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Town of Shutesbury

Building Envelope Inspection Report

October 3, 2022

BUILDING ENCLOSURE RETROCOMMISSIONING

Retrofits to lower your maintenance, decrease operational costs, increase comfort, and improve carbon-footprint

TARGET: TO MAKE YOUR BUILDINGS PERFORM THE WAY THEY WERE DESIGNED – OR SHOULD HAVE BEEN.

- To increase comfort, decrease complaints, and make people happier where they work
- To decrease drafts and hot/cold spots
- To decrease energy and maintenance budgets, so funds are available elsewhere
- To help the environment by decreasing greenhouse gasses and carbon footprint through lower energy use
- To fund retrofits through decreased utility spending, so they pay for themselves over time
- To decrease energy and maintenance budgets, so funds are available elsewhere

The scientific understanding of how air barriers and insulation impact building performance has increased dramatically in recent years. Yet, most people still do not know that many of their discomforts and maintenance headaches are due to a leaky building enclosure, a missing air barrier, or poor insulation. When evaluating building envelope projects, they think first about saving energy and decreasing utility bills. But the real payoff is beyond energy. Uncontrolled airflow alters humidity and makes temperature control difficult, if not impossible. People are uncomfortable, and building components can be damaged, e.g., premature roof failure and rotting floor joists. It can lead to ice dams, as well as mold and mildew. Odors, noise, insects, and other pests also can pass through the gaps, cracks, and holes that most of us never notice. Each defect may be small, but they can add up to leaving a barn door open 24 hours a day, 7 days a week, 365 days a year.

Since 2006, Energy Conservation, Inc. has followed a systems approach to air sealing and insulation. We look from basement to rooftop for the keys to the puzzle of building performance and leave nothing on the table. We use cutting-edge testing technologies – e.g., ASTM E1186 infrared, tracer smoke, ultrasound, and hot-wire anemometer, and ASTM E779 multi-fan tests. Our experts bring 30+ years' experience to you and your project. Key staff sit on the ASTM E committee that sets the standards for testing, co-chair the Air Barrier Association of America existing buildings committee, and were founding director of the Building Performance Institute (BPI). Our standard work specifications and proprietary quality assurance system helps us be on time, on budget, and defect-free. You will barely know we're there, other than experiencing the improvements in your building.

Standard operating procedure addresses the symptoms, not the cause. Our scope will fix the root causes. E.g., air-sealing the gaps, cracks, and holes will stop the unconditioned air entering that creates drafts and discomfort. As a bonus, you save on energy bills and decrease operational and maintenance costs.

FINANCIAL: The project is budgeted at $85,681.89, not including bond and/or QA/QC. The project will make people more comfortable, decrease energy use and greenhouse gasses, and allow money currently used for energy and maintenance to fund other needs. Our proposal is firm-fixed-price, with no change orders unless there is a mutually agreed scope change. Our work often qualifies for utility rebates or incentives. We can provide needed information to you and the utility. Unlike other capital improvements, fixing these defects will decrease utility and maintenance costs, paying for the work over time, freeing up funds for other budget items.

Town of Shutesbury, MA

Facilities Information			
Project:	Shutesbury, MA		
Facilities:	Shutesbury E.S. Fire Station DPW Library Town Hall		
Utility Information			
Heating Fuel(s):	Fuel Oil Propane	Cost:	$1.6720 - $2.3787/gallon $1.5166 - $3.4252/gallon
Other Energy:	Electricity	Cost:	$0.2002 - $0.2449/kWh
Contact Information			
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Inspection Information			
Inspector Name(s):	Larry Harmon		
Inspection Date:	8/26/2022		

Inspection Performed

Building envelope inspections were performed at 5 building(s) located in Shutesbury, MA. The site(s) inspected are listed on the Project Information page. The inspector used infrared imagery, airflow measurement devices, and smoke tracer tests in accordance with ASTM E1186 to identify the location and severity of air leakage paths. Other inspection tools that may have been used include blower doors and duct blasters per ASTM E779. Micro leakage detectors may have been used per ASTM E783. When necessary, ultrasound detection is used per ASTM E1186.

These air leakage paths are detailed in the scope of work. Areas inspected include: roof-wall joints, elevation changes, soffit areas, roofs, walls, windows, doors and other penetrations.

While it is never economically feasible to address all the penetrations in a building envelope, our work scope addresses the equivalent of a **19.73 square foot** hole, in total, across the buildings studied. The work can be done at a reasonable cost and will have a significant impact on future energy consumption and carbon emissions. In addition to energy impacts, the Significant Issues section outlines other benefits from the work.

Significant Issues

Repairing the air barriers and/or insulation will help solve a number of significant problems that the client is experiencing. Below are some examples at specific sites, as well as some general issues that our inspector(s) encountered.

Shutesbury E.S. (Ref #1)

There is no effective air barrier between the conditioned space and the attic. An air barrier should bend, move, or sag to ensure effectiveness and longevity. There is poly below the fiberglass. It does not meet these criteria and it will continue to fail over time.

The lack of an air barrier is causing issues beyond higher energy bills. The air exchange can lead to comfort issues. Insects and other critters can enter the building more easily. Most importantly, the life of the roof is being shortened. Moisture drives from warm to cold. In the winter, the warm, moist air from the building is being forced out into the asphalt shingles, where freezing causes them to deteriorate before their expected lifespan. This has probably contributed to the current condition of the school roof. Installing an air barrier will stop this pathway and prolong the roof, while also increasing comfort, decreasing utility bills, and making entry into the building more difficult for pests.

We evaluated spraying a layer of 2-component, spray polyurethane foam over the existing fiberglass to seal this huge hole and to align the thermal (insulation) barrier and air barriers so the insulation will function as designed. Unfortunately, the payback was too long for Green Communities. If the town would like we can provide a quote for this work. We highly recommend that this be taken care of before a new roof is installed.

Town Hall (Ref #5)

One window has a broken balance that makes the window inoperable. We will replace the balance and make the window work again.

Client Responsibilities and Mobilization Prerequisites

All Sites

- Arrange access for a minimum of 10.5 hours per day, four days a week, so that crews can work 10-hour shifts, plus lunch.
- When applicable, ensure weekend parking is available for Energy Conservation, Inc. vehicles(s).
- Provide a small area of heated storage for sealants and other temperature-sensitive components.
- Provide access for placing a dumpster or CONEX, if needed.

General Issues

Beyond these specific problem areas, we identified several building enclosure problems. The buildings do not perform to their full potential because of these defects. Addressing the deficiencies will reduce operational and maintenance costs; improve the comfort of the building occupants; improve indoor air quality; extend building component life by blocking moisture that deteriorates parts; mitigate noise, odor, and pest problems; and reduce energy usage.

The key leakage areas are:

- Exterior doors
- Window systems
- Roof-wall joints
- No air barrier above drop ceilings

We found problems ranging from missing or defective air barriers to misalignment of the building's thermal and air barriers. The flaws are the result of a combination of design issues, poor construction implementation, and deterioration of materials over time. Our proposed scope will repair these building flaws and alleviate the issues they cause.

Considered by Dropped

As mentioned above, we evaluated the following measure(s) but did not include them in the proposal.

Shutesbury Elementary School (Ref #1)

The top of the building does not have an effective air barrier between the interior and the attic. Unfortunately, the options for fixing this defect are labor and material intensive and they did not screen looking at energy-only savings. As mentioned in the Significant Issues, the lack of an air barrier also leads to other problems with the building, beyond energy use. We recommend the Town consider this work, potentially blending other funding sources with Green Communities. We would be happy to provide a quote for what additional funding would be needed. We highly recommend that this be taken care of before a new roof is installed.

Concerns List

We also identified an area that is functioning well now but will need work in the future.

DPW (Ref #3)

We propose to fix the gaps in the foil-faced Astro-barrier here. This will work for a period of time, but the Town should keep an eye on it for future degradation. Generally, air barriers need to not bend, move or sag. This product does not meet those requirements. However, it is mostly intact at the moment. Ultimately, installing a rigid air barrier would be advisable, but it is not needed at this point in time.

"By Others"

We also identified a few problems that don't fall into one of our core competencies. We are mentioning them to bring them to the staff's attention, as they should be addressed.

These include:

All Sites

Reducing the heating and cooling loads should help the central HVAC system's performance, but we highly recommend that a full evaluation of the HVAC systems be performed (**by others**). Part of that evaluation should be to balance the systems after air-sealing retrofits are performed.

Pricing

The total price of building envelope work scoped in this document is **$85,681.89** with estimated annual **savings of $4,649.36,** resulting in a combined **payback of 18.43** years **and a reduction of 6.02%** from the baseline energy consumption. Tables by building, and a summary tab, are provided in the savings calculation spreadsheets, as well as below. Similarly, unit savings by fuel unit and carbon emissions are provided in the spreadsheets and table below.

Cost and Savings by Building/Site

Ref #	Building Name	Estimated Costs	Estimated Annual Savings	Simple Payback
1	**Shutesbury E.S.**	**$ 47,794.64**	**$ 2,576.32**	**18.55**
2	**Fire Station**	**$ 11,965.16**	**$ 645.49**	**18.54**
3	**DPW**	**$ 10,849.24**	**$ 566.78**	**19.14**
4	**Library**	**$ 1,519.01**	**$ 126.86**	**11.97**
5	**Town Hall**	**$ 13,553.83**	**$ 733.91**	**18.47**

Pricing Assumptions and Terms

Energy Conservation, Inc. has conditioned its proposal on the following assumptions and terms. If wage, tax, insurance, or other requirements are different than these assumptions, a pricing adjustment may be needed.

- We priced labor using prevailing wages, specifically, Massachusetts State prevailing wage for the town of Shutesbury, MA: Laborer – Laborers Zone 3 classification.

- We are not charging sales tax. A tax-exempt or resale certificate will be required before mobilization.

- No fire-rated foam, intumescent coating, or other fire-rated material is required, except where indicated in the work scope. If the local jurisdiction calls for such measures in other areas, pricing will need to be adjusted to cover the additional cost.

- Measurements and counts are approximate.

Intellectual Property

All information, including, but not limited to, report language and format, shall remain CONFIDENTIAL AND PROPRIETARY to Energy Conservation, Inc. unless the Company grants prior written permission. Information may be shared, without written permission, with the organization(s), agency(s), municipality(s), etc. that would fund measures in the Detailed Scope of Work section.

All Plans and Specifications and copies thereof furnished by or purchased are property of Energy Conservation, Inc. and are not to be used on other work. Except for one complete set, Client must return all documents upon contract completion. NO PORTION OF THIS DOCUMENT SHALL BE SHARED WITH ANY PARTY OTHER THAN THE CLIENT FOR WHICH IT IS PREPARED WITHOUT EXPRESS WRITTEN PERMISSION FROM ENERGY CONSERVATION, INC. This includes any direct or indirect reference to the scope, materials, or methodologies outlined in this report. Again, this **excludes** the organization(s), agency(s), municipality(s), etc. that would fund measures in the Detailed Scope of Work section.

Energy Savings and Carbon Footprint

The proposed scope of work will decrease operational and maintenance costs, as well as utility bills. The table below outlines the energy savings that drive the utility savings. If a site uses two types of fuel for heating, there will be an entry for Heating Fuel Type 1 and Type 2. If there is only one heating fuel, Heating Fuel Type 2 will be blank. The table reports total carbon equivalent emission savings across all fuels. Carbon savings are derived from the USEPA Greenhouse Gas Equivalencies Calculator and its Calculations and References page, as well as www.carbonfootprint.com. Values were also compared to the U.S. Energy Information Administration for the most recent year available.

Ref #	Building Name	Heating Fuel Type 1	Savings	Unit	Heating Fuel Type 2	Savings	Unit	Cooling Fuel Type	Savings	Unit	CO2e Savings (lbs)
1	Shutesbury E.S.	#2 Fuel Oil	1,362.64	Gallons	N/A	N/A	N/A	Electricity	1,469.49	kWh	33,078.80
2	Fire Station	Propane	374.67	Gallons	N/A	N/A	N/A	Electricity	119.87	kWh	4,826.44
3	DPW	#2 Fuel Oil	252.05	Gallons	N/A	N/A	N/A	Electricity	-	kWh	5,683.69
4	Library	Propane	35.29	Gallons	N/A	N/A	N/A	Electricity	24.43	kWh	475.65
5	Town Hall	#2 Fuel Oil	249.35	Gallons	Propane	56.22	Gallons	Electricity	269.94	kWh	6,750.16

Modeling Assumptions

Baseline Utility Data

Heating Fuel Type
Multiple heating fuel types were provided for the Town Hall (Ref #5). For our savings estimates, we assumed that both were used for heating purposes and created a blended MMBtu rate.

Heating System Efficiency
No heating system data was provided. For our savings estimates, we assumed default heating system efficiencies for the following sites:

- All sites; 75% HSE

Cooling Fuel Rate
For all sites, cooling fuel rate was provided for only June of 2022. For our savings estimates, we assumed their respective rates were comparable across the preceeding 12 months to determine the total annual cost.

Percent of Building Cooled
No percentage of building cooled data was provided. For our savings estimates, we assumed that 100% of a building's envelope was cooled, except in cases where there are garages/high bays:

- Shutesbury E.S. (Ref #1); 100%
- Fire Station (Ref #2); 36%
- DPW (Ref #3); 0%
- Library (Ref #4); 100%
- Town Hall (Ref #5); 100%

Building Occupancy Data

Temperature Setpoints
Setpoint data was not provided. For savings estimates, we assumed default occupied and unoccupied heating setpoints of 72 and 67 degrees, respectively, and occupied and unoccupied cooling setpoints of 73 and 78 degrees, respectively. This is the case for the following sites:

- All sites

Weekly Occupied Hours

Occupied hours/week data for was not provided. For savings estimates, we assumed figures within the context of the building’s purpose, unless their operating hours were readily available online. For example, a building that fulfills emergency services would operate at an occupied state for 168 hours/week. This approach was taken at the following sites:

- Shutesbury E.S. (Ref #1); 50 hours/week (assumed five 8-hours day with additional hours at beginning and end of each day)
- Fire Station (Ref #2); 168 hours/week (full time use)
- DPW (Ref #3); 50 hours/week (assumed five 8-hours day with additional hours at beginning and end of each day)
- Library (Ref #4); 42 hours/week (online hours with additional hours beginning and end of each day)
- Town Hall (Ref #5); 35 hours/week (online hours with additional hours beginning and end of each day)

Shutesbury E.S. (Ref #1)

The Shutesbury E.S. was initially built in 1972. The last renovation done was 1993. It has wood framing and an asphalt shingle roof. It is in fair condition and well-maintained by staff. The building envelope is quite leaky, due to failing weatherstrip and sealants, as well as construction framing details along several sections of the structure.

Doors

The exterior doors are leaky. Air-seal the doors (except the exterior door into the boiler room), per the Quality Assurance System (QAS) manual and floor plan.

- Weatherstrip the nonstandard-sized exterior doors, **total 13 doors**
- Weatherstrip nonstandard-sized exterior double doors, **total 4 double-door sets/8 door slabs**

Attic Hatches – New Entry

There are currently no attic access hatches needed because there is no air barrier above the drop ceiling. Once the air barrier is installed on top of the fiberglass, there will need to be dedicated hatches to access the attic space. New hatches need to be cut, framed, and installed to provide access for attic work.

- Build, frame, and install new insulated, dammed, and weatherstripped 2' x 2' attic hatch(es), **total 3 hatch(es)**

Windows

There are multiple window assembly types (WATs). The windows tested leaky at the frame-wall. Air-seal the windows, per the QAS manual and floor plan. Identify any operability issues or defects on the quality assurance forms.

- Seal the frame-to-wall/trim junctures, **total 4,408 LF**

Roof-Wall, Metal Deck, and Elevation Changes

The roof-wall joints, metal deck, and elevation changes are accessible in some areas of the building and tested leaky. Air-seal the roof-wall junctures, per the QAS manual and floor plan.

- Air-seal the roof-wall junctures, elevation change, metal decking, and any framing penetrations, **total 932 LF**

Fire Station (Ref #2)

The Fire Station was built in 1985. It has wood framing and an asphalt shingle roof. It is in fair condition and well-maintained by staff. The building envelope is somewhat leaky, due to failing weatherstrip and sealants, as well as construction framing details along several sections of the structure.

Doors
The exterior doors are leaky. Air-seal the doors, per the Quality Assurance System (QAS) manual and floor plan.

- Weatherstrip the standard-sized 3’ x 7’ exterior doors, **total 3 doors**

Attic Hatch – New Hatch/Existing Frame
A new hatch needs to be fabricated to replace the existing hatch that is in poor shape. Build and install the new hatch, per the QAS Manual and floor plan.

- Build and install new insulated and weatherstripped 2’ x 3’ attic hatch panel with frame to mount weatherstrip, **total 1 hatch**

Overhead Doors
There are sectional-type overhead doors that need work. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip the sectional-type overhead door(s), **total 5 door(s)**

Miscellaneous Sealing
The top of the knee wall sheetrock joint needs to be sealed. Seal the joint, per the QAS manual and floor plan.

- Seal the sheetrock joint at the top of the knee wall, 1-line, **total 100 LF**

DPW (Ref #3)

The DPW was built in 1950. It has wood framing. It is in fair condition and well-maintained by staff. The building envelope is moderately leaky, due to failing weatherstrip and sealants, as well as construction framing details along several sections of the structure.

Doors

The exterior doors are leaky. There is one door that needs rust repairs. Air-seal and repair the doors, per the Quality Assurance System (QAS) manual and floor plan.

- Weatherstrip the standard-sized 3' x 7' exterior doors, **total 2 doors**
- Weatherstrip the standard-sized exterior double doors, **total 1 double-door sets/2 door slabs**
- Repair the rust, **total 1 door**

Overhead Doors

There are sectional-type overhead doors that need work. The doors are located in the heated section. The doors tested leaky. Weatherstrip the doors, per the QAS manual and floor plan.

- Weatherstrip the sectional-type overhead door(s), **total 3 door(s)**

Air Barrier Repair

The foil-faced Astro-barrier is mostly intact but needs some repairs. Seal the barrier, per the QAS manual and floor plan.

- Air seal the foil-faced barrier, **total ½ crew day**

Library (Ref #4)

The library was built in 1902. It has had energy efficiency upgrades over the years. It is in very good condition and well-maintained by staff. The building envelope is slightly leaky, due to failing weatherstrip.

Doors

The exterior doors are leaky. Air-seal the doors, per the Quality Assurance System (QAS) manual and floor plan.

- Install sweep only, **total 1 sweep**
- Weatherstrip the nonstandard-sized rear double doors, **total 1 double-door sets/2 door slabs**

Town Hall (Ref #5)

The Town Hall is an older building. It has wood framing and an asphalt shingle roof. It is in very good condition and well-maintained by staff. The building envelope is somewhat leaky, due to failing weatherstrip and sealants.

Doors
The exterior doors are leaky. Air-seal the doors, per the Quality Assurance System (QAS) manual and floor plan.

- Weatherstrip the nonstandard-sized exterior doors, **total 4 doors**

Windows
There are 3 window assembly types (WATs).

The WAT-1 and WAT-2 units tested leaky at the frame-wall. There is one sash with a broken string balance that makes it difficult to operate. Air-seal and repair the windows, per the QAS manual and floor plan. Identify any operability issues or defects on the quality assurance forms.

- Seal the frame-to-wall juncture, **total 2,046 LF**
- Replace the balances where broken (left and right side), **total 1 window/2 balances**

Building envelope retrofits improve deficient areas of a building's thermal and/or air (pressure) boundaries. For thermal deficiencies, the R-value of building components is increased by either replacing components (e.g., single-pane to double-pain windows) and/or by installing insulation. For pressure-related deficiencies, the retrofit focuses on sealing up areas where unwanted air migration occurs.

Air movement across the building's pressure boundaries may be intentional – designed to introduce fresh air or to exhaust stale air – or unintentional. Intentional air movement is known as ventilation. Unintentional air movement is known as air leakage. Air leakage can result in conditioned air moving from inside the building to outside and/or unconditioned outside air moving into the conditioned building. Many times, intentional efforts at ventilation result in additional unintentional leakage via building junctures due to pressure imbalances acting on defects in the building enclosure.

The Effects of Pressure and Hole-Size on Air Flow in Buildings

A simple orifice calculation for airflow is:

$$\sqrt{P} \times A\ in^2 \times 1.07 = \text{flow in CFM} \quad \text{(if the pressure is in pascals)}$$

The two main factors impacting air leakage are pressure and hole size. Airflow increases by the square root of the pressure and linearly with hole size. When evaluating a building envelope for retrofit, we are constantly on the lookout for gaps, cracks, and holes that provide pathways to the exterior – the linear component.

Three driving forces move air across the pressure boundaries of a building:

- Stack Effect – pressure caused by the density difference between outside and interior air, due to temperature differentials
- Wind Effect – wind-driven pressures
- Mechanical Effect –either deliberate or inadvertent pressure imbalances created by the HVAC systems.

The potential for unintentional airflow exists in all buildings due to the presence of these three physical effects. This airflow can either be into the structure – infiltration; or out of it – exfiltration. The airflow itself is made possible by the flaws in the building envelope – gaps, cracks, and holes.

So, the two fundamental concerns are the continuity of the building's air barrier and the pressures at which the building operates.

Savvy design engineers will attempt to balance a building's HVAC systems to reduce the effects of all three driving forces. Buildings so balanced perform much better from an airflow standpoint but are still regularly subjected to forces outside the range of intentional design parameters, and are susceptible to changes by occupants and staff.

A study on building commissioning recommended that buildings be reviewed every five years or so to determine if they are still in balance and make adjustments if needed. In the majority of the buildings we investigate for building envelope retrofits, we request that the building be "re-balanced' following the building envelope repairs.

The leakier the building, the more difficult it is to maintain that balance. The various pressure effects working on the building have larger swings with larger holes, and the energy penalty of keeping the desired pressure increases. Tightening the building envelope decreases energy use and increases the likelihood that the building will perform within design pressure parameters. Some physicists and engineers are beginning to speculate whether building pressurization is necessary with a tight building envelope.

How Leaky Are Buildings?

Many believe that institutional and commercial buildings are tight structures. Several pieces of research, as well as our direct observations in the field over many years, belie this assumption.

"It is often assumed that commercial and institutional buildings are fairly airtight and that envelope air leakage does not have a significant impact on energy consumption and indoor air quality in these buildings. Furthermore, it is also assumed that more recently constructed buildings are tighter than older buildings. The fact of the matter is that very few data are available on the airtightness of building envelopes in commercial and institutional buildings. The data that do exist show significant levels of air leakage in these buildings and do not support correlations of airtightness with building age, size, or construction." ***Airtightness of Commercial and Institutional Buildings: Blowing Holes in the Myth of Tight Buildings****, Andrew K. Persily, Ph.D.****,*** *Thermal Envelopes VII Conference, 1999.*

“Many discussions in the popular press and the technical literature still refer to commercial and institutional buildings, and newer buildings in particular, as being airtight. ’Tight buildings’ often are blamed for a host of indoor air quality problems, including high rates of health complaints and more serious illnesses among building occupants. Furthermore, discussions and analyses of energy consumption in commercial and institutional buildings frequently are based on the assumption that envelope air leakage is not a significant portion of the energy used for space conditioning. These statements are almost never supported by any test data or airflow analysis for the buildings in question.” ***Airtightness of Commercial Buildings in the U.S.*** *Steven J. Emmerich and Andrew K. Persily, Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, MD, USA.*

Retrofitting a building’s envelope generally involves sealing various gaps, cracks, and holes that, left alone, allow uncontrolled migration of air between the inside and the outside of the building. Building envelope retrofits provide wonderful opportunities for energy savings. There are many non-energy benefits associated with the work, and these, while sometimes challenging to monetize, can be as much or more important than energy savings. Occupants are more comfortable as drafts and airflow decrease. Indoor air quality improves as outside pollutants can no longer enter the building. Pressure differences from mechanical system imbalances are mitigated. Pest, odor, and water infiltration headaches are often taken care of by building envelope retrofit work. Desired humidity levels can be maintained. In many instances, repairing the building envelope can increase the time before structural issues manifest themselves, e.g., roof shingles and sheathing last longer if the attic is air-sealed, stopping moisture drive and condensation.

Common Air Sealing Needs

Lack of continuity in a building’s air barrier exists from basement to rooftop. Typical measures include roof-wall joint sealing, blocking of soffit openings, weatherstripping, applying sealants to windows and doors, and more

Doors: Doors are very cost-effective to weatherstrip. The proper weatherstrip should be ample, durable, and capable of transitioning between seasonal variations. It should be completely airtight at all times the door is closed. Many products have thin bulbs, which cannot accommodate seasonal variances. Others have brushes that close the hole down but do not entirely seal it. Frequently the “fuzz” product in a frame is worn or lacks a silicone or Teflon tab in the middle to completely block the flow. Carefully selected replacement weatherstrip products for windows and doors have been proven over time to be durable and effective.

Windows: Windows are also a common measure. Replacement windows generally have extremely long paybacks. Whenever possible, it is much more cost-effective to air seal and weatherstrip windows rather than replace them. Many times, new replacement windows still leak around the frames due to the installation procedures. These can be made airtight with appropriate sealants.

Roof-wall: Often, the juncture where the roof and the wall meet is not airtight. The usual approach is to seal this joint with 2-component, closed-cell polyurethane foam. This repair provides a durable, monolithic seal and stops leakage around the perimeter of the roof. Elevation changes – where second or third stories attach to lower structures – are sometimes areas of considerable leakage. In addition to 2-component foam, backer rods and caulks are occasionally appropriate for these junctures, or rock-wool and fire-rated mastic.

Soffits: Soffits are often areas of significant leakage. Some have openings several feet high, going around the entire perimeter of the building. The severity of the problem varies – we find them ranging from wide open to totally sealed. Fiberglass insulation may have been installed in the past in an attempt to block and insulate the hole, although often, it has fallen, leaving a gaping hole. Even with fiberglass still in place, it is not a good seal in and of itself. The rule of thumb is that if it does not hold water, then it will not stop airflow. Similarly, we see failures of polyethylene and other non-rigid materials used in attempts to air seal these junctures. These materials are not able to stand up to the building pressures they experience, are easily pierced and torn, and cannot be effectively fastened.

Penetrations: There are other miscellaneous penetrations throughout buildings, including utility chases, plumbing and electrical penetrations, HVAC duct penetrations and boots that are not sealed, rooftop fan curbs with gaps and cracks, and more. A well-trained inspector is needed to identify all the penetrations and what to do to fix them.

Insulation and Bypasses: Finally, we often see misalignment of the thermal and air barriers of the building. When the air barrier is not in direct contact with the thermal boundary, the insulation is bypassed and does not function at its rated values. Similarly, cold air can intrude behind the insulation and make direct contact with the air barrier. This contact provides an opportunity for condensation on internal building surfaces. The condensation can lead to building degradation and/or mold problems. On occasion, buildings lack insulation in the walls or attic/roof deck, and insulation needs to be added.

There are three applicable standards for determining airflow in buildings. They are ASTM E1186, ASTM E779, and ASTM E783.

ASTM E1186

ASTM E1186 ***Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*** cites several different methodologies for determining leakage locations. The pertinent ones for testing at this site are:

- Section 4.1.1 Combined building depressurization (or pressurization) and infrared scanning;
- Section 4.1.2 Building depressurization (or pressurization) and smoke tracers;
- Section 4.1.3 Building depressurization (or pressurization) and airflow measuring devices; and
- Section 4.1.4 Generated sound and sound detection.

We use a variety of tests depending on the local conditions. A popular methodology is section 4.1.1, the infrared (IR) approach. However, it has its flaws. Air leakage can be very difficult to detect using IR, and it is easy to misinterpret the data. If the building is cooled or heated, and the outside weather is sufficiently different, then this method may yield good results depending on cladding, cloud cover, etc. – and, most importantly, operator skill. Section 4.1.2, smoke tracer testing, is the gold standard within the retrofit industry as it is not subject to as many of the limitations as are the other methodologies. It can still show no leakage, despite holes, if there is no driving force moving air at the time of the test. Section 4.1.3, airflow measuring devices, works when there are sufficient pressure differentials across the building envelope. Section 4.1.4, generated sound, can help when conditions are benign, with limited pressure differentials. In this instance, the inspector deploys a noisemaker and listens for sound signals that come through any gaps, cracks, or holes in the building envelope. We can also use fan pressurization/depressurization to spur smoke movement, allowing the use of IR, and enabling anemometers to record flows. The other applicable standards are tracer gas testing and chamber tests in conjunction with pressure differentials.

ASTM E1186 is a strictly qualitative test standard. Its purpose is to locate the sources and pathways of air leakage. It does not quantify the extent of the leakage. When calculating potential savings, we base crackage estimates on direct observation by the inspector, our experience with measuring quantified leakage from conducting E779 and E783 tests, and engineering estimates. We then check the assumptions against baseline consumption data for reasonableness during our fit-testing process.

To determine the actual amount of air leakage in a building requires different tests. There is a quantitative approach to determining the amount of air leakage. Buildings can be pressure tested in conformance with the ASTM E779 to quantify the airflow across the building envelope at various pressure differentials.

ASTM E779

ASTM E779 ***Standard Test Method Determining Air Leakage Rate by Fan Pressurization*** is the standard driving the U.S. Army Corp of Engineers' (USACE) test protocol for new construction projects. The same whole building tests are appropriate for testing existing structures. This standard is significant because the practices described under ASTM E1186 are qualitative, determining the air leakage *sites* rather than determining quantitative leakage *rates*. So, for Measurement and Verification (M&V), E779 testing can document and verify the actual reductions forecast in the initial site inspection.

The standard allows the technician to test buildings under pressurization or depressurization. A minimum of six measurements are required, but it is preferable to take ten. Readings must be in increments between 25 and 75 pascals. Baseline pressure measurements must be recorded before conducting the test and immediately following the test.

This type of testing can supplement the ASTM E1186 tests and quantify leakage rates. They may be included for M&V, to document actual reductions. Generally, we rely on pre- and post-tests using the E1186 tests only, due to the significant costs and inconvenience associated with multi-fan blower door testing.

ASTM E783

ASTM E783 ***Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors*** uses microleakage detection devices. Microleakage testing requires setting up to measure leakage at a specific opening, taking the measurement, tearing down the testing setup, installing the measure, then repeating the testing process. Each test takes approximately one hour for the pre-test and one hour for the post-test. During the testing, the window or door is not available for egress. Again, these tests are usually not necessary but are available if needed or desired.