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Automated Air Sealing Demonstration: Denver Federal Center Building 40

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Disclaimer

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GSA's Green Proving Ground (GPG) program and DOE's Office of Energy Efficiency and Renewable Energy enable federal and commercial building owners and operators to make sound investment decisions in next-generation building technologies based on their real-world performance.

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Introduction

Executive Summary

This project aimed to demonstrate building airtightness achieved by automated air sealing in a commercial building setting. The automated air sealing demonstrated in this project uses a modified blower door to pressurize and distribute the sealing aerosol to achieve the required building airtightness. To demonstrate this technology, Building 40 at the Denver Federal Center, a federally owned campus under the jurisdiction, custody and control of the U.S. General Services Administration (GSA), was selected for testing (Figure 2). This building is currently undergoing several retrofit projects, including increasing insulation, installing high-performance windows, and adding advanced equipment, control systems, and automated air sealing.

This demonstration project involved installing automated air sealing and measuring the improvements in the building's airtightness. The automated air sealing was installed over two days by AeroBarrier, the vendor. An external blower door test contractor measured the airtightness of the demonstration space before and after air sealing. The new airtightness value and the percentage increase in airtightness were used to evaluate the energy savings potential of automated air sealing. These airtightness values were used to compute the energy savings and CO_2 emissions reduction for different climate zones, building types, and initial airtightness conditions. In addition, the heating, ventilation and air conditioning (HVAC) load reduction attributable to the reduced building air leakage was studied. This study included research to determine the cost and time reduction of automated air sealing. Finally, the automated air sealing performance was evaluated qualitatively using a focus group discussion that included GSA and Bristol, the general contractor.

The installation has shown the demonstration site, with a floor size of 4,462 ft^2, air leakage has reduced by more than 50% in less than 7 hours, including preparation, site sealing, and cleanup.

The performance objectives were classified as quantitative or qualitative based on the evaluation metrics used to assess the project’s success. The key performance objectives for this project were the level of airtightness achieved, the time and cost required to perform the sealing, and the HVAC load reduction attributable to air sealing. Table 1 shows the quantitative performance objectives.

Table 1. Quantitative Performance Objectives

Quantitative Performance Objectives	Metric	Data Requirement	Demonstration Result
Building Airtightness	cfm/ft^2 at 75 Pa	Pre- and post-installation third-party blower door test for the first and second floors	0.109 cfm/ft^2 at 75 Pa 52.60% less air leakage
Energy Savings	kWh	HVAC energy consumption (whole-building modeling)	For leaky buildings, a total percentage of energy savings between 6% and 63.4% was achieved.
Greenhouse Gas (GHG) Savings	CO_2 (tonnes)	Whole-building modeling: Airtightness values and electricity source used	For leaky buildings a 3.5% to 59% percentage of CO_2 emission reduction is achieved.
Reduced Air Sealing Cost	$ spent/ft^2	The total air sealing expense compared with the cost of first-floor sealing	$1.0/ft^2 -$1.25/ft^2
Reduced Time of Installation	Air sealing installation time/1,000 ft^2	Air sealing contracting hours (including preparation, air sealing, and cleanup time) compared with the time of first-floor sealing.	1.5 hrs/1000 ft^2
Potential for HVAC Capacity Reduction	HVAC cooling and heating capacity	Modeled for the entire building: HVAC cooling capacity (modeled), kBtu/h; HVAC heating capacity (modeled), kBtu/h	The major heating and cooling equipment loads were reduced by 70.7% and 67.1%.
Cost-Effectiveness	Simple payback, years savings-to- investment ratio (SIR)	Energy savings Installation cost HVAC capacity reduction savings	SIR>1 was achieved in most climate zones.

In addition to the quantitative performance metrics, qualitative assessment objectives were set to evaluate the success of the automated air sealing demonstration project.

User feedback was used to assess concerns regarding safety measures, installation time, and quality of work. Table 2 shows the qualitative performance objectives.

Table 2. Qualitative Performance Objectives

Qualitative Performance Objectives	Metric	Data Requirement	Feedbacks Given
Facility and Construction Manager feedback	Interviews and focus group questionnaires for the standard operating procedure for envelope sealing and automated sealing.	Interview and focus group feedback	GSA regional staff recommend that automated air sealing be included as part of the original solicitation and that the General Contractor manage the process.
Ease of Coordination	Obstacles to continuing other retrofit tasks and damages to existing work.	A visual inspection to check that the cleanup process was done properly and damages were not made to the existing retrofit work.	No damage was observed. The cleanup work had no issues.

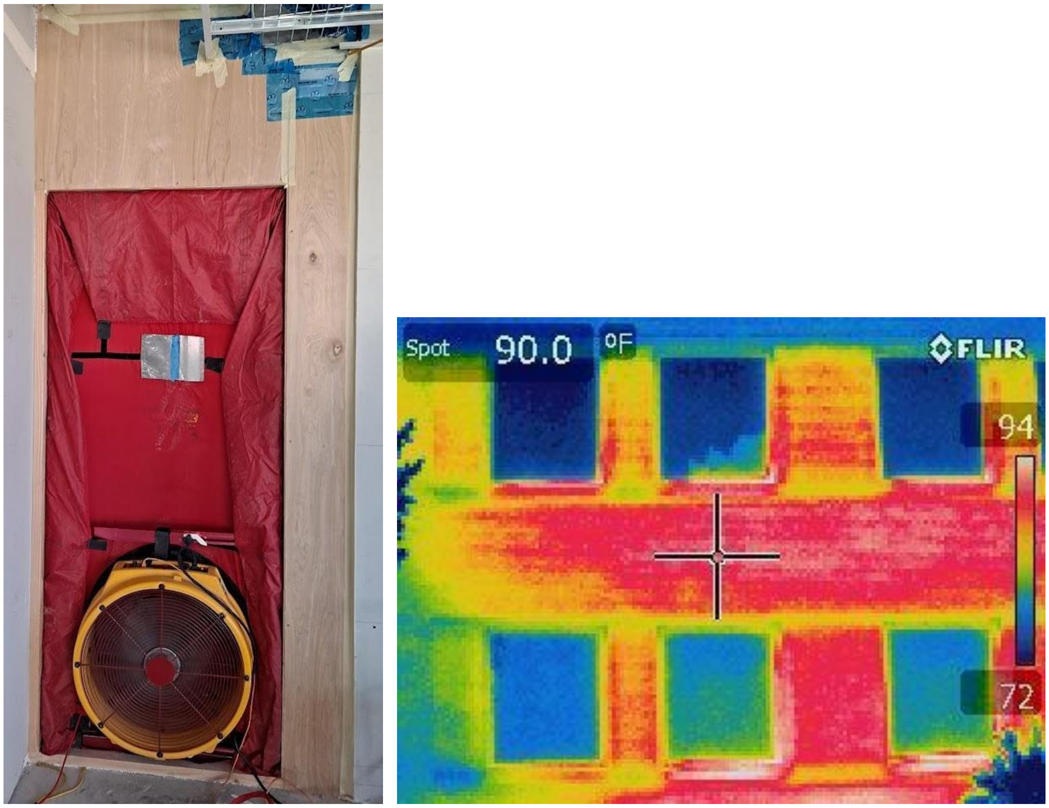
Background

Commercial buildings' energy consumption is significantly affected by building air leakage. Air leakage accounts for approximately 4 quadrillion Btu per year and amounts to approximately 4% of the energy used in the United States [1]. The other consequences of air leakages include moisture damage, lack of thermal comfort, degraded indoor air quality, and affecting the operation of mechanical ventilation systems.

A tighter building envelope plays a crucial role in supporting building electrification and decarbonization efforts. When the seal between the interior and exterior of a building is improved, less energy is required to heat or cool the space, which reduces energy bills for occupants and the strain on the electric grid. Additionally, a tighter envelope provides better control over indoor air quality and temperature, which can improve tenant satisfaction and productivity. Overall, a tighter building envelope is essential to building decarbonization and can significantly contribute to a more sustainable and energy-efficient built environment.

Bohac et al. [2] conducted leakage reduction measurements for air sealing large buildings using spray foam to seal accessible wall or roof joints and upgrade exterior door weather stripping. The buildings Bohac et al. tested were built between 1936 and 2007 in Minnesota; the floor area varied between 1,100 and 22,900 m^2. An air sealing test took place in 2007 and airtightness increased between 6% and 17%.

A blower door test is the most common method of identifying a building air leakage. This method pressurizes or depressurizes a building using a temporary built panel mounted on a doorway. During the test, the fan is used to create a pressure differential between the inside and outside of the building. This pressure differential causes air to flow through any gaps or openings in the building's envelope, such as around windows and doors, through walls, and through the ceiling and floor. The pressure gauge measures the flow of air and the resulting pressure differential, which can be used to calculate the airtightness of the building. A large, variable-speed fan maintains a pressure differential between the inside of the building and the outdoor environment [3]. This method is usually paired with the use of a thermal camera to detect leakage locations. Figure 1 shows a blower door test being conducted and thermal images taken of Denver Federal Center Building 40.



(a) (b)

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

Unlike residential buildings code, commercial buildings were subject to no code restrictions regarding airtightness until 2021. The 2021 International Energy Conservation Code (IECC 2021) section C402.5.3, "Building thermal envelope testing," [4] requires an air-tightness of less than 0.4 cfm/ft^2. In addition, some standards can be used as guidelines for commercial building air leakage requirements. The U.S. Army Corps of Engineers [5] and ASHRAE's Standard 189.1-2020 [6] set the acceptable maximum air leakage rate at 0.25 cfm/ft^2. GSA's Facilities Standards for the Public Buildings Service (PBS-P100) [7] sets a baseline standard of 0.4 cfm/ft^2 and has additional high-performance standard targets of 0.25 cfm/ft^2 for Tier 1, 0.15 cfm/ft^2 for Tier 2, and 0.1 cfm/ft^2 for Tier 3. Table 3 summarizes the airtightness standards for commercial buildings.

Table 3. Commercial buildings airtightness standards

Standards		Requirement (cfm/ft^2) @75 Pa
IECC 2021 C402.5.3 Building thermal envelope testing [4]		0.4
U.S. Army Corps of Engineers (2012) [5]		0.25
ASHRAE Standard 189.1-2020, Standard for the Design of High-Performance Green Buildings [6]		0.25
PBS-P100, *Facilities Standards for the Public Buildings Service* [7]	Baseline	0.4
	Tier 1 high performance	0.25
	Tier 2 high performance	0.15
	Tier 3 high performance	0.1

Technology Description

The technology used for automated envelope air sealing seals the building envelope by pressurizing it, using a modified blower door, and then distributing an atomized non-toxic water-based sealant that is automatically drawn to leaks. System software monitors the temperature, air pressure, and humidity of the space while controlling the distribution of sealant and recording progress in real time. Before the automated system is deployed, all finished horizontal surfaces, as well as openings that should not be sealed, are covered. The space is then pressurized, and a wireless mesh network controls an array of nozzles and distributes sealant by following the air leaking from the building. The sealant particles, which are ultra-low volatile organic compounds, with no off-gassing, 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 treatment. The system can seal holes up to ½ in diameter. Once the sealing procedure is complete, the space can be re-entered within 30 minutes.

Evaluation Plan

Demonstration Site

The Denver Federal Center Building 40's west wing, which is undergoing a major retrofitting (see Figure 2), was selected as the site for the air sealing test. Building 40 is a two-story office building with a steel frame and brick facade with approximately 46,000 ft^2 of floor space. Figure 3 shows the west wing portion of the building.

Figure 2. Denver Federal Center Building 40.

Figure 3. Map location of the Denver Federal Building and (*red rectangle*) the west wing.

The second floor of the west wing is 97 ft long, 46 ft wide, and has a ceiling 12 ft high. This demonstration site has a floor size of 4,462 ft^2, a volume of 53,544 ft^3, and a total surface area (4 walls, the ceiling, and the roof) of 12,356 ft^2. Figure 4 shows the second floor of the west wing at the Denver Federal Center Building 40.

Figure 4. Denver Federal Center Building 40’s west wing second floor.

The existing construction initially had a 4-in. brick cladding and an 8-in. concrete masonry unit (CMU). As a retrofit, a 3 and 5/8-in. closed-cell spray-applied insulation with a 4-in. composite metal hybrid Z-grid system was used as interior insulation. The interior cladding was gypsum board 5/8 in. thick. Figure 5 shows a drawing of the wall system. The building was also equipped with quadruple pane windows, insulated fiberglass frames, warm edge spacers, and krypton gas fill between panes.

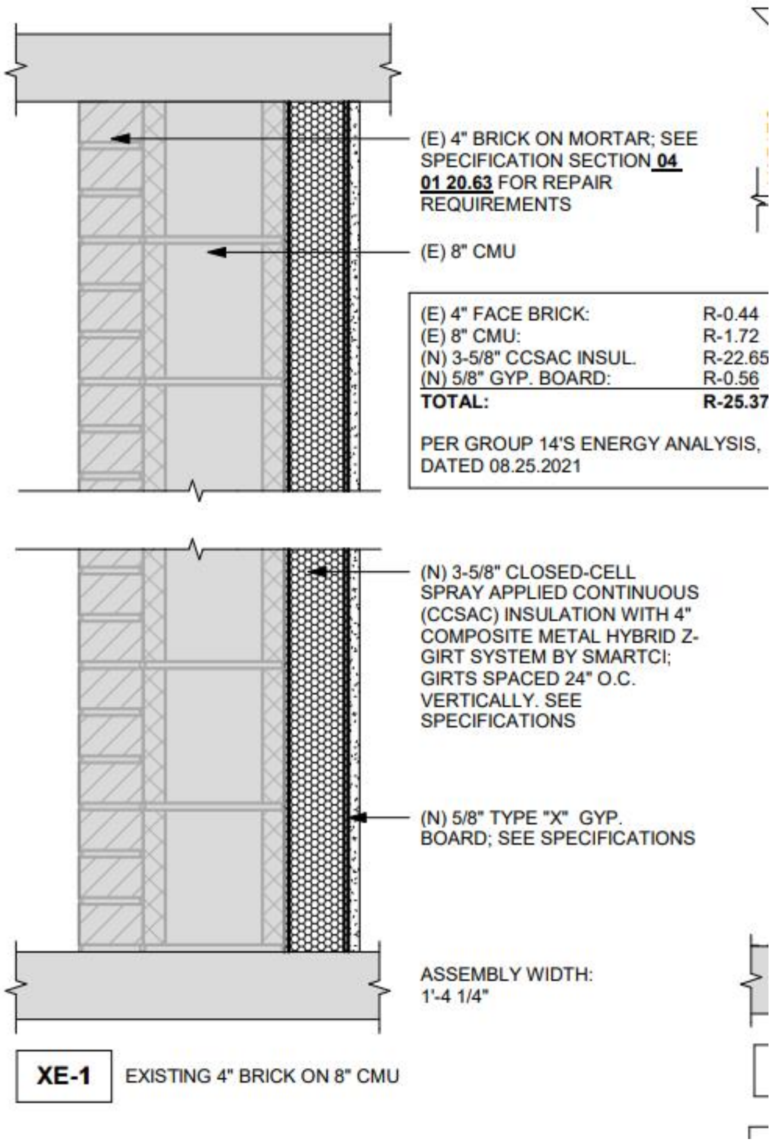


Figure 5. The retrofit wall system of Building 40.

One of the primary challenges encountered during this project was locating a suitable demonstration site. This challenge stemmed from the scarcity of available buildings willing to cease operations for the purpose of the demonstration. Additionally, the task of preparing a building that was already occupied proved to be challenging, as it needed to be done without disrupting its daily operations. The site selection requirements are discussed in Table 4, and the criteria are classified as “required,” or “preferred.”

Table 4. Site Criteria

System	Characteristics
Facility Type	A small or mid-sized office building that has not been retrofitted or built in the past 5 years.* An office building that is not built to the current code airtightness requirement.* Preferably a building with high contrast façade (façades such as CMU, concrete, or brick are preferred in comparison to Vinyl siding) **
Location	Any geographic area is acceptable, but to measure the full contribution of automated air sealing to energy savings , a heating climate zone (zone 5 or above) is preferred.**
Occupancy	Stable occupancy, operations, and internal loads for 2 months before and after the test start date. **
Site Engagement	The building management and occupants' flexibility and the building's availability are required during pre- and post-air sealing testing, air-sealing preparation, and air-sealing test phases.*
Whole-Building Electricity Data	Monthly whole building gas use, electric use, and peak demand ** Interval whole building electricity usage data (hourly or sub-hourly) **
Historical Electricity Data	Historical baseline electrical (interval) and gas (monthly) data for 12 months ** Historical baseline electrical (interval) and gas (monthly) data for 24 months **
Documentation	Proper documentation of floor plans, as-built drawings and equipment schedules*
Control System	Presence of a remotely accessible Building Automation System with direct digital controls, compatible with Niagara framework ** or an independent heating/cooling monitoring system.**
Lighting Controls	No specific requirement.
HVAC	Built-up HVAC systems that are in good working condition**
Size	Small to mid-sized facility (up to 50,000 ft^2)**
Submetered Electricity Data	Submetering at the panel level, to disaggregate energy consumption of HVAC, lighting, and plug loads. ** or Independent HVAC measuring panel.**
*Required ** Preferred	

Technology Demonstration

Air leakage is a significant driver of energy use within buildings and, in some instances, is the largest driver of heating and cooling loads. The technology used for automated envelope air sealing is discussed in the Technology Description section, above. The technology was installed post-drywall.

The first task of the automated air sealing installation team was preparing and installing two temporary walls on the west wing of the second floor. As shown in Figure 6(a), one of the walls was fully sealed and the other wall was prepared for a blower door test. In addition to the temporary walls, intentional openings, such as electrical outlets and mechanical systems' openings, were covered with a polyethylene sheet, as shown in Figure 6(b). This task required the maximum number of hours during the demonstration owing to the intricacy of covering openings with several pipes passing through or crossing the demonstration area, as shown in Figure 6(a).

(a)

(b)

Figure 6. (a) Temporary wall and (b) covered intentional openings.

Once the temporary walls were erected, an independent blower door test contractor conducted an airtightness test. This process took approximately 30 minutes.

After covering the intentional openings, the automated air sealing equipment was connected and installed, and a blower door and six aerosol spraying stations were placed at different locations, as shown in Figure 7. The space was pressurized using the blower door. Using the automated air sealing connect system, the air sealing process occurred while researchers watched the airtightness become enhanced in real time. The sealing process was completed in 2.5 hours. After completing the air sealing, the building's airtightness was checked by the independent blower door testing vendor.

Figure 7. Aerosol sealing station and blower door equipment.

The final step of the demonstration was cleaning after air sealing. The automated air sealing crew collected its equipment and removed the tapes from electrical outlets and mechanical systems, and the temporary walls were dismantled and removed from the demonstration site. The time to complete this process was 1 hour 15 minutes. Table 5 shows the schedule of the entire air sealing demonstration.

Table 5. Schedule of the air sealing demonstration

Duration	Task
2 hrs 45 min	Constructed temporary walls and automated air sealing prep
40 min	Third-party blower door testing
15 min	Connected automated air sealing equipment
2 hrs 10 min	Air sealing
25 min	Packed up automated air sealing equipment
30 min	Began prep removal for prep not in the pressure boundary
30 min	Third-party blower door testing
45 min	Temporary wall and prep removal

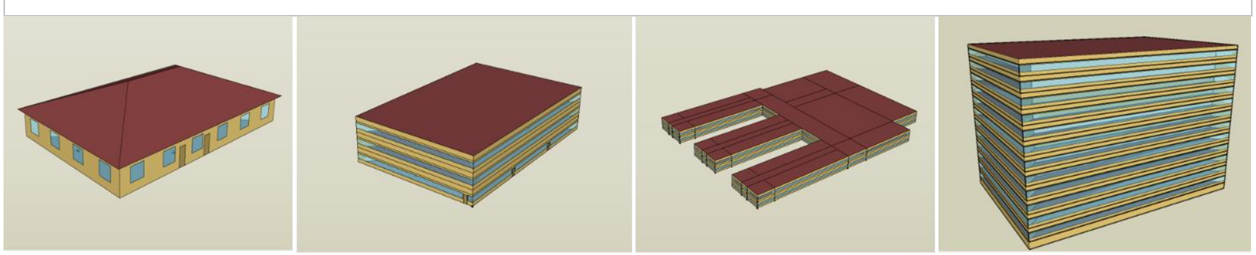
Energy Savings Simulation Design

Based on the measured building airtightness, the overall building energy consumption under different parameters was computed to better understand the contribution of automated air sealing to the building's energy savings. 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.

The selected parameters in this study include five climate zones, three different types of airtightness, and four building types, as shown in Table 6 and Figure 8. Prototype building models that were developed by the U.S. Department of Energy (DOE) and followed the ASHRAE 90.1 2013 standard were used for the analysis. Using ORNL's air infiltration calculator, the calculation was performed for two out of four building types (Medium office and Large 2-story), and their exposed area to outdoors (walls and roof) are shown in Table 6. Energy simulation was performed for the other two building types (Small office and Large 12-story) without using CONTAM simulation, which is explained in Appendix B. This was done because, for the latter two building types, the energy savings database was unavailable in ORNL's air infiltration calculator. The results of these simulations were analyzed to identify where automated air-sealing can be used to greater advantage.

Table 6. Energy savings calculation parameters

Parameter	Type of Parameters	Selected Values
Climate zone	Hot dry	Zone 2B (Phoenix)
	Mixed dry	Zone 4B (Albuquerque)
	Mixed marine Cold humid Cold humid	Zone 4C (Seattle) Zone 5A (Chicago) Zone 6A (Minneapolis)
Building type (No. floors / floor area / surface area / core zone to perimeter zone)	Small office	1 floor / 5,500 ft^2 / 8,526 ft^2/ 0.41
	Medium office	3 floors / 53,620 ft^2 / 75,544ft^2 / 1.45
	Large 2-story Large 12-story	2 floors / 210,887 ft^2 / 252,500 ft^2 / 0.11 12 floors / 498,588 ft^2 / 623,400 ft^2 / 2.75
Initial building airtightness	Leaky	1.20 cfm/ft^2 at 75 Pa (0.3 in. wc)
	Medium [7]	0.40 cfm/ft^2 at 75 Pa (0.3 in. wc)
	Airtight [7]	0.25 cfm/ft^2 at 75 Pa (0.3 in. wc)
in wc: inch water column		



(a) (b) (c) (d)

Figure 8. DOE representative buildings (a) Small office; (b) Medium office; (c) Large 2-story; (d) Large 12-story.

Results

Air Tightness Results

A third-party contractor hired by GSA conducted a 10-point pre- and post-air sealing blower door test and the test results are shown in Table 7.

Table 7. Pre- and post-sealing blower door test

Fan pressure	Pre sealing cfm	Post sealing cfm
-30 Pa	1668	790
-35 Pa	1819	856
-40 Pa	1968	936
-45 Pa	2108	991
-50Pa	2235	1054
-55 Pa	2355	1120
-60 Pa	2476	1170
-65 Pa	2504	1222
-70 Pa	2718	1276
-75 Pa	2827	1348

The airtightness values were calculated as cfm/ft^2 and Air Change Rates (ACH_n) where n is the fan pressure (50 Pa and 75 Pa).

Table 8 shows the air tightness values as cfm/ft^2 and ACH at 50 Pa and 75 Pa and the percentage increase in building airtightness. As can be seen in the table, the demonstration site was initially airtight. However, the automated air sealing has increased the building airtightness by slightly more than 50%.

Table 8. Demonstration site's pre- and post-sealing air leakage rate

	ACH@75pa	**ACH@50pa**	**cfm/ft^2 @75Pa**	**cfm/ft^2 @50Pa**
Pre-sealing	3.17	2.504	0.23	0.18
Post-sealing	1.51	1.18	0.11	0.09

	ACH@75pa	ACH@50pa	cfm/ft² @75Pa	cfm/ft² @50Pa
% Increase	**52.37%**	**52.84%**	**52.60%**	**52.78%**

Energy Savings

As discussed in the Energy Savings Simulation Design section, different climate zones, building types, and building airtightness were selected for energy savings analysis. Phoenix, Arizona was selected for zone 2B; Albuquerque, New Mexico was selected for zone 4B; Seattle, Washington was selected for zone 4C; Chicago, Illinois was selected for zone 5A; and Minneapolis, Minnesota, was selected for zone 6A. Electricity and natural gas consumption for HVAC application was calculated for each combination of building type and city. In addition, the energy consumption was calculated for different leakage rates listed in Table 6 for each building type and city.

Airtightness values were selected for the baseline building models as leaky (1.20 cfm/ft^2), medium (0.40 cfm/ft^2), and airtight (0.25 cfm/ft^2). The energy consumption of these buildings was compared with the energy consumption of buildings with the airtightness value measured after installation (0.109 cfm/ft^2) at Denver Federal Center Building 40. Table 9 shows the baseline and post-automated air sealing airtightness values.

Table 9. Simulated pre- and post-air sealing air leakage rates.

Airtightness	Air leakage rate (cfm/ft^2)	
	Baseline (BL) [7]	Automated Air Sealing (AAS)
Leaky	1.20	0.109
Medium	0.40	
Airtight	0.25	

The energy savings results are first presented in terms of energy use intensity (EUI). EUI is the combined electricity and natural gas consumption per unit floor area for an HVAC load. Figure 9 shows the overall EUI reductions for the cities in the five climate zones for which the calculations were performed. The results are presented for leaky, medium, and airtight airtightness for Medium office and Large 2-story buildings. As shown in Figure 9, in all three air-tightness levels, the EUI savings were the highest in the cold climate of Minneapolis, followed by Chicago. As expected, the savings were highest when air sealing was performed on Leaky buildings. The highest savings of 11.33 KWh/ft^2 (122 kWh/m^2) were observed for the Large 2-story building with Leaky airtightness in Minneapolis when automated air sealing air tightness was achieved. The lowest EUI savings were recorded in initially airtight buildings in Phoenix and Albuquerque.

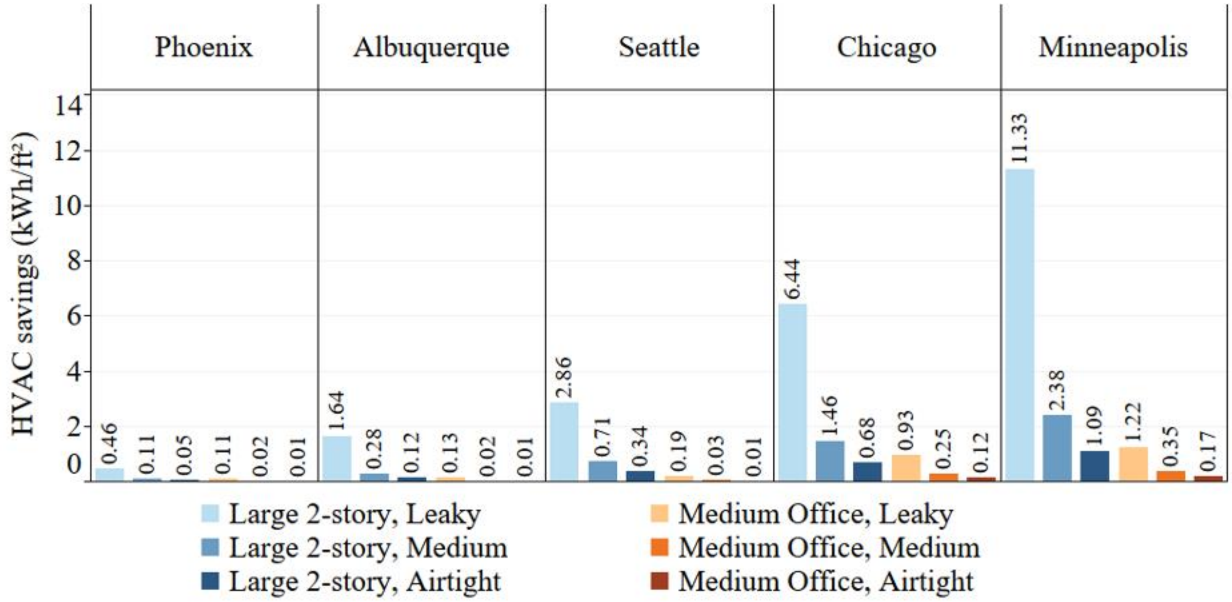


Figure 9. Overall HVAC EUI reductions for five cities, three building types, airtightness levels, and different airtightness values after air sealing.

Figure 10 and Figure 11 show the segregated electricity and natural gas EUI savings. For both cases, the highest savings were recorded in Minneapolis for a Large 2-story building with Leaky airtightness. The highest EUI savings values were 2.03KWh/ft^2 (22 kWh/m^2) for electricity and 31.74KBtu/ft^2 (342 kBtu/m^2) for natural gas. The electricity EUI savings were lower in other locations. Natural gas EUI savings was lowest in Phoenix because of low heating requirements in the hot climate zone.

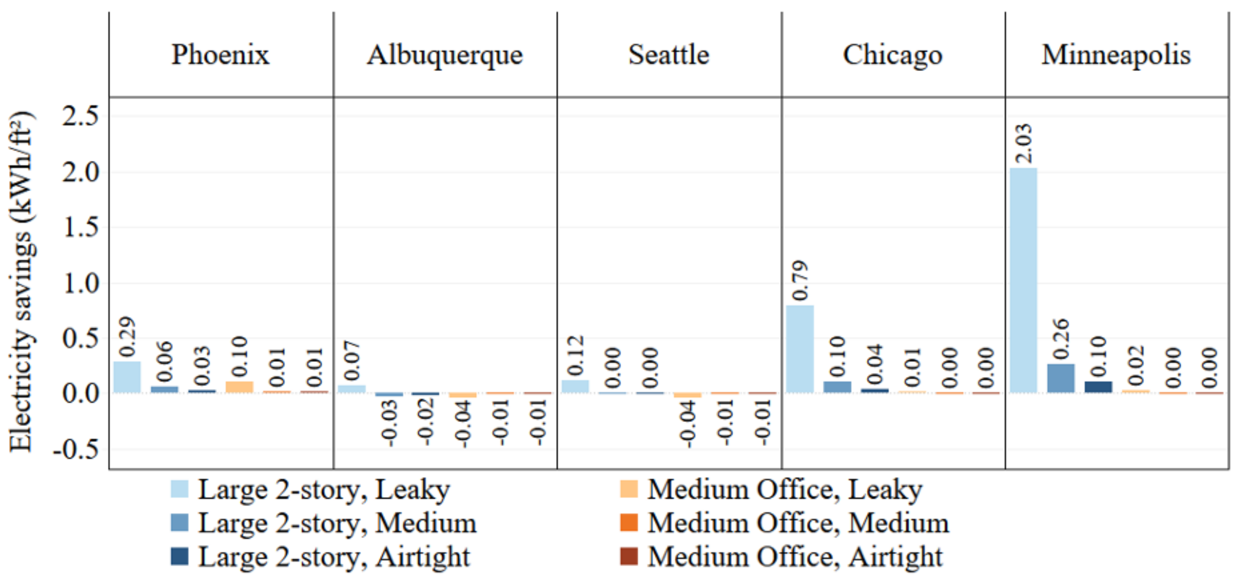


Figure 10. Electricity EUI reductions for five cities, two building types and three airtightness levels.

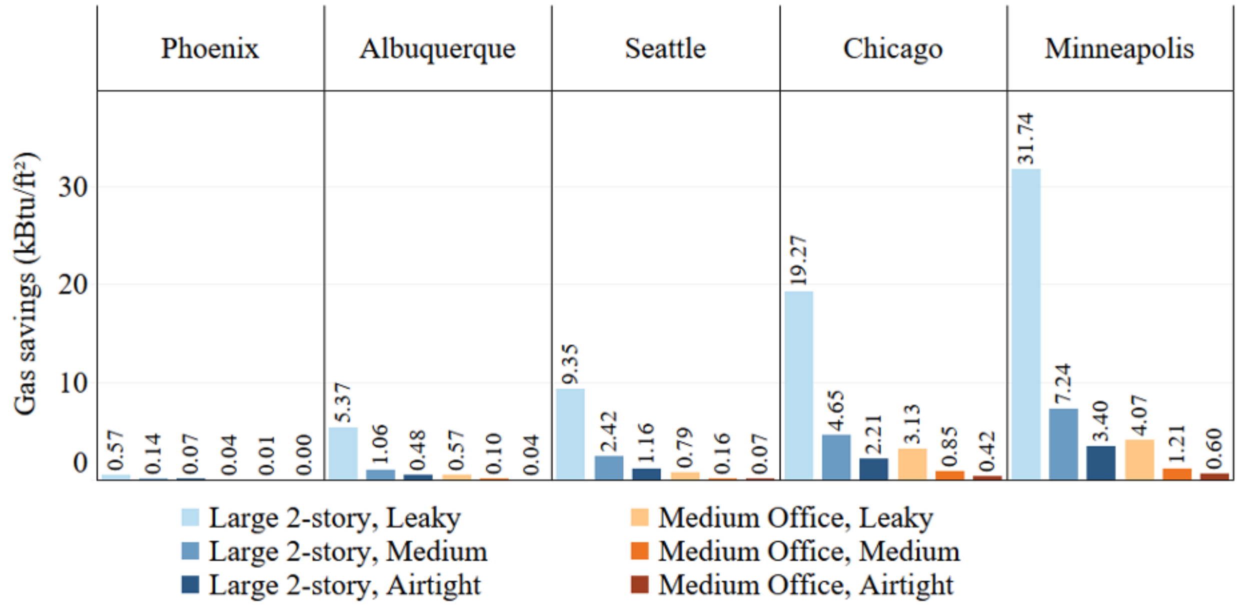


Figure 11. Natural gas EUI reductions for five cities, two building types and three airtightness levels.

The percentage savings for electricity and natural gas are provided in Figure 12 and Figure 13, respectively. The percentage savings for electricity was also the highest for the Large 2-story building when sealed to the AAS airtightness. Figure 13 also shows a significant percentage reduction in natural gas was achieved for leaky buildings, whereas the reduction in electricity consumption was not significant for the medium and airtight airtightness levels.

The leaky Large 2-story building sealed to the automated air sealing had 2% to 20% electricity savings at various locations. Under similar conditions, the natural gas savings ranged from 13% to 79%. The natural gas consumption savings were also significant when the buildings initially had medium airtightness. The total percentage of energy savings for the Large 2-story and Medium office buildings is shown in Figure 14.

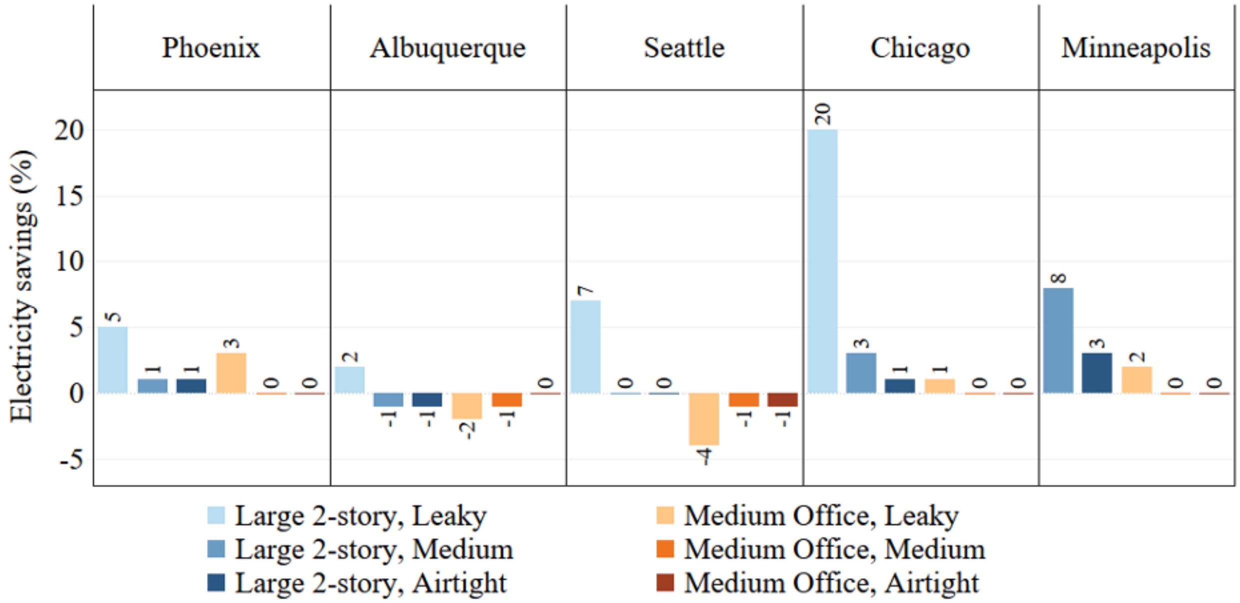


Figure 12. Percentage energy savings for electricity.

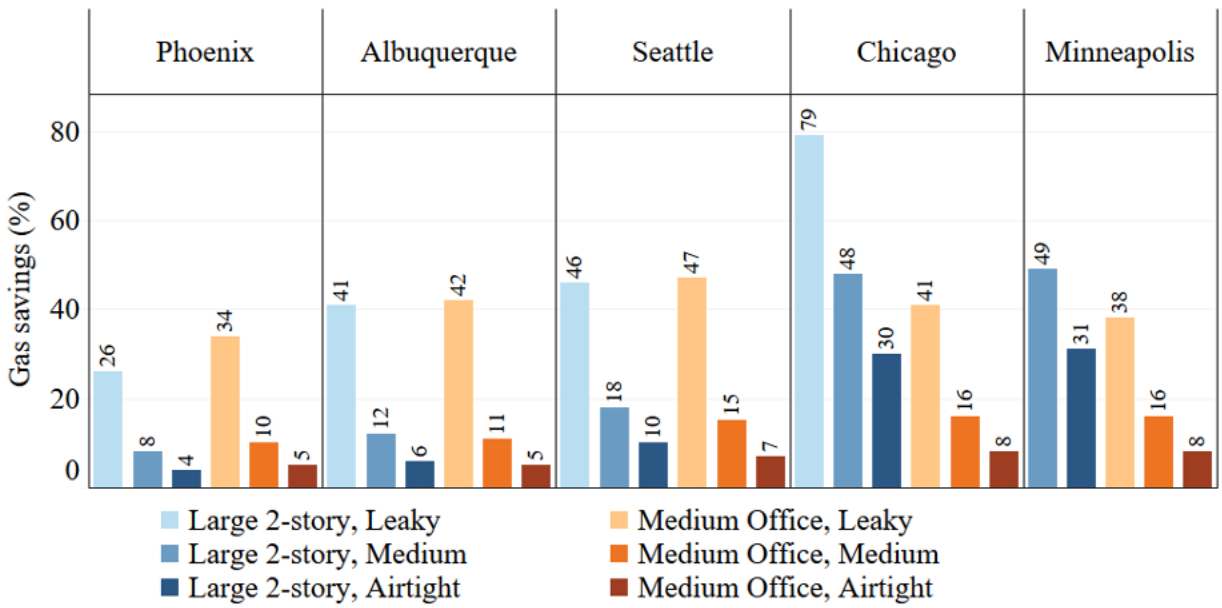


Figure 13. Percentage energy savings for natural gas.

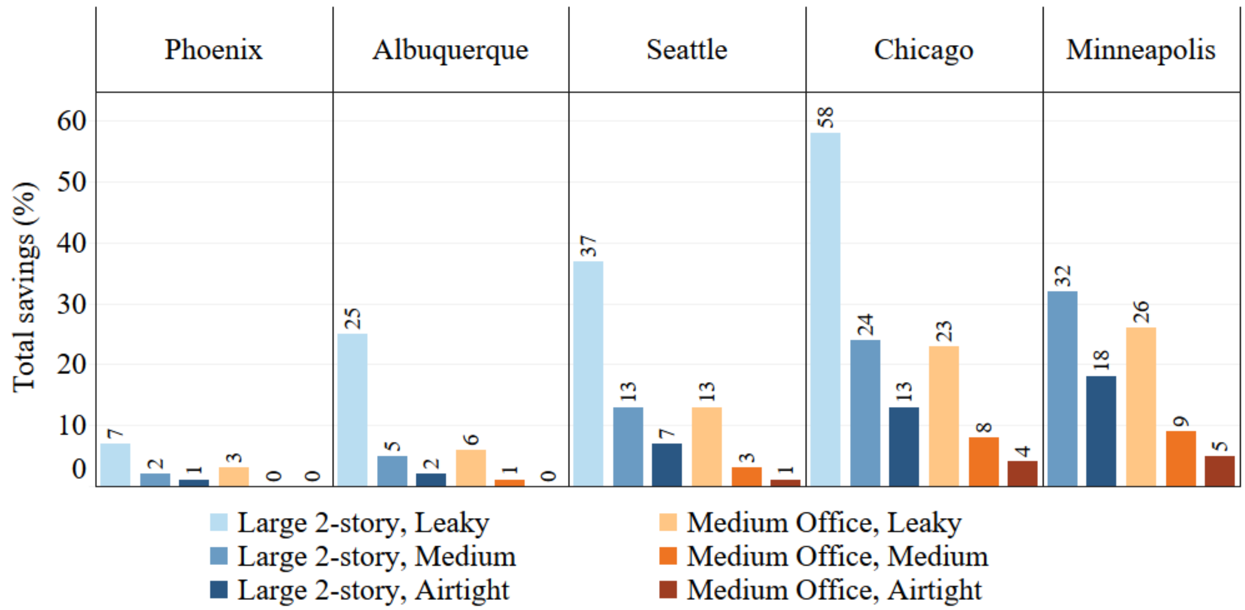


Figure 14. The total percentage energy savings.

The overall and the percentage reductions for EUI, electricity and natural gas for the Small office and Large 12-story buildings are presented and discussed in Appendix B.

The findings from the energy savings analysis reveal that greater savings can be achieved primarily in colder climates, buildings with initial air leaks, and to some extent, in structures with larger exposed surface areas and a lower ratio of perimeter zone to core zone. The study involved four prototype building models designated by the Department of Energy (DOE): a small office, a large 2-story office, a medium-sized office, and a large 12-story office. These prototypes differ in terms of core zone to perimeter zone, wall construction, window-to-wall ratio, building height, internal equipment load, and HVAC heating and cooling systems, as shown in Appendix C. Consequently, the outcomes of this study illustrate the impact of various factors such as climate zone and building airtightness rate, rather than indicating which types of buildings generate greater energy savings and which ones do not.

CO_2 Emission Reduction

Reductions in CO_2 emissions for Large 2-story and Medium office buildings are shown in Figure 15. While the CO_2 emissions reductions for small office and large 12-story buildings are shown in Appendix B.

Figure 15 shows a similar trend as the EUI reduction in Figure 9. The Large leaky 2-story in Minneapolis has the highest CO_2 emissions reduction, 520 metric tons. Another location with high CO_2 reduction was Chicago which was, again, a cold climate. In all the locations, the CO_2 reductions were lower in Medium Office due to its smaller size and exposed surface area, similar to lower relative savings as shown in Figure 12 and Figure 13. The CO_2 reduction was lowest in Phoenix, which has a hot-dry climate, among the five locations for which calculations were performed. The CO_2 reduction was also lowest in buildings that were initially airtight among the buildings with different baseline airtightness.

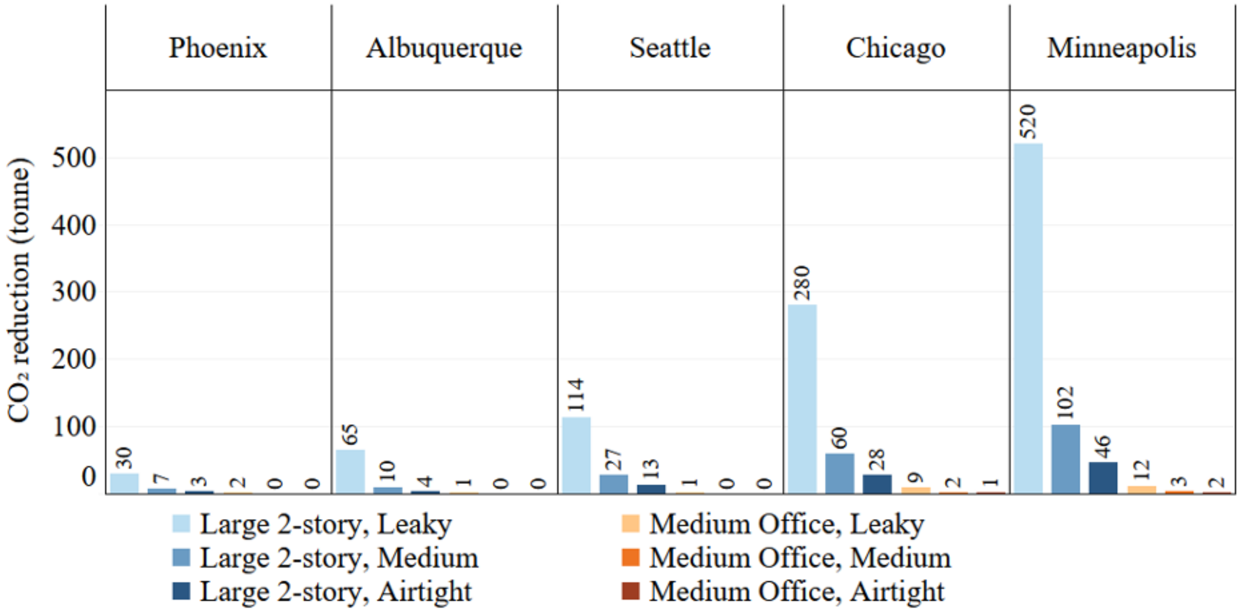


Figure 15. CO_2 emission reduction for different cities, building types, initial airtightness.

HVAC Size Reduction

An EnergyPlus simulation was conducted to evaluate the HVAC size reduction owing to enhanced airtightness from automated air sealing. A large 2-story building model with a conditioned floor area of 210,886 ft^2 located in Minneapolis and built in the 1980's was used in this analysis. The building had two baseline airtightness values: leaky (1.2 cfm/ft^2) and medium (0.4 cfm/ft^2). The building's cooling system comprised a chiller with a variable air volume (VAV) system in most zones and a packaged roof air conditioner in 5 zones. The heating system used a boiler with a VAV system in most zones and a gas furnace in 5 zones. Table 10 shows the pre- and post-sealing air leakage rates.

Table 10. Leakage rates (in cfm/ft^2 at 75 Pa)

Airtightness	Baseline	Automated Air Sealing (AAS)
Leaky	1.2	0.109
Medium	0.4	0.109

The reductions for different HVAC components of the baseline building are shown for the leaky airtightness baseline in Table 11 and the medium airtightness baseline in Table 12. Automated air sealing reduced chiller size by 67.1% and boiler size by 70.7% compared with the initially leaky baseline building. When the automated air sealing was performed on the medium airtightness baseline building, the reduction in chiller size was reduced to 25.8%, and the boiler size was reduced to 41.4%.

The cost savings were calculated for gas-fired boilers and air-cooled chillers as used in the simulation. EIA's Updated Buildings Sector Appliance and Equipment Costs and Efficiencies (2023) [8] datasheet was used to calculate the cost reduction. Based on this data, the total installed cost to the total input capacity was calculated as $40.56 KBtu/hr for commercial oil-fired boilers and $700/ton for air-cooled commercial reciprocating chillers. The leaky buildings savings are approximately $495, 234 for the boiler and $504,765 for the chiller. Similarly, the savings on the medium leaky building were estimated to be $144,652 and $85,988 for the boiler and chiller, respectively.

Table 11. Reduction in HVAC size compared with the leaky baseline

Component type	Baseline (W)	AAS(W)	Reduction (W)	Reduction (%)	Savings ($)
Boiler	5,058,947	1,480,636	3,578,311	70.7	495,234
Chiller	3,780,818	1,244,879	2,535,939	67.1	504,765
DX cooling coil	1,185,842	904,599	281,243	23.7	–
Gas heating coil	3,045,656	2,774,844	270,812	8.9	–
Pump	62,915	19,757	43,158	68.6	–

Table 12. Reduction in HVAC size compared to medium baseline

Component type	Baseline (W)	AAS(W)	Reduction (W)	Reduction (%)	Savings ($)
Boiler	2,525,824	1,480,636	1,045,188	41.4	144,652
Chiller	1,676,884	1,244,879	432,005	25.8	85,988
DX cooling coil	942,183	904,599	37,584	4.0	–
Gas heating coil	2,808,954	2,774,844	34,110	1.2	–
Pump	29,546	19,757	9,789	33.1	–

In addition to HVAC cost reductions, 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

Time and Cost Savings

As shown in Table 5, the automated air sealing demonstration took 6.5 hours on the first day and 1 hour 45 minutes on the second day. Out of the total 8 hours spent on the demonstration, 1 hour 10 minutes was spent to conduct a pre– and post–air sealing blower door test by a third party. Thus, a total working time of 6 hours 50 minutes was required to seal an area of 4,461 ft^2. Based on this study, it took 1.5 h/1,000 ft^2 to air seal the demonstration site in comparison to the set criteria of 4 h/1,000 ft^2.

Cost-Effectiveness

The cost-effectiveness analysis is done from HVAC energy savings. This calculation does not incorporate other savings and advantages, such as HVAC equipment reduction, CO2 emission reduction, national energy security, and occupant thermal comfort. The annual electricity savings for all climate zones for the 2-story large building is shown in Table 13. This data is obtained from EIA's 2021 States' average electricity price and cost of natural gas per thousand square feet [8, 9]. In addition to the 2- story large building, the HVAC savings of a small office were studied for Climate Zones 2B, 4B, 4C, 5A, and 6A. The buildings considered were not initially retrofitted and an automated air sealing installation lowered the air tightness from 1.20 cfm/ft^2 (Leaky Baseline) to automated air sealing airtightness (0.109 cfm/ft^2).

The electricity and natural gas savings were calculated as $/kWh and $/100 ft^3. The utility prices used in this study in all climate zones are shown in Table 13. The IECC U.S. climate zone map is shown in Figure 16.

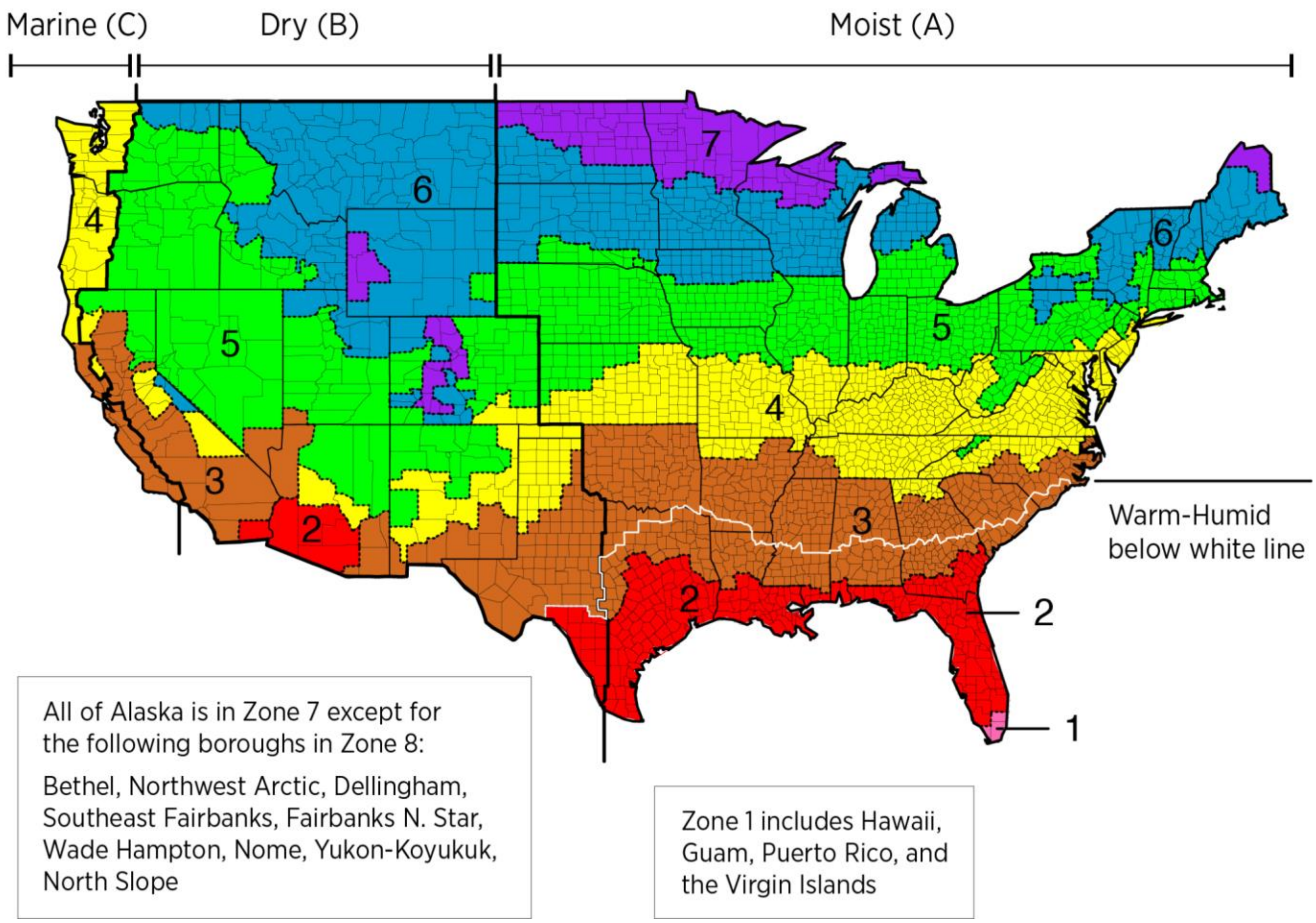


Figure 16. IECC climate zone map [10].

Table 13. Cost of electricity and natural gas

Climate Zone	City	Cost of electricity ($/kWh)	Cost of natural gas ($/1000ft^3)
1A	Miami, Fl	0.11	12.09
2A	San Antonio, TX	0.09	8.49
2B	Phoenix, AZ	0.10	8.68
3A	Atlanta, GA	0.10	8.59
3B	Las Vegas, NV	0.09	6.56
3B-CA	Los Angeles, CA	0.20	12.04
3C	San Francisco, CA	0.20	12.04
4A	Baltimore, MD	0.11	11.97
4B	Albuquerque, NM	0.09	7.87
4C	Seattle, WA	0.08	9.14
5A	Chicago, Il	0.09	7.26
5B	Boulder, CO	0.11	7.97
6A	Minneapolis, MN	0.11	7.79
6B	Helena, MT	0.10	8.70
7A	Duluth, MN	0.11	7.79
8A	Fairbanks, AK	0.20	12.03

The Savings-to-Investment Ratios (SIRs) are calculated assuming the energy price will remain the same. Vendor's simulating tests of 50 years of service, the HVAC energy savings in those years, and the installation investment are the parameters used to calculate the SIR. A $1.25/ft^2 installation cost was used to calculate the total automated air sealing installation cost. Installation costs may be lower for buildings with fixed windows or that are less leaky. Table 14 shows the payback period, and the SIR values for all climate zones for the 2-story Large Building model, and the payback periods and the SIR values for 5 climate zones were computed for the Small Office Building model.

Table 14. HVAC energy savings payback periods and Savings-to-Investment Ratio

Climate zone	City, State	Air sealing cost ($)	Annual electricity saving (KWh)	Annual natural gas saving (MMBTU)	Total annual saving ($)	Payback period (yrs.)	SIR
Two-Story Large Building							
1A	Miami, Fl	263,609	90268	58.2	10,634	25	2
2A	San Antonio, TX	263,609	65669	535.6	10,525	25	2
2B	Phoenix, AZ	263,609	61995	118.2	7,226	36	1
3A	Atlanta, GA	263,609	62891	1269	17,192	15	3
3B	Las Vegas, NV	263,609	90527	781.6	13,277	20	3
3B-CA	Los Angeles, CA	263,609	8844	242.9	4,6945	6	9
3C	San Francisco, CA	263,609	-3049	544.1	5,941	44	1
4A	Baltimore, MD	263,609	61513	1874.4	29,207	9	6
4B	Albuquerque, NM	263,609	13806	1110	9,985	26	2
4C	Seattle, WA	263,609	25407	1932.7	19,700	13	4
5A	Chicago, Il	263,609	167107	3982.3	43,958	6	8
5B	Boulder, CO	263,609	52313	1923.1	21,084	13	4
6A	Minneapolis, MN	263,609	428285	6559.5	98,225	3	19
6B	Helena, MT	263,609	30368	1676.5	17,625	15	3

Climate zone	City, State	Air sealing cost ($)	Annual electricity saving (KWh)	Annual natural gas saving (MMBTU)	Total annual saving ($)	Payback period (yrs.)	SIR
7A	Duluth, MN	263,609	65904	5510.7	50,185	5	10
8A	Fairbanks, AK	263,609	107565	6192	96,018	3	18
Small Office Building							
2B	Phoenix, AZ	6875	2555	0	0.255	26	2
4B	Albuquerque, NM	6875	2703.15	5223.5	0.284	24	2
4C	Seattle, WA	6875	4505.24	3482.3	0.392	17.5	3
5A	Chicago, Il	6875	19823.07	33082	2.024	3.4	15
6A	Minneapolis, MN	6875	32437	103598	4.375	1.6	32

As shown in Table 14, cold climate zones have the fastest payback periods, followed by warmer climates, whereas mild climates require a more extended period of energy savings to break even. For example, climate zones 6A, 7A, and 8A require 3, 5, and 3 years, respectively, to pay back the automated air sealing cost through HVAC energy savings only in the Large 2-story building setting. All these climate zones are either Cold or subarctic zones. Hot-dry (3B) and Mixed-dry (3C) climate zones, such as Los Angeles, CA, and San Francisco, CA, have shown minimal energy savings, and hence their payback periods are the highest and SIR the lowest of all simulated cases. Buildings in these zones might need less air sealing than similar conditions in cold or hot climates.

The humid climate zone has shown higher savings in similar heating/cooling climates, such as between climate Zone 2A vs. 2B and 4A vs. 4B. This is believed to be the air infiltration in leaky buildings that brings in humid air and the HVAC system will be tasked with dehumidification in addition to heating/cooling loads. In the case of the Small Building model, once again, cold climates of 5A and 6A have shown a payback period of 3.4 and 1.6 years, respectively. The SIR values for all climate zones under Small Building models were more than 1.

For comparison, the Denver Federal Center Building 40's automated air sealing (0.109 cfm/ft^2) payback period is calculated from the retrofitted building air tightness (0.23 cfm/ft^2) and an assumed initial leaky building (1.18 cfm/ft^2). Since the retrofitted building's airtightness was already significantly airtight, applying an automated air sealing requires more than 100 years of payback period. However, the payback period for Building 40 is expected to be around 10 years by applying automated air sealing to an initial leaky building.

Qualitative Results

The qualitative results were gathered through discussion with GSA regional members, building managers, and general contractors. A post-sealing cleanup was checked to ensure no damage was done, and no obstacles that could affect the upcoming construction work existed.

Highlights of the discussion included the following:

- There were no major impacts post-installation. Staff found a few sealant particles on the windows, but these were easily wiped off.
- Because construction was already underway when the testbed evaluation began, it was challenging to sequence the operations and fit the automated air sealing into the schedule. GSA regional staff recommended that automated air sealing be included as part of the original solicitation and that the General Contractor manage the process.
- In the initial discussion, staff felt that the technology was best suited for major retrofits when the building is taken down to the studs and replacing the ceiling. In a follow-up discussion, staff expressed interest in using the technology in minor retrofits and occupied space.
- Staff identified a perceived challenge in using automated air sealing in larger projects is that different floors are at different phases of construction.
- Once staff saw the energy savings results, they expressed interest in using automated air sealing at additional locations.
- Without more long-term data on how automated air sealing holds up over time, staff were uncomfortable downsizing HVAC equipment or altering current envelope-sealing practices like using spray foam. They said with one to two years of data, they would consider changes if the product was specified from the beginning. GSA plans to run additional blower door tests at this demonstration site after one, two, and five years.
- Because they wanted more long-term data on automated air sealing longevity, GSA staff wanted automated air sealing to pay for itself through energy savings rather than HVAC capacity reduction or reduced costs for existing practices for air sealing like replacing spray foam with fiberglass.

Additional entry points for automated air sealing is provided by the vendor and is attached in Appendix A.

Conclusion

Summary of Findings

The automated air sealing capability of an emerging technology was demonstrated in Denver Federal Center Building 40's west wing on the second floor. The demonstration building was retrofitted with 3-5/8 in. closed cell spray foam and quadruple glazing and proper installation of these materials made the building already airtight. In this 6-hour 50-minute demonstration, the building air leaks were further reduced by 52%, and the overall air leakage was reduced from 0.23 cfm/ft^2 at 75 Pa to 0.109 cfm/ft^2 at 75 Pa. Both these airtightness values outperform the set criteria of 0.4 cfm/ft^2 at 75 Pa. In comparison, a typical manual air sealing using spray foam and upgrading the weather stripping can increase the airtightness between 6% and 17% [2].

Based on the enhanced airtightness, the energy consumption reductions were calculated as total EUI and separately as natural gas and electricity consumptions. Five climate zone representative cities were selected: Phoenix (2B), Albuquerque (4B), Seattle (4C), Chicago (5A), and Minneapolis (6A). Initial airtightness values before air sealing were varied. Four types of commercial building designs were used. After applying automated air sealing, the initial energy consumption was compared with the energy consumption of a building with reduced airtightness values. The largest energy savings were recorded in a leaky building and a building with a larger exposed surface area in the cold climate zone. In this study, the leaky building is defined as 1.20 cfm/ft^2 at 75 Pa The 12-story office building and the 2-story large building models have shown the highest energy savings from the studied building models. The percentage of energy savings of a leaky small office building in climate zone 6A was 58% for electricity and 63% for natural gas. In comparison, the energy savings of the 2-story large building was as high as 41% for electricity and 81% for natural gas.

The percentage of CO2 emission reduction was similar to that of energy savings for different climate zones and building types. CO2 emissions were reduced by 520 metric tons for the Large 2-story building and 770 metric tons for the Large 12-story building annually because of increased air tightness.

The simulations showed a size reduction of 70.7% for the boiler and 67.1% for the chiller in the leaky 2-story large building in a cold climate. For the medium airtightness building, the automated air sealing decreased the required boiler size by 41.4% and the chiller size by 21.8%.

The automated sealing method, based on the field demonstration and the modeling work, can have a significant benefit in the following buildings and climate zones:

- Buildings with higher leakage rate (buildings that are relatively old, historic, or not built to code)
- Buildings with a large exterior exposed area
- A gut retrofit or internal retrofit eases the preparation work because the building's interior is more likely vacated than an exterior retrofit
- In new construction, after the drywall is erected

- Buildings in cold climates followed by hot climate zones save more energy and reduce carbon emissions in comparison to mild climate zones
- Buildings in humid climates benefit more than those in dry climates.

Lessons Learned, Best Practices

The main lessons learned, and recommendations made from this demonstration are as follows:

- In occupied buildings or when automated air sealing is not considered as a part of a new construction plan, out of the three main steps of automated air sealing (preparation, air sealing and cleanup), the cleanup process takes the longest time of the automated air sealing process.
- Automated air sealing should be included in the design stage to achieve advantages such as HVAC size reduction.
- In new and retrofit projects, automated air sealing should be part of the design and construction planning.
- For major renovation, analyzing the impact on the mechanical system before proceeding is important. Envelope tightening can cause an existing HVAC system to become oversized, leading to short-cycling and increased energy use.

Deployment Recommendations

- Automated air sealing is best suited to new construction or gut retrofits. Automated air sealing can be done in occupied buildings, but 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. Because of the additional prep work, automated air sealing in occupied buildings costs about twice as much, $2.50/sf.
- HVAC energy savings are greatest for buildings in cold climates with more exterior surface exposure that do not meet air tightness code (such as IECC 2021).
    - To calculate the exposed surface of a building, the perimeter of the bottom floor space to the number of floors should give the information needed to calculate the exposed surface area. However, if the perimeter information is unavailable, the ratio of the total surface area to the number of floors should show an approximate surface area. In general, the higher the floor area to a number of floors indicates a larger exposed area of the building.
- Appropriate for historic buildings and interior brick, concrete, and limestone facades where other air sealing methods are impossible.

Appendices

Appendix A: Entry points for Automated Air Sealing

The vendor provided the following considerations for installing automated air sealing at different entry points. In general, the closer automated air sealing can be to the exterior point of assembly, the more effective it is:

- Prior to insulation/post-electrical, mechanical, data, and plumbing
  - Provides the biggest impact because it can reach the furthest exterior points.
  - Can reduce overall cost of insulation.
    - Less expensive fiberglass, cellulose or Rockwool insulation can be used instead of spray foam insulation on exterior walls.
    - Interior caulks or foams, or both—excluding fire caulking.
    - Gaskets for electrical boxes, plumbing penetrations, and data boxes
    - Acoustical sealants, backer rod foam.
  - Will need a non-vented attic space OR drywall on the top floor to pressurize the space (like a balloon).
  - Automated air sealing installation takes 20% to 30% longer due to it being the “first” application of air sealing during the construction process.
- Post-insulation/Pre-drywall.
  - Can fix problems with spray foam insulation if it has delaminated from the framed structure.
  - If fiberglass insulation has been used, automated sealing can take longer and be more expensive. The vendor recommends a manual inspection and additional air sealing before installing fiberglass insulation.
  - Can penetrate closer to the exterior façade of the building than post-drywall.
- Post-drywall (mud/tape).
  - Can correct envelope’s air or vapor barrier, or both, which may have been removed/damaged by other contractors during the construction process.

- Most common phase for automated air sealing given the flexibility of installation.
- Typically, the least amount of time spent sealing a building due to other insulation methods already in place.

Appendix B: Additional Modeling Results

Energy savings and Carbon emission reduction results for Small Office and Large 12-story buildings

For the two building types (Small Office and Large 12-story buildings), EnergyPlus simulations were performed since the database for these buildings were not available in ORNL's air infiltration calculator. EnergyPlus "ZoneInfiltration: DesignFlowRate '' object was used where the field "Flow per Exterior Surface Area" was specified based on the leakage rate for each case. The EUI savings for total HVAC load for these buildings are shown in Figure B1. The Figure shows that EUI savings are higher in cold climate zones (Chicago and Minneapolis) than hotter climate zones and provide similar results to Medium office and Large 2-story buildings described in the Energy Savings section. The savings were also highest when the automated air sealing was applied to leaky buildings for all climates. The EUI (kWh/ft^2) reduction was higher for the Large 12-story compared to the Small Office at all the locations except Phoenix. This implies that higher EUI reduction in the Large 12-story building mostly comes from heating load reduction. This can be seen in Figure B2 where HVAC-related electricity per unit floor area has a higher reduction in the Small Office compared to the Large 12-story, while HVAC-related natural gas per unit floor area has a higher reduction in the Large 12-story compared to the Small Office as shown in Figure B3.

The relative reduction in HVAC-related electricity and gas use compared to the Baseline (BL) case is shown in B4 and Figure B5, respectively. In the Large 12-story building, the relative electricity saving is low, i.e., -2 to 6%, and the Small office building has an electricity saving range between 0 to 58%. The percentage savings for natural gas is higher in hot and mild climate zones and lower in cold climates in Small Office compared to Large 12-story (Figure B5). The percentage of natural gas savings was also higher in the Leaky baseline compared to the Medium or Airtight baseline. From these reductions in electricity and natural gas consumption, the overall and percentage CO2 emission reduction results for all 5 climate zones are shown in Figures B6 and B7.

Lastly, Table B1 provides the cost analysis results for medium office and large 12-story buildings.

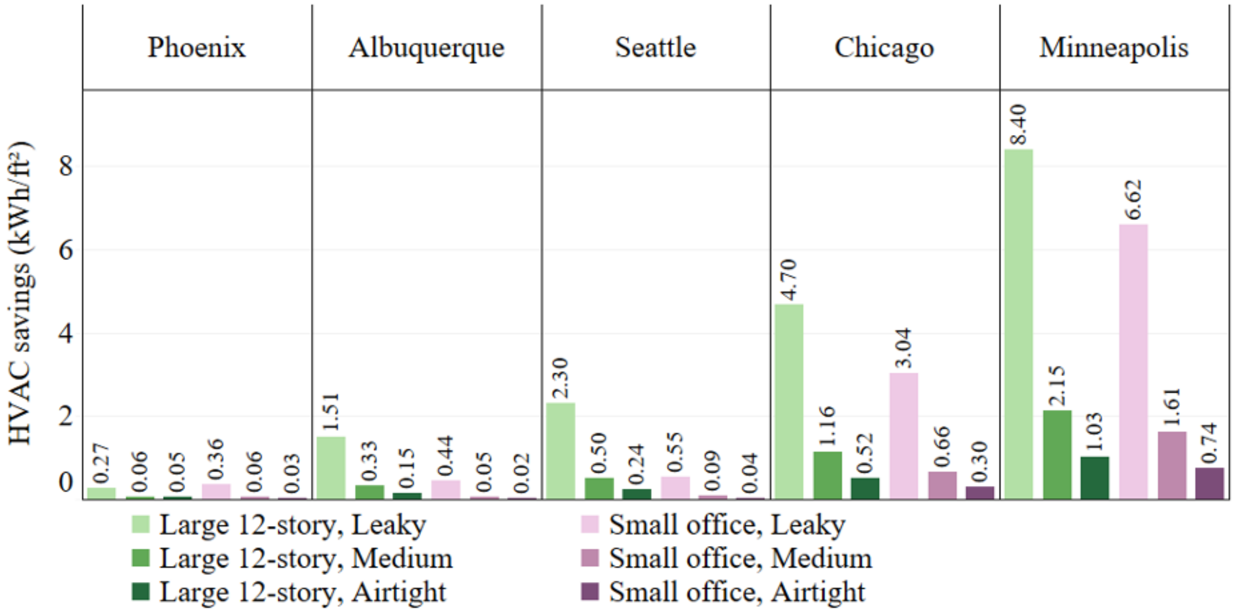


Figure B1. HVAC EUI reductions for Large 12-story and Small Office building at five locations and three baseline airtightness.

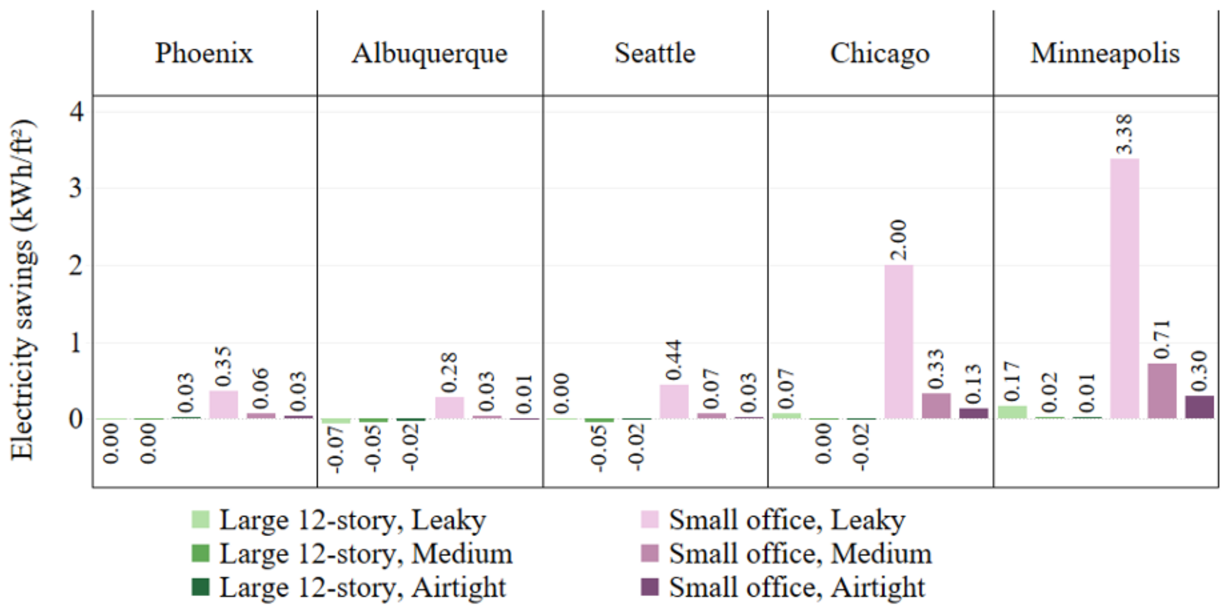


Figure B2. HVAC-related electricity EUI reductions for Large 12-story and Small Office building at five locations and three baseline airtightnesses.

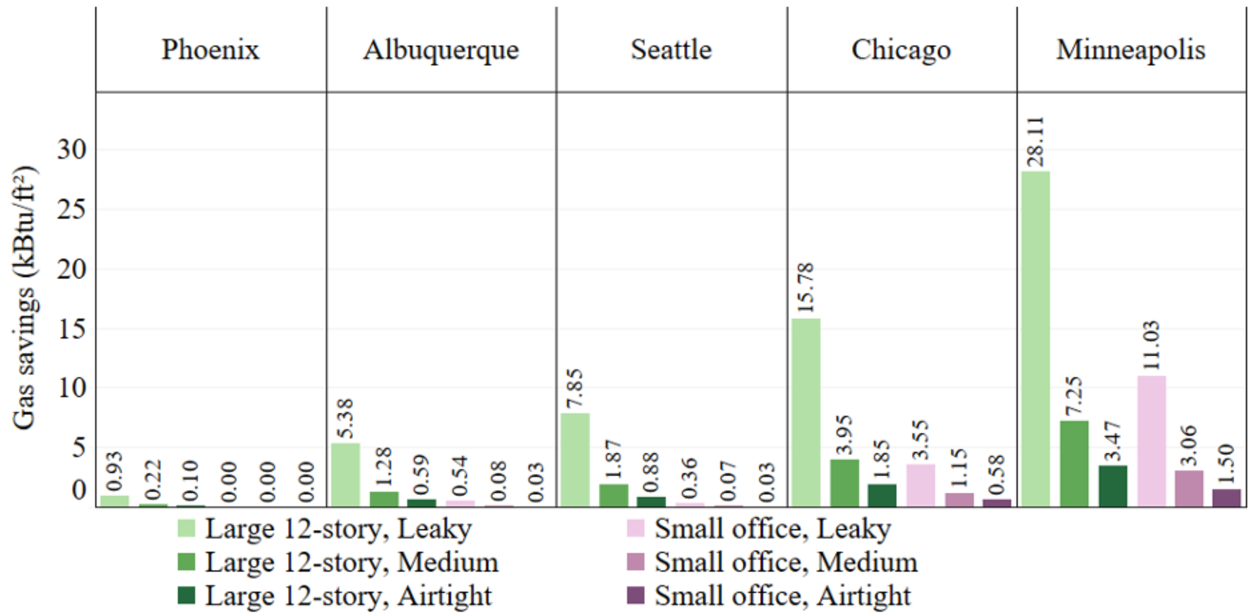


Figure B3. HVAC-related natural gas EUI reduction for Large 12-story and Small Office buildings at five locations and three baseline airtightness.

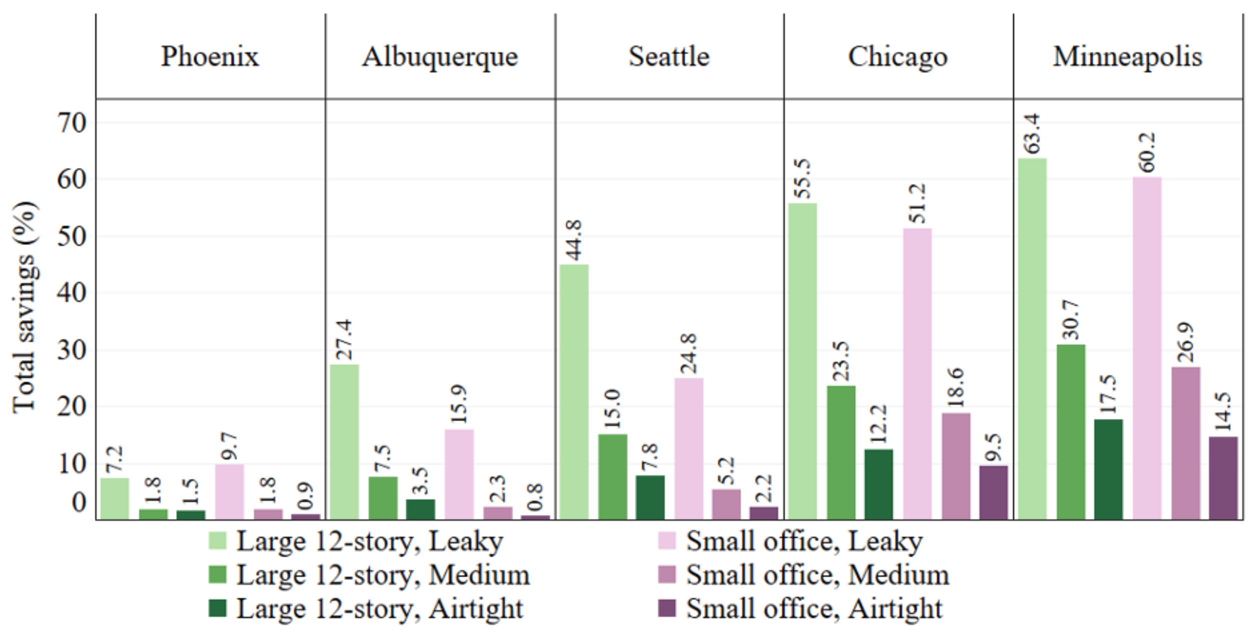


Figure B4. Relative electricity savings compared to BL for Large 12-story and Small Office buildings at five locations and three baseline airtightness.

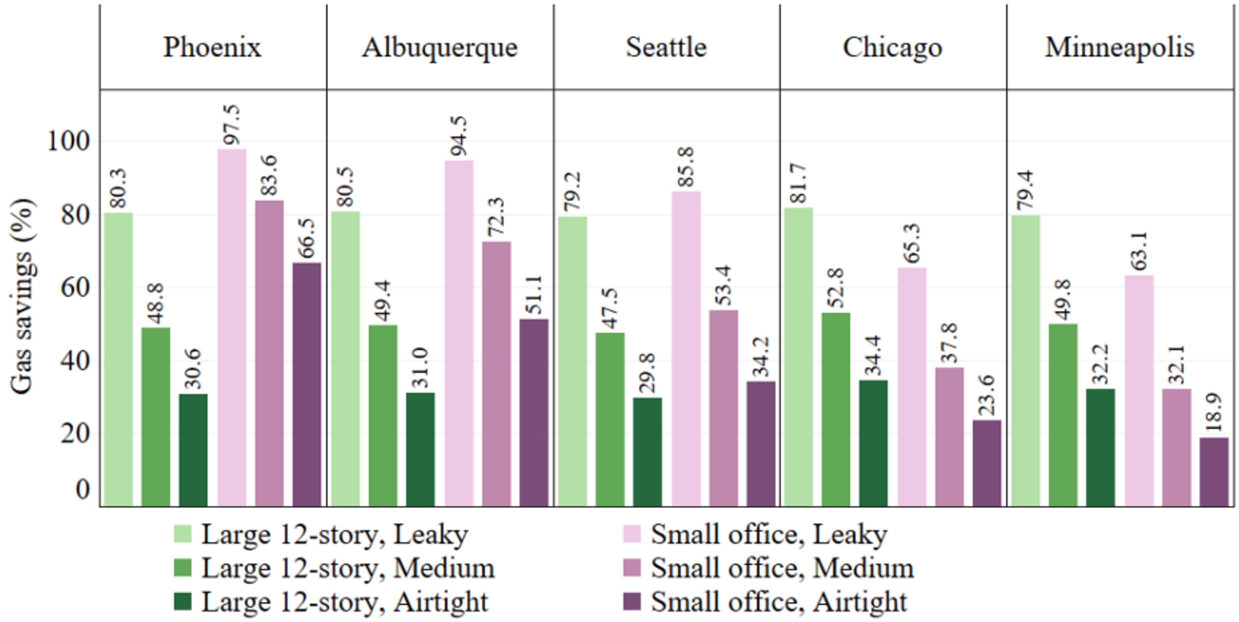


Figure B5. Relative natural gas savings compared to the baseline air tightness for Large 12-story and Small Office buildings at five locations and three baseline airtightness.

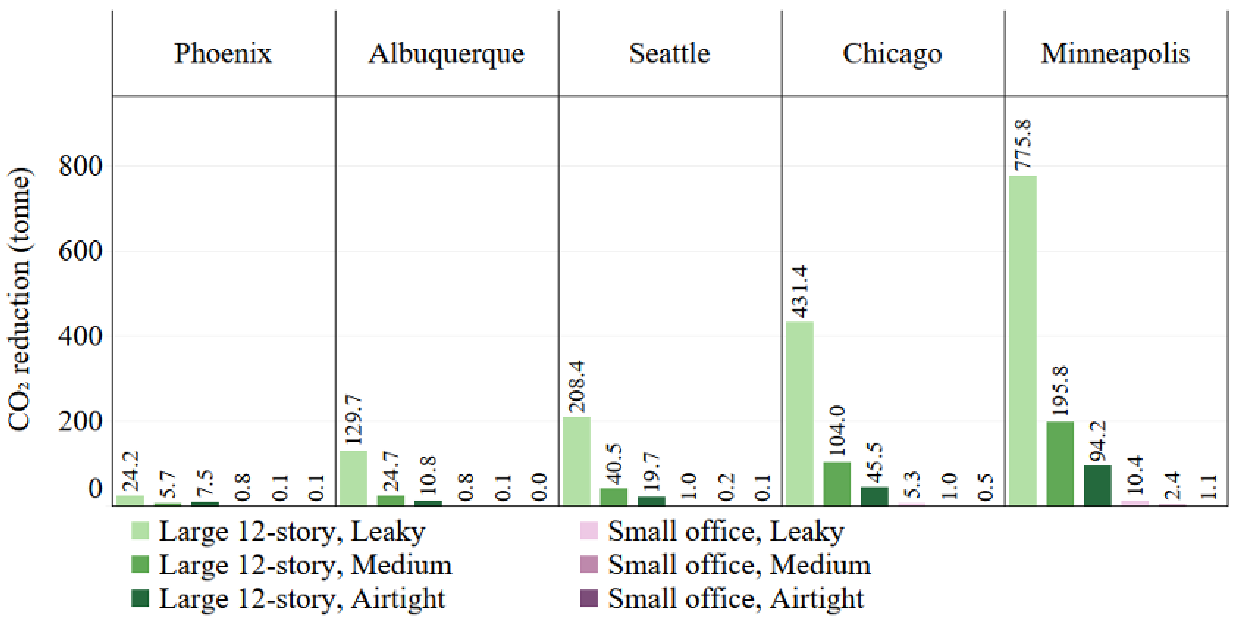


Figure B6. CO_2 reduction for Large 12-story and Small office building at five locations and three baseline airtightness.

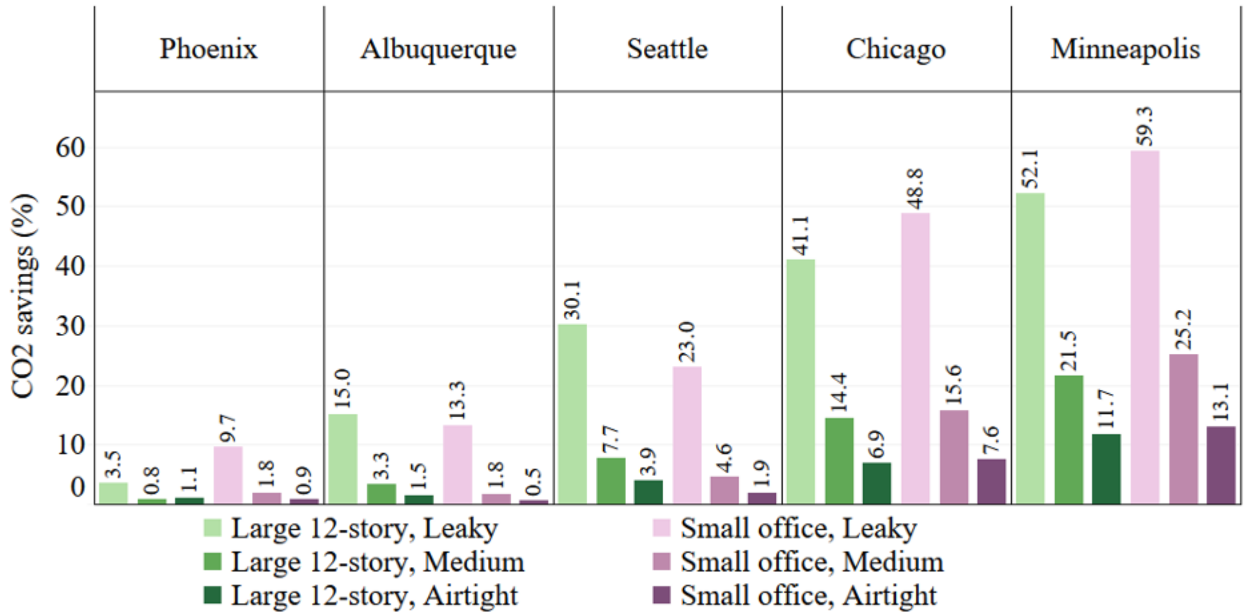


Figure B7. Relative CO_2 2 reduction compared to BL for Large 12-story and Small office building at five locations and three baseline airtightness.

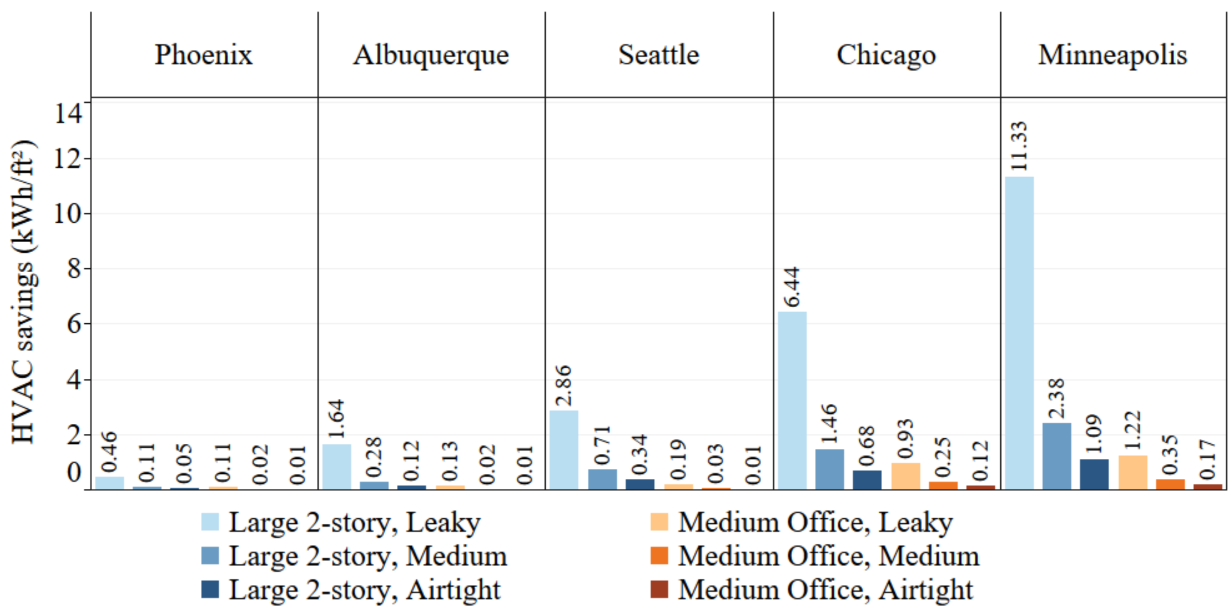
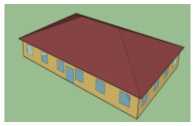
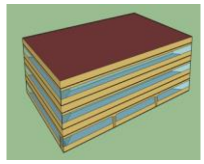
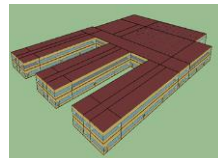
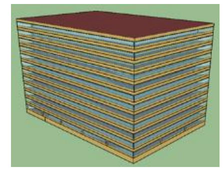


Figure B8. The total energy savings per ft^2 for Large 2-story and Medium office building.

Table B1. Cost analysis results of automated air sealing for Medium office and Large 12-story buildings from an initially leaky building

	Air sealing cost ($)	Annual electricity saving (KWh)	Annual natural gas saving (MMBTU)	Total annual saving ($)	Payback period (yrs.)	SIR
Large 12-Story Building						
Phoenix, AZ	623235	0	3.87	3870.00	>100	0.31
Albuquerque, NM	623235	-4173.18156	2.03	16178.21	38.52	1.30
Seattle, WA	623235	0	34.23	34230.79	18.21	2.75
Chicago, Il	623235	4173.18156	55.03	59200.33	10.53	4.75
Minneapolis, MN	623235	10201.11048	105.24	115438.85	5.40	9.26
Medium Office						
	Air sealing cost ($)	Annual electricity saving (KWh)	Annual natural gas saving (MMBTU)	Total annual saving ($)	Payback period (yrs.)	SIR
Phoenix, AZ	67025	5339	2.16	552.61	>100	0.41
Albuquerque, NM	67025	-2069	30/80	56.24109	>100	0.04
Seattle, WA	67025	2301	42.63	573.70906	>100	0.43
Chicago, Il	67025	701	16.91	1291.09	51.91	0.96
Minneapolis, MN	67025	1337	21.94	1855.89	36.11	1.38

Appendix C: The prototype building models

	Small office	Medium office	2-story large office	12-story large office
				
Number of Floors	1	3	2	12
Floor area	5500	53,600	210,900	498,600
Volume	55,065	697267	3,362,978	4,450,877
Core area to Perimeter area	0.41	1.45	0.11	2.75
Window-to-Wall Ratio	24.4% for South and 19.8% for the other three orientations	33%	33%	40%
Exterior Construction	Wood-frame walls (2X4 16 in o.c.) 1in. Stucco + 5/8 in. gypsum board + wall Insulation + 5/8 in. gypsum board	Steel-Frame Walls (2X4 16IN OC) 0.4 in. Stucco+5/8 in. gypsum board + wall Insulation+5/8 in	Steel-Framed Walls (2X4 16IN OC): 0.4 in. Stucco+5/8 in. gypsum board + wall Insulation+5/8 in	Mass (pre-cast concrete panel): 8 in. heavy-weight concrete + wall insulation + 0.5 in. gypsum board
HVAC-Heating type	Air-source heat pump with gas furnace as backup	Gas furnace inside the packaged air conditioning unit	1. Gas furnaces inside packaged air conditioning units 2. Gas-fired boiler	Water-source DX cooling coil with fluid cooler for datacenter in the basement and IT closets on other floors Two water-cooled centrifugal chillers for the rest of the building

	Small office	Medium office	2-story large office	12-story large office
HVAC-Cooling type	Air-source heat pump	Packaged air conditioning unit	1. Packaged air conditioner 2. Air-cooled Chiller	VAV terminal box with damper and hot-water reheating coil except non-data center portion of the basement and IT closets that are served by CAV units.
Internal equipment load	48.29	750.07	2371.59	14676.31

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Manufacturer Cut Sheet

AEROBARRIER X1 AEROSOL-APPLIED, WATERBORNE ACRYLIC SEALANT

AeroBarrier X1 is a safe, non-toxic, waterborne acrylic sealant for use with AeroBarrier air sealing systems. AeroBarrier pressurizes the building envelope and aerosolizes the sealant before injecting precise levels of this sealant mist into the building.

Sealant particles are automatically drawn to each leak, building a complete and tight seal. System software records progress in real time, noting before and after ACH. AeroBarrier X1 has no VOCs or off-gassing and meets multiple, exacting industry tests and standards. AeroBarrier seals remain firmly in place for years, staying completely pliable and flexible. This reduces energy loss and mitigates moisture, sound, and odor infiltration to improve indoor air quality and overall comfort.

Features and Benefits

- Seals leak up to ½" and as small as a human hair.
- Most economical to install at rough in or drywall stage of construction but can be applied to unoccupied, finished spaces.
- In multi-family applications, a tighter building envelope offers reduction in noise transmission, mitigates odor transfer, reduces pest migration and enhances climate control.
- Sealant does not stick to vertical surfaces like walls, windows, or doors.
- AeroBarrier is UL GreenGuard Gold certified and is safe to use in any type of building.
- Ultra-Low VOC and has no off-gassing.

Applicable Standards

AeroBarrier X1 has been tested to the following industry standards:

- GreenGuard Gold Certification
- ASTM E84: Standard Test Method for Surface Burning Characteristics of Building Materials
- ASTM C719: Standard Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants Under Cyclic Movement
- ASTM D543: Standard Practices for Evaluating Chemical Compatibility
- NFPA 285*: Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Wall Assemblies Containing Combustible Components
- ASTM E2357*: Standard Test Method for Determining Air Leakage of Exterior Air Barrier Assemblies

Limitations

- AeroBarrier is intended for use on the interior surfaces of residential and commercial building envelopes.
- Do not apply to damp, contaminated or frost-covered

surfaces. – Not to be used as a permanently exposed surface.

- When applying in cold weather conditions, follow cold weather applications/protocols as defined by manufacturer.
- Keep product from freezing.

Storage

Store AeroBarrier X1 in original, undamaged packages in a clean, dry, protected location with temperatures from 40 to 100 °F (5 to 37 °C).

Shelf Life

1 year when stored in accordance with storage instructions.

Sealant Information	
Property	**Description**
Part Number	AERO-128
Packaging	5-gal (19-L) pails

Weight	45 lbs (20.41 kg)
Storage Temperature	40 to 100 °F (5 to 37 °C) *Do Not Freeze*
Shelf Life	1 year
Application Temperature	Above 40 °F (5 °C) and rising. If installing below 40 °F (5 °C), please refer to Cold Weather Air Barrier Installation Technical Bulletin or contact AeroBarrier Technical Service

Technical Data	
Property	**Description**
Sealant Base	Acrylic
Color	White
Dispersion	Water
Application	Aerosol
Solids	18.5 to 21.5%
VOC	12 g/l

Warranty

AeroBarrier warrants its products to be free of defects in materials but makes no warranty as to sealant appearance or color. Since methods of sealant application and on-site conditions are beyond our control and can affect performance, AeroBarrier makes no other warranty, expressed or implied, including warranties of MERCHANTABILITY, and FITNESS FOR A PARTICULAR PURPOSE with respect to AeroBarrier products. Aeroseal LLC's sole obligation shall be, at its option, to replace or to refund the purchase price of the quantity of AeroBarrier products proven to be defective, and Aeroseal shall not be liable for any loss or damage. Please refer to our website at https://aeroseal.com/aerobarrier for the most up-to-date product data sheets.

Please refer to our website at https://aerobarrier.net for the most up-to-date Product Data Sheets.

NOTE: All AeroBarrier Safety Data Sheets (SDS) are in alignment with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) requirements.

Precautions

Installer should wear full-face respirator with an organic vapor type breathing cartridge, if inhalation exposure is possible. Keep out of reach of children. Refer to full SDS sheet for health hazard information. For use and application by trained AeroBarrier certified and professional installers only.

AeroBarrier X1

Safety Data Sheet

according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations Date of issue: 10 April 2019 Revision date: 07 June 2019 Supersedes : 13 May 2019 Version: 1.2

SECTION 1: Identification

1.1. Identification

Product form : Mixture

Trade name : AeroBarrier X1

1.2. Recommended use and restrictions on use

Use of the substance/mixture : Sealant

1.3. Supplier

Aeroseal LLC
7989 South Suburban Road
Centerville, OH 45458
T:1-877-349-3828

1.4. Emergency telephone number

Emergency number : 877-349-3828 Mon-Fri 8:00am-5:00pm

SECTION 2: Hazard(s) identification

2.1. Classification of the substance or mixture

GHS-US classification

Not classified

2.2. GHS Label elements, including precautionary statements

GHS US labeling

No labeling applicable

2.3. Other hazards which do not result in classification

No additional information available

2.4. Unknown acute toxicity (GHS US)

Not applicable

SECTION 3: Composition/Information on ingredients

3.1. Substances

Not applicable

3.2. Mixtures

Name	Product identifier	%	GHS-US classification
Water	(CAS-No.) 7732-18-5	50 – 70	Not classified
Acrylic Polymer	TSRN 51721300-5277P	20 - 40	Not classified
Silica, amorphous	(CAS-No.) 7631-86-9	1 – 5	Not classified
Propylene Glycol	(CAS-No.) 57-55-6	1 – 5	Not classified

*Chemical name, CAS number and/or exact concentration have been withheld as a trade secret

SECTION 4: First-aid measures

4.1. Description of first aid measures

First-aid measures after inhalation : Remove person to fresh air and keep comfortable for breathing. If experiencing respiratory symptoms:Call a poison center or a doctor.

First-aid measures after skin contact : Wash off immediately with soap and plenty of water. Seek medical attention if irritation develops.

First-aid measures after eye contact : Rinse with plenty of water. Remove contact lenses, if present and easy to do. Continue rinsing. Seek medical attention if irritation develops.

First-aid measures after ingestion : Rinse mouth. Do not induce vomiting. Get medical advice/attention.

4.2. Most important symptoms and effects (acute and delayed)

Symptoms/effects after inhalation : Not expected to present a significant inhalation hazard under anticipated conditions of normal use.

Symptoms/effects after skin contact : Not expected to present a significant skin hazard under anticipated conditions of normal use.

Symptoms/effects after eye contact : Not expected to present a significant eye contact hazard under anticipated conditions of normal use.

Symptoms/effects after ingestion : Not expected to present a significant ingestion hazard under anticipated conditions of normal use.

4.3. Immediate medical attention and special treatment, if necessary

Treat symptomatically.

SECTION 5: Fire-fighting measures

5.1. Suitable (and unsuitable) extinguishing media

Suitable extinguishing media : Water spray. Dry powder. Foam. Carbon dioxide.

Unsuitable extinguishing media : None known.

5.2. Specific hazards arising from the chemical

Fire hazard : On combustion, forms: carbon oxides (CO and CO2).

Explosion hazard : No direct explosion hazard.

5.3. Special protective equipment and precautions for fire-fighters

Firefighting instructions : Exercise caution when fighting any chemical fire.

Protection during firefighting : Do not attempt to take action without suitable protective equipment. Self-contained breathing apparatus. Complete protective clothing.

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

6.1.1. For non-emergency personnel

Emergency procedures : Ventilate spillage area.

6.1.2. For emergency responders

Protective equipment : Do not attempt to take action without suitable protective equipment. For further information refer to section 8: "Exposure controls/personal protection".

6.2. Environmental precautions

Avoid release to the environment.

6.3. Methods and material for containment and cleaning up

Methods for cleaning up : Soak up spills with inert solids, such as clay or diatomaceous earth as soon as possible. Collect spillage. Dispose in a safe manner in accordance with local/national regulations.

Other information : Dispose of materials or solid residues at an authorized site.

6.4. Reference to other sections

For further information refer to section 8: "Exposure controls/personal protection". For disposal of residues refer to section 13: "Disposal considerations".

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Precautions for safe handling : Ensure good ventilation of the work station.

Hygiene measures : Handle in accordance with good industrial hygiene and safety practice. Do not eat, drink or smoke when using this product. Always wash hands after handling the product.

7.2. Conditions for safe storage, including any incompatibilities

Storage conditions : Store in a well-ventilated place. Keep cool.

Incompatible materials : None known.

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Water (7732-18-5)
Not applicable

Acrylic Polymer (TSRN 51721300-5277P)
Not applicable

Silica, amorphous (7631-86-9)		
ACGIH	ACGIH TWA (mg/m³)	10 mg/m³ (biologically inert, insoluble or poorly soluble particles - inhalable particles)

Silica, amorphous (7631-86-9)

IDLH	US IDLH (mg/m^3)	3000 mg/m^3
NIOSH	NIOSH REL (TWA) (mg/m^3)	6 mg/m^3

1,2-Propanediol (57-55-6)

AIHA	WEEL TWA (mg/m^3)	10 mg/m^3

8.2. Appropriate engineering controls

Appropriate engineering controls : Ensure good ventilation of the work station. Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure.

8.3. Individual protection measures/Personal protective equipment

Hand protection:

Impermeable protective gloves

Eye protection:

Chemical goggles or safety glasses

Respiratory Protection:

Use full-face respirator when exposed to spray in an enclosed area.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state : Liquid
Color : White, milky
Odor : Characteristic
Odor threshold : No data available
pH : No data available
Melting point : No data available
Freezing point : No data available
Boiling point : No data available
Flash point : No data available
Relative evaporation rate (butyl acetate=1) : No data available
Flammability (solid, gas) : Not applicable.
Vapor pressure : No data available
Relative vapor density at 20 °C : No data available
Relative density : No data available
Solubility : No data available
Log Pow : No data available
Auto-ignition temperature : No data available
Decomposition temperature : No data available
Viscosity, kinematic : No data available
Viscosity, dynamic : No data available
Explosion limits : No data available

Explosive properties : No data available

Oxidizing properties : No data available

9.2. Other information

No additional information available

SECTION 10: Stability and reactivity

10.1. Reactivity

The product is non-reactive under normal conditions of use, storage and transport.

10.2. Chemical stability
Stable under normal conditions.

10.3. Possibility of hazardous reactions
Hazardous polymerization will not occur.

10.4. Conditions to avoid
None known.

10.5. Incompatible materials
None known.

10.6. Hazardous decomposition products
On combustion, forms: carbon oxides (CO and CO2).

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Acute toxicity (oral) : Not classified (Based on available data, the classification criteria are not met)

Acute toxicity (dermal) : Not classified (Based on available data, the classification criteria are not met)

Acute toxicity (inhalation) : Not classified (Based on available data, the classification criteria are not met)

Skin corrosion/irritation : Not classified (Based on available data, the classification criteria are not met)

Serious eye damage/irritation : Not classified (Based on available data, the classification criteria are not met)

Respiratory or skin sensitization : Not classified (Based on available data, the classification criteria are not met)

Germ cell mutagenicity : Not classified (Based on available data, the classification criteria are not met)

Carcinogenicity : Not classified (Based on available data, the classification criteria are not met)

Reproductive toxicity : Not classified (Based on available data, the classification criteria are not met)

Specific target organ toxicity – single exposure : Not classified (Based on available data, the classification criteria are not met)

Specific target organ toxicity – repeated exposure : Not classified (Based on available data, the classification criteria are not met)

Aspiration hazard : Not classified (Based on available data, the classification criteria are not met) Viscosity, kinematic : No data available

Likely routes of exposure : Ingestion. Inhalation. Skin and eye contact.
Symptoms/effects after inhalation : Not expected to present a significant inhalation hazard under anticipated conditions of normal use.
Symptoms/effects after skin contact : Not expected to present a significant skin hazard under anticipated conditions of normal use.
Symptoms/effects after eye contact : Not expected to present a significant eye contact hazard under anticipated conditions of normal use.
Symptoms/effects after ingestion : Not expected to present a significant ingestion hazard under anticipated conditions of normal use.

SECTION 12: Ecological information

12.1. Toxicity
Ecology - general : This material has not been tested for environmental effects.

12.2. Persistence and degradability
No additional information available

12.3. Bioaccumulative potential
No additional information available

12.4. Mobility in soil
No additional information available

12.5. Other adverse effects

No additional information available

SECTION 13: Disposal considerations

13.1. Disposal methods

Waste treatment methods : Dispose of contents/container in accordance with licensed collector's sorting instructions.

SECTION 14: Transport information

Department of Transportation (DOT)

In accordance with DOT

Not regulated

Transportation of Dangerous Goods

Not regulated

Transport by sea

Not regulated

Air transport

Not regulated

SECTION 15: Regulatory information

15.1. US Federal regulations

No additional information available

15.2. International regulations

CANADA

No additional information available

EU-Regulations

No additional information available

National regulations

No additional information available

15.3. US State regulations

WARNING: This product can expose you to ethyl acrylate and formaldehyde, which is known to the State of California to cause cancer, and Methanol, which is known to the State of California to cause birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

SECTION 16: Other information

according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

Revision date : 07 June 2019

SDS US (GHS HazCom 2012)

This information is based on our current knowledge and is intended to describe the product for the purposes of health, safety and environmental requirements only. It should not therefore be construed as guaranteeing any specific property of the product.