Guidelines for Improving Energy Efficiency in Historic Buildings

Maine Preservation

Our Heritage, Our Legacy

Historic buildings have great potential to achieve substantial energy efficiency improvements that save money while preserving historic character. A common sense, simple and holistic approach to energy efficiency works well with historic buildings as well as with other existing buildings. When considering improvements to historic buildings, it is vital to use careful planning and a flexible approach to solving energy, building code, and rehabilitation issues.

Since the downturn in the economy beginning in 2008, rehabilitation of buildings has encompassed a larger portion of the construction industry. Contrary to popular belief, well maintained historic buildings are typically more energy efficient than many buildings constructed in the second half of the 20th century. Over the next 25 years, billions of square feet of rehabilitation represent an opportunity for owners and construction professionals to achieve substantial energy savings and reduction in carbon emissions and operate more cost-effectively. Historic buildings are currently exempt from meeting the energy code standards under the Maine Uniform Building and Energy Code (MUBEC), however, reducing energy consumption in older properties is critical for their livability and our broader societal goals of reducing fuel dependence.

The following guidelines and recommendations include some short examples with photographs that outline specific measures to use with historic buildings and approaches to avoid. You can find further information including bibliography and a list of professional resources at www.mainepreservation.org/energy

Historic Preservation Guidelines for Energy Efficiency and Sustainable Practices

1. Initiate your project by identifying and evaluating the historic features of the building.
2. Conduct a building performance evaluation.
3. Seek to retain historic features that were designed to save energy and increase comfort. Think about restoring original systems and use patterns rather than introducing new ones.
4. Determine the most cost-effective energy-saving strategies: **insulate attics; retain and weatherize historic doors and windows; seal gaps and penetrations to minimize air infiltration.**
5. Develop a long-term energy efficiency plan that prioritizes rehabilitation decisions and establishes short-, middle- and long-term phasing for desired goals.
6. Employ durable and repairable materials with a lifetime of 30 years or more.
7. Make changes that are reversible and can be monitored and inspected. Be wary of unproven materials on the market.
8. Control for moisture, particularly in walls and basements, and for unhealthy air quality.

1. Initiate your project by identifying and evaluating the historic features of the building.

- Conduct a thorough survey of all existing materials to avoid needless or wholesale replacement.
  - From this survey, identify the character-defining features of the historic structure and seek to preserve these features when planning for energy efficiency improvements. Once these historic features are removed, even carefully duplicated materials will almost never have the same quality, durability, compatibility, and craftsmanship of the original. Paint layering, gouges and dings, wear patterns and patched materials are part of the patina and history of use of a building, adding to its character. Your local or statewide preservation group may help identify these historic features if you are unsure.
  - *Recommended:* Retain and repair exterior features such as windows, doors, trim, detailing and siding that define the historic character of buildings; removal of these materials causes a loss of architectural integrity that can diminish buildings' historical significance and diminish property valuations.
  - *Recommended:* Work with and around structural members and avoid damaging other intact historic interior features such as baseboards, ceiling trim, window and doorframes, doors, stairways, plaster, flooring, etc.

- Selective repair of character-defining features saves labor, materials, expense, and historic integrity, while preserving property valuation.

Photo Credit: "Your Pal Dave"

2. Conduct a building performance evaluation.

- Perform an energy audit on the building using a certified professional (BPI or HERS qualifications) who is also experienced in the evaluation of historic buildings.
  - *Recommended:* Ask the energy auditor to provide an energy improvement plan that establishes priorities and alternatives, including life cycle analysis. Seek solutions that save the most energy using the least destructive, invasive, and costly means. Such solutions will pay for the cost of the audit quickly.
    - o *Example:* A blower door test, seen in Figure 1, calculates the rate and volume of air that leaks from a building while the doors and windows are closed. An energy audit completed on this building will be used to identify cost-effective ways to improve the comfort and efficiency of the building without compromising its historic features. Such measures include the addition of interior attic insulation, weatherstripping historic wooden storm windows, and re-glazing several of the original windows.

- Computer simulations by an experienced energy efficiency expert can help determine the most effective energy conservation measures for a building in terms of both energy performance and cost.
  - *Recommended:* For major upgrades to commercial buildings invest in a computer simulation. Detailed simulations greatly reduce guesswork in choosing the best measures to implement and will help ensure a near-optimal solution. Hourly or half-hour building simulations should be performed using software packages with weather data from a nearby location.

- If a commercial building is occupied, consider conducting an occupant comfort survey. A survey can provide an assessment of occupant's comfort as it relates to thermal, acoustic, indoor air quality, lighting level, cleanliness, along with optimal work patterns, work station locations and other comfort issues.

Figure 1
Historic Building Energy Audit

Photo Credit Zack Bowen for Horizon Maine

3. Seek to retain historic features that were designed to save energy and increase comfort. Think about restoring original systems and use patterns rather than introducing new ones.

- Before modifying historic systems, be sure to fully understand how they operate. This will allow for better integration of new and old, leading to greater energy savings. Homeowners in past generations built and adapted their homes for seasonal weather conditions. Investigate how they may have done so in your building, with respect to heating, ventilation and lighting, before making major modifications.

- Consider the orientation of the structure with respect to passive solar heat gain and lighting. Optimize these factors by retaining and utilizing design elements that contribute to them.
  - *Recommended:* Maintain/restore passive energy systems such as windbreaks, shade trees, porches, shutters, awnings and window coverings.
    - o *Example:* Use interior shutters, energy-efficient blinds, or draperies to reduce heat loss at night in winter.
    - o *Example:* Use deciduous trees on the south, east and west sides of a building to provide shading in the summer and allow for solar gain in the winter. Use evergreens on the north/northwest sides for winter windbreaks.
  - *Recommended:* Maintain or restore historic features to recapture original functions that support energy-efficiency.
    - o *Example:* Repair or reopen historic transoms to improve airflow and cross ventilation to either better distribute, or exhaust heat.
  - *Avoid:* Removal of historic features that improve energy efficiency.
    - o *Example:* Awnings, as seen in Figure 2, historically were used to provide shade and keep a building cooler in the summer. If awnings were in place historically, replace them or repair existing awnings to working order.

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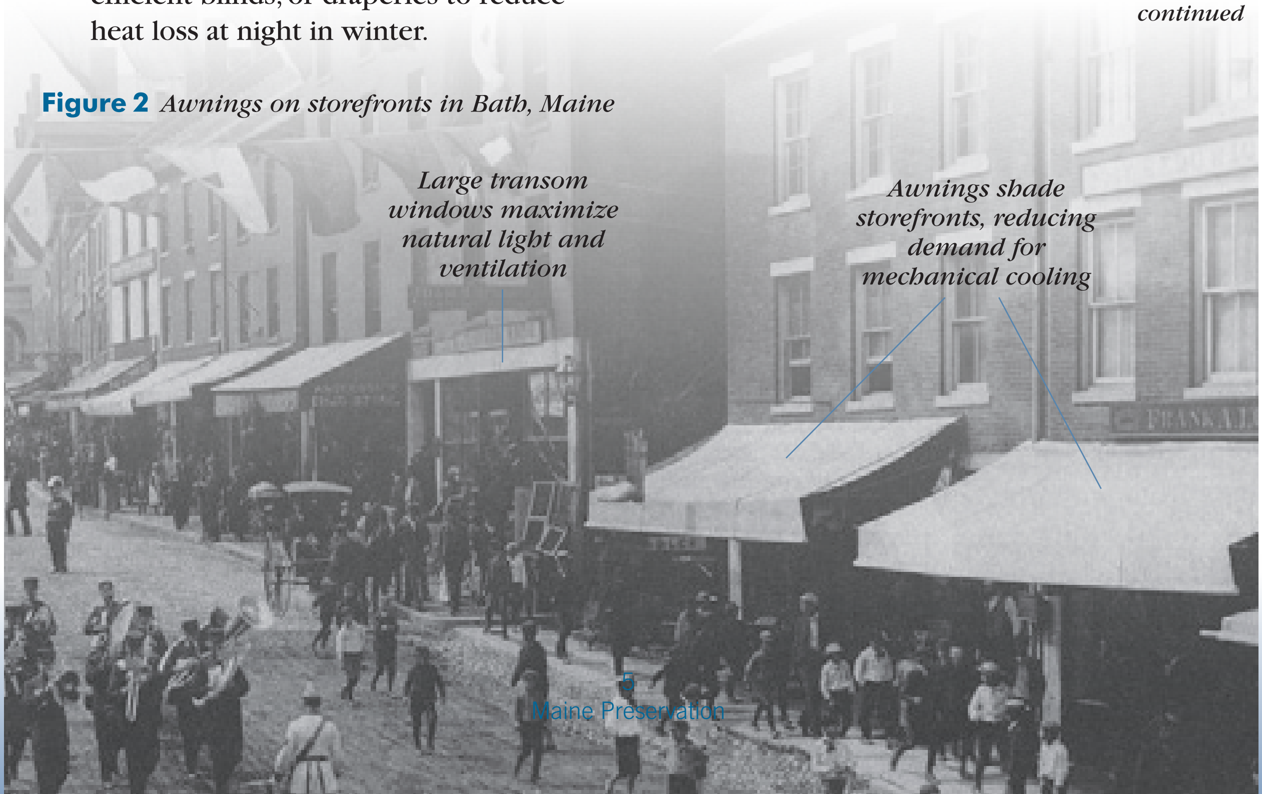
Figure 2 *Awnings on storefronts in Bath, Maine*



- Consider how the original ventilation system worked, prior to installation of a heating system.
  - *Recommended:* Research how the original systems functioned. Elements such as tall windows or light wells in schools, commercial buildings and mills were often designed to bounce natural light into the buildings and to ventilate the building. These features are integral parts of the whole design.
    - o *Example:* The Emerson School in Portland, as seen in Figure 3, was built in 1899.The former school has thick masonry walls that store thermal energy and each classroom has a wall of large windows to provide natural light and ventilation. Note, too, the dormers and cupola for ventilation.The circle-head window above the entry and the skylight provide natural lighting.

Figure 3 *Large Windows for Ventilation*

- Consider not just individual systems, but also the interconnectivity of the building's systems.
  - *Avoid*: Changes to one part of the building that undermine other parts of the building or its overall functioning.
    - o *Example*: Some historic buildings have a widow's walk or attic hatch at the top of a central hall. Opening this widow's walk or attic hatch in the summer can create an upward draft to vent the hot air out of the building and draw breezes in the lower windows. Permanently closing off the widow's walk or attic hatch to prevent heat loss eliminates an effective passive cooling feature for the warmer months.
  - *Recommended*: Many areas of historic buildings are dependent on air exchange between the building and the outside. When sealing to minimize this air infiltration, take steps to ensure that these systems—particularly roof ventilation channels—are not compromised.
    - o *Example*: Historic buildings nearly always had roofs that froze and thawed in winter based on the outside temperature, thus minimizing fluctuations in freeze-thaw cycles.When the attic and roof are sealed, insulated and improperly vented, the roof surface will thaw with frequency. This results in melting the bottom layer of snow, which will run down the roof and refreeze at the eaves, creating ice dams that back up water under the shingles—and into the building. When insulating and sealing attics and roofs, seek to prevent ice dams, ideally with both soffit or eave venting, combined with a ridge vent or at least gable louver vents that allow the roof surface to remain frozen in cold temperatures.

4. Determine the most cost-effective energy-saving strategies.

- The top three actions to take for energy savings that minimize costs while maximizing payback are: attic insulation; weatherizing historic windows and doors; and sealing gaps in siding and interior walls, sill openings, holes and utility penetrations, and other leaking joints.
  - *Recommended:* Install or upgrade attic floor insulation to an R-60 rating if possible. Install or keep open existing ventilation channels between the rafters where they intersect the top wall plate.
  - *Recommended:* Repair and weatherstrip historic windows and doors. The ideal option is to use draft-proof interlocking zinc, bronze or stainless steel weatherstripping. In addition, add or tighten exterior or interior storm windows and doors with gasketing, but be certain to allow for weep holes along the bottom rail to drain or vent condensed water vapor.
  - *Recommended:* Determine and seal locations of air infiltration. Open or poorly-fitted chimney flue dampers are a major source of heat loss, as are areas around exterior ducts, pipes, and other penetrations, attic hatches, unlocked double hung sashes that fall open, and the joint between the foundation and the house frame (the sill plate).

- Beyond the top three actions, additional cost-effective strategies can result in large energy savings.
  - *Recommended:* Routinely service and calculate the efficiency of existing mechanical systems and controls. Evaluate the performance and efficiency of existing heating systems, available fuel sources, appliances, and lighting fixtures. When upgrading heating, consider reusing components (such as ducts, radiators, etc.) of existing systems after verifying their condition and capacity. Research, select, and complete planning for these upgrades prior to the system's failure to avoid hasty emergency-based decisions. This will also allow time to identify and take advantage of tax incentives, rebates, and other programs.
  - *Recommended:* Where appropriate, consider supplementing systems with enhancements such as programmable thermostats, attic and ceiling fans, timed bathroom fans, windproof dryer and bathroom vents, and motion-sensing light fixtures.
  - *Recommended:* Replace inefficient appliances. Install efficient lighting and low-flow water fixtures.
  - *Avoid:* Replacement windows. Replacement windows are expensive, can seldom be repaired or rebuilt, are not recyclable and have a limited life span. Once original windows are replaced (and usually discarded) this decision is not reversible. Replacement windows have

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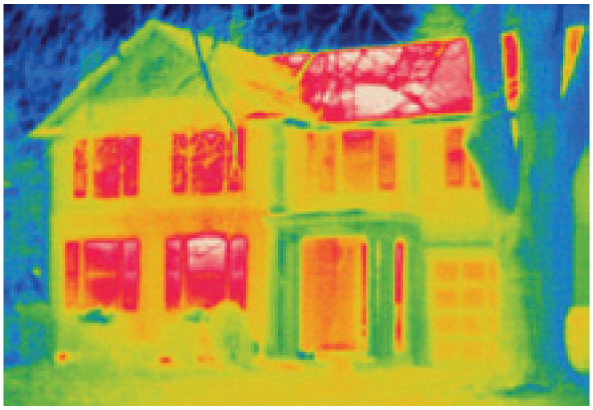
Photo Credit
"Houlton Downtown"
by lumierefl

a long payback period (up to 250 years) that typically exceeds their relatively short service lifetime (15-30 years). Installation of stock replacement windows often requires costly alteration of the rough opening, meaning either enlargement or reduction in the size of the window frame. Independent research in upstate New York[1] and in Boston, Massachusetts[2] has found that new windows do not save enough energy in their lifetime to warrant replacement.

- *Carefully evaluate:* Adding wall insulation. Experts do not agree on the effectiveness and monetary return of insulating walls in historic buildings, particularly wood frame buildings, in light of internal accumulated moisture concerns. For a more detailed discussion of wall insulation, please see Section 8.

5. Develop a long-term energy efficiency plan that prioritizes rehabilitation decisions and establishes short-, middle- and long-term phasing for desired goals.

- Short-term phasing includes minimal cost options that most building occupants/owners can complete on their own, such as: replacing standard incandescent bulbs with compact fluorescent light (CFL) bulbs or LED light bulbs, installing window shades or thermal blankets, unplugging electronics when not in use, and caulking obvious areas of air infiltration.



- Middle-term phasing includes medium priced options that may require professional installation such as: adding attic insulation and insuring roof ventilation is adequate, sealing against air infiltration in difficult to observe or reach locations, weatherstripping and reglazing windows.

- Long-term phasing includes higher priced options that will need to be addressed eventually, such as: major heating or fuel modifications, hot water heating or major installations such as solar or geothermal systems.

[1] Research by Michael Blasnik, an independent energy efficiency consultant with over 25 years experience.
[2] *A Comparative Study of the Cumulative Energy Use of Historical Versus Contemporary Windows* by Shirley, Gamble, and Galvin.

6. Employ durable and repairable materials with a lifetime of 30 years or more.

- Consider return on investment over the life-cycle of materials and the value that durable materials add to a building. Durable traditional materials, such as old growth wood, hardwoods, granite, slate, and terrazzo add value to a building, reduce ongoing maintenance and replacement costs, and can enhance energy savings over time.
  - *Recommended:* Retain and restore as much old growth wood as possible. Old growth wood was harvested from trees hundreds of years old. The wood from these trees is as much as ten times denser, and is stronger and less prone to insects, fungus, warping, or damage than the softer, plantation-grown woods commercially available today. Because nearly all of these ancient trees have already been harvested and are no longer readily available in nature, this wood is only preserved in the structural timbers, floors, shingles, and windows of historic buildings and cannot be sustainably replaced.
  - *Recommended:* Restore historic windows that are made of old growth wood and can be continually repaired and weatherized, providing a greater return on investment than replacement vinyl windows, which have short life expectancies. Most replacement vinyl windows are "maintenance free" because even minor cracks or other problems cannot be repaired and the entire window must be replaced. In addition, they are composed of multiple materials that cannot be recycled.
  - *Avoid:* Removing old-growth durable timber and exterior wood trim and replacing with short-lived, wide-grained contemporary wood or vinyl.
  - *Avoid:* Removing largely intact historic plaster which can be a better insulator than sheetrock. Instead, repair the plaster cracks or areas with broken keys with repair washers and drywall screws or by chipping out plaster cracks to at least an inch in width and replastering.

- Consider: the embodied energy of historic materials. Retain and repair historic materials instead of demolishing and replacing with new materials - to avoid wasting the energy initially expended in extracting, fashioning, transporting and erecting these materials, and the energy used in demolishing and disposing of the existing materials.

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Old Growth Wood—In the photo above, the top board is in the ballpark of 300 years old with up to 30 growth rings per inch. The second board is 175 years old with 10 growth rings per inch. The bottom board is current lumber sold at a major home improvement supplier with 6 growth rings per inch. (The older wood was salvaged from demolished buildings.)

- When new materials are introduced, determine their compatibility with retained historic materials, and the projected life expectancy of these assemblies. Use long-lasting materials that are repairable and that perform effectively with historic materials while allowing measurement of energy-efficiency.
  - o *Example:* Many historic structures, such as the Alna Meetinghouse (1789) shown in Figure 4, were constructed from old growth wood. Where the old growth wood roof sheathing was damaged beyond repair, new boards were installed. By avoiding wholesale replacement of historic materials, more long-lasting materials were retained, thus extending future life expectancy of the meetinghouse. Only replace what needs replacing.

Figure 4
Old Growth Wood with Patching

7. Make changes that are reversible and can be monitored and inspected. Be wary of unproven materials on the market.

- Changes in technology can introduce new materials that are not fully tested, particularly for their application in older buildings. New materials may require unexpected replacement or unintended consequences may arise from their use. As such, strive to make changes that can, if necessary, be easily reversed and restored to the previous condition or prior function.

o *Example:* Polybutylene, a plastic water supply line pipe developed in the 1970's, was promoted as "the pipe of the future." The perceived advantages of polybutylene were the low cost over copper and the ease of installation. But in the 1980's structures with polybutylene started reporting leaks caused by the interior walls of the pipes and fittings breaking down and flaking apart. The breakdown of the pipes could usually not be seen from their exterior. These pipes had to be entirely replaced.

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- Only implement changes will allow continued future inspection and monitoring.
  - *Avoid:* Irreversible modifications such as the installation of closed cell spray foam insulation, particularly in wood-framed structures. Foamed-in-place insulation hides the condition of the structure, individual members, and their fastenings, and does not easily allow for upgrading or inspection of wiring, plumbing, or other in-wall systems. This material is also flammable and when spray-applied, varies widely in dimensional thickness and performance. It must be professionally monitored for moisture levels since, despite its vapor-retarding capacity, cracks and gaps in foamed insulation can allow moisture penetration and structural deterioration. Better options are cellulose, rockwool or foil-clad rigid foam board, which can be removed for inspection or if later proven hazardous and/or underperforming. Fiberglass does allow some air flow through the fibers and carries some respiratory health risks.
    - o *Example:* Urea Formaldehyde Foam Insulation (UFFI), seen in Figure 5, was an insulation retrofit product used in the 1970's. It was later banned in Canada and the United States after elevated levels of formaldehyde (a known carcinogen) were found in a small number of homes. Not only was it dangerous to have in the walls, but it was also a hazard to remove. Beyond its formaldehyde content, the insulation did not allow for inspection or upgrading of various wall systems, allowing potentially dangerous structural conditions to go unnoticed.

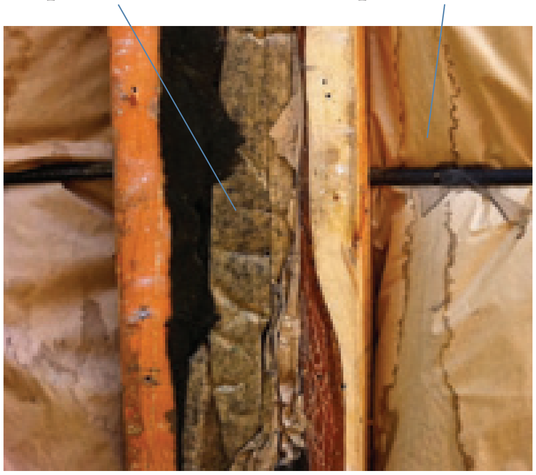
Figure 5
Urea Formaldehyde Foam Insulation

8. Control for moisture, particularly in walls and basements, and for unhealthy air quality.

■ Monitor and manage roof runoff from precipitation.

- *Recommended:* Remove moisture from the immediate surroundings of a building by maintaining roof and exterior siding, installing a crushed stone building apron beneath the dripline with subsurface drains, extending downspouts and/or adding splashboards to direct water away from the foundation, keeping gutters clear, and ensuring proper grading directs water away from the building.
- *Recommended:* Monitor moisture infiltration in the basement and remediate through re-grading, adding new subsurface or French drains, a dehumidifier, vapor barriers and other measures, in consultation with an expert.

Open Wall Mold



■ Monitor and manage interior moisture generation and ventilation.

- *Recommended:* Ventilate kitchen and bathrooms fans, and dryer vents, directly to the exterior. Reconfigure systems that ventilate into an attic or interior space. Locate vents to be effective and unobtrusive.
- *Recommended:* Before adding or changing insulation or installing air conditioning in any part of a building, ask an expert to evaluate the dew points in the walls and ceilings as well as vapor ventilation characteristics of the structure and the insulation. Failure to do so could result in condensation within walls or in the building—contributing to eventual structural deterioration.
- *Carefully evaluate:* Adding wall insulation. Insulating walls is extremely complicated considering the framing and obstructions within walls, variability in the location of the dew point within walls and the effects of condensation, air exchange (or absence of) within the wall cavity, as well as insulation product performance or degradation over time within the wall assembly. Air and water vapor passes through un-protected wall plaster and drywall, if not covered with a vapor-retardant paint on the interior or by a vapor barrier immediately backing the plaster or drywall.

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Vapor condenses into water inside walls in cold weather. Bathrooms, kitchens, laundries and dampness from cellars, as well as human and pet respiration can increase water vapor entering the walls. Heat loss estimates for walls are relatively low, though range significantly from many sources and types of construction, and typically may fall between 12–25% of the total heat loss of the building.

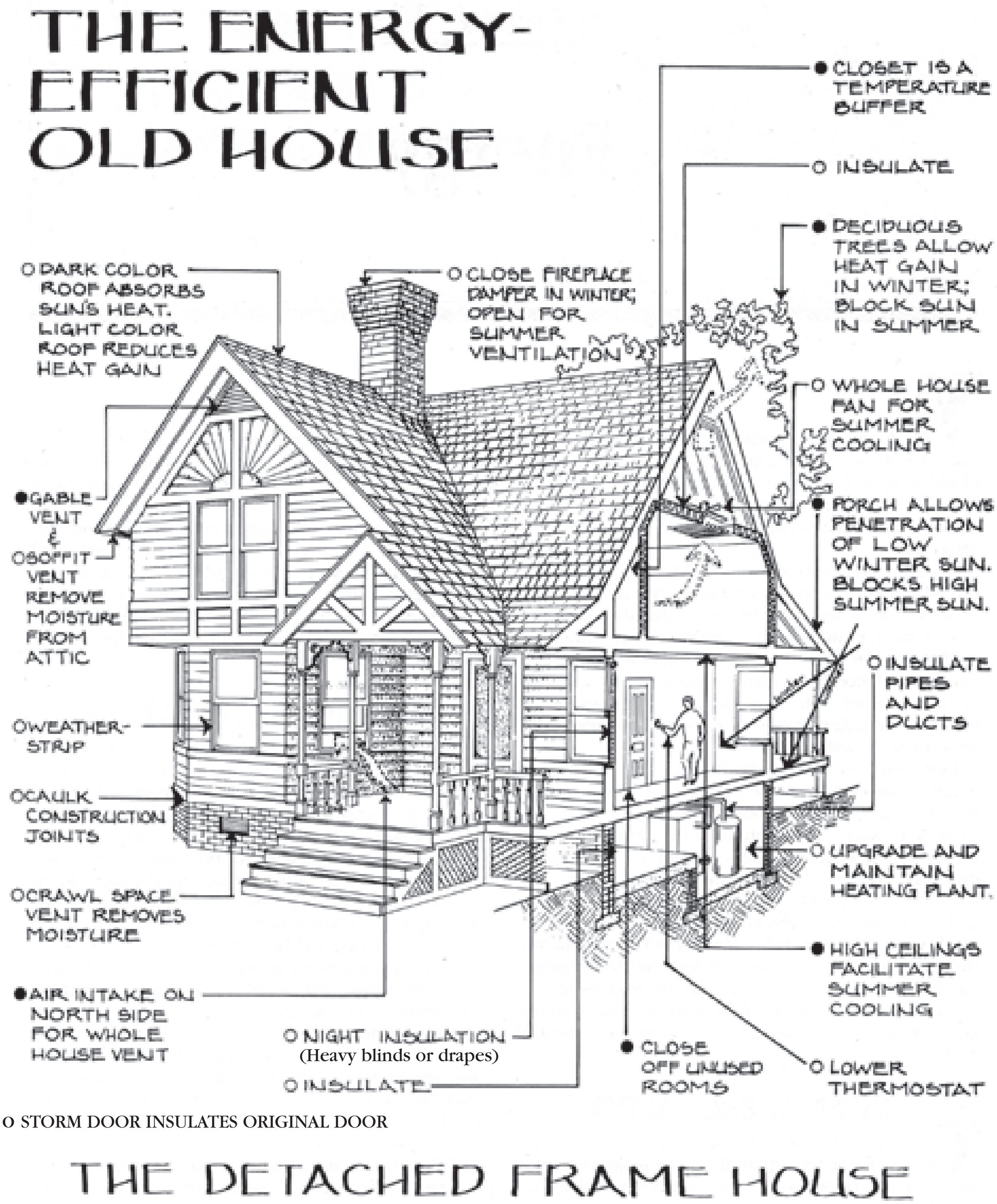
- *Advice:* A "one size fits all" recommendation is not advisable for insulating walls in historic buildings. Many experienced tradespeople advise not to insulate historic walls at this time. Insulated walls require a vapor barrier facing the living space, with sealed joints, inside of the wall. The most opportune time to insulate is when the wall cavity is open from the outside or the inside. Removing plaster and lath is not advised, as thick, sound plaster is a superior insulator to drywall, as well as an effective sound deadener. Replacement of original sound clapboards generally decreases durability. Spray-in options generally do not permit use of a vapor barrier. Choose insulation materials carefully, as synthetics can carry the risk of carcinogens, off-gassing hazardous vapors to the interior and increase flammability of the wall section. Irreversible insulation (like spray foam) is not recommended in difficult-to-access walls. Consider, too, if a superior product is made available in the future, whether your insulation is easily removable for upgrade.

o *Example*: Mildew on the exterior of this early 19th century house, seen in Figure 6, appears to be the result of insulation installed in the wall cavities without an adequate internal vapor barrier, as the structural framing (corner braces, studs) is not discolored.

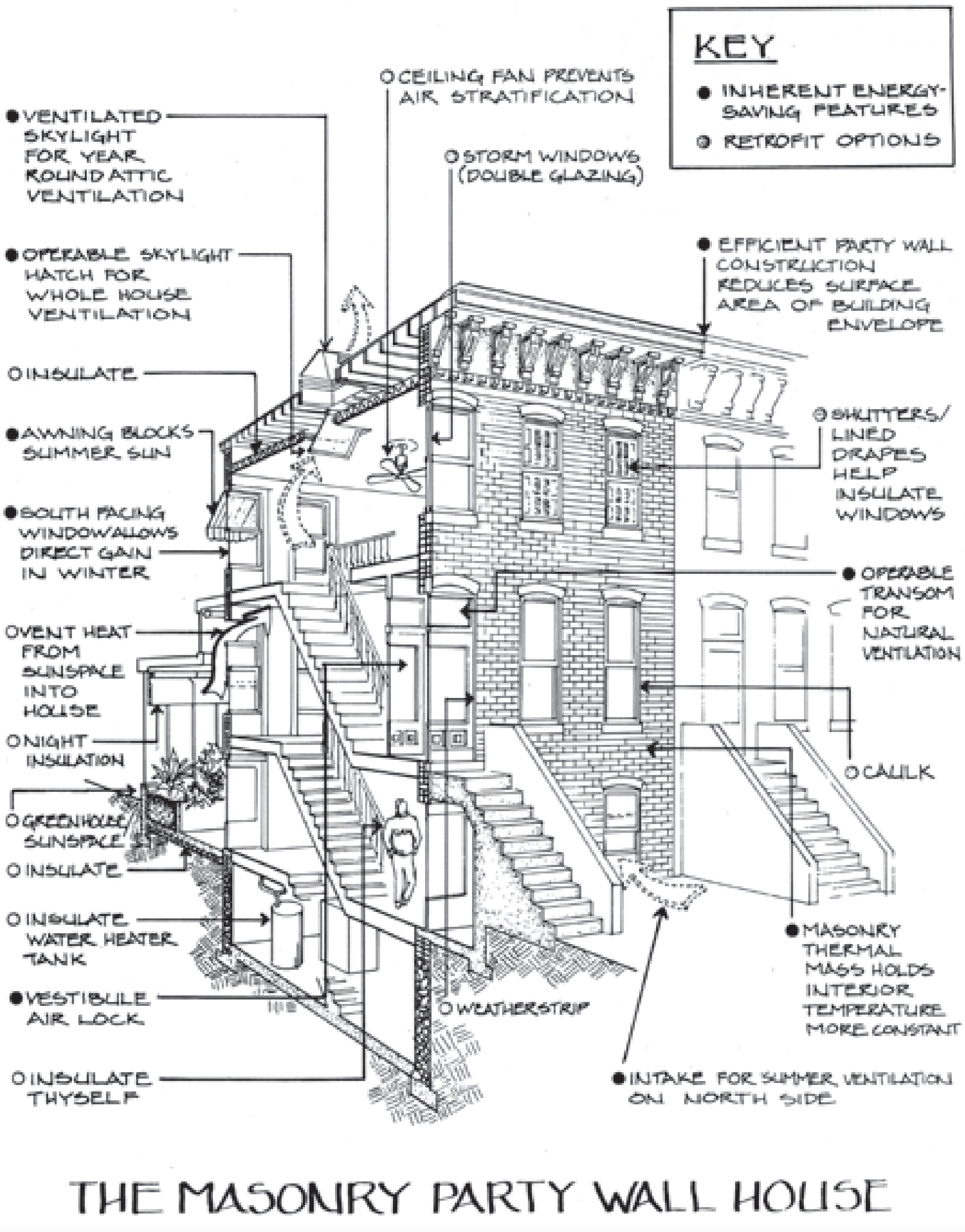
Photo Credit Historic New England

Figure 5 *Mildew on Exterior*

For further reading on how to conserve energy and improve efficiency in historic houses in Maine, see Greater Portland Landmarks' publication *The Energy Efficient Old House: A Workbook for Homeowners*, for sale at www.portlandlandmarks.org.



The Old House Journal Guide to Restoration (1992).



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Our Heritage, Our Legacy
233 West Main Street
Yarmouth, Maine 04096
www.mainepreservation.org

The Guidelines for Improving Energy Efficiency in Historic Buildings seeks to provide a set of standards or principles that should be applied to historic buildings when energy upgrades are planned and implemented. These guidelines are not intended to be a thorough manual of practice for complete energy upgrades of historic buildings.

Because it is organized by the guidelines, some topics are discussed under more than one guideline. Please use the Index to cross-reference specific topics or building features. Additional information, including a bibliography and other related material, may be found at www.MainePreservation.org/Energy.

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Authors
Anne Ball, Anne G. Ball Consulting
Greg Paxton, Maine Preservation

Research and Editors
Robert O'Brien, Maine Preservation
Ryan Carmichael, Intern, Maine Preservation

Project Management and Support
Sue Inches, Maine State Planning Office — project conception
Jody Harris, Maine State Planning Office — project manager
Erin Tobin, Preservation League of New York State; Marilyn Kaplan, New York State SERDA; Hilary Bassett, Greater Portland Landmarks; Nancy Barba, Barba + Wheelock — initial support

Design and Layout
Jeannine Owens, Gliddon Owens Design

Energy Efficiency Advisory Group
Deb Andrews, City of Portland
Rochelle Bohm, Maine Preservation
Steve Caulfield, Turner Building Science
Christopher Closs, Greater Portland Landmarks and Maine Preservation
Danuta Drozdowicz, Context Green
Margaret Gaertner, Barba + Wheelock
Scott Hanson, Sutherland Conservation & Consulting
Al Hodson, Resurgence Engineering and Preservation
Mike Johnson, Maine Historic Preservation Commission
Dick Lambert, City of Saco
Roberta Lane, National Trust for Historic Preservation
Don McGilvery, Maine State Housing Authority
Mike Nugent, Town of Old Orchard Beach
Mike Pullen, WBRC Architects and Engineers
Colin Schless, Fore Solutions
Anne Stephenson, Professor and Consultant
Peter Taggart, Taggart Construction
Rebecca Williams, National Trust for Historic Preservation
Sally Zimmerman, Historic New England