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BUILDING AMERICA BEST PRACTICES SERIES

Energy Performance Techniques and Technologies:

Preserving Historic Homes

PREPARED BY

Pacific Northwest National Laboratory
& Kaufman Heritage Conservation

February 28, 2011

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Energy Performance Techniques and Technologies:

Preserving Historic Homes

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Preface

Building AMERICA U.S. Department of Energy

You can learn more about Building America and download additional copies of this document, other best practices, research reports, and case studies at

www.buildingamerica.gov

This guide is a resource to help contractors renovate historic houses, while addressing issues such as building durability, indoor air quality, and occupant health, safety, and comfort. The best practices described in this document are based on the results of research and demonstration projects conducted by Building America's research teams. Building America brings together the nation's leading building scientists with over 300 production builders to develop, test, and apply innovative, energy-efficient construction practices.

Acknowledgments

The U.S. Department of Energy's (DOE's) Building America Program comprises public-private partnerships that conduct systems research to improve overall house performance, increase housing durability and comfort, reduce energy use, and increase energy security for America's homeowners.

Program activities focus on finding solutions for both new and existing homes, as well as integrating clean onsite energy systems that will allow the homebuilding industry to provide homes that produce more energy than they use. In addition to DOE management and staff, the Building America Program includes 15 consortia, four national laboratories, and hundreds of builders, research organizations, manufacturers, and service providers.

The DOE Building America Program funded the development of this guide. DOE also funded the Building America consortia and national laboratories to conduct the research that forms the basis for these recommendations. The consortia have taken on the hard work of applied research, field testing, training builders, and transforming results into building practices. Numerous drawings, descriptions, photos, and case studies originated with these research partners. Examples from these partners are used throughout this guide to illustrate construction best practices.

Contents

1. Introduction

The U.S. Department of Energy's (DOE's) Building America Program is an industry-driven research program that promotes the accelerated development and adoption of advanced building energy technologies in new and existing homes. The program gives home builders and remodelers access to the nation's leading building science developments to build high-performance homes that use less energy, are more comfortable, healthier to live in, and long lasting. This guide is a resource for contractors and owners of historic houses who want to improve the energy efficiency while protecting historic character.

Although older buildings require attention and maintenance, they repay the effort as assets that gain value over time. More and more, homeowners value historic houses for their appealing aesthetic character, lifestyle advantages, and quality of life. Depending on the circumstances, these advantages may include beautiful ornamentation, spacious room proportions, natural lighting, outdoor spaces, and—not least of all—a feeling of history, tradition, and permanence. Furthermore, time has shown that even the most unappreciated historic styles eventually become popular; so, even if you have mixed feelings about the appearance and design of a historic house, bear in mind before doing anything to diminish its historic character, that the next occupants may love that style—and that may affect the selling price.

Special energy-retrofitting challenges include preserving the home's historic features, being aware of and adhering to regulations related to historic designations, and addressing health and safety issues. Building America's research provides field-tested approaches to help address these challenges.

Sponsored by the U.S. Department of Energy, the **Building America Program** is industry-driven research designed to accelerate the development and adoption of advanced building energy technologies in new and existing homes (for more information, see www.buildingamerica.gov.) Building America's renovation case studies illustrate proven techniques applied to historic houses in a variety of climates (for published examples, see www.eere.energy.gov/buildings/building_america/climate_specific_publications.html).

Retrofitting homes that are designated as "historic" may require a formal review process, but all homes deserve a thoughtful approach to maintaining their character.

Retrofitting homes that are designated as "historic" may require a formal review process, but all homes deserve a thoughtful approach to maintaining their character. If you are a contractor, share this guide with your clients so they can understand how you will make their homes more comfortable, durable, and energy efficient, while respecting the homes' historic qualities.

Following Building America-sponsored research, this document focuses on planning energy-efficient improvements for historic houses by combining energy-efficient best practices with the process of historic renovation. The background for retrofitting and preserving older homes that may be designated as "historic" is introduced. Steps to consider when planning a whole-house energy retrofit are highlighted. Strategies for maximizing the potential energy efficiency of an original house design and preserving its character are presented. Aspects of retrofitting a historic house while preserving its character are addressed. Finally, the document describes health and safety concerns related to past building materials and practices. Refer to the resources cited throughout this guide for additional information. This document does not delve into the details of installation techniques. These practices vary depending on construction materials, methods, and climate zones, but references are provided so readers can access installation information.

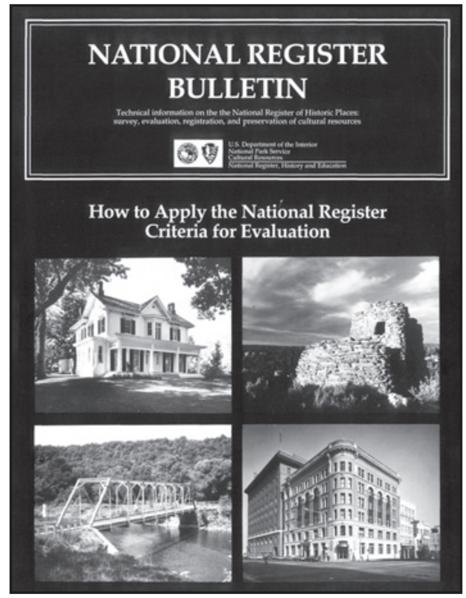
2. Background: The Historic Building Context

Improving energy performance using Building America's quality-management practices and whole-house energy approach helps deliver more energy-efficient and durable historic houses. The historic nature of a home requires additional thought and sensitivity to its construction and design features. When contemplating a historic house remodel, it is important to determine whether there is any possibility the property may be historically significant. Contact the local building and planning departments to inquire about a local historic preservation ordinance and whether:

- THE HOME IS ELIGIBLE FOR LISTING IN THE NATIONAL REGISTER OF HISTORIC PLACES
- THE PROPERTY IS LOCATED WITHIN A HISTORIC NEIGHBORHOOD OR DISTRICT
- ANY LOCAL OR STATE HISTORIC ORDINANCES APPLY. Understanding the regulatory requirements for preserving the character-defining features of the home is as important as assessing the home's inherent energy-conserving potential. It is important to improve historic houses through maintenance, upgrading, and environmental retrofitting, but do not destroy its historic fabric and regret it later.

Because effective retrofitting considers the historic character of a home and the materials used to construct it, the builder may need to confer with a historic preservation consultant. The State Historic Preservation Office and local historic preservation office, society, or commission may be able to identify preservation design consultants and restoration contractors who have experience with similar projects. As preservationists, they want to preserve historic structures from demolition or degradation. They can help determine how to best blend retrofitting additions with the existing decorative details and historic features of the home without damaging its character.

Builders need to be familiar with the identification and preservation of historic houses, related state and local resources, how codes might affect retrofitting, and any federal permitting issues. If working with preservationists on the project team, they also need to share a common language as they work together to assess, plan, and decide how to retrofit the home. This section provides an overview of these needs.



www.nps.gov/nr/publications/index.htm

A good reference for anyone considering working with a historic house is the **National Register Bulletin 15, "How to Apply the National Register Criteria for Evaluation,"** which is available both in print and online (http://www.nps.gov/nr/publications/bulletins/nrb15/).

The National Park Service also developed The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring, and Reconstructing Historic Homes (hereafter Secretary's Standards; see www.nps.gov/history/hps/tps/standards_guidelines.htm). These standards and design guidelines have been adopted by state preservation agencies and by many local ordinances and programs (see www.energysavers.gov/your_home/energy_audits/index.cfm/mytopic=11160 and http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_airsealing_report.pdf).

"The [National Register] criteria do not describe 'exceptional,' nor should they. Exceptional, by its own definition, cannot be fully catalogued or anticipated. It may reflect the extraordinary impact of a political or social event. It may be a function of the relative age of a community and its perceptions of old and new. It may be represented by a building or structure whose developmental or design value is quickly recognized as historically significant by the architectural or engineering profession. It may be reflected in a range of resources for which a community has an unusually strong associative attachment."

For more information go to www.nps.gov/history/nr/publications/bulletins/nrb22/nrb22_I.htm

Identification and Preservation of Historic Places

The National Register of Historic Places (NRHP or National Register)—a division of the National Park Service (NPS)—is the authority on the topic of historic buildings. According to the National Register criteria, homes over 50 years old may be considered historic if they were designed by a master architect, have high aesthetic value, typify a style or type of construction, or are associated with significant individuals or historic trends. In particular, the National Register criteria (www.nps.gov/nr/publications/bulletins/nrb15/nrb15_2.htm) for evaluation of historic sites state that:

The quality of significance in American history, architecture, archaeology, engineering, and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling, and association, and:

- **THAT ARE ASSOCIATED WITH EVENTS** that have made a significant contribution to the broad patterns of our history; or
- **THAT ARE ASSOCIATED WITH THE LIVES** of significant persons in or past; or
- **THAT EMBODY THE DISTINCTIVE CHARACTERISTICS** of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
- **THAT HAVE YIELDED OR MAY BE LIKELY TO YIELD INFORMATION** important in history or prehistory.

Homes under 50 years old can also be considered historic, but they must have "exceptional" significance, with "exceptional" referring to the recognition of locally significant historic resources that, by appearance or association with persons or events, provide communities with a sense of past and place.

Homes located in historically designated neighborhoods must follow the requirements of the district even though specific homes may not meet the National Register criteria for eligibility.

Related Local and State Resources

Before making any energy improvements on a historic house, it is important to fully understand the local, state, and federal rules and regulations that may govern changes to the historic house. Resources for this information will vary by community, but start by contacting the local building department, planning department, or historic preservation office, society, or commission.

Although the criteria for defining "historic" may have been developed by a federal agency, it is most often a local ordinance that affects a project. If the jurisdiction has adopted by ordinance a historic district, neighborhood, or a listing of historic houses, there will be design guidelines to follow, and a review board may need to evaluate and approve the project before a building permit may be issued. The design review may carry extra costs that the contractor or owner needs to factor into the budget.

For example, Eureka, California, originally settled in the mid-to late-1800s, has a heritage rich in lumber history, as is reflected in its stock of historic houses. If you were considering a project on an existing home in Eureka, a call to the building or planning department (or visit to its website: www.ci.eureka.ca.gov/depts/cd/permits_n_forms.asp) would provide you with the Historic Preservation Ordinances administered by the planning department. The information found on the website would tell you the Historic Preservation Commission is responsible for the following:

- MAINTAINING A LIST OF LOCALLY, REGIONALLY, AND/OR NATIONALLY SIGNIFICANT PROPERTIES AND DISTRICTS called the "Local Register of Historic Places."
- HAVING AUTHORITY TO REVIEW APPLICATIONS for additions, alteration, new construction, or demolition of all or part of any structure, or landscape element (such as historic walls and trees designated in the Historic Preservation Application) that is located on a property listed in the Local Register of Historic Places.
- HAVING THE AUTHORITY TO REVIEW AND MAKE DECISIONS for all requests from property owners to have property placed in, or removed from, the Local Register of Historic Places (City of Eureka, Historic Preservation Packet_2010).

The Magdalena Zanone House
Photo by Ron Kuhnel

The federal government does not monitor the renovation of privately funded historic buildings. All regulations directly affecting the project can be found at the local and state levels.

A state's SHPO contact information can be found through the National Conference of State Historic Preservation Officers (www.ncshpo.org/find/index.htm#top).

Regional and local guides will provide information specific to the climate and building materials of your region.

Be sure to confirm whether local or regional design guides exist; these will address local climate conditions, locally specific building methods and construction practices over time, and often local building materials. For example, the Sustainable Solutions for Historic Houses in Northern California (www.epa.gov/brownfields/sustain_plts/reports/green_home_guide_final.pdf), addresses local climate issues and the extensive use of redwood.

A resource for information on building energy codes is www.energycodes.gov.

If the planning or building department in your community uses a similar approach, verify whether the property in question is listed and determine the associated process for application submittal, review, public hearing, and decision by the commission prior to being granted a building permit. Any or all of these steps will affect the budget and design process.

As noted earlier, the ordinances that affect your project will be local, but they often rely on the Secretary's Standards for the treatment of historic properties and guidelines for preserving, rehabilitating, restoring, and reconstructing historic houses. In the Eureka, California example, the review process includes a review of the project to ensure consistency with the Secretary's Standards. Other jurisdictions have developed their own standards you will need to work with.

In addition to being aware of local restrictions, contact the State Historic Preservation Office (SHPO) to determine whether specific historic preservation design guidelines have been developed for your state. The SHPO will also have information about any historical surveys that have been completed or significant issues that have been raised regarding the property you are considering renovating, and can provide guidance in determining appropriate local resources.

Building Codes

Building permits may be required for energy improvements, and the historic nature of the project may affect how the local building codes apply to the project. The local code official will provide information about which codes have been adopted, and how they are enforced relative to historic properties. For example, the International Residential Code (IRC), which regulates construction of single-family houses, two-family houses (duplexes), and buildings consisting of three or more townhouse units, has been widely adopted by jurisdictions nationwide.

The International Energy Conservation Code (IECC) has also been widely adopted, and, like the IRC, it applies to building additions, alterations, and repairs. However, as Section 101.1.2 of the 2009 IECC states, properties that are listed, locally designated as historic, or for which an opinion has been granted that it is eligible to be listed are exempt from the IECC. This is particularly important when considering energy retrofit projects, such as windows and insulation.

Historic Rehabilitations

Some jurisdictions have also adopted the International Existing Building Code (IEBC), which is specific to the use and reuse of existing buildings, both residential and commercial, with Chapter 11 being specific to historic buildings. It can be adopted by jurisdictions as a means to codify exceptions for historic buildings, and it can be used in historic districts. An important distinction is that the IECC excludes properties that "could be" listed, while the IEBC in general applies to all historic properties (IEBC Chapter 11, Historic Buildings, applies *only to* ***listed*** properties). If your jurisdiction has adopted the IEBC, it is important to clarify which code will apply to your project, because the IEBC, IECC, and IRC interface and overlap.

Preservation Project Classifications and Related Standards

While contractors, building officials, and codes classify projects as additions, alterations, or repairs, depending on how extensive the work is, preservationists typically classify projects as preservation, rehabilitation, restoration, or reconstruction, based on the goals of the project and resulting impacts on the historic integrity of the building. Before the project begins, decisions need to be made about how the property will be used, and if there are historic features that can be retained. The National Park Service provides definitions to help determine the project classifications. Note that additions and alterations are both considered rehabilitation.

The National Park Service identifies five examples to help illustrate these classifications.

Preservation — Jacksonville National Historic District (www.nps.gov/history/hps/workingonthepast/case_studies/jacksonville1.htm).

Rehabilitation 1 — Baker Historic District (www.nps.gov/history/hps/workingonthepast/case_studies/bakercity1.htm).

Rehabilitation 2 — Ladd's Addition Historic District (www.nps.gov/history/hps/workingonthepast/case_studies/laddsaddition1.htm).

Restoration — Monteith Historic District (www.nps.gov/history/hps/workingonthepast/case_studies/monteith1.htm).

Reconstruction — Oswald West Coastal Retreat (www.nps.gov/history/hps/workingonthepast/case_studies/oswaldwest1.htm).

- **PRESERVATION** focuses on the maintenance, stabilization, and repair of existing historic materials and retention of a property's form as it has evolved over time. The historic features of the home are not limited to one time period.
- **REHABILITATION** acknowledges the need to alter or add to a historic property to meet continuing or changing uses while retaining the property's historic character.
- **RESTORATION** depicts a property at a *particular period* of time in its history, while removing evidence of other periods. Restoring a home is significantly different from preserving or rehabilitating it; less flexibility is allowed in "modernizing" the building and mixing elements from various time periods. All modern changes to the house are removed so that only one period is interpreted.
- **RECONSTRUCTION** re-creates vanished or non-surviving portions of a property for interpretive purposes. While houses as a whole aren't typically reconstructed, independent elements of a home, i.e., chimneys, porches, and so forth, can be and often are reconstructed.

It is important for contractors and homeowners to know how to historically categorize their project, because the local or state ordinance may base the design review of the project on this classification and the applicable design guidelines from the Secretary's Standards.

3. Planning the Historic House Whole-House Energy Retrofit

Armed with information about any local ordinances or resources and applicable building codes, planning for the retrofit can begin. Don't forget that, as old-fashioned as it may seem, a historic house actually may have some environmental advantages that would be hard to duplicate now: high-quality timber and windows, non-toxic interior materials, heat-retaining masonry walls, mature shade trees, through-ventilation, natural lighting, and so forth. Make these the basis of your environmental retrofit. But most of all, remember that the mere fact the house exists represents an environmental plus: you don't have to build a new one! By retrofitting the old one instead of demolishing and building new, you are saving valuable materials, reducing the amount of waste going into the landfill, and—above all—reducing carbon use and greenhouse gas emissions. As an added bonus, you are enhancing the character of your community.

With these advantages in mind, consider how the retrofit of the historic home will differ from retrofitting a more contemporary home. As with their modern counterparts, historic houses operate as systems, but they work differently from contemporary homes, and the systems vary depending on the era and style of architecture. Understanding how these systems work and diagnosing their needs are important steps in retrofitting historic houses. Using an integrated design approach is just as important in retrofits as it is in new construction.

Building America's systems approach to home design acknowledges that as buildings become increasingly efficient, the interactions of all of the home's components and subassemblies must be taken into account to maximize performance and avoid unintended consequences. This "whole-building" approach recognizes that changes in one or a few components can dramatically change how other components perform, thereby affecting the overall building energy use, comfort, and durability. The integrated design process used to improve the home's efficiency and performance can also be applicable to remodeling and preserving historic houses.

Whole-building design suggests that a single change in a home's structure or other systems can affect the rest of the home.

A key idea behind integrated planning is that decisions about all building systems, including equipment selection, sizing, and placements, are made within the design process, not as afterthoughts in the field. The decisions are made with the help of analytical tools and the input of all relevant disciplines. Rather than a linear traditional process, the integrated process involves looping in ongoing input from relevant sources.

The REGREEN Program is a partnership between the American Society of Interior Designers and U.S. Green Building Council. The remodeling guidelines address sustainable remodeling practices and have been applied to historic houses. (www.regreenprogram.org).

42,226 homes have been built to date using technologies and strategies developed through Building America research to construct high-quality, energy-efficient homes (http://apps1.eere.energy.gov/buildings/building_america/cfm/project_locations.cfm).

Sealing air leaks may result in a need for ventilation.

For example, adding insulation and sealing air leaks can improve the energy efficiency of a home and improve its comfort and durability. However, every change made to the building's envelope (walls, floors, and ceiling) will affect the performance, health, and safety of the house. Sealing air leaks in the building envelope without providing appropriate ventilation can cause pressure imbalances or negative pressure inside the house. This negative pressure can cause fireplaces, furnaces, or other fuel-burning appliances to release dangerous fumes into the house instead of exhausting them through chimneys or flues.

A home energy audit is conducted to help understand how a historic house operates as a system and diagnose its particular needs. As described below, a certified contractor or auditor conducts the audit and understands how historical systems work together to keep a house operating as it should, and how changes will affect the whole system.

The Energy Audit: A Vital Step in Retrofitting a Historic House

Whole-house energy audits and inspections typically do the following:

- **ASSESS** how much energy the home consumes.
- **DETERMINE** what measures to take to make the home more energy efficient.
- **EVALUATE** whether basic health and safety criteria are met.

Experienced auditors or HVAC contractors will conduct computer simulations—ACCA Manual J runs—to determine the how large the furnace and air conditioner should be, based on their inspection and findings.

The audit should be conducted by a certified professional, preferably one with experience working with older homes and historic preservation issues. (See the next section for how to find a certified auditor.) The auditor should first confirm whether the National Register has listed the home as a historic building. The audit will then identify problems that may, when corrected, save significant amounts of money and energy over time. It will pinpoint where the house is losing energy and determine the efficiency of the home's heating and cooling systems. The audit may also identify ways to conserve hot water and electricity.

A professional auditor uses a variety of techniques and diagnostic equipment to measure how a house performs in ways that cannot be seen by eyes alone. These tests may include a blower door test to determine air leakage and house pressurization problems, tests to detect drafts and the effectiveness of the ducts, combustion safety testing, and carbon monoxide sampling.

The auditor will also estimate the costs of making various improvements and will use a computer program to estimate the annual savings expected from each improvement. The cost of the measures divided by the annual savings will provide the "simple payback" or how many years the measures will take to pay for themselves. Some energy measures may be as simple as stopping unwanted heat transfers by tightening leaky windows and doors. Addressing the simple fixes will reduce the number of big-ticket fixes needed. As experienced energy auditors know, for big-ticket fixes, like new furnaces, it is important to weigh all of the available options and install the smallest system needed.

The recommended energy-saving improvements derived from the audit results must be weighed against their impacts on the historic character of the home and associated regulations, and any retrofitting decisions must take into account the unique costs of historic house, such as custom windows. Note, the cost built into a standard audit may not capture the customized work needed for a historic house.

More importantly, historic houses may contain open-combustion appliances, such as gas-burning furnaces that use the air in the room for the fuel-burning process. Safety problems of open-combustion appliances can be exacerbated when retrofitting a home. When cracks and leaks that once let in air are sealed, carbon monoxide and air pollutants from cleaning chemicals, combustion appliances, and off-gassing household products can build up, creating an unhealthy and even dangerous environment in the home.

These older homes also may have dry rot and moisture problems. A certified contractor follows an auditing process that ensures that any health, safety, and moisture problems are solved during the whole-house energy retrofit. With ongoing attention to the homeowner's health and safety, the contractor also identifies any potential problems related to historically used materials, such as lead and asbestos, that can cause major health problems (see Health and Safety Concerns in the Appendix).

Finding a Contractor to Retrofit a Historic House

There are two nationally recognized energy certifications for home energy auditors and contractors: the Building Performance Institute, Inc. (BPI) Building Analyst certification and the Residential Energy Services Network (RESNET) Home Energy Rating System Rater certification. To date, BPI certification has focused on understanding the building science of retrofitting *existing* homes, and BPI will

Atmospheric combustion

For more information about home energy assessments and air sealing, see www.energysavers.gov/your_home/energy_audits/index.cfm/mytopic=11160 and the Building America air sealing document (http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_airsealing_report.pdf).

CERTIFIED PROFESSIONAL

Shutters and awnings

be the best resource for historical home energy audits. BPI is a nonprofit organization that accredits auditors, contractors, and other building professionals. Auditors or building analysts specialize in evaluating building systems and potential energy savings in homes. The certified BPI Building Analyst energy auditor has passed both written and field exams, and must recertify every 3 years. Contractors learn about building systems and are trained to install energy-efficiency measures. For more information about BPI's standards and credentials for retrofitting work, see www.BPI.org. A certified professional home inspector who has experience working with historic houses can be found by contacting the local historical society for suggestions. The Historic Building Inspectors Association is another excellent resource depending on its availability in your local area (also see http://inspecthistoric.org).

4. Historic House Upgrades

Improving energy efficiency in a historic house involves paying careful attention to how to make the most of its original design features , ensuring the durability of the home, and preserving the home's character during the remodel.

Making the Most of the Potential of the Original Design

Building America's research clearly indicates that climate zones affect building and retrofitting decisions. For example, radiant barriers are not recommended in cold climates because of the moisture problems they can cause. Historic builders intuitively understood some of these climate-specific features, and most of the features should be retained during the energy retrofit. For example, builders often incorporated features into the site and building design that helped moderate interior temperatures or provided for comfortable outdoor living areas—features like operable windows, awnings, heat-retaining masonry walls, high ceilings, through-ventilation, shade trees, and so forth. These features are still the basis of good design, and contemporary homeowners will benefit from maximizing their potential in terms of comfort or energy savings, while also retaining the historic character of the home. The National Trust for Historic Preservation (NTHP) identifies the following historically useful cold and hot climate features (also see www.preservationnation.org):

- **SHUTTERS AND AWNINGS** used in both hot and cold climates, with adjustable louvers allow for air circulation and block solar gain on hot days. Operable shutters reduce drafts on colder days and block solar gain on hot days. Post-Katrina construction in

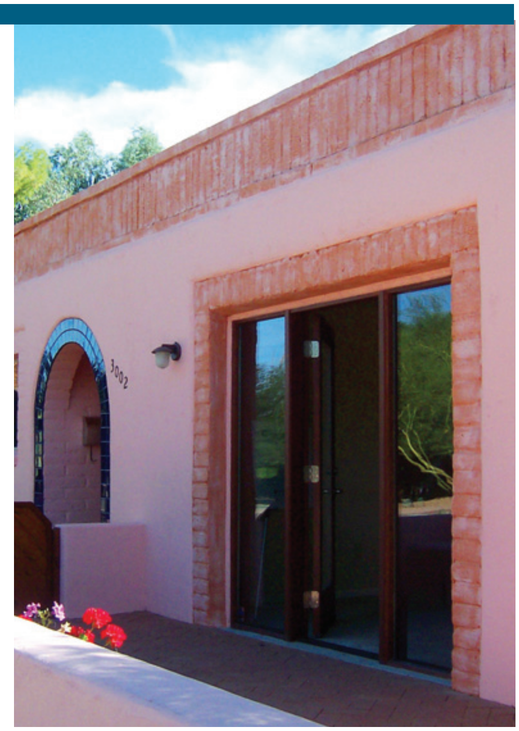
New Orleans and on the Gulf Coast is seeing the reinstitution of more historic louver shutters that admit air, while providing shade. Removable or permanently attached awnings protect the windows from solar gain on hot days, allowing for winter solar gain.

- OVERHANGS, EAVES, AND COVERED PORCHES provide shaded outdoor living space and protect the walls from the hot summer sun and precipitation. If siding is being replaced, an overhang could allow for the addition of exterior rigid foam to help insulate the walls.
- SEASONALLY SHADED INTERIOR COURTYARDS provide outdoor living space for hot summer days and warm protected areas on cooler days.
- BRICK AND ADOBE provided thermal mass to moderate the temperature swings, releasing heat gained during the day into the cooler night.
- CROSS VENTILATION is encouraged with the use of double-hung windows both upstairs and downstairs, creating an air flow through the house and exhausting hot air from the upper story.
- VEGETATION is used to provide windbreaks and provide shade for the hot summer days. Evergreen trees provide year-round wind protection while deciduous trees provide seasonal shade, allowing for winter solar gain.

Taking advantage of retaining these features will benefit the home by preserving its historic integrity, increasing the comfort of the homeowners, and reducing the need for additional energy-efficiency features.

Air Sealing

Whether a home is located in a hot and dry or very cold climate, one of the least expensive and potentially most effective energy-retrofitting measures is air sealing. The Building America's Best Practices Guide, *Air Sealing: A Guide for Contractors to Share with Homeowners* (http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_airsealing_report.pdf), provides comprehensive guidance for air sealing existing homes. The guide helps identify ways to make homes more comfortable, more energy efficient, and healthier to live in. It also identifies the steps to take to seal unwanted air leaks while ensuring healthy levels of ventilation and avoiding sources of indoor air pollution. Studies show that air-sealing measures described in the guide can typically achieve whole-house energy savings of 10% to 20% over pre-retrofit energy usage. In older homes or homes with greater air leakage, the savings may be much greater.



Miller placed rigid foam insulation and a new three-coat stucco finish over the original adobe walls but kept the historic masonry parapet visible to retain the home's southwestern character.

The Building America Asdal case study illustrated the use of rigid foam sealed in place with spray foam to insulate the band joists (top) and the use of spray foam around piping and wiring holes (www.eere.energy.gov/buildings/building_america/cold_case_studies.html).

Establishing the continuity of the air barrier system of a building is the goal of air sealing, which should be an integral part of all aspects of the retrofit from roof to cellar to window repair. However, it is important to remember the building is functioning as a system, and all parts of the system must work together to keep moisture from causing damage to the structure or being a health hazard to the occupants. As an air quality issue, the growth of mold and mildew may be exacerbated by the reduction in air leakage, but air sealing in general does not inhibit drying of the structure, unless it results in encapsulating the structure with vapor-impermeable material. Mold and mildew growing in moist areas may cause allergic reactions and damage building materials. If the air movement through the structure was allowing parts of the structure to dry out, sealing the building may require the addition of mechanical ventilation.

Two key examples of air sealing in historic houses and approaches taken to avoid indoor air quality problems are described below.

Pittsburgh Depression Era Bungalow

The Building America *Asdal Builders, LLC Pittsburgh Case Study* (Pittsburgh; http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_cs_retrofit_asdal_builders.pdf) demonstrates the way one change can trigger another in the house as a system. The renovators caulked the sill plates, air sealed the unfinished basement walls, and sealed the band joists with spray foam and rigid foam insulation. The extensive air sealing provided a very "tight" house, demonstrated by blower door tests. However, the tight house necessitated another step—providing adequate combustion air. The natural gas boiler used combustion air drawn from inside the home, thereby drawing oxygen from the living environment—a health concern in tightly sealed homes. The solution was to install a new boiler, with "power venting" drawing combustion air from the outside.

Newburgh 18th Century Brick

The Building America *Habitat for Humanity, Newburgh, New York Case Study* (Habitat Newburgh; http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_cs_retrofit_newburgh_habitat.pdf) illustrates how to handle historical elements that are also air leakage problems. The goal was to reach a final infiltration rate of 0.60 air changes per hour—the ENERGY STAR requirement for new homes. The fireplace contributed to the air leakage, but was a historical element of the home. The solution was to close off the fireplace and carefully seal around it, but retain it as a decorative element for its historical value.

When air leakage is significantly reduced, mechanical air ventilation may be necessary. American Society of Heating, Refrigerating and Air-Conditioning, Inc. (ASHRAE) Standard 62.2 for ventilation and acceptable indoor air quality in low-rise residential buildings provides the related standards and guidelines (ASHRAE 2007). Installing ENERGY STAR exhaust fans on timers can provide adequate ventilation.

For more information on air sealing, refer to Building America's Best Practices Guide, Air Sealing: A Guide for Contractors to Share with Homeowners (http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_airsealing_report.pdf).

Insulation Moisture Issues

A second key energy-saving practice for existing homes is installing increased insulation in basements, above-grade walls, and attics. The energy audit will have provided information about air leakage, moisture issues, and desired insulation levels. Attic and basement insulation, in particular, can increase the energy efficiency of a home without damaging its historical integrity, and the installation of insulation often can occur without affecting architectural features or details. However, altering the air-sealing and thermal properties of attics and basements can result in significant moisture issues. DOE's Building Technologies Program "Insulation Fact Sheet" (www.ornl.gov/sci/roofs+walls/insulation/ins_06.html) describes the issue as follows:

> When moist air touches a cold surface, moisture may form as condensation. If moisture condenses inside a wall, or in your attic, you will not be able to see the water, but it can cause a number of problems. Adding insulation can either cause or cure a moisture problem. When you insulate a wall, you change the temperature inside the wall. That can mean that a surface inside the wall, such as the sheathing behind your siding, will be much colder in the winter than it was before you insulated. This cold surface could become a place where water vapor traveling through the wall condenses and leads to trouble. The same thing can happen within the attic or in a crawlspace or basement. With careful design the new temperature profile could prevent condensation and help keep your walls or attic drier than they would have been.

Massachusetts 1760 Cape

Basement walls may have historical significance, contributing to the difficulty of adding exterior insulation. Basement walls, typically found in colder climates, can present other specific challenges as demonstrated in The Building America *National Grid Deep Energy Retrofit Pilot Program: Clark Residence, Belchertown, Maine* (Clark Residence; www.buildingscience.com/documents/case-studies/cs-ma-ngrid-deep-energy-retrofit?topic=resources/retrofits). Prior to the retrofit, there were occasions of standing water in the Clark Residence basement. Trenching, piping, and gravel mitigated

In the Clark Residence, the basement is conditioned with 3 to 5 inches medium-density spray foam insulation applied directly to field stone and concrete foundation walls. Spray foam insulation is painted with ignition barrier paint. A 12-inch-high strip of 2-inch foam insulation at the slab edge provides a thermal break and allows foundation walls to drain to the sub-slab drainage system. Several trenches with drainage pipes and filled with gravel carry bulk water to drain. The new cast concrete basement floor slab is installed over 6-mil poly, 2-inch foam insulation, and a continuous bed of gravel.

The Building America New Bedford Farmhouse case study illustrates significant energy retrofits while maintaining the historic character of the building (www.buildingscience.com).

The National Trust for Historic Preservation offers guidance in weathering roofs of historic houses (www.preservationnation.org/issues/weatherization/roofing/).

the drainage. The retrofit solved a potential condensation problem on the slab and walls by insulating with 3 to 5 inches of medium-density spray foam applied directly to the field stone and concrete foundation walls and adding a gravel base, a vapor barrier, and rigid insulation beneath the new slab.

Roofs

A leaky roof will set the stage for damage, decay, and potential health and safety issues in a house. Repairing a leaky roof can provide an opportunity to add insulation. The energy audit and roof inspection should provide the information needed to determine the performance of the roof, identifying repair needs or the potential for increasing insulation levels. The audit should answer key questions, like those of the NTHP's *Start with the Roof – A Guide to Keeping Weather Tight* (www.preservationnation.org/issues/weatherization/roofing/additional-resources/nthp_roofing.pdf):

- Is my roof energy efficient?
- How do I know if my roof is failing?
- What type of roof form is on my building?
- When replacing my roof, do materials matter?

In addition to answering these questions, when planning to re-roof consider how the pitch and materials of the roof distinguish its historical period and character. In a historic house, the overall shape, pitch, and construction of the roof, as well as its framing members may also have historic quality, because of the materials or construction methods used. These elements may limit the available options for adding insulation or other improvements.

Examples of reducing energy use by air sealing and insulating the roofs of historic houses are described below.

Massachusetts Mid-19th Century Farmhouse

The Building America *Bedford Farmhouse High-Performance Retrofit Prototype* (Bedford Farmhouse; www.buildingscience.com/documents/case-studies/cold-climate-bedford-farmhouse-retrofit-case-study), demonstrates "massive energy use reductions in a type and age of building that is widespread in the region. The project also demonstrates the application of specific high performance techniques to an older building. By respecting and maintaining the historic character of the building and elevating its aesthetics, the project also allays concerns that a high performance retrofit threatens the character and appeal of a neighborhood."

The 150-year-old Bedford Farmhouse is located in the Building America Cold and Very Cold Climate Zone, which necessitates significant improvement of the insulation levels. The solution for this structure was to seal and insulate the attic and basement as conditioned spaces. The attic was unvented, and foil-faced polyisocyanurate insulating sheathing was placed on top of the existing repaired roof sheathing, while unfaced fiberglass batt insulation was placed in the rafters. The resulting R-56 insulation contributed to an overall estimated 35% reduction in energy use over the Building America benchmark and an estimated annual savings of $930.

Tucson Adobe

The Building America John Wesley Miller Company renovation of a historical adobe home in Tucson (Adobe renovation; http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_cs_retrofit_john_wesley_miller.pdf) grappled with a very different climate and roof type. Located in the Building America Hot and Dry Climate Zone, the home has a traditional flat roof design, which required a different solution in energy retrofitting. In this case, the original roofing was removed from the flat roof assembly, but the framing and plywood sheathing were retained. Two inches of polyisocyanurate rigid insulation (R-13) were installed on top of the sheathing, followed by a new built-up roof, which was painted reflective white for solar reflectance in the hot and sunny climate.

Florida Victorian

The Florida Solar Energy Center (FSEC) dealt with the issue of historic framing in its restoration case study of the Williams home in *Cooling Load Reduction and Air Conditioner Design in a 19th Century Florida House Museum* (Williams House; see Chasar [2004] available at www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1508-05.pdf). One of the project goals was to reduce the cooling loads of the house, which necessitated the addition of attic insulation. Although spray polyurethane foam products applied to the roof deck would have provided both air sealing and insulation, it would have hidden part of the historical features of the house and the decision was made to add insulation at the ceiling level instead.

As exemplified by the case studies, roofing solutions for energy retrofits will vary with the climate zone, roof construction, and historic details of the home.

(Top) The Building America New Bedford Farmhouse case study sealed and insulated the attic as a conditioned space, placing foil-faced polyisocyanurate on top of the existing repaired roof. Building Science Corporation. 2010. "Bedford Farmhouse High Performance Retrofit Prototype" (Case Study), (www.buildingscience.com), Somerville, Massachusetts.

(Bottom) Blown-in insulation can be used to dramatically increase insulation values.

Another resource for historic roof projects is the 1978 NPS Preservation Brief 4: Roofing for Historical Buildings (www.nps.gov/history/hps/tps/briefs/brief04.htm).

(Top) The Building America Chesapeake Habitat for Humanity case study demonstrates a solution for brick walls: installing rigid insulation between bricks and framing, air sealing, and filling the new cavity with batts (www.eere.energy.gov/buildings/building_america/mixed_humid_case_studies.html).

(Middle/Bottom) The Building America SEER case study in New Jersey demonstrated the use of blown-in and foamed insulation under the siding (http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/36474.pdf).

Walls

Walls can be sources of air and moisture leaks, and in historical homes they may be uninsulated. In addition to air sealing, an energy retrofit will seek opportunities for increasing the insulation levels of exterior walls. However, insulating walls in historic houses can be challenging.

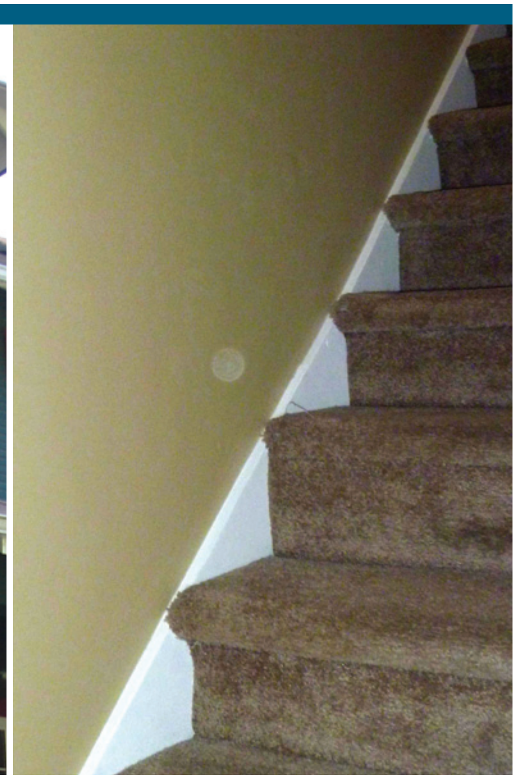
Chesapeake Habitat for Humanity

The Building America *Chesapeake Habitat for Humanity Baltimore, Maryland Case Study* (Chesapeake Habitat; http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_cs_retrofit_chesapeake_habitat.pdf) developed a solution for insulating brick-walled homes. The technical directors on the project—Steven Winter Associates—were seeking a solution to the thermal bridging that was occurring when framing inside the above-grade walls and filling the cavities with fiberglass batts. Their R-21 wall solution was to install a 1/2 inch of rigid insulation between the bricks and stud framing, air seal the edges and gaps with foam, and then fill the new interior stud wall with R-19 batts. The existing gap between the double brick wall allowed for ventilation, so moisture did not penetrate to the foam.

New Jersey 19th Century

The Building America Strategies for Energy-Efficient Remodeling 2003 retrofit in rural New Jersey (Drumheller and Wiehagen 2004; http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/36474.pdf) demonstrates solutions for a different set of issues. In this case, a 19th century home had uninsulated 2x4 walls, with wood siding and partial interior sheathing. However, the siding had deteriorated and needed to be replaced. The case study shows that based on the existing wall conditions, two wall cavity insulation choices were available—the use of blown-in insulation materials or foam-in-place insulation. Blown-in and foamed insulation materials provide more of an opportunity to completely fill irregular wall cavities and may be installed through small openings in the framing bay. They also are particularly adaptable to insulating wall sections that have coverings on both the exterior and interior of the framing members. Additional insulation on the exterior of the framing was also considered because the siding was being replaced. The Building America partners ultimately chose blown and foamed insulation in the wall cavity and sheet insulation under the siding.

Another option for wood-clad buildings is the “drill-and-fill” method of opening 2-inch holes and injecting fiberglass or cellulose insulation into the cavity, resulting in an R-13 to R-21 insulated wall, depending on the cavity depth and type of insulation.



(Left) Drill-and-fill wall insulation on a house located in a Portland, Oregon historic district. Typically narrow strips of siding are removed before drilling, and sealed holes are hidden when siding is reinstalled.

(Right) Blown-in insulation can be installed in walls from the interior. Care must be taken to match existing wall finish textures.

Windows

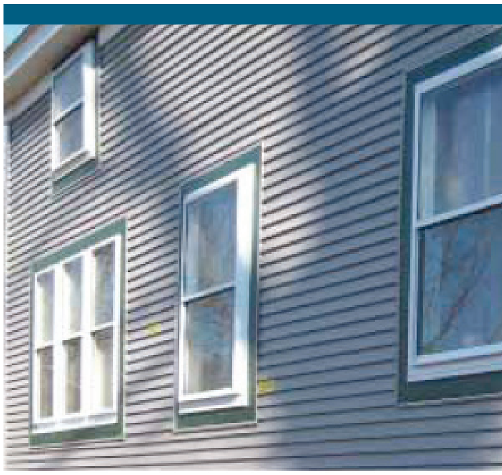
The energy audit will have identified moisture and/or air leakage around windows and any other problems that exist with the current windows. Window treatments may include the following:

- air sealing, flashing, and weatherstripping
- repair and reconstruction
- addition of storm windows
- replacement with historically accurate replicas
- replacement with wood windows of similar design (e.g., replacing double hung with double hung outfitted with similar material).

Which option is best suited to the project depends on the results of the energy audit, climate, and the project objectives—preservation, rehabilitation, or restoration. Because of the highly visible nature of windows and their direct bearing on the historical integrity of the building, the NTHP promotes rehabilitating existing windows whenever possible. If there is water damage to the sills or around the window, evaluate whether the window needs resetting with an improved drainage plane.

As noted earlier, it is important to first maximize the inherent potential of the house to be energy efficient. Existing awnings or shutters that provide appropriate shading, serve to ventilate the

The window may not be the problem, but the installation may be. The Building Science Corporation, in Building Science Digest-105: Understanding Drainage Planes (https://www.buildingscience.com/documents/digests/bsd-105-understanding-drainage-planes/files/bsd-105_understanding_drainage_planes.pdf), provides a variety of window installation solutions for different wall types.



(Top) The Building America Clark Residence retrofit case study demonstrates the use of high-quality storm windows (www.buildingscience.com) a solution to improving window efficiency.

(Bottom) An Insulated Glass Unit (IGU) is installed as a storm window over stained glass. *Photo by Bruce Kinzey*

"There is a need to demonstrate there are ways to be energy efficient without replacing windows, and that historic buildings often have natural advantages to ventilate, heat, and cool," said Rock Island Preservation Commission Chairman Robert Braun.

home, and/or are part of the historic character of the house should not be removed but maintained in good operating condition. If the original design included these features but they are no longer part of the structure, consider replacing them in a manner consistent with the Secretary's Standards for the treatment of historic properties and guidelines for preserving, rehabilitating, restoring, and reconstructing historic houses.

Massachusetts 1760 Cape

The Clark Residence retrofit (www.buildingscience.com/documents/case-studies/cs-ma-ngrid-deep-energy-retrofit?topic=resources/retrofits) demonstrates how a Cape Cod home, circa 1760, can be energy efficient and retain a good deal of its historic character. The original windows had been replaced with relatively new wood-frame windows, but they did not offer sufficient thermal performance and the homeowners were disinclined to replace them. Building Science Corporation, a Building America team, determined that adding "high quality exterior storm windows offered the best combination of improved thermal performance, interior condensation control, and exterior rain shielding for the windows." The resulting window specifications included new storm windows over existing wood-framed, double-glazed, low-E windows. When considering the house as a system, in this case there was concern that air-impermeable and vapor-retarding insulation, would put the structure at risk because it could no longer dry to the inside. To avoid this problem, the renovators installed new flashing and made other corrections to the water drainage plane to keep the water away from the structure.

The Color of Glass

An issue to consider when adding storm windows or replacing windows is the color of the glass. Glass color will influence the quality of light within a building and can also contrast with other glass already present or being added to the building. Often, operable windows like casements and sliders are replaced and storm windows are added to fixed windows. The storm and the replacement windows may incorporate glass from different sources and appear different if compared side-by-side. The same type of comparison may be true when replacement or storm windows are installed near windows that are left as-is. Perhaps more importantly, tinted glass may obscure existing window features. Discuss this issue with the window supplier to ensure the selection of consistent glass color, and glass that does not obscure original window features.

Systems for Heating and Cooling a House

Pasadena Ranch House

The comprehensive energy audit on the Building America *Hartman Baldwin Design/Build, Pasadena, California retrofit* (Pasadena; http://www1.eere.energy.gov/buildings/building_america/hot_dry_mixed_case_studies.html) provided direction before the team began sealing the building shell and installing a new HVAC system. The homeowner was surprised to learn that the bottom of the return plenum had rusted out and was open to the crawlspace floor.

The Building America Pasadena Ranch House case study demonstrates the value of beginning with an energy audit. Illustrated here is an open plenum discovered in the crawlspace (www.eere.energy.gov/buildings/building_america/hot_dry_mixed_case_studies.html).

Not all audits will point to such clear problems, but they will provide the information to address the heating and cooling system needs. Depending upon the age of the home, it may have a heating and cooling system that is very different from most contemporary homes—one that may have relied heavily on passive heating or cooling, such as shading and cross ventilation from open windows. Before installing a new system, ensure that these passive historic heating and cooling features have been maximized. Also ensure that the recommended energy retrofitting derived from the energy audit has been completed.

All ducts should be sealed, especially in attics, vented crawlspaces, and rim areas. For more information, see Building America's Air Sealing: A Guide for Contractors to Share with Homeowners (http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_airsealing_report.pdf).

If the home has open chases, floor vents, or built-in chimneys to provide air flow and ventilation, make sure they are currently being used as efficiently as possible. Retain the associated grilles or other finishing features for their historical character. Even unused radiators may contribute to the historic character of the house, so consider retaining them.

Ceiling fans help with both cooling and heating. Window fans can exhaust hot air or bring cool air in overnight. Whole-house fans, installed over stairway halls or elsewhere, exhaust hot air that rises through the house, while pulling in fresh air from the ground level where it is coolest. Ordinary room fans can make a remarkable difference in the summer, and the difference in terms of energy use can be significant.

In homes with existing central heating and cooling systems, sealing or repairing the existing duct system may reap significant benefits. As noted in the Building America Best Practices Guide, *Air Sealing: A Guide for Contractors to Share with Homeowners*, all ducts should be sealed, especially in attics, vented crawlspaces, and rim areas. In older homes, wall cavities and floor joist cavities are sometimes used as return "ducts" to bring air from the return registers back to the air-handler unit, but these building cavities are

This historic home uses Unico's Small Duct High Velocity HVAC equipment, to heat and cool the home without modifications to the original historic structure.
Photo by Unico

rarely air sealed and should be replaced with sealed ducts. Refer to the aforementioned Building America Best Practices Guide for specific guidance on repairing and sealing existing systems (http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ba_airsealing_report.pdf).

Briefly, three situations a renovator may face when replacing a system include the need to replace the duct system, replace electric resistance or steam heating, or add air cooling. The limitations of replacing existing systems, based in part on *U.S. Department of Energy – Energy Efficiency and Renewable Energy, Energy Savers: Limitations When Replacing Existing Heating Systems* (www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12320), are highlighted below:

- **INSTALLING NEW DUCT SYSTEMS.** When intending to install new duct systems in a historic house, plan the air delivery system carefully. It should be efficient without changing the home's historic character by introducing unsightly transoms, dropped ceilings, etc. While new homes should always have their furnaces and air handlers located in a conditioned space, this is not always possible in historic houses. However, if the attic and/or basement/crawlspace have been converted to conditioned space these spaces will generally be the best locations for the equipment and ducts.

  In some multi-story homes, however, a different option will be needed. High-velocity mini-ducts may provide a solution, because they force air through plastic feeder ducts that are only 2 inches in diameter. These ducts can be easily threaded through cavities in walls, floors, and ceilings.

  A downside of installing mini-ducts is that they generally require more outlets (2-inch-diameter round ducts): roughly five outlets per ton of cooling, or one outlet for every 2400 Btu of heating. These outlets will likely result in higher costs to install the system. When installing mini ducts, keep in mind the appearance of the house during preliminary planning. Outlets can stand out in a room and their placement is very important, especially when preserving or restoring a home. Consider putting the outlets in the corners of floors and ceilings.

- **REPLACING ELECTRIC RESISTANCE OR STEAM HEATING WITH HOT-WATER BASEBOARD HEATING.** In homes without ducts, replacing electric resistance baseboard heaters or steam systems with a hot-water baseboard system can avoid the need for new ducts, and may limit the overall cost. Replacing an electric resistance system usually will require extensive plumbing, but installing it may be less problematic than installing new ducts. Converting steam systems to hot water is generally only feasible in two-pipe steam systems.

- **ADDING AIR COOLING TO A HEATED FORCED-AIR (DUCT) SYSTEM AND INSTALLING DUCTS.** This can be accomplished by adding central air to a forced-air system or switching to a heat pump. System sizing should not be done before the energy audit has been carried out and all weatherization has been completed. While heat pumps typically require larger duct systems, duct systems in existing homes are often unnecessarily large and rather than being energy efficient, end up wasting energy and money. Once the home has been made more efficient the sizing may be appropriate.

Massachusetts Mid-19th Century Farmhouse

In the case of the Bedford Farmhouse, the retrofit accomplished its goals by insulating the attic and basement to create conditioned spaces. The gas furnace was installed in the newly conditioned space, and the air handler and distribution system were located entirely within conditioned space, using sheet metal trunks and run-outs and ducted returns from the upstairs bedrooms.

Florida Victorian

The Williams home project faced a different challenge to maximize the original design of passive cooling. Because the home was to be used as a museum with fixed hours throughout the summer months, the decision was made to provide cooling. First, the natural system was optimized, reducing the amount of humidity and dry air loss through air sealing, insulation, and shading/reflectivity. The builder used the high-velocity mini-duct distribution system, citing two advantages in its situation—because the outlets are smaller, they are less noticeable, and the delivered air temperature is colder than conventional systems, which improves the dehumidification properties of the cooled air. Dehumidification was important—as the builder energy-retrofit the home and added air conditioning it changed the system, affecting the way temperatures and humidity moved through the building and building envelope.

Building America's Bedford Farmhouse High-Performance Retrofit Prototype accomplished its retrofitting goals by locating the gas furnace in the conditioned attic and locating the air-handler and distribution systems within conditioned space (for more information, see www.buildingscience.com/documents/case-studies/cold-climate-bedford-farmhouse-retrofit-case-study).

The Williams home project —Cooling Load Reduction and Air Conditioner Design in a 19th Century Florida House Museum—optimized the home's natural system and installed a high-velocity, mini-duct distribution system (for more information, see www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1508-05.pdf).

When retrofitting with can lights, make sure they are insulation-contact air tight (ICAT) and labeled as meeting ASTM E283 when tested at 1.57 psf (75 Pa) pressure differential with no more than 2.0 cfm of air movement and sealed with a gasket or caulk between the housing and interior wall or ceiling covering.

Lighting Options

Incandescent lighting has traditionally delivered about 85% of household illumination. Incandescent lamps operate without a ballast, are dimmable and instantly controllable, and light up instantly. Most familiar are the standard pear-shaped, screw-in "A"-type incandescent light bulbs. They produce a warm light and provide excellent color quality. They have a low efficacy compared to all other lighting options (10 to 17 lumens per watt) and a short average operating life (750 to 2500 hours).

Fluorescent lamps use 25% to 35% of the energy used by incandescent lamps to provide the same amount of illumination (efficacy of 100 lumens per watt) and last about 10 times longer (7,000 to 24,000 hours). Improvements in technology have resulted in fluorescent lamps with color temperature and color rendition that are comparable to incandescent lamps.

LED lights use 35% to 50% of the energy used by an incandescent lamp to provide the same amount of illumination (luminaire efficacy of about 70 lumens per watt) and last longer than incandescent or fluorescent bulbs. (Good-quality white LEDs in well-designed fixtures are expected to have a useful life of 30,000 to 50,000 hours.) LED device efficacy doesn't tell the whole story. Good LED system and luminaire design is imperative to energy-efficient LED lighting fixtures. For example, a replacement LED downlight combines thermal management and optical design to produce up to 700 lumens using only 6 to 7 watts.

Citation: from LED Basics: What retailers, energy efficiency advocates, and consumers need to know to make informed buying decisions (2 pages, November 2009; www.eere.energy.gov/buildings/ssl/factsheets.html).

Lighting

Artificial lighting consumes almost 15% of household electricity, and significant energy savings can be achieved by retrofitting a home's lighting. Note that older homes started out with no lighting or gas lighting and have already been modified at least once. Use of new lighting technologies can reduce lighting energy use in homes by 50% to 75%. Advances in lighting controls offer further energy savings by reducing the amount of time lights are on but not serving a useful purpose. Advanced lighting controls also offer a new amenity—lights that come on automatically when they are needed (http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/26467.pdf).

Unlike other energy-retrofitting techniques, lighting changes have fewer impacts on other house systems; the biggest impact is on reducing the cooling load in summer. New compact fluorescent lamps can be found for many socket styles and sizes. Their use will reduce the heating load and the energy budget of the home. Consider installing and using task lighting and LED applications that will enhance the feel of the room. LEDs are particularly appropriate for downlighting, under-cabinet lighting, and specific task lighting. Furthermore, use of a wide range of sensor light fixtures on the market, if used properly, will help to conserve energy.

Existing light fixtures are an important element of a historic house whether or not they are functional. For example, unused gas light fixtures can be retained as historic elements of decor.

Finally, careful trimming of exterior landscaping elements that detract from the natural interior lighting also should be considered to improve lighting in the home.

Solid-State Lighting Research:

Solid-state lighting technologies are changing and improving rapidly, and products arriving on the market exhibit a wide range of performance. The DOE Commercially Available LED Product Evaluation and Reporting (CALiPER) program provides reliable unbiased product performance information (www.eere.energy.gov/buildings/ssl/caliper.html).

Other Considerations During an Energy Retrofit

Several retrofitting options won't necessarily be the focus of the energy audit, but they should be considered in an energy retrofit, e.g., porches, landscaping, and seismic retrofits

Porches

Porches should not be ignored when considering ways to make a home more energy efficient; efficiencies can be gained from insulating and air sealing points where porch roofs intersect house walls. Before adding insulation, make sure the drainage plane is not allowing water to run between the porch and house, or within the porch roof structure.

There are also simple ways of making a porch a more temperate and attractive place to spend time. For example, installing an awning or planting shade trees can transform the space. Adding a ceiling can keep the heat from bearing down on occupants. Installing a ceiling fan can ensure air movement, without detracting from the general feel and historical quality of the porch.

Originally designed for shade and shelter from the elements and outdoor living area, porches are sometimes walled in and finished to provide additional interior space. Doing this may detract from the flow of spaces within the home and change its historic character. If additional interior space is needed, consider adding it where it will have less of an impact on the historic image that the home presents to the street. If a glassed-in front porch already exists, consider returning it to its original configuration. This will enhance the historic character of the house while providing an attractive, shaded outdoor space.

Landscaping and Siting

If the property landscaping has been maintained over the life of the home, it will likely include trees and other features that are aesthetically compatible with the home and provide shade and wind breaks. Historic landscape features may also include valuable or even irreplaceable plant material, such as mature trees and flowering shrubs that would take many decades to replicate. Before removing historic plantings, consider that they are there for a reason and they are part of the home's historic character.

The Building America Tucson Adobe case study retained the historic landscaping with plants and ground cover that require minimum irrigation (www.eere.energy.gov/buildings/building_america/hot_dry_mixed_case_studies.html).

Landscaping

Significant changes in grade or material can alter drainage patterns and create moisture problems that did not previously exist. If historic landscaping might cause damage to the home or has grown to the point where natural lighting is blocked, consider contacting a tree surgeon. By removing a weak limb, trimming back some overgrown branches, or thinning branches, you can save the appearance of the home, and retain the value of the historic landscaping.

Also note that if the house is located in a historic district, landscape guidelines may dictate style, plant use, or use of hardscape features.

Seismic Retrofits

Preserving the historic features of a home when performing a seismic retrofit, typically for structural stabilization, can create a particular challenge. Recognizing how critical structural stabilization can damage the historic value of buildings, the National Park Service has developed related guidance in Preservation Brief 41, *The Seismic Retrofit of Historic Buildings Keeping Preservation in the Forefront* (www.nps.gov/history/hps/tps/briefs/brief41.htm). The Brief identifies three keys to successfully interfacing historic preservation with a seismic retrofit:

- **PRESERVE AND RETAIN** historic materials to the greatest extent possible and do not replace them wholesale in the process of seismic strengthening.
- **RESPECT THE CHARACTER AND INTEGRITY** of the historic building and make them visually compatible with its design whether installing hidden or exposed new seismic retrofit systems.
- **MAKE SEISMIC WORK “REVERSIBLE”** to the greatest extent possible to allow its removal for future use of improved systems and traditional repair of remaining historic materials.

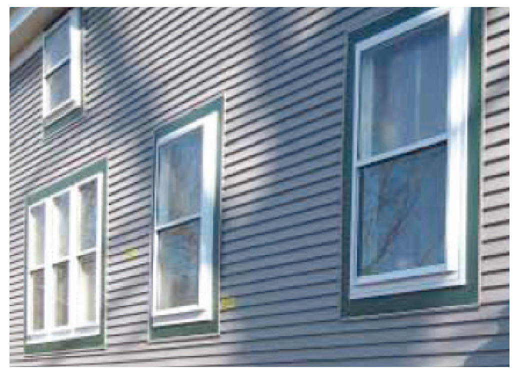
5. Conclusion

As indicated in Chapter 4, renovation efforts, including energy-efficiency improvements, can have broad impacts on the home. In addition to changes in the whole-house system that may occur during a retrofit, care must be taken to avoid changing any of the following original design elements that might affect the historic character of the home:

- roof profile and materials
- windows
- porches
- special period architectural features
- interior finishes and trims
- landscape features
- equipment (visible features, such as lighting fixtures, heating registers, ductwork, vents and stacks).

Once the home energy audit and inspection identify the recommended retrofitting needs of a home, balancing them with historic preservation needs can seem overwhelming. Luckily, numerous resources are available to the building contractor and homeowner alike to inform and ease the process. For example, the National Trust for Historic Preservation also provides leadership, education, advocacy, and resources to save America's diverse historic places and revitalize its communities. The National Institute of Building Sciences through its *Whole Building Design Guide* (www.wbdg.org/) offers a one-stop shop for building-related guidance, criteria, and technologies from the whole-building perspective, as well. And closest to home, local design guides provide guidance specific to local climate conditions and architectural considerations. Building America continues to work with research teams and these agencies to provide research results for whole-house energy-efficient retrofits.

Investing money and time in retrofitting older homes in a way that respects their historic character can promote environmental conservation and preservation both. Use the resources cited herein and recommended practices derived from Building America's renovation case studies and series of best practices guides. Inform yourself and plan your integrated approach to building and renovating historic homes. To achieve energy-efficient, high-performance dwellings, build upon the inherent durability of the existing home and preserve its historic character, while also improving its indoor air quality and enhancing the health, safety, and comfort of its occupants.



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Appendix — Health and Safety Concerns

Contractors need to keep safety and health at the forefront of any retrofitting job, because some health and safety issues can result in death and huge costs, and they need to be considered when planning the project. The type of health and safety concerns encountered will depend upon the age and condition of the home and the type of project being undertaken. This section identifies some of the issues to be aware of and associated resources for further information.

The problems encountered in historic buildings include asbestos, lead, animal matter, radon, and underground storage tanks. Colorado Preservation, Inc., a private nonprofit, statewide historic preservation organization, provides a solid outline of health and safety concerns (www.coloradopreservation.org/faqs.html#05).

- **ASBESTOS.** Commonly present in historic buildings built or renovated after 1870, asbestos may be found in insulation, roofing materials, wallboard, flooring, chimneys, paint, plaster, wallpaper, exterior sheathing, and more. As a material used widely and in a multitude of applications, it is wise to assume that asbestos is present in your building. Mesothelioma is a lung cancer that may be caused by inhaling asbestos fibers. (See the *Whole Building Design Guide*, a program of the National Institute of Building Sciences, at www.wbdg.org/design/apply_process.php.)

  According to the U.S. Environmental Protection Agency (EPA), one of the most common places to find asbestos is in deteriorating, damaged, or disturbed asbestos-containing products such as insulation, fireproofing, acoustical materials, and floor tiles. Asbestos siding is also a significant concern for home renovators. The EPA website provides information about managing and removing asbestos, which are best done by professionals (see www.epa.gov/asbestos/pubs/pubs.html). Each state has training and accreditation services that will help you find a qualified, trained, and accredited professional.

- **LEAD.** Lead was used extensively in paint until the mid-1900s, and was outlawed for use in residential construction in 1978. As renovation activities disturb surfaces bearing lead-based paints, chips and lead-bearing dust may be ingested or inhaled, posing a significant health risk. Lead is also found in solder, roofing metals, piping, and other materials because of its waterproofing quality. (See the Historical Chrisfield Model at www.nps.gov/history/hps/workingonthepast/chrisfield.htm.)

  The National Trust for Historic Preservation provides guidance on working with lead paint and addresses the EPA's regulations—known as the renovation, repair, and painting rule—which went into effect in April 2010. Under the new rule, contractors "performing renovation, repair and painting projects that disturb lead-based paint in homes…built before 1978 must be certified and must follow specific work practices to prevent lead contamination." The EPA provides extensive guidance in working with lead (see www.epa.gov/lead/pubs/renovation.htm), and information to contact your local state agency for that can provide local information regarding certification and guidance in finding appropriately trained professionals.

- **ANIMAL MATTER.** Animal matter is present in the form of animal excrement, including rodent droppings, urine, and bat and pigeon guano, and feathers. Hantavirus is carried by rodent material and passed on to humans by inhaling airborne particles. Ornithosis, also known as psittacosis, may be harbored in guano and carried by airborne particles into the respiratory system (for more information, see www.coloradopreservation.org/faqs.html#05).

  Care must be taken to protect workers from inhaling contaminated particles, and the skin should be kept covered. Wear dust masks, goggles, and rubber gloves. Wash skin and clothing with disinfectant soap after each contact with potentially contaminated material.

  Homes that have been unoccupied or otherwise uncared for may have rodents, nests, or their droppings in insulation, duct runs, or air-handling equipment. Professional duct vacuuming can remove the problem from both the air handler and ducts, which would otherwise spread the potential contaminants through the house. For details about cleanup and working in a contaminated environment, contact your local public health department.

- **RADON.** Radon is a radioactive gas produced by the decay of radium. It is harmful when inhaled and is a known cause of lung cancer. It may accumulate in basements and crawlspaces and where ventilation is poor (see www.coloradopreservation.org/faqs.html#05).

  Radon is a localized concern, and your building department can tell you if it is a concern in your community. Test kits are available at hardware stores, or you may contact an environmental contractor for more extensive testing.

- **UNDERGROUND STORAGE TANKS.** Homes with oil heat or other fuel-storage needs may have underground storage tanks leaking and causing soil and potential groundwater contamination.

  Underground storage tanks may have been identified in disclosure statements at the last sale and purchase of the home, or they may be completely undocumented. Contact your building department for permitting history or the local historic district for information about the home; information may be available to determine if there is a tank onsite. Your state's department of environmental quality should provide guidance appropriate to local issues and soils.

- **COMBUSTION SAFETY.** Combustion appliances that draw their combustion air from the room in which they are located are called atmospheric vented or natural-draft combustion appliances. These appliances (which could include furnaces, water heaters, clothes dryers, wood stoves, and gas stoves) may have the potential to back draft under the right conditions. Combustion appliances should be tested for backdrafting before and after any other home weatherization work such as air sealing and insulating is completed. Ideally, older natural-draft combustion appliances would be replaced with higher-efficiency sealed combustion, induced draft, or power-vented appliances. Non-combusting appliances (for example heat pumps) are another safe option. Gas lines should also be checked for leaks. Homes with combustion appliances should have carbon monoxide detectors that meet UL 2034. See Building America's Air Sealing guide for more information www.eere.energy.gov/library.

Visit our Web sites at:

www.buildingamerica.gov

www.pathnet.org

www.energystar.gov

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Building Industry Research Alliance (BIRA)

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Consortium for Advanced Residential Buildings (CARB)

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Davis Energy Group

David Springer • Davis Energy Group • 123 C Street • Davis, CA 95616 • 530-753-1100 • fax: 530-753-4125 • e-mail: springer@davisenergy.com • deg@davisenergy.com • www.davisenergy.com/index.html

IBACOS Consortium

Brad Oberg • IBACOS Consortium • 2214 Liberty Avenue • Pittsburgh, PA 15222 • 412-765-3664 • fax: 412-765-3738 • e-mail: boberg@ibacos.com • www.ibacos.com

Industrialized Housing Partnership (IHP)

Philip Fairey • Florida Solar Energy Center • 1679 Clearlake Road • Cocoa, FL 32922 • 321-638-1005 • fax: 321-638-1439 • e-mail: pfairey@fsec.ucf.edu • www.baihp.org

National Association of Home Builders (NAHB) Research Center

Tom Kenney • National Association of Home Builders (NAHB) Research Center • 400 Prince George's Boulevard • Upper Marlboro, MD 20774 • 301-430-6246 • fax: 301-430-6180 • toll-free: 800-638-8556 • www.nahbrc.org

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