The ductwork in this 1970s home is poorly designed and undersized, creating year-round temperature problems. An assessment by the Pacific Northwest National Laboratory found that solving the home's comfort problems will also cut the owners' energy bills by an estimated 40%.

Building America's Deep Energy Retrofit Research Project

Case Study: 1970s Split-Entry Home

Richland, WA

Fixing a poorly designed duct system will help save 40% on energy costs

Maintaining comfort is difficult for the owners of a two-story, split-entry house in Richland, Washington. If the owners heat the cold basement in winter, the upstairs becomes too hot. In summer, the whole house is hot. However, a home energy assessment conducted by researchers from the Pacific Northwest National Laboratory brought good news: The same measures that will make the home comfortable will also cut its energy costs by 40%. The PNNL researchers conducted the work in support of the U.S. Department of Energy's Building America program.

The assessment revealed that the home's ductwork is poorly designed and undersized, restricting air flow and causing temperature problems. Reconfiguring the ductwork and installing more insulation and a new heat pump will save an estimated $720 a year, with a 13-year payback period. In the meantime, the home's comfort problems will be solved.

The Home Energy Assessment

This work is part of Building America's Deep Energy Retrofit Research Project (see Sidebar). Researchers are identifying cost-effective technologies and strategies for reducing energy use in existing homes by more than 30%. When the upgrades are complete, the researchers will measure and analyze the results to develop best practices for deep energy retrofits in a variety of climates.

Building AMERICA® U.S. Department of Energy

An air handler keeps air circulating through the home's duct system. The diameter of the return duct connecting to this air handler is too small for sufficient air flow.

As part of the energy assessment, the Building America researchers conducted a blower door test to measure air leakage and a pressurized duct test to measure duct leakage. They inspected insulation levels throughout the house and examined energy consuming appliances. The researchers entered the data in a computer model and identified the most cost-effective measures for improving the home's energy efficiency.

Problems, Opportunities, and Recommendations

The 1970s Richland home is located in the dry climate of eastern Washington, which has hot summers and cold winters. It has three bedrooms, 1,692 ft^2 of living space, and an attached garage. The upper story has front and back cantilevered floors that create cold spots during the winter.

HVAC upgrades. Duct systems distribute and return heated and cooled air to maintain comfortable temperatures throughout the home. The Richland home's ducts are poorly sealed and insulated. More importantly, the duct system has two major design flaws.

First, the builder used a framed building cavity for return air instead of installing a metal duct. When building cavities are used as return ducts, leaky joints in the building materials can lose conditioned air or pull in outdoor air and harmful pollutants.

The second design flaw is in the duct sizing. Tests show the ducted portion of the return register is too small for the heating and cooling system. This restricts the air supply by 50%. To compensate for the poor airflow, a previous owner installed an additional return duct in the garage. This failed to solve the air flow problem, since it didn't increase the overall diameter of the return duct. Worse, it created health and safety risks by pulling garage air into the duct system. Garage air often contains pollutants, such as carbon monoxide from car exhaust and fumes from paint or solvents stored in the garage. The hot or cold air entering from the garage also increases the load on the air conditioner and furnace.

The Building America researchers recommend reconfiguring, sealing, and insulating the entire duct system. This will not only increase the energy efficiency of the heating, ventilation, and air conditioning (HVAC) system, it will also improve comfort and air quality. According to the researchers' computer models, the recommended ductwork will cost the homeowners $1,000 upfront and save them an estimated $176 annually. In 6 years, the project will pay for itself.

The home's builder avoided installing a metal duct for return air by using this building cavity instead. Worn fiberglass batt insulation can be seen in this close-up of the building cavity. Fiberglass inside a duct may pose a health hazard. Minute shards of glass can be pulled into the airstream and circulated around the house.

The Building America researchers also recommend replacing the air conditioner and the 30-year-old electric furnace with a high-efficiency heat pump. This improvement will provide the biggest savings, cutting their energy bills an estimated 16%, for a savings of $285 per year. However, these energy savings come with a big price tag. New energy-efficient heat pumps typically cost about $7,000. With the low cost of electricity in the Richland area, it will take about 18 years to recoup the upfront cost.

However, if the homeowners choose to buy the heat pump and reconfigure the ducts at the same time, the purchase will be much more cost-effective. The estimated annual savings on their energy bill will jump to $685 per year, much higher than the sum of the separate projects. The reason for the jump is simple. Efficient ducts will reduce the heating and cooling load, so the heat pump will run less often. The homeowners will save enough energy to recoup the cost of the combined projects in 12 years. Meanwhile, their home will have good air quality and comfortable temperatures year-round.

Measure	Estimated Reduction in Energy Bills	Estimated Cost	Estimated Savings	Payback Period
Reconfigure, seal and insulate ducts	10%	$1,000	$176/year	4 years
Install heat pump	16%	$7,000	$285/year	18 years
Reconfigure, seal and insulate ducts and install heat pump *Recommended*	38%	$8,000	$685/year	12 years

Building America's Deep Energy Retrofit Research Project

This assessment is part of Building America's Deep Energy Retrofit Research Project, conducted by the U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL), Oak Ridge National Laboratory, and other research partners. The researchers are coordinating deep energy retrofits for at least 50 residences throughout the United States.

Deep energy retrofits use comp-rehensive, whole-house strategies to reach the highest cost-effective level of energy efficiency. For each home, the Building America researchers identify a package of cost-effective technologies and strategies to reduce energy use by more than 30%.

A deep energy retrofit usually requires an investment of $7,000 to $20,000. Rebates, tax credits and low-interest loans are often available.

Once upgrades are complete, the Building America researchers measure energy savings and improvements in comfort, health, and safety. Analysts will use the data to evaluate the benefits and cost-effectiveness of deep energy retrofits. These analyses will inform the U.S. Department of Energy's best practices for retrofitting homes in climate zones across the country.

A previous owner tried to improve the duct system by installing a second return air duct in the garage. This failed to solve the problem. Worse, it increased the home's energy use and created a safety risk. Garage air that is sucked into the home's ventilation system can carry carbon monoxide from car exhaust and fumes from paint and solvents stored in the garage.

Improving insulation. Attic insulation reduces the amount of unwanted heat transfer through the ceiling. Currently, the attic has about 3 inches of blown-in fiberglass with R-19 batts added on top. Because gaps around the edges of the batts degrade the R-value, the insulation varies from R-9 to R-28. The Building America researchers recommend blowing additional fiberglass insulation on top of the batts to fill in the gaps and increase the total value of the attic insulation to R-60.

The researchers identified other areas of the house needing insulation, including a portion of the basement wall under the stairs and the cantilever under the bedroom floor.

At a cost of $1,200, the additional insulation will increase comfort and reduce the homeowner's energy bills by an estimated 8% annually, with a payback period of just 8 years.

The Bottom Line

The Richland homeowners currently pay $1,772 in energy bills each year. The Deep Energy Retrofit measures recommended by the Building America researchers will cost a combined $9,200, but will reduce the annual energy bill by $720. This 40% savings should allow them to recoup their total investment in 13 years. Meanwhile, they will enjoy a healthier and more comfortable home.

Measure	Estimated Reduction in Energy Bills	Estimated Cost	Estimated Savings	Payback Period
Reconfigure, seal and insulate ducts and install heat pump	38%	$8,000	$685/year	12 years
Add insulation and air seal	8%	$1,200	$151/year	8 years
TOTAL SAVINGS*	40%	$9,200	$720/year	13 years

Total savings is not simply the sum of savings from each measure because the changes are interactive. Actual savings will depend on which measures are implemented, as well as any changes in usage patterns. Costs are calculated with data from the National Residential Efficiency Measures Database, assembled by the U.S. Department of Energy's National Renewable Energy Laboratory. These values are compared to local prices and quotes. Savings are modeled with REMRate software, based on the local electric rate of $0.068/kWh. A simple payback period is used, without adjustments for interest, inflation, or depreciation. Federal tax credits and locally available incentives may reduce the cost of some projects.

For More Information

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