Chapter Two

ENERGY EFFICIENCY AND HOUSING REHABILITATION

There are three basic phases to implementing an energy efficiency program. They include:

- **Phase One.** Develop an understanding of the availability and the relative costs and benefits of energy efficiency measures and strategies;
- **Phase Two.** Select the appropriate measures and strategies; and
- **Phase Three.** Complete the work in an effective manner.

The successful completion of each of these phases is equally important to the overall success of the program. For example, it is pointless to select the appropriate type of insulation for a home if it cannot be properly installed. Often, however, the work done during housing rehabilitation can negate the energy efficiency measures if the housing rehabilitation staff does not coordinate with the energy conservation team. PJs must learn to understand energy efficiency concerns and to integrate the measures into their routine. Similarly, the energy efficiency team must better understand the rehabilitation process, to learn how their work can be performed in tandem with the rehabilitation.

Three of the more important areas where housing rehabilitation and energy conservation work overlap are in thermal envelope improvements, space conditioning equipment, and water heaters. This chapter introduces some common energy efficiency measures for these areas. Readers should be aware, however, that this discussion is general, and that energy conservation measures that are effective in one setting may be less effective in another. An energy-efficient rehabilitation job should begin with an energy audit to identify and prioritize the most effective measures to be used.

THERMAL ENVELOPE IMPROVEMENTS

The shell or thermal envelope of a house shelters its occupants from the exterior weather including sun, wind, rain, and extremes of hot and cold. It is composed of walls, windows, doors, roof and attic, and foundation. From a rehabilitation standpoint, these components of a house must be able to withstand outside forces—for example, the force of the wind and the weight of snow accumulated on the roof. They must also create an impenetrable shelter from the rain. From the energy efficiency perspective, there are two additional concerns—the air tightness of the envelope and the thermal resistance of the envelope to heat gains and losses.

Air Leakage

Wherever the components of the thermal envelope meet, a crack or potential air leak exists. Air leakage from cracks and gaps in a house's thermal envelope accounts for approximately one-third of its energy losses. Although some gaps are intentionally placed in the envelope—such as windows, utility openings, etc.— they normally are sealed with caulk, weatherstripping, or some other material to prevent unintended air leakage. Untreated openings, structural bypasses, or structural damage permit the exchange of conditioned and unconditioned air, letting heat escape uncontrollably from the thermal envelope.

Air exchange can occur through infiltration or exfiltration. Infiltration refers to unconditioned air entering conditioned space through cracks in the thermal envelope. Wind-driven air currents (i.e., indoor/outdoor air pressure differences) cause infiltration, as do pressure differences between a conditioned area (e.g., a bedroom) and an unconditioned area (e.g., an attic overhead). Exfiltration refers to conditioned air entering an unconditioned area.

The housing rehabilitation's goal should be to create a thermal envelope that is sufficiently airtight to minimize the exchange of conditioned and unconditioned air without sacrificing ventilation rates.[11] A structurally sound housing unit, with properly installed utility connections, will have a relatively tight thermal envelope and a reasonable standard ventilation that is appropriate to the size and occupancy of the structure. The rehabilitation staff should identify cracks—using a blower door—in order to seal these unintentional openings (see Appendix B, Glossary).

Thermal Resistance of the Envelope to Heat Losses and Gains

The thermal envelope has several different components. Each component provides some resistance to heat transfer. The walls and attic typically have some degree of insulation installed. The windows, doors, and foundation are more likely to be constructed of a single homogeneous material that offers minimal insulating value.

Depending on climatic and structural conditions, up to one-third of the heat loss in a home may be attributed to the walls and attic, with another third attributed to the windows. Because doors and foundations have small surfaces compared with the surface area of an entire house—and are thus of relatively lesser importance to the overall performance of the thermal envelope—the following discussion focuses on the two most important components of the envelope—the level of insulation in walls and attics and the thermal resistance of windows.

Wall and Attic Insulation

Even a home with a tight thermal envelope may benefit from insulation to further retard the flow of heat into or out of the unit. Insulation is rated using an R-value—the value to which it resists heat flow. The higher the R-value, the more it prevents heat transfer. For typical wall and roof construction, each component contributes to the overall R-value, but the insulation material provides most of the insulating value.

The construction manager should decide whether additional insulation is cost-effective, which type to use, and where it should be applied. Two important factors limit the thickness of insulation used. The first factor is physical space. Walls are typically constructed with 2 x 4 studs, which provide limited space for insulation, but attics often provide unlimited room for additional insulation.

The second factor is the cost-effectiveness of additional insulation. An increase in R-value from R-10 to R-20 will yield a 50 percent reduction in heat loss. An increase from R-30 to R-40 will, however, yield only a 25 percent reduction in heat loss. Because both of these examples involve the installation of an additional R-10 (approximately 3 inches) of insulation, the cost for each case is identical. The cost-benefit ratio is only half as high in the second case, however, demonstrating that additional insulation is not always cost-effective.

The construction manager should examine different areas of the house for the presence and quality of insulation. If the work crew plans on doing roofing work, the manager should be sure to schedule the installation of attic insulation after that work is completed. The manager must also be sure that rain or snow does not penetrate the roof during the work, because water will damage existing insulation (see sidebar). If the basement is not used as a living area, the walls do not need insulation. Additionally, the ceiling/floor between the basement and the rest of the house should be insulated to prevent heat loss, and the heater should be wrapped in insulation as well. If the basement is part of the living area, the walls must be insulated as part of the thermal envelope. In either case, crawl spaces should be insulated to stop the formation of convective loops (internal movements of air that draw heat from intentionally conditioned air into intentionally unconditioned spaces).

If wall insulation is added to the structure, the housing rehabilitation contractor and the insulation contractor must coordinate their work. The installation of wall insulation is easier if the housing contractor plans to remove and replace the drywall. If the contractor installs the wall insulation by blowing it into the walls through small holes drilled from either the inside or

Moisture is a major concern with insulation, particularly in attics during the winter. Increased insulation causes a reduction in the attic temperature. If high levels of warm moist air are leaking in from the conditioned space into the attic, this moisture likely will condense either in the insulation, or on the attic roof and drip back down into the insulation. Wet insulation is almost totally ineffective and will eventually cause structural damage.

The first step to minimize a moisture problem is to seal tightly all cracks and openings between the conditioned space below and the attic above. Additional steps, if necessary, may include placing a continuous (unbroken) vapor barrier on the warm side of the insulation (below the insulation in cold climates), and providing adequate levels of attic ventilation. This third step often means providing larger ventilation grills, or attic fans to ensure proper ventilation rates. These additional costs should be considered as part of a cost-effectiveness analysis.

outside surface, there must be a continuous (unbroken) vapor barrier on the warm side of the insulation (inside surface in cold climates) to prevent moisture damage. Blown-in insulation should be avoided when no vapor barrier exists. If the work crew cannot open the walls to install a vapor retarder, the only way to provide one is to apply high-cost permanent paint to the wall surface, and neither option may be cost-effective. Finally, the insulation contractor should check carefully for framing details that will block the insulation from completely filling the wall.

Windows

Windows typically have R-values that are less than one-tenth of the R-value of the exterior walls. Thus, windows—especially older ones—are highly inefficient at preventing heat loss. New improvements in window unit design have made them better in three ways:

- Tighter construction—less air leakage;
- Greatly improved R-values; and
- Innovative solar control features.

Unfortunately, windows are typically very expensive to replace. If a house has very poor windows (e.g., broken or leaky), the potential improvements in energy efficiency may form a strong basis for deciding to replace the window units (i.e., including frames). By current standards, storm windows, although commonly used in the past, are relatively inefficient thermal barriers.[12] Thus, when rehabilitation staff consider window improvements, they should recognize that new double- and triple-window units are both more durable and far more thermally effective at reducing winter energy losses and summer heat gains than storm windows or less-expensive units. Early retirement of window units can be a cost-effective means of integrating rehabilitation goals and energy efficiency concerns.

SPACE CONDITIONING EQUIPMENT

The majority of the energy consumed in a house is used for space conditioning. The heating and cooling equipment together account for more than two-thirds of the energy requirements of a typical house. The proportionate need for heating primarily depends on the climate. Nonetheless, significant opportunities to reduce energy costs exist through the use and proper maintenance of high-efficiency heating appliances.

Rehabilitation and energy efficiency staff share a number of concerns when assessing the need for a furnace replacement, including: age and condition of equipment; existing type and availability of fuel; condition of ducts and pipes; and system operation and maintenance.

Age and Condition of Equipment

With regard to age, residential furnace systems have an "expected" life of 20 to 30 years depending on the type (e.g., forced air or hydronic). A well-maintained unit will last longer, but a poorly maintained unit will last considerably less than its expected life. Early retirements of functioning but old and poorly maintained equipment can be a highly cost-effective method of improving the energy efficiency of houses. Thus, a furnace that is about 15 to 20 years old and has not been well maintained has probably reached the end of its useful life and should be replaced with a more efficient unit.

The rehabilitation/energy efficiency team must determine the type and size of unit to use to maximize cost-effectiveness and efficiency. Sizing must be based on the condition of the thermal envelope and the size of the structure. Sizing specifications have been developed by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE). These specifications are fairly complex, and the rehabilitation staff should confer with energy-efficiency specialists to determine the appropriate size unit.

Existing Type and Availability of Fuel

The selection of system type must be based on the cost and availability of different energy sources, as well as the structural condition of the house. Generally, the lower the cost of the energy, the more desirable the system (see sidebar). For example, although electric heat is highly efficient and easily available, it should be avoided nonetheless, because of the higher cost of electricity relative to other fuels. On a per-unit-of-heat-provided basis, electric heat is often more than double the cost of gas or oil heat.[13] Converting homes from electric heat to gas or oil heat is not always possible, however, because these other fuels may not be available locally.

> **Heating equipment efficiency is an important factor to consider in determining whether to replace a furnace and the type of system that it should be replaced with. The efficiency of heating equipment is the ratio of energy produced to energy consumed. Older gas- and oil-fired furnaces have seasonal efficiencies of less than 70 percent, while new furnaces have efficiencies as high as 85 to 90 percent. Electric baseboard heaters have an efficiency of effectively 100 percent, and heat pumps have an efficiency of 100 to 200 percent, depending on climate.**

Condition of Ducts and Pipes

A final consideration for furnace replacement and repair is the need to minimize duct leakage. Installations are rarely tested, and as a result, excessive duct leakage is commonplace. Duct leakage can result in significant and unnecessary increases in energy use. Moreover, the heating, ventilating, and air conditioning (HVAC) system must be maintained and operated safely. An improperly vented furnace can create a deadly buildup of carbon monoxide gas. The work crew should ensure proper venting to prevent backdrafting or leakage of carbon monoxide into the house. Most heating service contractors can test the furnace for both efficiency of combustion (availability of combustion air) and exhaust leakage into living spaces. The contractor or work crew should perform diagnostic testing (such as pressurizing the ducts) to detect leakage. Leaks should be repaired, and all joints should be securely connected using a mastic (a sealing material for ductwork). In addition, all ductwork running through or into unconditioned areas should be insulated to prevent unintended heat transfer.

System Operation and Maintenance

In situations where the work crew has replaced one type of heating system with another, it is important to ensure that the household has a clear understanding of the operation and maintenance requirements of the new system. First, the homeowner should understand how to turn the system on and off and how to establish a fuel contract (e.g., for home heating oil). Second, the homeowner should understand how to minimize thermal loads in various parts of the house, and how to regulate the air flow to each part of the house to maintain comfortable conditions. (For example, if the house is unoccupied in the daytime, the thermostat should be turned down by 10 to 15 degrees to reduce energy use and costs.) With the awareness of how energy is being used wastefully, homeowners have the opportunity to choose to use less.

Finally, the program staff should instruct the homeowner on proper maintenance procedures and schedules to maintain consistent levels of energy efficiency over the life of the furnace. The homeowner does not need to perform major maintenance tasks, and can choose to purchase a service contract with an HVAC contractor or fuel company; however, the homeowner must be taught that routine maintenance is critical to the long-term health of the equipment. For example, in an air heating or cooling system, the homeowner should ensure that the filters are changed frequently (once a month, if possible) to prevent dirt from clogging the heat exchanger coils. The burner components in a gas- or oil-fired furnace should be tuned annually by a licensed professional to ensure efficient combustion of the fuel (i.e., a proper fuel to air ratio). Proper system maintenance will increase energy efficiency and reduce heating costs.

Water Heaters

The last item of concern is the condition of the water heater. The work crew should determine, first, whether the water temperature is adequate for the residents' needs; whether the flow of hot water out of the tap is adequate; and whether the supply of hot water is sufficient for the household's needs. If the answer to any of these questions is no, the work crew should examine the water heater to ensure the following:

- The water heater and pipes are in good condition—there is no evidence of leaks and the heater is no more than 15 years old (most water heaters last for 10 and 15 years);
- The water heater and pipes are insulated to prevent heat loss. If the water heater tank is warm to the touch, it is losing heat. The first 3 feet of all pipes exiting the tank should be insulated, as well as exposed hot-water supply lines running through unheated spaces; and
- The thermostat is set between 120°F and 140°F. Many water heater thermostats are preset to between 140°F and 160°F. 120°F is usually sufficient for most households' needs, and this lower setting can reduce the water heating bill by as much as 16 percent.

In addition, check plumbing fixtures in bathrooms and kitchens to ensure:

- Low-flow showerheads are installed where possible. The use of low-flow showerheads can reduce per-minute hot water usage for showers by up to one-third; and
- No leaking faucets are wasting hot water.

If the work crew wants to replace the water heater—because it is past its useful life or is too small to accommodate the household's needs—the crew should ensure that they have found the most efficient water heater that the budget can handle. In general, it is best to replace all types of heaters—storage tank, tankless, or instantaneous (demand) systems—with an appropriate-sized storage tank system. In addition, electric heat-pump water heaters are often the most efficient given budget limitations. (Water heaters come with Energy Guide labels providing information for use in calculating cost-efficiency.)

SELECTING THE APPROPRIATE MEASURES AND STRATEGIES

The discussion so far has been fairly general. Because each home that the housing specialist examines will have different rehabilitation and energy conservation needs, solutions to energy problems must be site-specific. Although some of these needs will overlap, others are specific to one program or the other. For example, replacement of a broken window could be performed by either a housing work crew or an energy work crew. Selection and installation of an energy-efficient heating system, however, may be a more appropriate job for the energy work crew. PJs with little experience in identifying the energy needs of rehabilitation projects may want to contract local weatherization programs or utility companies for an energy audit. An energy audit is a step-by-step analysis of a building's energy consumption. Energy auditors generally begin by interviewing the homeowner or building owner and reviewing past fuel bills and maintenance measures. They then inspect the entire unit, examining the heating and cooling systems, structural condition, building construction features and materials, and condition of (or lack of) weatherstripping, caulk, and insulation. PJs with greater familiarity with energy-efficient housing rehabilitation may undertake the energy audits themselves. (For some testing, such as the blower door test, the housing program still may need to contract with an experienced WAP or energy technician.)

The result of the housing inspection and energy audit should be a tabulation of the repairs that *must* be done (to meet HQS and, as applicable, CEECS) and the repairs that are optional, but would further increase energy efficiency. Many of the energy-related repairs may be directly related to the general rehabilitation performed to bring the unit up to HQS, such as roof and structural repair or replacement.

Following the energy audit, a three-step approach is typically used to identify the measures that will achieve the greatest savings for the investment. The first step is to identify general "opportunities" for improvement. Opportunities are the basic aspects of a building that are most deficient (e.g., windows, walls, roof, etc.), or those that will have the greatest payback (i.e., are most cost-effective). For example, a home that has numerous broken windows may have "windows" as its greatest improvement opportunity.

The second step is to identify specific "strategies" for each opportunity that can be addressed cost-effectively. Strategies are general approaches to remedy a given deficiency (or opportunity). For example, if a major opportunity is "windows," alternative strategies include: window repair; window replacement—same size; window replacement—size reduction; and window replacement—size enlargement. At this point, the strategies are still somewhat imprecise.

Once an appropriate strategy is identified for a given opportunity, specific measures for implementing the strategy can be identified and assessed. The identification and assessment of measures for each strategy constitutes the third and final step in the process. From the example above, if window size reduction is the desirable strategy, several alternative materials can be used to achieve the desired result—single-pane windows; double-pane windows; double-pane windows with low E glass; double-pane windows with tinted glass; or double-pane windows with argon glass.

At this level of detail, costs and energy savings benefits can be assessed. For example, if the installation of double-pane windows with argon glass will cost $300 but save $500 in current dollars in heating costs over the lifetime of the unit, the installation is cost-effective, but if it will cost $600 and save $500 in heating costs, it is not cost-effective. (See Appendix A for a more detailed discussion of cost-effectiveness.)

At each step in the process of selecting the appropriate energy efficiency measure, decisions must be made related to the overall building condition and project goals. Each of these decisions must be based on an integrated rehabilitation and energy efficiency perspective.

A FINAL WORD

In general, the work performed to promote energy efficiency can be effectively integrated with housing rehabilitation work. To effect this, however, all members of the construction team (i.e., rehabilitation specialists, energy specialists, construction manager, contractors, inspectors, etc.) involved in a project must coordinate their tasks and schedules. At each stage of the project, the construction manager is responsible for ensuring that the energy efficiency measures are not being undermined by poor rehabilitation techniques. At repeated points in the rehabilitation work—window replacement, electrical receptacle box installation, drywall, and roofing—abundant opportunities exist to improve energy efficiency and lower costs. Effective integration of rehabilitation and energy efficiency can be accomplished in a single effort—if both programs do it right!