Making Your Historic Building Energy Efficient: Volume 1 Principles & Approaches
August 2007

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Acknowledgement

This report was prepared by the Synertech Systems Corporation under an agreement with the Office of Environmental Affairs of the City of Boulder, Colorado as a supplement to a four-page brochure bearing the same title.

A number of people have responded to earlier drafts of the document, offering suggestions and clarifications that were useful in preparing this version of the report. Special thanks are due to Elizabeth Vasatka of Boulder's Office of Environmental Affairs, and to James Hewat of Boulder's Historic Preservation Division, both of whom made a number of useful suggestions for improving the text. All comments were offered in the spirit of joining in a common effort to enhance the usefulness of this document in helping buildings become more energy efficient while preserving their historic character and architectural integrity.

We appreciate the practical wisdom shared and suggestions made by others, most of which has been integrated into the text. However, the opinions expressed herein are those of the Synertech Systems Corporation's staff and do not necessarily reflect the views of anyone else or the organizations they represent. Are we not putting forth the City's position on theses issues in this literature?

Larry Kinney
August 2007

Foreword

In 2004, the important topic of historic preservation and energy efficiency in Boulder's older building stock reached a pinnacle of discussion in Boulder. Accordingly, Boulder's City Council directed two organizations, the Landmarks Board (LB) and the Environmental Advisory Board (EAB), to research, analyze and recommend how these two program areas that Boulder cares deeply about can find compatibility, where guidelines acknowledge both as important issues affecting the city's historic buildings.

The topic of whether to preserve existing material or replace it with more highly-efficient material in our designated or landmark buildings received a lot of worthy attention. This question was vetted by boards, experts and professionals in the historic preservation and energy efficiency fields, as well as with the community and the State Historical Society. We tried to turn over all the stones to understand this important and delicate topic.

With the city's passing of the Climate Action Plan in 2006 and its Historic Preservation Program, the overseeing boards and Council spent many hours discussing how both programs can coexist. All parties agree that the guidelines for Historic Preservation should clarity the criteria for measures being considered for restoration, rehabilitation, retrofitting and remodeling of historic structures.

It was recommended by the boards and directed by Council that city staff create resources for building owners who live in historic districts and in designated and landmarked buildings, to be able to access information on how to make their historic buildings more energy efficient without jeopardizing their historic character or the integrity of the buildings' original architectural significance. This document is part of the effort to provide useful information to all parties.

We welcome your comments and hope the information provided can inform you about your older home or building's performance. As energy prices increase, it is the city's aim to assist people with making energy efficiency retrofits that make good sense.

Chairs of the Landmark's and Environmental Advisory Boards

Table of Contents

Volume 1: Principles and Approaches

Volume 2: Technical Details

Appendix **Page**

Section 1
Principles

Introduction

The appropriate preservation of historically designated buildings and districts in Boulder has been legislated by ordinance since 1974. The early recognition of the importance of Boulder's historical environment has developed so that that today, the city boasts one of the most progressive historic preservation programs in Colorado and among the strongest in the United States. Historically on the forefront of environmental issues, in 2006 the city adopted a climate action plan to meet the Kyoto protocol goals of substantially lower emissions of greenhouse gasses. The following document is intended to provide owners of historically designated properties with detailed information as to how they can make their environmental footprint smaller. As you will see, it is almost always possible to undertake measures that will significantly improve the energy efficiency, comfort and operating systems of designated historic buildings without affecting their architectural or historic integrity.

The why and how to achieve this end is the subject of this document. Volume One covers principles and approaches to retrofit work, while Volume Two deals with technical details.

Figure 1-1. Historically contributing buildings located in designated historic districts, each of these houses had energy audits done in the winter of 2006-07. A number of opportunities were discovered for cost-effective energy-related retrofits in each house that will not affect their architectural or historic integrity.

This old building

When people describe their historic buildings, they often use phrases like "It's quite old, has no insulation at all, and there probably isn't much that can be done with it." The truth is that historic houses are by their nature adaptable, and much can be done to make them more energy efficient and comfortable. Most newer buildings are designed to be "maintenance free." Often, this means that when something breaks, you can't fix it and a specialized contractor must be hired to replace it. In older buildings, it is normal to find things that are broken, worn or otherwise deteriorated. However, most of the materials used to construct historic buildings—like wood, glass, brick and stone—are intended to last a long time and were used with the intention that over time they would need to be maintained and repaired. So unless deterioration is extreme, most problems with historic buildings are repairable, often without a large investment in either time or materials. The results of taking such steps will be worthwhile for you—and for the community at-large.

Why retrofit a historic building?

Economics
Saving energy keeps energy bills low. With energy prices rising, each year brings increases in the cost of heating, cooling and operating a building. Some people are reluctant to invest in energy-saving retrofits when up-front costs are high and savings occur gradually over time. For instance, people may hesitate before purchasing new warm tone compact florescent light bulbs (CFLs) which cost as much as four incandescent light bulbs, even though the CFLs save $70 over a lifetime of use. When energy retrofits are a part of a total package of rehabilitation work, the premium cost for efficiency is easier to pay. Further, since ENERGY STAR® labels make it easier to choose efficient appliances, consideration of the energy use of appliances before purchase is becoming standard practice.

Energy efficiency upgrades can breathe new life into an older building and offer the owner economic benefits beyond lower costs. A house with an upgraded heating system, fewer drafts and greater comfort gains resale value. Often, the changes that save energy while retaining historic and architectural integrity are the ones potential buyers look for. Insisting on “best practices” in energy retrofits ensures comfort now, fewer repairs in the future and higher value in the long run.

Happily, energy-efficiency mortgages (EEM) are now available. These loans qualify homeowners for extra funds to be spent on energy savings retrofits. The result can be a net improvement in cash flow because lower energy bills can often offset higher mortgage costs. These loans are available to both buyers and current homeowners wishing to finance energy efficiency retrofits. (See *FCIC: Energy Efficient Mortgage Home Owner Guide,* www.pueblo.gsa.gov/cic_text/housing/energy_mort/energy-mortgage.htm.)

Sometime older houses start to deteriorate because the burden of high energy costs appears to make preventative maintenance and repair unaffordable. However, the wholesale replacement of energy-challenged older houses is a poor economic choice for a family and a community. While the city’s historic preservation ordinance and design guidelines preserves the exteriors of designated buildings, careful energy retrofits preserve their integrity while freeing funds for continuing maintenance.

Environmental sustainability experts agree that there is substantial energy embodied in an existing building: bricks and mortar, quarried stone, ancient trees and the labor of those that constructed it. To demolish and rebuild—even a highly efficient newer house—may well result in little economic or environmental benefit. The net expenditure of energy and resources is unlikely to be recovered over the life of the new house assuming the lifespan of the average lifespan of a building is (30 years? – check this). This fact has prompted historic preservationists to claim that "greenist building is the one already constructed".

Older buildings are often more durable and forgiving of environmental stresses than are those built with newer construction practices and materials. An older house, correctly maintained and upgraded, will easily outlast a newer house built with plywood, plastic, and nails from pneumatic guns. High-quality, energy-efficiency upgrades on historic buildings are economical and environmentally sustainable in practice.

Comfort and wellbeing

Like a car, if a building does not function properly, it is unlikely to meet adequate standards for comfort and safety. Unimproved historic house will often not meet the performance of newer buildings. However, with high-quality energy retrofits and appropriate maintenance, historic buildings can provide the energy efficiency and convenience of a new house.

Historic preservation

Owners of historically designated experience the pride of owning a building that has been found to be of special historic, architectural or cultural significance to the city of Boulder. The city's historic ordinance and design guidelines provide direction on how to undertake appropriate alterations to designated buildings and those located within designated historic districts. Any changes to the ***exterior*** of such buildings require a landmark alteration certificate (LAC).

The purpose of an LAC is to ensure that work to building located in a historic district or an individual landmark property is appropriate and will preserve the character of the property and/or district in which it is located. Careful planning requires attention to the historic preservation ordinance and guidelines in addition to requirements for health, comfort and the use of space, is critical. Designing retrofits of historic buildings with efficient energy use in mind will result in the best investment of resources over time. More information on the LAC application and approval process can be found at www.boulderhistoricpreservation.org.

An older building's carbon footprint

Historic buildings are frequently adapted to allow for contemporary conveniences, including improved central heating, air conditioning, domestic hot water (DHW), wiring for electronics and expanded living spaces. Higher consumption of natural gas and electricity can accompany these improvements. The use of carbon-based fuels to run buildings, along with the structural changes to accommodate them, has led to substantial increases in the environmental imprint of tour built environment. (See Carbon Footprint Calculator at www.carbonfootprint.com.)

This effect can be reduced by auditing the energy efficiency of historic buildings and taking steps to appropriately adapt the building to its modern uses in energy conscious ways. An old building gives owners an opportunity to preserve both history and the planet for future generations.

Rehabilitate or replace: a historic building dilemma

As a general rule, it is worthwhile to repair an existing component of a house rather than to replace it. Saving material in place is almost always the most efficient use of resources. For historically contributing buildings in designated districts and on landmarked properties, the repair of exterior features and materials is stressed in order to preserve that materials and the character they impart. Further, it is difficult to retain authenticity and historic integrity when rebuilding with newer materials. For this reason historic preservation usually leads to rehabilitation of existing materials and features rather than their substitution in a manner that increases comfort, adapts to contemporary usage demands and reduces energy loads.

Although there are many low-cost materials and products on the market today, the sacrifice may be in performance, durability and longevity. A well-maintained, original door or window can usually be rehabilitated to meet the expectations of long-lasting performance. On the other hand, there will be circumstances where significant historic doors and windows will be so deteriorated they can not be repaired. In these rare instances, choosing new, efficient windows that closely match the historic in material, dimension, profile and appearance will be necessary. Consult www.boulderhistoricpreservation.org for more information regarding the process for applying to replace historic windows on designated buildings.

Deconstruct with care

While preserving as much of an existing building in place usually makes the most sense from a historic preservation and environmental standpoint, experts in those fileds agree that deconstruction rather than demolition is the preferable method of taking down a building when demolition is deemed necessary. Deconstruction is basically the reverse of construction where the components of the building are taken apart from the inside. The process begins with fixtures, cabinets, doors and appliances, proceeds to the roof and walls and finally the foundation. Local companies provide this service, and property owners can reap substantial tax deductions.

Identify and understand each element

Until World War II, most house were built by professionals who were trained through apprenticeships where workers learned the “old carpenters’ tricks” from their mentors. There was an evolving tradition of housing construction that developed through generations of trial and error. Often the problems with existing historic houses are the result of poorly executed “improvements,” modifications and add-ons accomplished without a thorough examination of how the building originally functioned. For example, many late nineteenth-century houses were fenestrated in such a way that natural cross-ventilation could be achieved during the hot summer months. Rehabilitating and making operable historic windows and providing for this type of cross ventilation can reduce or remove the need for air conditioning. Identifying the original design and understanding the reason for the elements of that design can always help prevent repeated correction flawed fixes. For instance, Yankee gutters (built into the roof edge) are an element of many Craftsman era houses that need to be repaired or replaced. It is typical to replace them with modern external gutter systems. However, if the old Yankee gutter ways are not properly sealed and roofed over, significant water damage can result.

Avoiding common pitfalls

Before describing sound energy retrofit practices, it is useful to list things to avoid:

- Damage to or removal of historic architectural elements.
- Replacement significant windows and/or doors on historically designated buildings.
- Using paint, caulk or glue that fails or that will destroy an original surface. For instance, silicone caulk is wonderful for bathroom tub enclosures, but is inappropriate for external seals between foundations and sill plates because it has poor adhesion qualities. Latex paint needs an alkyd base to successfully cover oil-based paint.
- Trapping moisture in building cavities. Despite Boulder's low humidity, placement of moisture barriers and sources of wetness must be examined with care.
- Creating water leaks with improper flashing or similar building details.
- Removing structural support walls.
- Replacing solid, historic materials or components with limited life-span substitutes. Natural wood structural systems last for many centuries if maintained carefully. Plywood and plastics have short lifetimes under certain conditions.
- Interrupting critical elements in the energy performance of the building. For instance, cutting off return air ducts lowers furnace efficiency.
- Blocking a radiator behind a decorative cover (which may reduce heat delivery)
- Covering over a floor register (which may put the entire heating system out of balance)
- Changing the air flow patterns in the house in ways that create air quality, moisture or heat distribution problems. Unbalanced heating/ventilation systems may backdraft combustion appliances. This is a primary cause of carbon monoxide poisoning, but it is rarely tested for. Replacing older furnaces and boilers with units that are closed-combustion or power-vented saves significant amounts of energy and helps to safeguard indoor air quality.
- Installing glazing inappropriate for a given elevation. Low-solar heat gain insulated glass on the south side reduces heat losses during the winter but also reduces the solar heat gain on cold sunny days when it is especially welcome.
- Painting windows or doors sloppily so they do not close properly. Older windows with built up paint and caulk are often replaced with inferior units. Basic repairs can provide for significant energy efficiency improvements to historic windows and doors at reasonable cost.
- Incorrect installation of weather stripping so that doors and windows do not close properly. A door not designed for weather stripping may not be improved with its application. A properly- functioning door can keep out the drafts and operate smoothly. An ill-fitting door needs repair.
- Overloading older wiring or the service panel. A thorough evaluation of electrical loads and capacity should be done before any major modifications of a building.
- Exposing occupants to lead dust, asbestos and other toxins. Do-it-yourself remodeling is potentially dangerous, especially to young children. Certified professional testing for these hazards is recommended.

Air leakage: a common problem

One of the most common and easily solved problems historic buildings is air infiltration. A cold draft blowing down the back of the neck is associated with both discomfort and higher energy bills. In many houses as much as 30 percent of wintertime energy use is wasted in heating air that escapes from cracks and seams.

When people think of weather-tightening, they usually think of adding insulation. However, insulation *per se* does not stop drafts. Its purpose is to add resistance to the flow of energy (heating or cooling) through solid materials—reducing conductive losses, not convective (air flow) ones. If the building is not air tight, conditioned air will leak out of the building and cold air will be drawn in. Therefore, it is very important to air seal virtually all the air leaks in a house before adding insulation. In most existing buildings, construction flaws, shifting foundations, damage and simple aging have opened up multiple cracks and seams.

Fortunately, in most cases, sources of air movement are fairly inexpensive to seal and frequently are the most cost-effective conservation strategies available. The sources of air movement are not always easy to find. Although infiltration leaks near a favorite chair are obvious, most leaks are not always noticed.

Except when a strong wind is blowing particularly hard, the dominant cause of convective losses in houses is called "stack effect" infiltration and exfiltration. It is caused by the buoyancy of warm air versus cold; warm air rises and cold air descends. As illustrated in Figure 1-2, in the winter when inside air is warmer than outside air, a negative pressure occurs on the bottom of the conditioned envelope—drawing cold outside air into the building (infiltration)—while a positive pressure develops at the top, pushing warm air out of the building (exfiltration). The greater the temperature difference–and the taller the dwelling–the greater the force of stack effect.

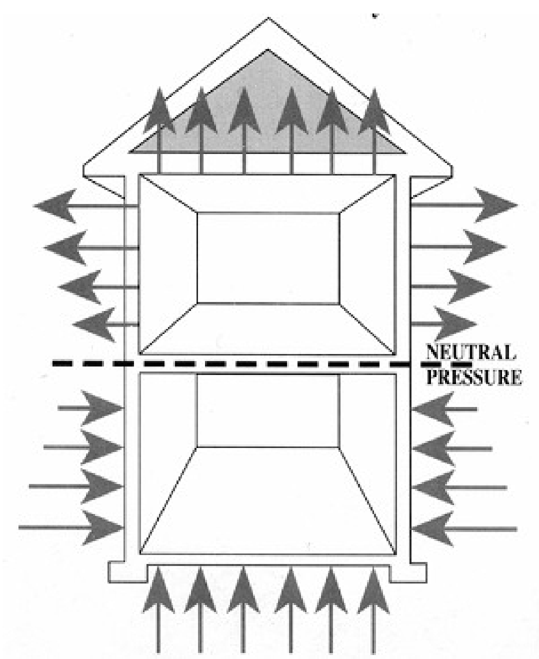


Figure1-2. Stack-effect infiltration and exfiltration forces are at a maximum at the bottom and top of the conditioned envelope.

Of course how much outside air flows through the house depends on the size and shape of holes and cracks at both the bottom and the top of the conditioned envelope. Since the pressure is neutral toward the middle of the house, very little air flows there due to stack-effect forces. However, a hole in the ceiling just below insulation can be a source of major exfiltration. And for every cubic foot of air that leaves the house, a cubic foot of air comes in. The resulting discomfort and energy waste is at a maximum on the coldest day of the year, when the heating system is working its hardest.

Appendix B - Volume 2 discusses curing a variety of commonly-occurring leakage areas in homes.

Section 2
A Systematic Approach to a Building's Performance

What to do first and what to do best

It's easy to be drawn in by the advertising hype that replacing all your windows, insulating your attic or buying a particular appliance are the best ways to save energy. While a particular measure may indeed be part of a rationally-conceived retrofit package, it is a mistake to proceed before conducting a thorough evaluation of the energy use and loss in your building. An energy audit is the best start. It helps in establishing priorities, choosing cost-effective and affordable measures and developing a workable sequence for a retrofit project. The "whole-house" approach treats the building and its components as the interactive system it is.

Steps for assessing the whole house

Home energy audit process
As with any complex project, there may come a time when making important decisions about your building requires more time, experience and diagnostic skills than you may possess. You can read pamphlets and books that provide general information and perhaps encourage thinking about your house, but they cannot tell you what is needed in your specific case.

An energy audit conducted by a trained professional begins with an analysis of energy use. The auditor then tests the house and systems with a blower door and other instruments, collecting data on duct condition, natural gas appliance efficiency and safety, pressure balances and electric use and safety.

Assessing energy consumption
In order to understand a building's energy use, it is useful to know the energy content of the various forms of energy sources it uses, such as electricity and natural gas. A British thermal unit (Btu) is a standard measure of energy content. One Btu is the energy necessary to raise a pound of water by one degree Fahrenheit, approximately the same amount of energy that results from burning a kitchen match to a crisp. Electric energy is measured in kilowatt hours, which has an energy content of 3412 Btu/kWh. There are 293 kWh of electricity per million Btus (MMBtu). A therm of natural gas has an energy content of 100,000 Btu, so there are ten therms of gas per MMBtu.

Table 2-1. Energy Equivalents and Costs of Some Common Energy Sources

Fuel	**Unit**	**Btu/Unit**	**Cost/ Unit**	**$/MMBtu**
Coal	Ton	28,000,000	$55	$1.96
Crude Oil	Barrel	6,300,000	$70	$11.11
Heating Oil	Gallon	140,000	$2.75	$19.64
Propane	Gallon	92,000	$1.85	$20.11
Gasoline	Gallon	125,000	$2.20	$17.60
Natural Gas	Therm	100,000	$1.10	$11.00
Electricity	kWh	3,412	$0.10	$29.30

Note that natural gas costs $11/MMBtu while electricity costs over $29/MMBtu. Thus, when there is an opportunity to conserve, saving electricity saves about three times as much money as does saving natural gas. Further, since over 80 percent of the electricity generated in Colorado comes from burning coal, a process that wastes about half a gallon of water per kWh produced, saving a kWh saves both three-quarters of a pound of coal and half a gallon of water at the power station.

It is not unusual for a house in Boulder to use over 100 MMBtu/year. At these usage rates, there are plenty of opportunities for reduction, which can lead to energy savings, decreases in utility costs and increases in the comfort in the house.

For new buildings, architectural drawings may be available. This is not generally true of older houses, but energy consumption information data from utility bills is available and is helpful in identifying waste. How does energy use match with the building's size? With household size? What patterns of month-by-month consumption are revealed and how do they follow the seasons? The school year? Holidays? Is there *ad hoc* electric resistance heating in a house whose primary source of heat is from a natural gas fired furnace or boiler?

Answers to these questions are helpful both in guiding an energy audit and in designing rational energy saving strategies.

Like miles per gallon consumed by a vehicle, an index of heating energy consumption adjusted for weather and dwelling size is useful in understanding the energy use in a building. Separating space heating energy use from other uses over a year of energy consumption by subtracting average consumption during non-heating months, allows for approximating monthly heating use. Divided by square feet of the living area (conditioned space), the result is Btu/ft^2, an index of the consumption of energy for space conditioning adjusted for a dwelling's size. Similarly, cooling energy used can be teased out of electricity use data.

The final step in assessing energy consumption is to adjust for weather. Weather data is routinely collected by a number of organizations and posted on websites (i.e.

www.wunderground.com/ or www.engr.udayton.edu/weather). The most frequently-employed technique for adjusting consumption for the severity of winter weather is to sum up the amount by which the average temperature of each winter day is below a given temperature, like a base of 65 degrees Fahrenheit (F). The "heating degree days" associated with a particular winter day are computed by taking the average temperature of the day (high plus low divided by 2) and subtracting the result from 65.

To take an example, if the high is 30F and the low 10F, the average is 20F, so 65-20 = 45, the number of heating degree days of the day. The heating degree days for a period for which consumption of fuel used for heating is available (from utility bills) are summed and the result is divided into the Btu/ft^2 figure for the period. This yields the desired index of heating energy consumption, Btu/ft^2/HDD. When this weather and size-adjusted index of wintertime heating is below 3 Btu/ft^2/HDD, the likelihood of finding substantial opportunities for cost-effective retrofits addressed to space heating savings are small (although not zero). When the index is between 3 and 8 Btu/ft^2/HDD, good opportunities are likely to be discovered. Numbers above 8 suggest the possibility of an energy-savings triple or even a home run. Savings follow waste!

The average annual heating degree days for Boulder and Denver are 5466 and 6023, respectively. For reference, the winter's heating degree days in Cheyenne, WY average 7315 and Phoenix, AZ 1444.

Convective losses

Although it is important to air seal dwellings wherever they are leaky, it is particularly important to seal dwellings in crawl spaces and between ceilings and unoccupied attics. Occupants can find many leaks on their own, but some of the most wasteful are often hidden from view. This is why energy auditors use a "blower door"—a calibrated, variable speed fan—to depressurize a home (Figure 2-1). This test determines the homes' degree of air tightness and assists in locating leaks in the building's envelope and in its duct system. After temporarily setting up the blower door in an exterior doorway, the technician configures the house for wintertime conditions, but turns off all combustion equipment for the period of the test. The technician then adjusts the speed of the fan to depressurize the house to the point where it simulates the effect of about a 20 mph wind on all sides of the building at once. If the fan must work hard to create this much pressure difference, flow through the fan is high and the house is quite leaky.

With the fan pulling air into the house from leakage areas, the technician systematically checks all areas within the building. Many leakage sites are unobvious—and some suspected sites are found not to leak at all. In all events, the process allows for pinpointing where infiltration/exfiltration lurks—and thereby where air sealing remediation should be undertaken.

Sometimes this process is made more precise by the use of an infrared (IR) temperature sensor that facilitates quickly determining temperatures on surfaces at some distance from the observer. The IR sensor pictured in Figure 2-2 shows a cold air leak close to the duct of a ventilation fan in a kitchen cabinet. Leakage from such places is difficult to find with the unaided eye, yet that was the largest leak found in this new house built for high energy efficiency.

Figure 2-1. The blower door can be set up in a variety of doorways. The meters allow for measuring flow versus pressure difference as the fan speed is varied. The results can help estimate the magnitude of convective losses over a heating season. The heating bill to offset convective losses in some homes in Boulder's historic district exceed $500 per winter.

Figure 2-2. Infrared (IR) sensors like this one measure surface temperatures at a distance.

Here is a list of some areas where blower doors and IR scanners sometimes reveal convective losses:

- Dropped ceilings and retrofit siding that may cover and obscure real problems
- Dumb waiters, chimney ways, laundry chutes and pocket doors
- Plumbing and electrical ways, including recessed (can) light fixtures
- Balloon framing that may not have fire stops or top plates in the attic
- Some (which?) interior walls (usually evidenced by leaky outlets and switches)
- Party walls between adjacent units
- Stairwells
- Anything built in
- Foundation walls and sill plates
- Vented crawlspaces
- Air ducts–both supply and return
- Additions to the structure, especially in the basement and attic
- Subtractions (where spaces have been at least partly sealed off from the rest of the dwelling)
- Hatchways, doors and other passages
- Windows
- Crannies, nooks and other unobvious and hard-to-get-to places

Conductive losses
Missing or substantially deteriorated insulation is quite common in older buildings. In addition, sometimes insulation is found in several areas, like a ceiling and floor in an attic area, part of which is next to an extra bedroom or office that was probably added well after the original house was built. Frequently, the insulation is inadequate and air leakage usually reduces the effectiveness of what there is to close to zero. The problem that needs to be solved in cases like these is to "define" the envelope with care, then ensure that it is air sealed and thoroughly insulated from the outside world (Figures 2-3 through 2-5).

Figure 2-3. Snow on the roof of this historic house suggests a lack of insulation toward the peak of the roof.

Figure 2-4. Sure enough, insulation under the rooftop is less than an inch thick.

Figure 2-5. A scan of a recessed light fixture in the hallway immediately under the rooftop shows a cold area owing to lack of insulation and failure of air sealing.

Figure 2-6 illustrates areas where insulation voids are common and Figures 2-7 and 2-8 picture two cases in a historic house in Boulder.

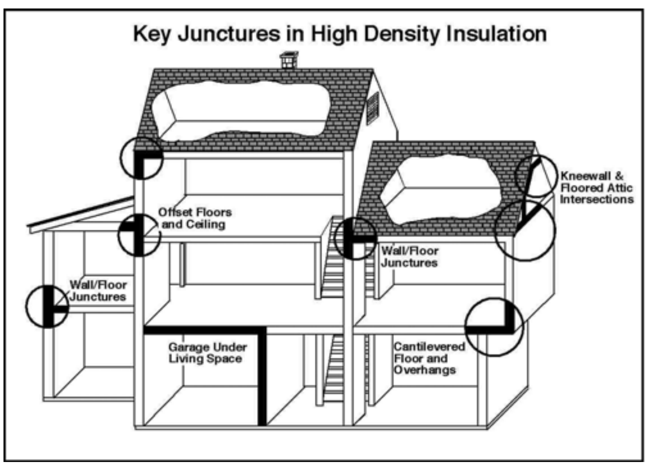


Figure 2-6. Areas where missing insulation is common

Figure 2-7. Areas like this that protrude from under windows are frequently sources of air leakage and are rarely insulated.

Figure 2-8. Measuring pressure differences between the outside and the cavity above the ceiling of this large porch while the blower door was running showed that the porch is thermally connected to the home's envelope. Blowing cellulose to high density in the cavities closest to the exterior wall will stop the flow of air, save energy, and increase comfort in the bedrooms above

All too often, contractors and homeowners try to solve these problems by simply adding another layer of insulation, whether by laying down additional fiberglass batts over attic flooring, installing a layer of foam board before residing or building out interior walls for added insulation (thereby sacrificing valuable living space). Frequently, a better strategy is to get back to the original structure and give it a high performance upgrade without disturbing either the interior or exterior. In most cases, this can be done through careful air sealing and the skillful blowing of high density cellulose insulation into existing wall and ceiling cavities.

With this technique, exterior siding or interior trim is temporarily removed, holes are drilled through the sheathing or plaster and a tube for blowing cellulose is inserted far into cavities between studs. The tube is slowly withdrawn as cellulose is blown into the cavity. The installer matches the withdrawal rate to the flow of cellulose and the size of the cavity to achieve densely packed insulation throughout the cavity. This technique can achieve complete coverage and sufficient density of the injected material to keep it from settling and eliminate the movement of air through the building cavities that could otherwise cause moisture problems. Of course, the job has to be done right, so a trained professional should be employed.

High-density sidewall cavity insulation can be a major comfort and savings boost. It saves energy by slowing both conductive and convective losses, but only if the right things are done cprrectly. Appendix C contains guidelines to direct the high density cellulose installation process.

Attic floor or ceiling insulation

If an attic is primarily used as storage space, with only occasional human occupancy, there is no reason to heat it. This will allow for defining the conditioned envelope at the attic floor. This can usually allow for better air sealing and more insulation, more cost effective retrofit work and lower energy use.

Mechanical systems

Energy auditors or technicians spend a good deal of time examining heating, cooling and hot water systems, as well as dryers, cooking stoves and ovens. The agenda is to inspect for both safety and efficiency issues with a view to making improvements. Typically, older buildings have a labyrinth of gas piping and associated couplings and valves. In tracing what goes where, a combustion gas detector is used to identify any gas leaks which may occur along the line (Figure 2-9). Additionally, each appliance is fired and evidence of carbon monoxide, a deadly but odorless gas, is tested using multi-purpose digital equipment (Figure 2-10). Such devices also measure the temperature and portions of various gases in the exhaust stack (typically oxygen, carbon dioxide, and carbon monoxide) as the appliance is operated. The result yields a useful measure of both the safety and the relative efficiency of the combustion process.

Figure 2-9. ***Combustion gas sniffer at work.***

Figure 2-10. ***Combustion analyzer capable of measuring five functions. This one found a surprisingly high carbon monoxide reading associated with the broiler in a modern, high-end cooking stove.***

This combustion analysis measures what is termed "steady-state" combustion efficiency, which is how efficiently the appliance burns fuel when operating at full bore. Many older appliances rely on natural venting chimneys to exhaust their combustion by products, so these appliances also suffer significant "standby losses" as heat generated during the burning process continues to escape up the chimney when the appliance not firing. Standby losses can amount to another 10 to 20% reduction in overall seasonal operation efficiencies, typically designated Annual Fuel Utilization Efficiency (AFUE).

Ducts

Duct work that distributes air to and from the furnace frequently results in discomfort, energy waste and safety issues. Modern furnaces have powerful fans that direct conditioned air through supply ducts to the far reaches of the house, pulling return air through other ducts and a filter to the heat exchanger in the furnace. Such systems can be somewhat leaky and when the ducts pass through unconditioned spaces are often inadequately insulated. Energy auditors use a variety of instruments to assess the condition of ducts, determine the extent of leakage outside of the envelope and find areas where remediation would be appropriate. Air sealing and insulating ducts can sometimes save a good deal of energy while achieving substantially improved comfort with better distribution of heating (or cooling) air (Figure 2-11).

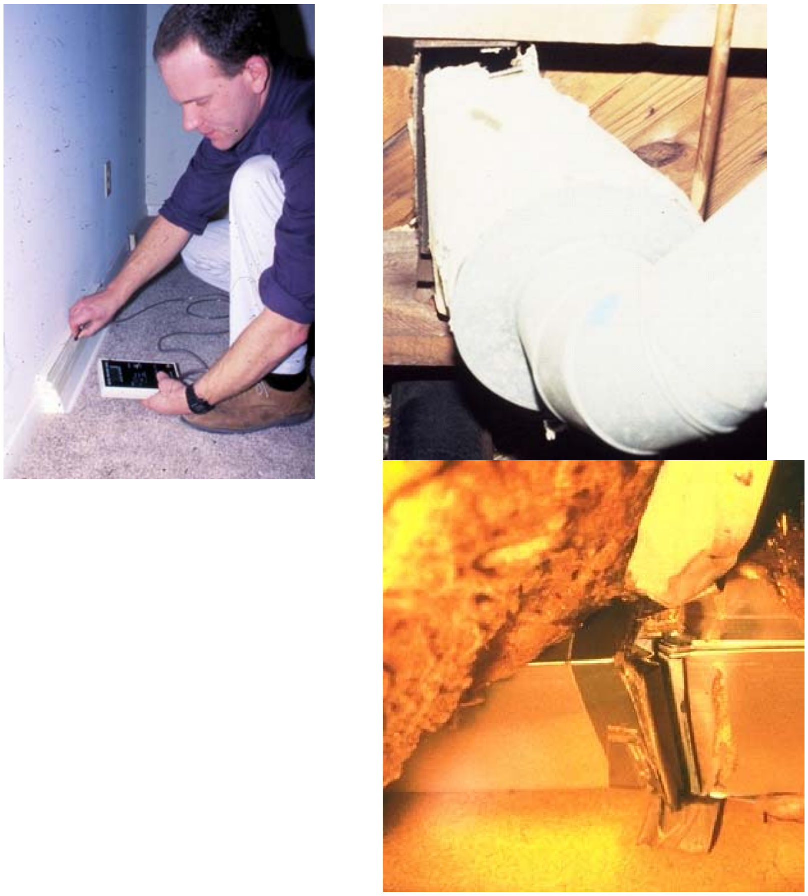


Figure 2-11. Auditors use pressure testing and careful looking around to find duct leakage. Once found, curing leaks like these is not difficult, and usually saves energy and improves comfort.

Testing a residential building's duct systems is appropriate, especially when the ductwork passes through unconditioned spaces. Even in houses where the ductwork is totally enclosed within a semi-conditioned basement, air sealing and insulating can provide a great deal of additional heat and comfort to the living space above, while allowing the basement to cool down.

Thermostats

Furnaces, hot water systems, refrigerators and other equipment routinely employ thermostats to control various functions. The energy auditor checks the function and setting of each piece of equipment to ensure that they are set in ways that achieve efficiency while safeguarding comfort. Often modern electronic thermostats can be installed to control furnaces, air conditioners or boilers in ways that will save substantial energy quite cost effectively while retaining adequate performance.

Multi-set-back electronic thermostats are now widely available at modest costs. They are easy to install and energy (and money) can be saved automatically without causing discomfort (Figure 2-12).

Most thermostats have an override mode that reverts back to the normal setting after a period of override. Thus, if the thermostat is set to go down to 60F at 8 a.m. on school days and back to 67F at 3:30 p.m. when kids come home from school, an override leaving the thermostat at 67F can be used on holidays or when a child is sick. However, the next day it will automatically return to the original program. Every degree F of lower settings on the thermostat that controls heat in a house saves about 3 percent on the annual fuel bill if left lower for 24 hours a day. About 1 percent per year per degree F setback applies for 8 hour per day setbacks

Figure 2-12. Electronic thermostats can save energy while preserving comfort.

Water heating systems

Domestic water heating is typically produced using either gas—natural or liquid petroleum (LP)—or electricity as the energy source. Electric water heaters are less expensive to purchase and do not require a vent or combustion air supply. However, since electricity costs almost three times as much as natural gas, the operating costs of electric water heaters can be substantially higher than gas-fired units. Whenever practical, gas-fired units are recommended. The only exception is when a solar hot water system provides almost all of the hot water needs. The few times per year when the solar hot water system comes up short, it may be more cost effective to use an electric back up system. Further, there are safety advantages to not bringing gas into the dwelling.

When gas is used to heat domestic water, all gas piping should be carefully checked for leaks, just as with other gas-fired appliances. The importance of this task can not be overstated. The energy auditor should follow all gas piping with an analyzer and trace around all fittings to pipe connections with care–especially valves and unions as these tend to be the fittings that are most troublesome.

Domestic hot water systems often store and deliver water that is too hot to use directly. It is then mixed with cold water either at the faucet or in an anti-scald device. In either case, fuel is used to heat the water only to have it mixed with cold water at the point of use. For most applications, hot water of 125F or less is adequate. Adjusting the water temperature down also reduces standby losses through the storage tank walls and piping, even when they are insulated. The simple payback of saving energy and dollars for turning down the water temperature is almost immediate.

After the water has been reduced to an appropriate temperature, the flow rates at shower heads should be checked. This frequently presents an easy and inexpensive opportunity to reduce both water heating energy and water use. Many shower heads have flow rates in excess of four gallons per minute (gpm). If a typical shower lasts 10 minutes, 40 gallons of water is used. Using a 1.5 gpm shower head with a good spray pattern will provide a comfortable shower. During the same length shower, the water usage is reduced to 15 gallons, which is a 62% reduction. Figure 2-13 illustrates dollar savings associated with changing shower heads that consume more than 1.5 gallons per minute with those which use only 1.5 gpm.

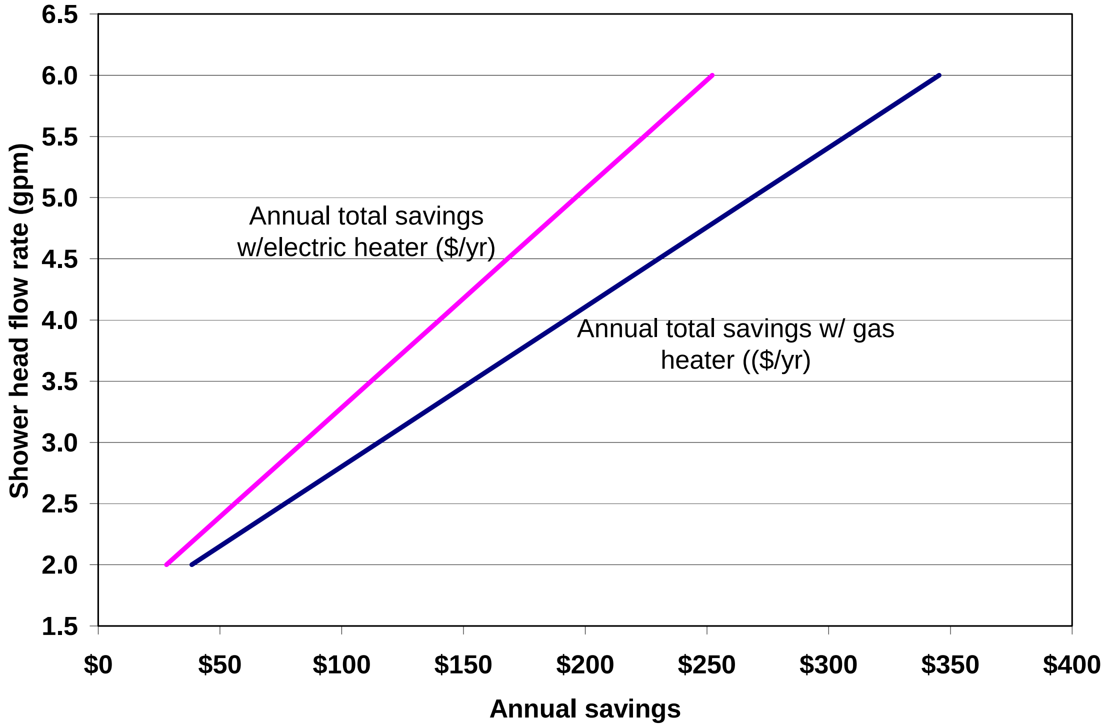


Figure 2-13. Annual savings of gas and water associated with changing existing shower heads for those that use 1.5 gmp. Assumptions are that the shower head costs $8 plus $10 for installation, and that two showers of six minutes duration are taken per day.

Electric

Wiring safety

Wiring in historic buildings can often be a hodgepodge of old and new. Sometimes connections in junction boxes, outlets or even the circuit breaker box have become corroded over the years, causing points of resistance. Under small loads, these may not cause problems, but if a circuit has a larger load on it from time to time (like from a space heater or iron), a corroded connection can become quite hot. If the house is to be insulated for the first time in its life, the new insulation can impede the flow of heat from a junction box or outlet, creating a hazardous condition. Accordingly, an energy auditor uses a special circuit tester that puts a 15 amp load on a circuit for a very short time and measures the voltage drop that results, expressing the result as a percentage. Voltage drops of more than five percent are considered abnormal, those above 8 percent call for remedial work. Usually tightening up connections in the outlet itself or at other outlets between the outlet being measured and the circuit breaker box will solve the problem. If several outlets indicate similar readings, the problem could be the connection at the circuit breaker or in a junction box that cannot be easily accessed. In extreme cases, a line may need to be replaced.

The "Suretest™" meter also measures wire resistance, the integrity of the neutral and ground and several other parameters (Figure 2-14.) All of the outlets in a house should be measured during an energy audit and rechecked after major work such as wall or attic insulation, is installed just to be sure no wiring was disturbed by the work itself.

Assessing electric energy use in refrigerators and freezers
After testing the outlets associated with refrigerators and freezers, the auditor routinely installs a simple watt hour meter to monitor electric energy use of these appliances over the period of the audit (Figure 2-15). This enables normalizing consumption data for a longer period (month or year) to estimate if it would be cost effective to replace a particularly inefficient model with a modern refrigerator or freezer. Refrigerators and freezers represent a substantial portion of the electric bill in many homes, about 12 percent nationally. Many older units use 1200 kW/year or more - but new ENERGY STAR-rated units typically consume well less than 500 kW/year.

Figure 2-14. Suretest multipurpose circuit testing meter.

Figure 2-15. Kill-a-Watt electric power and energy meter

Lighting
Most historic buildings can have a lot of inefficient lighting inside and out. Nonetheless, energy-efficient lighting that is both attractive and cost effective has become widely available. It is time to adopt the best lighting technology and to integrate it into historic buildings.
In order to understand the energy consequences of lighting, it is useful to examine the amount of light produced by various lighting sources per unit of power required to produce it. This is called "luminous efficacy", measured in lumens per watt (lm/W).

Everyone knows that a candle puts out a lot more heat than light, but that is also the case for the incandescent light bulb. Large wattage incandescent bulbs may produce 16 or 17 lm/W, but smaller ones—like those in refrigerators—only 11 lm/W or so. Light sources that require a good deal of electrical energy to produce a given amount of light also produce considerable heat. The consequence of this inefficiency is starkly obvious in the case of lights in refrigerators, but it is also of concern in buildings that requires cooling in the summer. Accordingly, using incandescent lighting produces two costs: one for the lighting and one for the cooling system to remove the additional waste heat. The obvious solution is to use more efficient lighting in the first place.

Modern fluorescent lighting fixtures have a luminous efficacy in the order of 60 to 75 lm/W, which is four times greater than incandescent lights. In addition, the best compact fluorescent lights (CFLs)—those recognized by ENERGY STAR—have lifetimes that are typically longer than the lifetimes of incandescent lights by a factor of 8 to 12. As a consequence, a typical 25 watt CFL that costs around $2.50 will save more than $75 over its lifetime in Boulder. The quality of light of modern CFLs is excellent thanks to modern electronic ballasts and they produce no sound. Further, CFLs fit almost anywhere incandescents do (Figure 2-16).

Recessed lighting fixtures

Over 20 million recessed lighting fixtures are installed every year, and substantial percentages are installed at the interface between ceilings and attics. Figure 2-17 shows typical installations in a historic home in Boulder.

Figure 2-16. This painting is illuminated by a pair of 4 watt CFL lights small enough to fit in one's hand rather than a pair of 20 watt tubular incandescent bulbs.

Figure 2-17. An auditor prepares to assess a recessed lighting fixture on the 1st story of a 3rd story house for air leakage (with the blower door running.) It was quite leaky.

There are many reasons why recessed fixtures, especially in the top floor ceiling, are a bad idea:

- The holes are put at the point where stack-effect exfiltration forces are at a maximum. Even “Insulated Ceiling” (IC) cans (recessed fixture) leak to some extent; those that are not IC rated leak like a sieve.

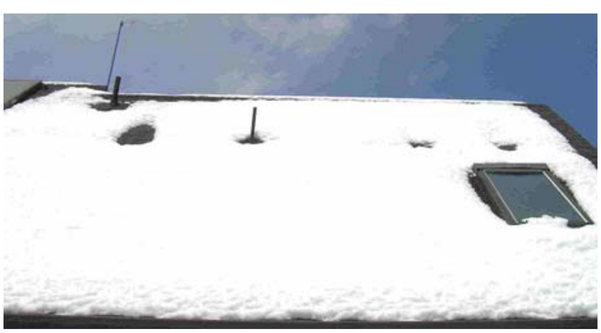
- When a light is illuminated in a can, the heat it produces causes “flue effect” exfiltration to increase dramatically. (When the flue pipe/chimney combination from a water heater, furnace or boiler is hot, the buoyancy of hot air tends to pull air out of the home at a rate that increases with temperature.) All other factors being equal, a 13 watt bulb increases infiltration through a leaky can by 60 percent when it is illuminated, a 50 watt by 170 percent and a 100 watt by 400 percent! Along with wasting energy, this can deliver warm air with plenty of moisture to the attic where it can help make giant icicles and shorten the life of the roof deck.

- Being particularly inefficient, incandescent bulbs heat up the can itself to the point where placing insulation on top of could be a fire hazard. Although cans have temperature-sensitive safety switches that turn off the light when the fixture gets too hot, to play it safe, ordinary cans should not be insulated. The result is conductive energy losses as well as convective ones, an unhappy combination that raises energy costs and may cause discomfort as well.

- Light from cans creates bright spots on the ceiling, causing glare.

- Finally, it is simply wasteful to put incandescent bulbs in any building, as they create substantial heat when giving off light, which wastes energy.

Figures 2-18 and 2-19 show before-and-after photographs of a home in Colorado on snowy days. The house had leaky can lights in the ceiling that were successfully retrofitted. Even when lights are not used, leakage of warm air via stack effect is powerful enough to cause snow melt. The cans were retrofitted with a completely air sealed reflector-and-ballast system then insulated as described in Section 3.



Figures 2-18 and 2-19. Pre- and post-retrofit effects of solving convective and conductive problems with recessed (can) lights in a second floor room of a well-insulated home.

Ceiling Fans

Ceiling fans are found in a number of historic buildings. Some use inefficient motors with poor blade design which means that they are very inefficient at moving air and do not produce much comfort when they do. In addition, many include incandescent bulbs that should be retrofitted with CFLs. The figure of merit of overhead fans is the ratio of air moved in cubic feet per minute versus electric power for each speed (cfm/W). For all fans, whether efficient or not, the higher the speed, the less efficient they are. So keeping a fan at low speed is wise—and keeping it off is wiser still. Ceiling fans are best used to cool the occupants in a room. They do nothing to make the house cooler and in fact, they add heat when operating. The usefulness of ceiling fans in winter is questionable. More often than not they create a wind-chill effect that makes occupants uncomfortable and except for spaces with particularly high ceilings, have little advantage for heat de-stratification.

Ventilating fans

Ventilating fans are important components in any building to remove unwanted odors and moisture when operating, but when not operating they can be an unwelcome hole in the conditioned envelope. The trick is to make sure they are well designed to do their job well, efficiently, and quietly; that they are controlled properly to run when needed (and to be turned off when not needed); and that they are installed properly so they function as designed and are maintainable. The other critical detail is to ensure their dampers are well designed and work well.

An energy auditor can test the flow of exhaust fans and determine if they meet the ventilation needs of the home.

In practice, the energy auditor often sees very dirty fans and associated dampers whose installation was done incorrectly. It is important to vent fans completely outside, not merely into the attic, and to air seal the penetration of the exhaust duct from the fan as it passes through a sidewall or attic. Ducting to the outside should be smooth metal pipe of adequate size with minimal bends to avoid restriction of air flow. Lengths should be kept as short as is practical and have no dips that could collect condensate. Ductwork should be insulated when passing through unheated spaces to avoid condensation.

There are many new high-quality exhaust fans on the market. Look for a unit which has a sone (noise) rating of 3 sones or less.

Finally, keeping the damper and fan clean is important to fan function and avoiding unwanted infiltration. It is a good idea to operate the kitchen fan whenever the stove or oven is on. The fan in the bathroom is best turned on before the shower starts and run until five minutes after it ends. Some fans are directly wired into the light switch in the bathroom to ensure they are turned on when the lights are on. The use of a mechanical timer on a bathroom fan is also convenient because they allow the fan to run for as long as needed without having to remember to turn it off. Bathroom exhaust fans with motion detectors are also available.

More sophisticated exhaust fans have two stages–one for providing a constant background ventilation level and then a more powerful stage when conditions demand. Low-flow settings use much less electricity than high settings.

Many property owners are choosing to retrofit their buildings with heat-recovery ventilation systems, also known as air-to-air heat exchangers. These central units guarantee your home has the ventilation it needs without the energy penalty of having to reheat incoming fresh air, since that job is mostly accomplished by the exhaust air. Energy is exchanged, but pollutants are not. This retrofit is particularly useful after the home is thoroughly air sealed.

Final notes on energy auditing

The discussion above is representative of systems observed during an energy audit, but it is by no means comprehensive. An instrumented energy audit conducted by a skilled and experienced technician frequently reveals circumstances that are unique to a particular building. This is particularly the case with older historic houses which more often than not have been modified over the years. On every job, the auditor's aim is to identify health, safety and energy problems and to figure out the best ways to solve them cost-effectively.

Volume two of this report discusses details on adding performance value to historic preservation project and explores a handful of retrofit measure that are sometimes recommended.

Section 3
Resources

City of Boulder

"Chautauqua Design Guidelines", 1989

"Chamberlain Historic District Design Guidelines", 1996

"Downtown Urban Design Guidelines", 2002

"General Design Guidleines for Boulder's Historic Districts and Individual Landmarks", 2003

"Historic Preservation/Environmental Sustainability Integration Project – Baseline Information" Binder, 2006

"Making Your Historic Building Energy Efficient" 2007 Brochure

Section 9.11 of the Boulder Revised Code (Historic Preservation Ordinance)

"West Pearl Historic District Guidelines", 1996

National Trust for Historic Preservation

The most useful resources for homeowners interested in preserving the historic character of their home are available from the National Trust for Historic Preservation at www.cr.nps.gov/hps/TPS/tpscat.htm

Publications available at reasonable costs from the Department of the Interior include:

The Secretary of the Interior's Standards for the Treatment of Historic Properties with Illustrated Guidelines for Preserving, Rehabilitating, Restoring, and Reconstructing Historic Buildings. The 1995 Standards.188 pages. 79 illustrations. GPO stock number: 024-005-01157-9. $28.00 per copy.

Preservation briefs

Preservation Briefs assist owners and developers of historic buildings in recognizing and resolving common preservation and repair problems prior to work.
http://www.cr.nps.gov/hps/TPS/briefs/presbhom.htm

Preservation Briefs #1-14 Sold only as a set. 1998. GPO stock number: 024-005-01026-2. $18.00.

- # 1: Assessing Cleaning and Water-Repellent Treatments for Historic Masonry Buildings.
- # 2: Repointing Mortar Joints in Historic Masonry Buildings.
- # 3: Conserving Energy in Historic Buildings.
- # 4: Roofing for Historic Buildings.

- # 5: The Preservation of Historic Adobe Buildings.
- # 6: Dangers of Abrasive Cleaning to Historic Buildings.
- # 7: The Preservation of Historic Glazed Architectural Terra-Cotta.
- # 8: Aluminum and Vinyl Siding on Historic Buildings: The Appropriateness of Substitute Materials for Resurfacing Historic Wood Frame Buildings.
- # 9: The Repair of Historic Wooden Windows.
- # 10: Exterior Paint Problems on Historic Woodwork.
- # 11: Rehabilitating Historic Storefronts.
- # 12: The Preservation of Historic Pigmented Structural Glass (Vitrolite and Carrara Glass).
- # 13: The Repair and Thermal Upgrading of Historic Steel Windows.
- # 14: Exterior Additions to Historic Buildings: Preservation Concerns.

Preservation Briefs #15-23 Sold only as a set. 1991. GPO stock number: 024-005-01085-8. $15.00 per set.

- # 15: Preservation of Historic Concrete: Problems and General Approaches.
- # 16: The Use of Substitute Materials on Historic Building Exteriors.
- # 17: Architectural Character - Identifying the Visual Aspects of Historic Buildings as an Aid to Preserving Their Character.
- # 18: Rehabilitating Interiors in Historic Buildings - Identifying Character-Defining Elements.
- # 19: The Repair and Replacement of Historic Wooden Shingle Roofs.
- # 20: The Preservation of Historic Barns.
- # 21: Repairing Historic Flat Plaster--Walls and Ceilings.
- # 22: The Preservation and Repair of Historic Stucco.
- # 23: Preserving Historic Ornamental Plaster.

Preservation Briefs #24-34 Sold only as a set. 1994. GPO stock number: 024-005-01147-1. $15.00 per set.

- # 24: Heating, Ventilating, and Cooling Historic Buildings: Problems and Recommended Approaches.
- # 25: The Preservation of Historic Signs.
- # 26: The Preservation and Repair of Historic Log Buildings.
- # 27: The Maintenance and Repair of Architectural Cast Iron.
- # 28: Painting Historic Interiors.
- # 29: The Repair, Replacement, and Maintenance of Slate Roofs.
- # 30: The Preservation and Repair of Historic Clay Tile Roofs.
- # 31: Mothballing Historic Buildings.
- # 32: Making Historic Properties Accessible.
- # 33: The Preservation and Repair of Stained and Leaded Glass.
- # 34: Applied Decoration for Historic Interiors: Preserving Historic Composition Ornament.

Preservation Briefs #35-42 Sold only as a set. 2004. GPO stock number: 024-005-01219-2. $19.00 per set.

- # 35: Understanding Old Buildings: The Process of Architectural Investigation.
- # 36: Protecting Cultural Landscapes: Planning, Treatment, and Management of Historic Landscapes.
- # 37: Appropriate Methods of Reducing Lead-Paint Hazards in Historic Housing.
- # 38: Removing Graffiti from Historic Masonry.
- # 39: Holding the Line: Controlling Unwanted Moisture in Historic Buildings.
- # 40: Preserving Historic Ceramic Tile Floors.
- # 41: The Seismic Retrofit of Historic Buildings: Keeping Preservation in the Forefront.
- # 42: The Maintenance, Repair, and Replacement of Historic Cast Stone.

Government Printing Office (GPO) Single Sales Only

- Preservation Brief 43: The Preparation and Use of Historic Structure Reports. 16 pages. 25 illustrations. 2004. GPO stock number: 024-005-01191-9. $2.50 per copy. 2004.
- Preservation Brief 44: The Use of Awnings on Historic Buildings: Repair, Replacement and New Design. 16 pages. 25 illustrations. GPO stock number: 024-005-01222-2. $2.75 per copy. 2004.

Technical reports

Technical Reports address in detail problems confronted by architects, engineers, government officials, and other technicians involved in the preservation of historic buildings.

- Metals in America's Historic Buildings: Uses and Preservation Treatments. GPO stock number: 024-005-01108-1. $15.00 per copy.
- Moving Historic Buildings. $10.00 each. Publications Department, IASM, P.O. Box 2637, Lexington, SC, 29071-2637.
- Accessibility and Historic Preservation: Entrances to the Past. (Video) $19.05 from Historic Windsor, Inc., PO Box 21, Windsor, VT 05089-0021. Call: Historic Windsor (802) 674-6752.
- Preservation Tech Notes dealing with historic windows are included in The Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings. $32.00. Historic Preservation Education Foundation, P.O. Box 77160, Washington, DC, 20013-7160.

Windows

Planning and evaluation

- Windows No. 1: "Planning Approaches to Window Preservation," by Charles Fisher. (1984)
- Windows No. 10: "Temporary Window Vents in Unoccupied Historic Buildings," by Charles Fisher and Thomas Vitanza. (1985)

Repair and weatherization

- Windows No. 14: "Reinforcing Deteriorated Wooden Windows," by Paul Stumes, P. Eng. (1986)
- Windows No. 16: "Repairing and Upgrading Multi-Light Wooden Mill Windows," by Christopher Closs. (1986)
- Windows No. 17: "Repair and Retrofitting Industrial Steel Windows" by Robert Powers. (1989)

Double glazing historic windows

- Windows No. 2: "Installing Insulating Glass in Existing Steel Windows," by Charles Fisher. (1984)
- Windows No. 3: "Exterior Storm Windows: Casement Design Wooden Storm Sash," by Wayne Trissler and Charles Fisher. (1984)
- Windows No. 5: "Interior Metal Storm Windows," by Laura Muckenfuss and Charles Fisher. (1984)
- Windows No. 8: "Thermal Retrofit of Historic Wooden Sash Using Interior Piggyback Storm Panels," by Sharon Park, AIA. (1984)
- Windows No. 9: "Interior Storm Windows: Magnetic Seal, by Charles Fisher. (1984)
- Windows No. 11: "Installing Insulating Glass in Existing Wooden Sash Incorporating the Historic Glass," by Charles Fisher. (1985)
- Windows No. 15: "Interior Storms for Steel Casement Windows," by Charles Fisher and Christina Henry. (1986)

Replacement frames and sash

- Windows No. 4: "Replacement Wooden Frames and Sash," by William Feist. (1984)
- Windows No. 6: "Replacement Wooden Sash and Frames With Insulating Glass and Integral Muntins," by Charles Parrott. (1984)
- Windows No. 12: "Aluminum Replacements for steel Industrial Sash," by Charles Fisher. (1986)
- Windows No. 13: "Aluminum Replacement Windows with Sealed Insulating Glass and Trapezoidal Muntin Grids," by Charles Parrott. (1985)
- Windows No. 18: "Aluminum Replacement Windows with True Divided-Lights, Interior Piggyback Storm Panels, and Exposed Historic Wooden Frames," by Charles Parrott. (1991)

Screens, awnings, and other accessories

- Windows No. 7: "Window Awnings," by Laura Muckenfuss and Charles Fisher. (1984)

Co-published books

- Caring for Your Historic House. National Park Service/Heritage Preservation, Inc. Published by Harry N. Abrams, Inc. 1998. $45.95 hardcover or $29.50 softcover.
- Preserving the Recent Past. 1995. $55.00, Historic Preservation Education Foundation, P.O. Box 77160, Washington, DC, 20013-7160.

- Preserving the Recent Past II. This volume is invaluable in dealing with historic properties from 1920s to the 1970s. Published in 2000 by the Historic Preservation Education Foundation and National Park Service. $50.00, Historic Preservation Education Foundation, P.O. Box 77160, Washington, DC, 20013-7160.
- Window Guide for Rehabilitating Historic Buildings: code compliance, energy conservation, maintenance, custom fabrication, repair techniques, and historic technology. 1997. $55.00, Historic Preservation Education Foundation, P.O. Box 77160, Washington, DC, 20013-7160.
- The National Trust for Historic Preservation, "Energy Conservation and Solar Energy for Historic Buildings."
- HUD : "Energy Conserving Features Inherent in Older Homes"

Energy auditing

The below-mentioned publications are all available for free downloading in PDF form from Boulder-based Synertech Systems Corporation's website, www.SynertechSystemsCorp.com.

- *Residential Energy Auditing Techniques*, by Larry Kinney, Gary Cler, Wyncia Clute, and Tom Wilson, November 2006, 95 pp.
- "Lighting Systems in Southwestern Homes: Problems and Opportunities," by Larry Kinney. Prepared for the USDOE's Building America Program, July 2005.
- "Duct Systems in Southwestern Homes: Problems and Opportunities," by Larry Kinney. Prepared for the USDOE's Building America Program, April 2005.
- "Windows and Window Treatments," by Larry Kinney. Prepared for the USDOE's Building America Program, September 2004.
- "New Evaporative Cooling Systems: An Emerging Solution for Homes in Hot Dry Climates with Modest Cooling Loads," by Larry Kinney. Prepared for the USDOE's Building America Program, March 2004.