Building is pressurized, then a non-toxic water-based sealant is aerosolized and drawn to leaks
- Removes human error and reaches inaccessible areas



Automated Air Sealing Process



Automated Building Envelope Sealing from Aeroseal

System Features

- Seals holes from 0.0001” to ½” in diameter
- Sealant is ultra-low volatile organic compounds (VOCs) with no off-gassing. Space can be re-entered within 30 minutes of sealing.
- Sealant particles build on each other incrementally, closing envelope leaks to the degree specified by the system software.
- The system creates a digital record, tracking air leakage before and after.

Non-Energy Benefits of a Tighter Envelope

- Improved Thermal Comfort
- Better Indoor Air Quality
- Moisture Control and Long-Term Durability
- Noise Reduction
- Compliance with Building Codes and Standards

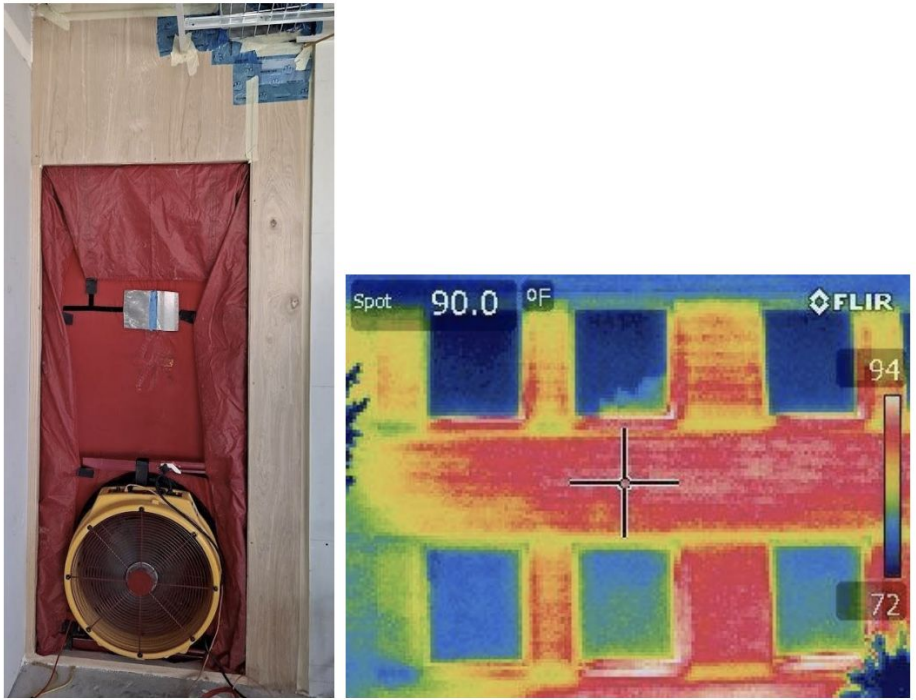
Automated Building Envelope Sealing Testbed

Denver Federal Center, Bldg. 40, Denver, CO

- Two-story office building with steel frame and brick façade
- 46,000 ft^2
- Built in 1940

Evaluation Framework and Schedule

- Installed 4,461 ft^2 of space during a major renovation in 2022
- In preparation for the sealing, two temporary walls were installed, and intentional openings, such as electrical outlets and fan vents, were covered.
- Blower door tests were performed before and after sealing



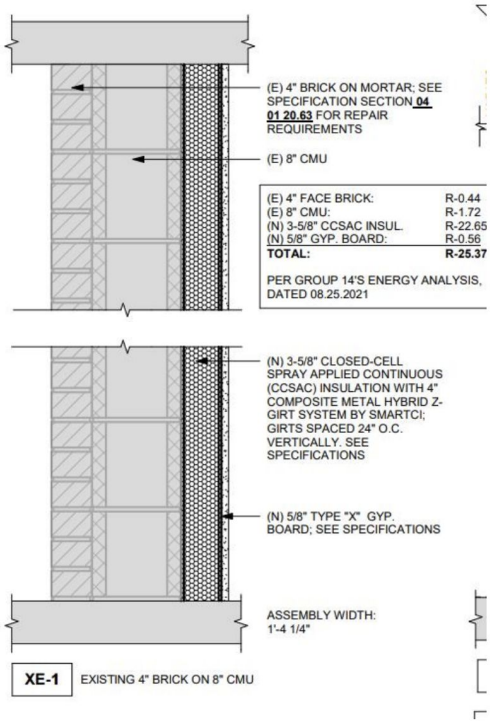
(a) (b)

Figure 1. (a) Blower door test and (b) thermal images of Denver Federal Center's Building 40.

Retrofit Wall System

Building airtight before demonstration

- Retrofitted with 3 5/8 in. closed cell spray foam
- Quad-pane windows



M&V Performance Results

Quantitative Objective	Results
Building Airtightness	53%*
Energy Savings	6% to 63%**
HVAC Capacity Reduction	67% for cooling and 71% for heating**
Cost-Effectiveness	Savings to Investment ratio > 1**

* From a baseline of an airtight building: 0.23 CFM/t^2

** From a baseline of a leaky building: 1.2 CFM/ft^2 , savings vary based on climate and building characteristics such as exposed surface area

Airtightness

- 53% increased airtightness, from an already tight envelope of 0.23 CFM/ft^2 to 0.11
- Meets P-100 Tier 3 performance standards
- Manual sealing with spray foam/weather stripping typically reduces air leakage 6% to 17%*
- Unlike residential buildings code, commercial buildings were subject to no code restrictions regarding airtightness until 2021.

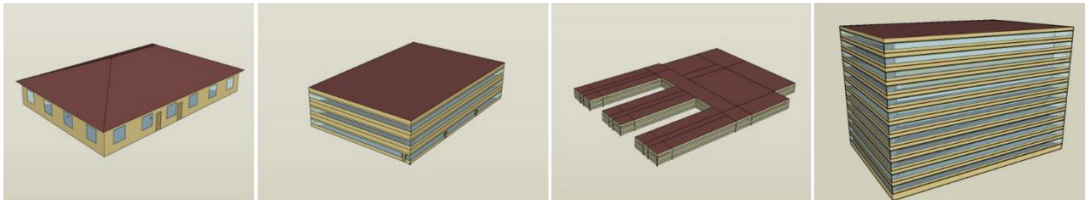
Standards	Requirement (CFM/ft^2)	DFC Testbed
GSA PBS P-100 and IECC 2021C402.5.3	0.40	
P-100 Tier 1 high performance	0.25	Baseline 0.23
P-100 Tier 2 high performance	0.15	
P-100 Tier 3 high performance	0.10	Automated air sealing 0.11

* D. Bohac, M. Hewett, J. Fitzgerald, J. Novacheck, and A. Lutz. 2014. “Leakage Reductions for Large Building Air Sealing.” International Journal of Ventilation 12, No. 4 : 307–316

Energy Savings Simulation Design

- The models used in this study were EnergyPlus v.9.3 and ORNL's Air Infiltration Calculator.
- ORNL's infiltration calculator used CONTAM simulation for whole building air leakage calculations and EnergyPlus simulation for whole building energy calculations.

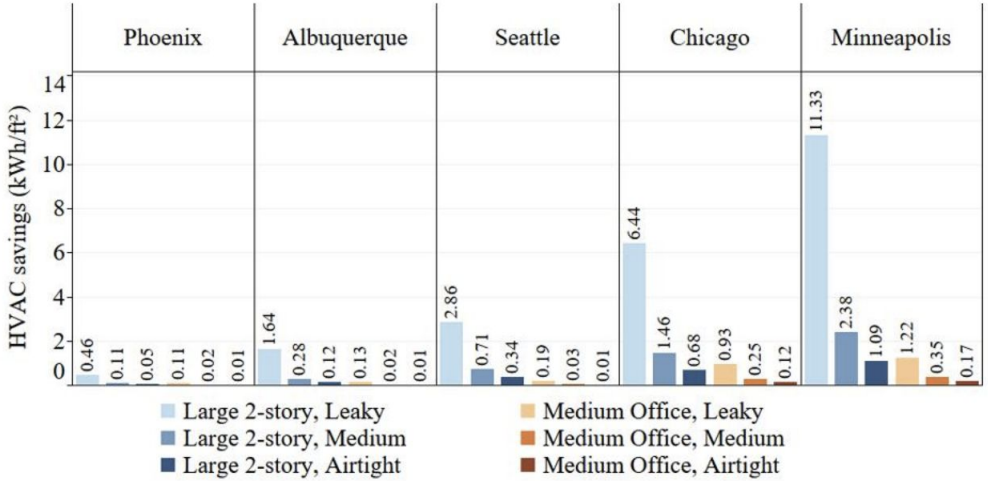
Parameter	Type of Parameters	Selected Values
Initial building airtightness*	Leaky Medium Airtight	1.20 cfm/ft^2 0.40 cfm/ft^2 0.25 cfm/ft^2
Building type (No. floors / floor area / surface area / core zone to perimeter zone)	Small office Medium office Large 2-story Large 12-story	1 floor / 5,500 ft^2 / 8,526 ft^2 / 0.41 3 floors / 53,620 ft^2 / 75,544 ft^2 / 1.45 2 floors / 210,887 ft^2 / 252,500 ft^2 / 0.11 12 floors / 498,588 ft^2 / 623, 400 ft^2 / 2.75



* Across ASHRAE climate zones 1A - 8A

Energy Savings Simulation Results

- Leaky buildings, in cold climates with more exposed surface area have the greatest savings.
- In similar heating/cooling climates, humid climates showed two times greater savings because HVAC systems use additional energy for dehumidification.



HVAC Capacity Reduction: Supports Electrification

Heat Pump Capacity Requirement*				
Building Airtightness	**Baseline** kBtu/hr	**Savings**** kBtu/hr	**Capacity Reduction** (%)	**Capacity Cost Savings** ($)
Leaky 1.2 CFM/ft^2	4316	3053	71%	$506,798
Medium .40 CFM/ft^2	2155	892	41%	$148,072

*2-story, 210,887 ft^2 building in Minneapolis. EIA 2023, Updated Buildings Sector Appliance and Equipment Costs and Efficiencies: Typical 2022 heat pump installed cost: $166/kBTu/hr; COP: 3.37-3.4; Capacity: 90 kBtu/hr. **Automated air sealing = 1,263 kBtu/hr (.11 CFM/ft^2)

Additional Savings Possible

Automated air sealing can reduce costs of:

- Interior caulks or foams, or both—excluding fire caulking
- Gaskets for electrical boxes, plumbing penetrations, and data boxes
- Acoustical sealants, backer rod foam
- Spray foam for exterior wall application—subbed with automated air sealing and fiberglass or cellulose or Rockwool insulation

Energy Savings Payback for Leaky Buildings

Leaky buildings in cold climates have ROI based on energy savings alone

Location		Leaky Baseline (1.2 CFM/ft²)*		
CLIMATE ZONE	**CITY**	**ELECTRICITY** Savings kWH/ft²/yr	**GAS** Savings kBtu/ft²/yr	**PAYBACK** Years
2B	Phoenix, AZ	0.29	0.57	31
4B	Albuquerque, NM	0.07	5.37	21
4C	Seattle, WA	0.10	9.35	12
5A	Chicago, IL	0.79	19.27	5
6A	Minneapolis, MN	2.03	31.74	2

* Assuming an installed cost of $1.25 ft² for a 2-story, 210,887 ft² building and average GSA utility rates of $0.12/kWh for electricity and $9.6/MMBtu for gas

Payback with HVAC Capacity Reduction*

Leaky buildings have immediate payback with capacity reduction

Climate/Building Airtightness	Installation ($)	Capacity Cost Savings ($)	Annual Energy Savings ($)	Payback, energy savings alone	Payback, including capacity reduction
Cold: 6A Minneapolis					
Leaky 1.2 CFM/ft^2	$263,608	$506,798	$114,384	2	Immediate
Medium .40 CFM/ft^2	$263,608	$148,072	$21,237	12	5

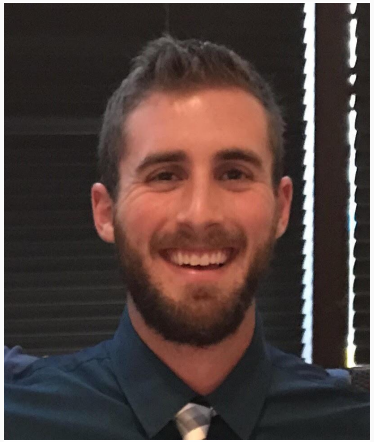
* Assuming an installed cost of $1.25 ft^2 for a 2-story, 210,887 ft^2 building and average, GSA utility rates of $0.12/kWh for electricity and $9.6/MMBtu for gas

Deployment Recommendation

Supports building electrification

- Efficient electrification requires a tight building envelope.
- Applicable to historic buildings and may be particularly effective for brick, concrete, and limestone façades where other insulation methods are not possible.
- Specify in the design phase to reduce HVAC equipment and insulation costs.

GSA Feedback



Tyler Cooper
Supervisory Energy PM, Mechanical Engineer
Green Proving Ground Technical Committee, GSA Region 8

Electrification at the DFC

- An efficient envelope can reduce the upfront cost of electrifying by allowing the building to operate with less powerful (lower-capacity) equipment
- Currently planning to electrify the entire DFC campus (excluding a few buildings) via NDER6 ESPC
    - Combination of Geothermal and Heat Pump technologies
- Savings at the building envelope will directly reduce the number of Geothermal Wells required and allow for lower/higher supply water temperatures for heating and cooling the spaces.

1-Day Installation

- Sealing completed in 2.5 hours. The entire process took just under 7 hours, including preparation, sealing, and cleanup.
- No issues post-installation.

Installation Preparation for Occupied Space

- Automated air sealing can be done in occupied buildings, but requires additional prep work: plastic, tape, and protective coatings must be covered on all horizontal surfaces.
- In addition, personal belongings, fixed cabinetry, and appliances must be covered or removed from the space temporarily.
- Costs are more expensive for occupied space: $\$1.75/ft^2$ vs $\$0.90\text{-}\$1/ft^2$ for new construction

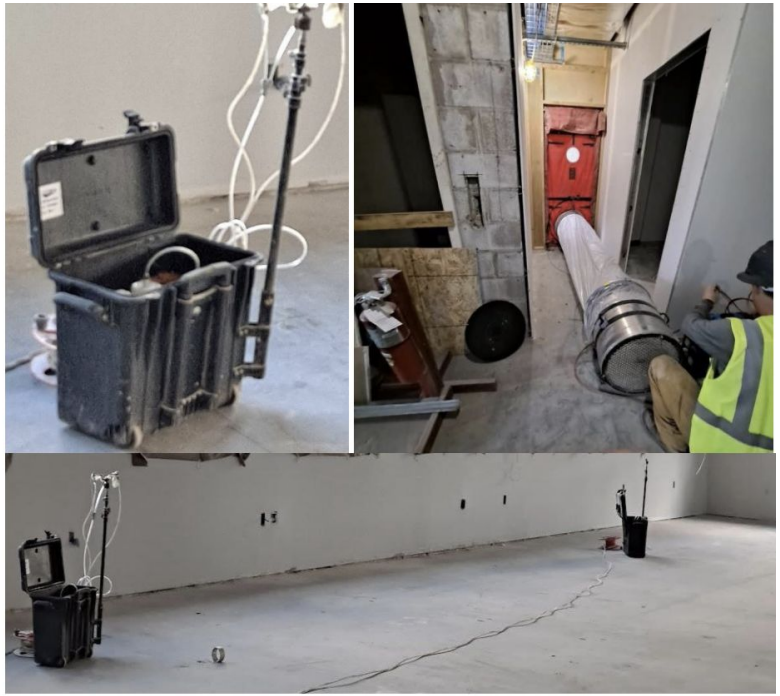
Best Practices and Lessons Learned

- **Specify in the design phase.** Additional cost reductions for HVAC capacity and insulation can be realized, increasing the opportunities for a positive return on investment.
  - Energy modeling is critical for optimizing savings
- **Savings are site specific.** Energy savings are highly dependent on building leakage, climate, and exposed surface area
- **General Contractor** should manage the installation process.

Entry Points for Automated Air Sealing

Post-insulation/post-electrical, mechanical, data and plumbing

- Can reduce the overall cost of insulation by using less expensive insulation instead of spray foam. It can also reduce the cost of interior caulking, acoustical sealants, and gaskets for electrical boxes, plumbing penetrations, and data boxes.
- Provides the biggest impact because it can reach the furthest exterior spaces.
- If using fiberglass insulation, use automated air sealing before insulating, or after drywall.



Entry Points for Automated Air Sealing

Post-insulation/pre-drywall

- Can fix problems with spray foam insulation if it has delaminated from the framed structure.

Entry Points for Automated Air Sealing

Post-drywall (mud/tape)

- Can correct the envelope's air or vapor barrier that may have been removed or damaged during construction.
- Most common entry point because it provides the most flexibility in the construction schedule.

Deployment

- Sealing the building envelope is integral to reducing heating and cooling loads and reaching our net-zero goals.
- We see the biggest bang for our buck if we can reduce the size of our HVAC equipment at the same time as we seal the envelope, demonstrating the effectiveness of technology stacking


Q&A

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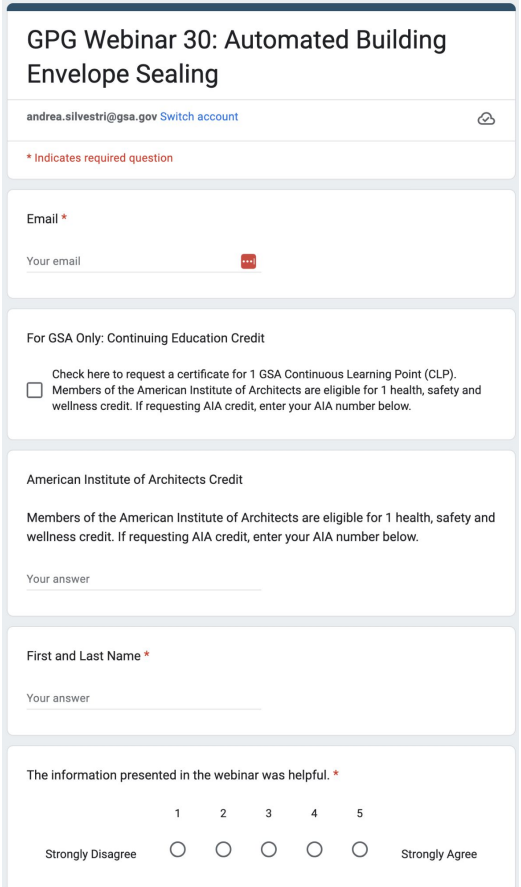

GPG Webinar 30: Automated Building Envelope Sealing

andrea.silvestri@gsa.gov Switch account

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Your answer

First and Last Name *

Your answer

The information presented in the webinar was helpful. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

Thank you

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