

COMPREHENSIVE ENERGY RETROFIT

Case Study: Consortium for Advanced Residential Buildings (CARB) – Washington, D.C.



“Each retrofit, no matter how small, can incorporate the principles of the whole building approach,” says Amanda Magee, an engineer with Steven Winter Associates, which leads the Consortium for Advanced Residential Buildings (CARB), one of six residential research teams that are part of the U.S. Department of Energy (DOE) Building America program.

This whole-building approach was followed in retrofitting a 145-year-old row house in Washington, D.C.’s Capitol Hill district. As part of this Building America demonstration project, CARB provided the homeowner with an approach and technical analysis to meet the program goal to reduce heating and hot water energy consumption by 30%.

“The research we did for this house was incorporated into our guide—*The reHABITAT Guide for Energy- and Resource-Efficient Retrofit Strategies*,” says Magee. “It is the takeaway from this project and work we have done for Habitat for Humanity.” The guide provides homeowners and builders with a whole building approach for achieving affordable energy-efficient retrofits specifically for brick homes located in historic urban districts. It can be accessed online at www.eere.energy.gov/buildings/building_america/pdfs/36057.

A Whole Building Retrofit Process

The “whole building” approach is based on the principle that the components and systems of a house are interdependent. For example, sealing air gaps in a home is important for energy efficiency. However, such sealing prevents fresh air from circulating in the home, which is essential for a healthy home. Therefore, if you seal air gaps, you need to provide another means to bring in fresh air, such as with a mechanical ventilation system. CARB followed the steps outlined here to achieve a successful energy-efficient retrofit, which are the same steps defined in more detail in *The reHABITAT Guide*.

Step 1. Set Goals and Develop a Plan

The homeowner of the row house had several overall design goals. He wanted to reduce heating and hot water energy consumption by 30% while creating more usable space and meeting the historic requirements of his neighborhood. As part of this demonstration project, Building America paid for design planning and analysis, and the homeowner paid for all retrofit costs. (His budget in 2005 costs was \$85,000.)

The whole-building approach was followed in retrofitting this 145-year-old house in Washington, D.C.’s Capitol Hill district.

BUILDER PROFILE

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Featured Project:

145-year-old row house in Washington, D.C.’s Capitol Hill neighborhood

Goal:

30% heating and hot water energy use reduction

Construction Type:

Brick exterior

Size:

2-story, 1,440 sq. ft., plus basement

Rehab Cost:

\$85,000



Rainwater collecting next to a home's foundation can impact the structural integrity of the home.

To mitigate moisture problems at this home, CARB suggested cleaning out drains, sloping soil away from the home where possible to direct water away from the foundation, and installing an under-deck drainage system to divert rainwater away from the house.

The CARB staff conducted a site visit and documented a detached two-story masonry house of 1,440 square feet with its own entrance and a basement. They noted extensive details including exterior brick walls with no insulation and single-pane windows. The roof contained R-11 batt insulation in the front half and R-38 blown-in insulation in the back, with no insulation around the skylights. The mechanical equipment located in the basement included radiators for heating hot water, an 80% AFUE Hydrotherm Atmospheric Gas Boiler, and an A.O. Smith 40-gallon atmospheric gas water heater.

Based on information from the site visit and the goals of the homeowner, CARB staff performed computer modeling and developed three options for achieving 30% energy savings. Details of the option the homeowner selected are provided in step 3 below.

Step 2. Mitigate Health and Safety Issues and Understand Historic Guidelines

Health and safety issues that can need mitigating include lead-based paint, asbestos, radon, mold, and carbon monoxide. Approved methods for identifying and remediating these issues need to be defined during the planning stages. A professional who is licensed to address health and safety issues, such as asbestos removal, should examine the home before determining the feasibility of a rehab since abatement can be expensive.

It is important before beginning a rehab project to consult the local building department to determine whether historic requirements apply. The State Historic Preservation Officer can also provide guidance. For this project, the windows on the front façade required wood frames.

Finally, Section 504 of the Rehabilitation Act of 1973 (Section 504) requires that handicap accessibility be incorporated into newly constructed and rehab projects if there is any amount of federal financial assistance, regardless of whether that assistance is handed directly to the developer or funneled through other sources. It is important to consult the local building department to determine whether building code and state and local requirements for access apply.

Step 3. Protect and Prevent Damage to the Building's Structural Integrity

Before addressing energy efficiency, the building's site and foundation must be evaluated and a plan developed that will support the building's durability over time.

During the CARB visit, the team determined the structural integrity of the building to be sound. However, the site had drainage problems because the drains installed in the pavement had filled with sediment over the years, resulting in moisture problems around the foundation. Also, improper flashing of the two back decks caused water penetration into the house. As part of Building America's whole-building approach, it is essential to address moisture problems on the exterior of the house to help prevent interior moisture problems.

To solve the moisture problems, CARB recommended cleaning out the drains, sloping soil away from the house to direct water flow away from the foundation, properly flashing the decks, and installing an underdeck drainage system to divert rainwater away from the house.

Step 4. Apply Energy- and Resource-Efficient Retrofit Strategies

The following strategies were recommended on the Washington, D.C. home:

Roofing

The roof had been leaking for a year and needed to be replaced. CARB recommended stripping the roof down to the roof decking, repairing the roof decking as needed, and installing a thermoplastic polyolefin (TPO) single-ply roofing membrane on top of 5-inch polyisocyanurate rigid foam insulation (R-30).

The highly reflective and emitting TPO roofing is both ENERGY STAR qualified and California Cool Roof compliant, ensuring the house will stay cooler in the summer than a home with a standard roofing system. Installing insulation on top of the roof decking allowed the attic to become part of the conditioned space, eliminating the need to access and insulate the cramped attic and permitting it to dry out.

Windows

The single-pane windows leaked and were deteriorating. CARB suggested replacing these with soft-coat, low-emissivity double-pane windows. Wood-framed windows (U-0.39, SHGC 0.46) were used in the home's front to meet historic compliance and vinyl-framed windows (U-0.36, SHGC 0.45) were used in the back.

Insulation and Air Sealing

The walls consisted of plaster on brick with no insulation. Originally, CARB recommended the walls be insulated. However, the homeowner did not want to lose floor space or incur the cost of refinishing all the exterior walls. Therefore, CARB recommended installing ¾-inch polystyrene (XPS) rigid insulation (R-3.75) against the interior side of the exterior brick walls. CARB also recommended extensive air sealing of all cracks, gaps, and air leaks, including where the walls met the floors and ceilings, and around stairwells.

Space and Water Heating

The original home had hot water radiators served by an 80% AFUE hydrotherm modular gas-fired boiler and an atmospheric combustion-gas tank hot water heater. Window air conditioning units were used for cooling.

The radiators were replaced with a radiant floor heating system, using PEX pipes installed under the tongue and groove wood flooring, which was removed and re-laid. A Teledyne Laars Endurance boiler/hot water heater distributes hot water through the pipes for heating and also provides domestic hot water.

Radiant heat warms objects near the floor (people and pets) as opposed to forced hot-air systems that warm the air. Radiant floor heating eliminates issues associated with forced air systems, such as dust, drafts, noise problems, and unsightly duct chases and regulators. In this historic home, the radiant floor heating allowed the homeowner to maintain the historic appearance of the floor.

Instead of central air conditioning, the homeowner installed ceiling fans and two skylights: one of the skylights could be opened to allow natural ventilation. He also made operable the historically designed transoms above the doors and added more transoms for ventilation.



This single-pane aluminum-framed window was replaced with a soft-coat, low-emissivity wood-framed window (U-0.39, SHGC 0.46). Wood frames are required on windows visible from the street in the historic district.



The pre-rehab roof leaked at its connection with the skylight.

Mechanical Ventilation

With the building envelope more tightly sealed, mechanical ventilation was needed for moisture control and good indoor air quality. To achieve this, CARB recommended upgrading the bathroom exhaust fan to the Panasonic WhisperLite Series fan/light combination, which provides 70 CFM with a sound rating of 0.3 sones.

Lighting

Fluorescent lights last at least seven times longer and consume one-fifth the electricity of incandescent light bulbs. Before the retrofit, the energy-conscious homeowner had already upgraded the lighting to compact fluorescent lighting.

Plumbing and Plumbing Fixtures

CARB followed the water-saving recommendations of the Energy Policy Act of 1992:

- low-flow, air-induced toilets (1.6 gallons per flush or less)
- faucets with low-flow aerators (2.5 gallons per minute or less)
- low-flow showerheads (2.5 gallons per minute or less).

Key Energy-Saving Features

5 inches of polyisocyanurate rigid foam insulation in roof under a highly reflective, ENERGY-STAR qualified, thermoplastic polyolefin single-ply roofing membrane.

Low-e double-pane windows

¾-inch XPS rigid insulation in walls

New high-efficiency Teledyne Laars Endurance boiler for radiant floor heating and domestic hot water

Ceiling fans, openable skylight, restored transoms for natural ventilation

Mechanical ventilation provided by high-efficiency 0.3 sone bath fan for 70 CFM air changes

CFL lighting

Low-flow faucets, showerheads, and toilets

Table 1. Before and After Comparison of Energy-Efficiency Upgrades

Measure	Pre-Retrofit	Post-Retrofit
Roof	Standard flat roof	Highly reflective, ENERGY-STAR qualified, thermoplastic polyolefin single-ply roofing membrane
Roof insulation	R-11 batt in front, R-38 blown in back	5 inches of polyisocyanurate rigid foam insulation under roofing membrane
Space heating	80% AFUE atmospheric gas boiler and radiators	85.5% AFUE sealed vent gas boiler/water heater combo and PEX piped radiant floor heat
Water heating	40-gal atmospheric gas water heater	85.5% AFUE sealed vent gas boiler/water heater combo
Windows	Single-pane, aluminum-framed	Double-pane, low-e wood-frame in front (U-0.30, SHGC 0.46), vinyl-frame in back (U-0.36, SHGC 0.45)
Wall insulation	None	¾-inch XPS rigid insulation (R-3.75) plus extensive caulking and foam sealing of gaps and cracks
Mechanical ventilation	None	Panasonic WhisperLite Series bathroom fan operating at 70 CFM with a sound rating of 0.3 sones
Natural ventilation	Windows	Windows plus ceiling fans, operable transoms over interior doors, openable sky light
Lighting	CFL	CFL
Plumbing	Standard	Low-flow faucets, showerheads, toilets
Energy Savings		46% savings for space heating, 33% savings for hot water heating

The Bottom Line

A whole building approach for retrofits helps ensure that energy-efficient improvements can be made in the most cost effective and efficient manner. For the row house example, modeled results show that the suggested changes could potentially save the homeowner 46% for heating and 33% for hot water over the existing construction. This is a total heating and hot water savings of 43%.

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