

# Strategies for Energy-Efficient Remodeling: SEER 2003 Case Study Report

February 27, 2003—October 31, 2004



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# DEFINITIONS

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<b>ACH</b>	air changes per hour
<b>DOE</b>	US Department of Energy
<b>LOW-E</b>	low emissivity
<b>NAHBRC</b>	NAHB Research Center
<b>NJCEP</b>	New Jersey Clean Energy Program
<b>NREL</b>	National Renewable Energy Laboratory
<b>PV</b>	photovoltaic
<b>ROI</b>	return on investment
<b>SEER</b>	Strategies for Energy Efficiency in Remodeling

# INTRODUCTION

The goal of the Strategies for Energy Efficiency in Remodeling (SEER)<sup>1</sup> project is to provide information, based on research and case studies, to remodelers and consumers about opportunities to increase home energy performance. Opportunities to include energy efficiency often arise while undertaking general remodeling work. Of course, energy efficiency may always be pursued as a remodeling project unto itself to improve the comfort of the home and reduce monthly utility bills. A case study in the mid-Atlantic region was



*The "gut rehab" one year later*



*The site of the "gut rehab"*

undertaken to develop and test the application of energy efficiency strategies, to evaluate the benefits, and to identify any weaknesses in their design or application. Taken together as a system, the strategies provide opportunities for energy and cost savings, increased durability, and in-

creased comfort of the remodeled home.

This case study report examines the technologies, methods and installation of specific energy efficiency strategies. The information presented here stems from a "gut rehab" of a house in rural New Jersey as part of the SEER project through the Building America Existing Buildings Program<sup>2</sup>. A "gut rehab" project allows for consideration of a wide range of energy efficiency strategies and, accordingly, is a good basis of this initial effort. As other remodeling projects are

undertaken the knowledge base will expand and become more complete. The evaluation of this extensive rehab project provides many details of energy efficiency strategies that will lead to energy savings and can be implemented by remodelers and consumers over months or years.

<sup>1</sup> The SEER project was developed by the NAHB Research Center (NAHBRC) as part of the DOE Existing Buildings Program under the Building America umbrella.

<sup>2</sup> The Building America program is sponsored by the Department of Energy (DOE) through the National Renewable Energy Laboratory (NREL).



## THE FIRST SEER PROJECT – A CASE STUDY IN ALL OR NOTHING

The gut rehab project developed by remodeler Mr. Bill Asdal is detailed in his summary in the addendum and clearly demonstrates a remodeling “all-or-nothing” approach. The remodeler’s choice of the full renovation of a home that would otherwise be destined for the landfill provides an opportunity to demonstrate the extent to which existing housing can be made comfortable and energy efficient – while remaining cognizant of the costs. The remodeler selected to fully renovate the home and in so doing salvaged a building for continued useful life. The SEER project provided technical services to focus on the energy efficiency aspects of the remodel and in so doing is estimated to decrease the heating and cooling energy consumption by about 60%.

The first case study remodel project was part of a larger renovation project to completely rehab two homes and a barn on a section of farmland in west-central New Jersey. The smaller of the homes, referred to as the cottage house, is 1,400 square feet and has been unoccupied for 10 years. The home, shown above, was

uninhabitable when purchased. Many of the energy efficiency concepts applied to the cottage are also being implemented in the larger 4,000-square-foot home (which will serve as a Bed & Breakfast). The cottage house will serve as the case study home to demonstrate strategies for an energy efficiency remodel.



*The main house on the same property*

# SYSTEMS ENGINEERING APPLIED TO ENERGY EFFICIENCY RETROFIT – CHALLENGES AND CHOICES

The Building America model for a systems engineering approach states that new homes “can be cost effective to build as well as energy efficient to live in. In fact, the energy consumption of new houses can be reduced by as much as 50% with little or no impact on the cost of construction through a systems engineering approach.”<sup>3</sup> This theory is practiced through use of new building materials and systems as well as designs that can be serviced by smaller heating and cooling systems than used in typical designs. Through the process often termed “value engineering,” any increased costs in one area of construction (e.g., insulation) can be offset by savings in another area (e.g., downsized furnace).

However, existing homes present a larger challenge to implementing a systems approach to energy efficiency. Because remodeling jobs typically involve fewer systems (e.g., wall, window, mechanical systems) than new construction, it is more difficult to make value-engineering tradeoffs. In addition, since remodeling jobs often involve a limited budget, it is typically more expensive to retrofit energy efficiency solutions than it is to include them in new construction.

Still, a systems approach to energy efficiency remodeling can create not only opportunities for energy savings, but also improvements in durability and comfort. For example, existing homes may present more opportunities for the

***Throughout the design and construction process, the systems engineering approach considers the interaction between the building site, envelope, and mechanical systems, as well as other factors. It recognizes that features of one component in the house can greatly affect others and it enables the teams to incorporate energy-saving strategies at no extra cost. System trade-offs, like the tightened shell that enables an engineer to recommend a smaller HVAC system, can improve the quality and performance of a home without affecting its costs—to the builders or to the consumers.***

*Building America Program, Systems Engineering Research*

selection of energy efficiency upgrades since efficiency can often be included with other work being performed. One benefit to including energy efficiency in existing homes is that, often, people undertake extensive renovations with the intention of staying in the home for a long time. Therefore, savings from energy efficiency details become an investment from which they are likely to reap benefits. In addition, a major advantage is the opportunity to improve comfort, especially if the consumer has direct experience with uncomfortable conditions in the home.

Unlike new construction where energy efficiency upgrades can directly reduce costs in other areas, the existing home market will

have far fewer opportunities to directly reduce costs through construction tradeoffs except for gut rehabs and, possibly, attic/basement conversions and additions. Otherwise, the home already has selected framing, insulation, and heating and cooling equipment installed. In these cases, the remodeling work may focus on increasing the efficiency of a particular building system as it is being remodeled, or in some cases as additional work along with the general remodeling effort.

<sup>3</sup> Information on the Building America program’s System Engineering approach can be found at [http://www.eere.energy.gov/buildings/building\\_america/system.shtml](http://www.eere.energy.gov/buildings/building_america/system.shtml).

## BENEFITS TO HOME REMODELING PROJECTS THAT INCLUDE ENERGY EFFICIENCY STRATEGIES

Many homes constructed 30 or more years ago have little or no insulation in the walls and roof, single-pane windows that allow large amounts of air and heat loss, and inefficient (by today's standards) hot water systems, space conditioning equipment, lighting, and appliances. All of these factors result in large amounts of wasted energy and higher than necessary utility bills. While lowering monthly utility expenses is often a prime motivation for improving a home's energy efficiency, there are numerous other benefits to improving energy efficiency that are not as often considered. These benefits include the following:

- **Comfort**

Leaky and poorly insulated older homes often feel uncomfortable due to cold wall temperatures and drafts from windows. To accommodate, many homeowners turn up the thermostat in the winter. In summer, these homes are often subjected to large solar gains and high levels of humidity (from the outdoors), causing the homeowner to turn the thermostat down. When thermostats are turned up (or down), in addition to the additional energy required for heating and cooling the space, there is an associated increase in wasted energy through duct or hydronic system losses. In addition, drafty windows, cold wall surfaces, and poor duct

design often result in large temperature variations between rooms.

- **Durability**

Older, inefficient homes are often subjected to large indoor swings in temperature and humidity, causing wall and ceiling materials to swell and shrink and reducing durability of materials, paints, and caulk. In addition, to accommodate the high-energy needs of an inefficient home, mechanical equipment may operate frequently and for longer periods causing excess wear and tear. Attention to energy efficiency details can mitigate some durability problems, including those from moisture and unwanted air infiltration.

- **Environmental Performance**

While quantifying the value of the environmental benefits of energy efficiency upgrades is often difficult, the qualitative values are readily apparent. Benefits such as reduced energy use ultimately result in less air pollution and a slower rate of natural resources depletion. Some efficiency products use recycled materials, such as cellulose insulation. Many new air-conditioning systems use a refrigerant that is not harmful to the ozone layer. In addition, the systems approach to efficiency, comfort, and durability can make the existing space sufficiently comfortable and durable to extend the life of the home itself.

- **Affordability**

Energy efficiency upgrades have often been evaluated in relation to the monthly cost of ownership. Light bulbs are a good example where the highly efficient fluorescent bulbs are compared to the higher energy and replacement costs of incandescent bulbs, resulting in a relatively short payback period. Although the cost of energy efficiency upgrades raises the total remodeling project cost, monthly utility savings are measurable and continue throughout the life of the home – eventually resulting in a payback on the initial investment.

Although some remodeling elements could be argued as a recouped investment when one considers the resale market value of the home (e.g., kitchen and bath upgrades), most remodeling projects do not recoup their total investment. In addition, most new products used in the remodeling will age and depreciate. Improving energy efficiency is the one remodeling element that as an investment will have a continued annual return regardless of the resale market value.

# STRATEGIES FOR ENERGY EFFICIENCY IN REMODELING

Although any one strategy to enhance the energy efficiency of the home may be performed independently of the others, this case study combines many different strategies into a system that works together to achieve the goal of at least 30% energy savings. The strategy list evaluates each energy efficiency feature, comparing the “typical” approach with the “SEER” approach, to enhance the energy performance of the home. The overall energy efficiency features that were considered in the case study include the following:

- Insulation
- Windows and doors
- Air sealing
- Heating and cooling equipment
- Water heating system
- Lighting and Appliances
- Additions
- Renewable energy systems.

Each feature has within it strategies to achieve the goals of reduced energy consumption, increased comfort and durability, and if possible, energy production from renewable sources. An examination of specific strategies shows the effectiveness of incorporating these strategies into a remodeling project.

## 5.1 WALL INSULATION SYSTEM

The home originally had no insulation in the walls. Framed with full 2x4 construction, the wood siding on the outside and interior 1x6 sheathing provided the wall structure

that stood for more than 100 years. Since the home was unoccupied for almost 10 years, a prime goal was to remove the deteriorated siding and replace it with sheathing and house-wrap to protect the home’s interior during construction. This effectively left the exterior wall system with coverings on both sides of the framing. This condition made use of batt insulation materials nearly impossible. In addition, the irregular framing dimensions, including depth, meant that batt products would have an irregular fit.<sup>4</sup>

Based on the existing wall conditions, two wall cavity insulation choices became clear – the use of blown insulation materials such as fiberglass, cellulose and rockwool, or use of a foam-in-place insulation. Blown or 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. The blown or foamed insulation products 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 since the siding was being replaced. In older homes, the framing material accounts for more of the wall area than new homes today, so use of an exterior insulation can add a large benefit to the overall R-value of the wall system.

Typical products include sheet foam board of various thicknesses. However, another approach is to use products that combines the siding materials with the insulation.

### 5.1.1 WALL INSULATION – SEER CASE STUDY

The approach taken in the SEER case study was based on the wall conditions that were

- covered on both the interior and exterior of the framing
- constructed of rough cut, irregular framing members
- typical of large framing-to-cavity ratio (i.e., large amounts of framing).

Based on the wall structural assessment, the following wall insulation options were selected:

- Use blown or foamed insulation in the wall cavities
- Use sheet insulation under the siding.

The two most common options for insulating existing wall cavities with coverings on both the exterior and interior of the framing are spray foam and blown fibrous insulations, such as fiberglass and mineral wool, or blown loose-fill insulation, such as cellulose<sup>5</sup>. **Blown cellulose** was selected for this case study based on the following criteria:

- The much higher installed cost of foamed-in-place insulation<sup>6</sup>

<sup>4</sup> However, the irregular fit could be overcome with careful attention to batt installation details.

<sup>5</sup> Other blown insulation materials are manufactured but much less common and available.

<sup>6</sup> Based on estimates received by the remodeler.



- The capability of dense-pack cellulose to significantly decrease infiltration losses
- The availability of contractors and equipment to install blown insulation
- The ready availability of the material.

The estimated installation costs<sup>7</sup> for blown cellulose insulation is approximately \$0.43/sf with an additional \$1.74/sf to drill holes for blowing access. The total installed costs then for installed blown cellulose insulation is about \$2.17/sf of insulated wall area. Further, the estimated installed cost of the wall insulation of the case study house



**Blown cellulose insulation**



**Insulation blown into wall cavities**

with 1338 sf of retrofitted insulated wall area is \$2,900.

In addition to the insulation in the wall cavity, insulated sheathing was selected for application to the exterior of the framing. This is advantageous since in many older

homes large portions of the wall are wood members providing an R-value<sup>8</sup> of about 4. Compared with the insulated cavity of about R-14, this represents a large portion of the wall with an R-value of only about one-

third of the cavity. To mitigate some of these framing effects, rigid insulation is used under the siding. Two choices are available: board insulation applied over the framing (or existing wood sheathing) or insulated siding. In the case study, insulated vinyl siding was selected.

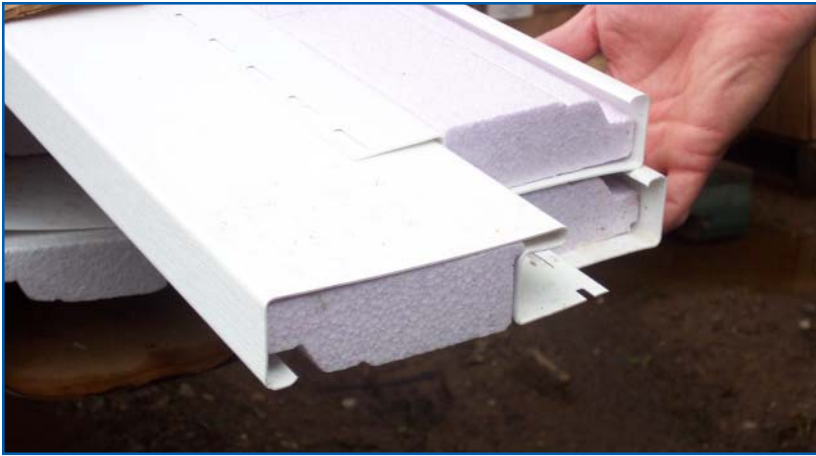
Features of the insulated vinyl siding<sup>9</sup> include a coverage of 19" vertical per horizontal run (standard vinyl at 7.5" to 10") and an insulated core of expanded polystyrene. The R-value as a tested system from the manufacturer data is R-4. A comparison of the cost of installing insulated vinyl siding with standard vinyl siding over a rigid foam board is shown in Table 1.

<sup>7</sup> Cost data primarily from RSMeans, 2004 with "Location Factors" applied.

<sup>8</sup> All R-value units in "F-hr-ft<sup>2</sup>/Btu.

<sup>9</sup> The insulated vinyl siding CraneBoard, is manufactured by Crane Performance Siding.





*Insulated siding trim*

Based on the cost estimates and primarily the labor savings with a larger coverage area, there is virtually no difference between the installed costs of each system. The cost of installing the board insulation to provide a thermal break for the framing adds approximately \$970, but with the selection of the insulated vinyl siding, the additional cost is about \$900.



*Insulated siding*

**Table 1 – Insulated Siding Cost Comparison**

<b>All values are normalized to a 100 square foot basis.            Cost estimates based on interviews or cost estimate tables.</b>	
Cost of standard 9" or 10" siding	\$60
Labor to install	\$81
¾" foam sheathing (~ R4)	\$26
Labor to install sheathing	\$22
<b>Total for vinyl siding over R4 rigid insulation</b>	<b>\$189 per 100 sf</b>
Cost of integrated insulated siding (R4)	\$132
Labor to install (40% faster)	\$49
<b>Total for R4 integrated siding</b>	<b>\$181 per 100 sf</b>

## 5.2 CEILING INSULATION SYSTEM

As with the wall system, there was no insulation in the ceiling or attic of the existing home. Similar choices of insulating materials is available for the ceiling or attic space, with blown, foamed or batt insulation products being applicable and easily installed.

Blown or foamed insulation products are often used in ceiling spaces following the installation of the ceiling covering. These products can be installed to various thicknesses depending on the level of insulation required. The blown insulation products can also be installed over any existing insulation.

Cathedral ceilings, however, pose more challenge to the blown insulation products since netting would be necessary to hold the insulation between the rafters. If the ceiling covering is in place, a similar installation method as existing walls can be used. Foam insulation products can be used easily in the rafter space since it can be applied directly to the underside of the sheathing and in various thicknesses.

An important issue to consider is the air space between the insulation and the sheathing. An air space under the sheathing is often required per the building code or shingle manufacturers. If vented soffit is used, the roof ventilation should extend to the ridge vent. In any case, sealing of air leakage into the attic (or rafter space if insulated) should be provided.

### 5.2.1 CEILING INSULATION – SEER CASE STUDY

Since the walls are being blown with cellulose insulation, the same material was selected for the ceiling of the existing home. Based on the installation of a nominal R-19 in the exposed attic floor, the cost for installing fiberglass batt insulation and cellulose is virtually identical. Other benefits such as air sealing favor the installation of blown cellulose insulation over batt products in some locations. The estimated cost for installing blown cellulose insulation in the existing home ceiling is approximately \$0.62/sf for an R-19 coverage (compared with \$0.67/sf for batt insulation). The cost for insulating the 560 sf existing ceiling with fiberglass batts is about \$375.

For the case study, however, the recommended R-value for the ceiling in this cold climate is R-38. Based on cost estimates, the cost of installing cellulose insulation in the case study ceiling is about \$672. The additional cost for the case study home is approximately \$297 to increase the ceiling insulation to R-38 over R-19.

## 5.3 BASEMENT OR FLOOR INSULATION SYSTEM

Many remodeling projects involve basement or crawl spaces that were originally uninsulated, as is true for this case study. Though constructed with a basement, the foundation space was and will continue to be unconditioned. Isolating the unconditioned basement space from the conditioned house was achieved simply by insulating the floor joist space. The most common insulation method for the floor joist space is batt insulation, using unfaced batts. However, this is also an excellent location for spray-applied foam insulation products, especially those with a low permeability.



*Floor insulation between joists*

For unconditioned basements and some crawl spaces, addition of wall insulation over the above-grade section of walls can help to temper the basement temperature. Rigid foam insulation attached by vertical glue beads is a simple method of installing the foam board. Check with local building codes for any requirements for installing foam in unconditioned basements and crawlspaces.

### 5.3.1 BASEMENT OR FLOOR INSULATION – SEER CASE STUDY

For the case study home, where the basement is potentially subject to regular damp conditions, the floor was chosen for insulation rather than the basement walls. The floor insulation options include blown or foamed insulation and batt insulation. In this location, use of batt insulation is preferable due to the higher cost of installing blown or foamed insulation products. The typical insulation level required for this location would be at least R-19. Use of R-30 is preferable if the floor joists are nominal 2x10's as is the case with the case study house. The additional cost of upgrading the floor insulation from the minimum R-19 to R-30 is approximately \$328.

## 5.4 WINDOWS AND DOORS

The use of energy efficient windows and doors in the remodeling effort is very similar to that of new homes –

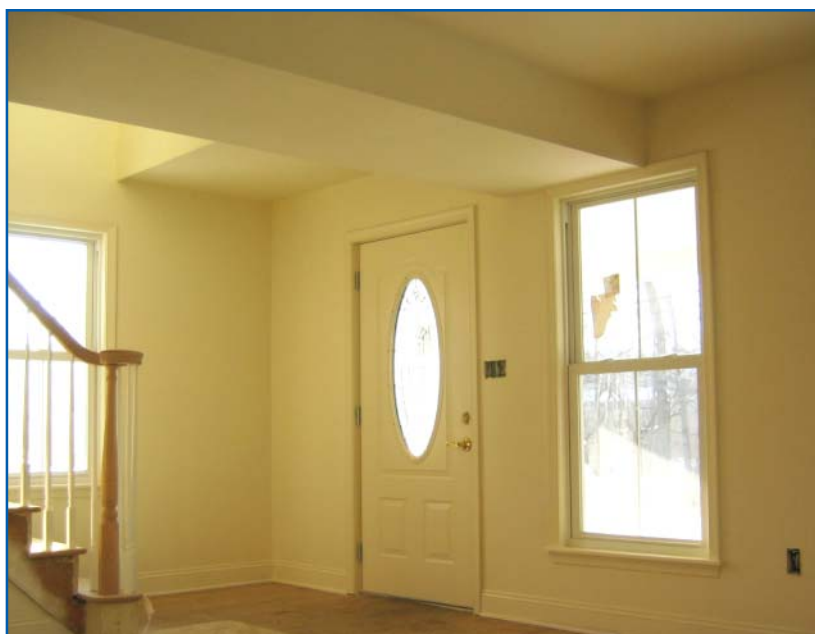
with the primary limitation to their use being simply the knowledge of available products. Information concerning appropriate windows for a given climate is easily available on the Internet and through window manufacturers. Use of low-e coatings, an energy benefit in most all climates, is commonplace for window glass yet must still be specifically requested in many locations, as is the addition of an inert gas for the space between the panes. Both the low-e and gas-fill options for windows will significantly increase the efficiency of the window while increasing the comfort of the room.

Similarly, doors have a range of energy efficiency performance, but the energy efficiency ratings are more difficult to identify directly on the product. A minimal amount of research will

identify doors with a better insulating value than another. Foam-core doors with little glazing will have the best energy performance.

### 5.4.1 WINDOWS AND DOORS – SEER CASE STUDY

The additional cost of selecting energy efficiency features for the windows varies significantly between manufacturers. Generally, the added cost of low-E coatings and gas fill ranges from a low of a few dollars per window to nearly \$100. But many manufacturers offer an energy efficient option that includes low-e coatings or a combination of low-e coatings and gas fill, for their windows at a cost of about \$2/sf of window area. For the case study house with 196 sf of windows then, the additional cost for energy efficient windows is about \$400.



*Energy efficiency windows and door in cottage*

## 5.5 AIR SEALING

Air sealing to prevent energy losses due to infiltration is an important part of the overall energy performance of the home, new or remodeled. Though this strategy is not specifically addressed in current building codes, significant improvement in energy savings and comfort can be achieved through simple and inexpensive techniques. Any place where air can leak from inside the conditioned area to other areas, including unconditioned basements, crawlspaces, attics, garages, etc., are points where energy is lost to the outdoors. Air sealing can be done whenever any part of the home is being remodeled, or on its own, to simply increase the efficiency and comfort of the home.

Many options are available to the remodeler when air sealing homes. Foams, insulations, caulks, gaskets, and sheet goods are all products suitable for achieving the goal of lowering infiltration losses in the home. Ideally, multiple strategies should be implemented during the construction phase. This will better ensure adequate sealing is achieved.

In choosing methods for the case study, preference was given to inexpensive solutions that could be executed during multiple phases of the remodeling process. A primary concern to the team was to reduce the migration of moisture-laden air from the

foundation areas and outdoors into the thermal envelop.

### 5.5.1 AIR SEALING – SEER CASE STUDY

For this “gut” remodel project, the air sealing effort is fairly extensive. Since the house was framed nearly 100 years ago, there are ample opportunities to fill gaps and holes where the

- framing adjoins block or stone
- top plate and ceiling joists intersect
- window and door rough openings are framed and irregular
- wires and pipes pass through to the attic, basement, and walls
- interior stairway exists to the basement.

Several trades were utilized during the remodeling phases

to achieve sealing of the building. These included a professional air-sealing consultant, the insulation contractor, the drywall contractor, and the remodeler’s own crew. The following techniques were utilized for the project:

- Exterior plywood sheathing was glued to framing
- Window frames were caulked to the framing
- Wallboard was glued to framing
- Sill seam and band joist areas were foamed
- Floor and wall penetrations (including at stairway) were foamed.

Though the choice of insulation was primarily made for other reasons, dense-packed insulation will also aid in controlling infiltration by reducing airflow within wall cavities. If air-sealing strategies had been ignored during the gut-rehab, it is estimated



*Air sealing around windows*





**Air barrier on outside of house**

that an additional 60% of heating and cooling energy would have been required to operate the home<sup>10</sup>.

An expeditious method to detail all of the air-sealing opportunities in existing homes is to obtain the services of specialized contractor. Costs for such services vary depending on the size and complexity of the project. Many times specialized energy contractors offer testing and guarantees of performance with their air-sealing service. For many remodeling projects, air-sealing costs will be low since there will be little added labor and materials if techniques are performed during the construction process with the same work crews. In this gut-rehab, the insulation contractor charged an additional \$500 to perform this work.

## 5.6 HEATING AND COOLING EQUIPMENT

Though complicated in their design, the equipment to heat and cool the home can be installed with attention to a few basic principles:

- Install a highly efficient cooling and heating system, maximizing efficiency with installation and operation costs
- Place all ducts and equipment in conditioned space
- Size the equipment per ACCA Manual J or other recognized sizing tool, use ACCA manual D to determine duct sizing
- Seal ducts preferably with mastic or silver<sup>11</sup> (not duct) tape
- Install passive returns where ducted returns are non-existent or impractical.

The type of heating and cooling equipment, its effi-

ciency and its location are most often at the recommendation of the installer. However, various types of technology can be considered as part of the evaluation of energy efficient heating and cooling equipment:

- Condensing over atmospheric furnace technology
- SEER ratings of greater than 10 for air-conditioning equipment
- HSPF ratings of greater than 7.0 for heat pump units
- Ground-source heat pump technology
- Active solar heating technologies
- Combined hot water/heating technologies.

The installation of the HVAC system including ducts or pipes is as important as the equipment itself. Attention to the entire process from equipment selection, to installation, to controls will show benefits long after the remodeling project is complete.

### 5.6.1 HEATING AND COOLING EQUIPMENT – SEER CASE STUDY

In the case study home, the plan had called for a SEER-10 air-conditioner compressor with an AFUE-80 propane furnace located in the basement. High electric prices (\$0.11-0.15/ kWh) and a significant heating season eliminated the option of an air-to-air heat pump system.

<sup>10</sup> Based on the reduction of infiltration losses from 1.0 ACH to 0.25 ACH with ventilation added.

<sup>11</sup> Typically listed UL 181 tape.





***Ground source heat pump in conditioned space***

Natural gas was not available on the property, and the builder desired not to use heating oil.

Since the site had a high water table, a ground source heat pump was investigated. After some consultations with several manufacturers, installation contractors, and energy modeling, this system was chosen for its low annual operational costs. The large lot enabled a cost-effective horizontal closed-loop configuration that was trenched and installed by the remodeler (with HVAC contractor) and served a total of three packaged units for the two homes on the site. The 2-ton compressor and air handler unit in the study home, as well as all supply and return ducts, are located within conditioned space. This dramatically reduces system losses throughout the year. In addition, all ductwork was rigid metal, and

mastic was installed on all duct connections. These improvements to efficiency of the distribution system allowed the unit to be downsized by 1/2 ton. Even

though the original design recommended ducted returns on both levels, the builder chose to install passive wall returns between all bedrooms and the open stairway where the central return was located.

The original estimate to heat and air condition the building using a single 3-ton SEER-10 system and AFUE 80% propane furnace was \$9,100 for all labor, equipment, and ductwork. The cost to install the 2-ton geothermal system was \$12,300, including all labor, equipment, ductwork, and ground piping. An additional cost estimate of \$600 would have been expected for the ground excavation work, but in this case was performed by the remodeler.

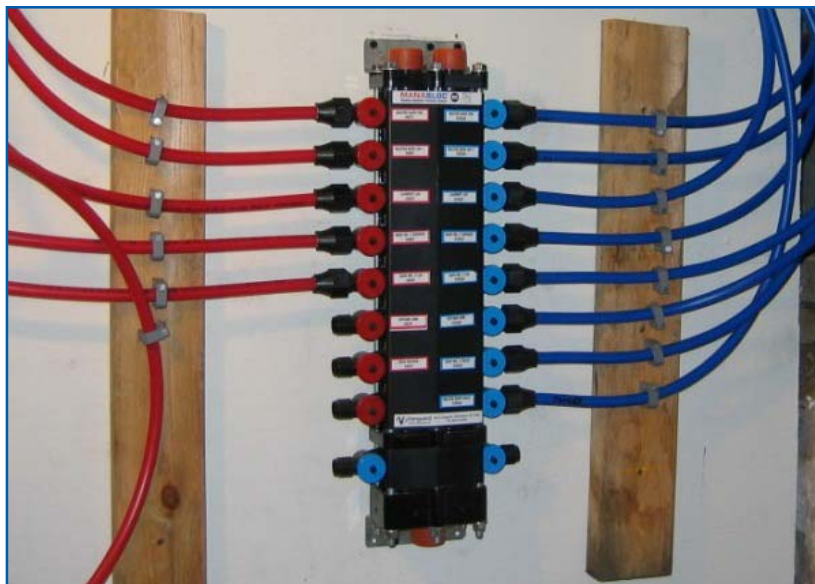


***All duct joints sealed***

## 5.7 WATER HEATING SYSTEM

The energy efficiency water heating system in the SEER case study involves all aspects of water heating, from cold water inlet to the hot water outlets and includes pre-heat systems, primary water heating equipment, and piping to the outlets. The primary goal of an efficient water heating system is to reduce energy losses in the water heating equipment and in the piping. To achieve this goal, a demand water heater and parallel piping systems are considered to be the best option in this climate. Other systems that would include, for example, a heat pump water heater or distributed water heaters at each outlet would increase efficiency even more, but at prohibitive costs at this time.

Demand water heaters, either fuel-fired or electric, are limited by the input energy that in turn limits the maximum temperature rise that can be achieved at a given flow rate. Tank water heaters do not suffer from this limitation since the volume of stored water can be supplied to the outlet at (theoretically) any flow rate. Tanks, however, cannot supply heated water beyond the capacity of the tank, and the outlet temperature of the water will decrease as it mixes with the incoming cold water. Also, tanks have a limited amount of input energy so that the recovery to bring the tank back to full temperature is over many minutes. In addition, tank storage of hot



*Manifold plumbing system*

water will lose energy to the surroundings, so that periodically the water will need to be reheated even if no water is used. If a demand heater can supply the anticipated hot water needs, it is almost always more efficient than tank storage heaters.

The hot water piping is another part of the overall water heating system that can be designed to reduce wasted energy by supplying hot water outlets with as small a diameter pipe as possible while maintaining the desired flow rate. This design results in a lesser volume of water in the pipe to the outlet with less energy wasted as the pipe cools to ambient temperature. Smaller diameter pipes, however, can not flow large quantities of water. Therefore, the piping system is designed as a parallel system so that only one outlet is supplied from a dedicated piping run from the water heater. A hot

water manifold is used for this purpose.

The system design in this case study uses an electric demand water heater feeding a parallel piping system. Electric demand heaters are typically limited to lower temperature rises at typical flow rates in homes. Therefore, to decrease the necessary size of the demand water heater while providing adequate hot water delivery, a pre-heat system can be used. The choice of demand heater is important when using this strategy, however, since not all products will properly account for variable input temperatures.

There are a number of choices to preheat the cold water prior to the demand water heating equipment:

- Desuperheater from the ground-source heat pump
- Solar thermal
- Waste heat from the drain.



Among the options, the most consistent source throughout the year, in this area, is the solar system, specifically, an active solar thermal system that charges a pre-heat tank.

The entire hot water system, taken together, can provide hot water to the outlets with fewer losses and with performance similar to that of much larger tank systems.

### 5.7.1 WATER HEATING SYSTEM – SEER CASE STUDY

As with other systems in the home, the water distribution and heating systems required replacement. An estimate of \$2,700 was obtained for the supply and installation of copper supply lines for the hot and cold water in the home. In comparison, a price of \$2,200 was secured to supply and install a single central manifold and PEX piping for all the supply lines in the home. This savings was primarily due to the reduced labor costs associated with running the flexible supply lines since the materials costs were very similar.

The original design for the water heating system was to include a “typical” propane-fired storage tank with an energy factor of approximately 0.56 located in the basement. While this would have been a relatively inexpensive option to purchase and install, the performance of this equipment, and expected standby losses due to its location in unconditioned space, would have cost significantly more to operate over its lifetime. The choice of



*Hot water system in cottage*



*Solar thermal collector with PV panel for pump*

a solar preheated tank and tankless demand heater limited the storage tank losses to energy generated only by the solar system. The solar contribution is expected to represent approximately 57% of the annual hot water load. The estimate for the cost of

the supply and installation of the solar preheat system with tankless backup heater is \$4,400. This, of course, is significantly more than the \$500 – \$700 cost to install a standard residential electric or propane tank.

## 5.8 LIGHTS AND APPLIANCES

Even energy efficient homes utilize many electrical devices that add to the energy consumption “bottom line.” Minimizing energy use is left to the consumer who must decide on individual appliances and select energy efficient options. Two main areas where this is easily done are larger appliances, such as refrigerators and washing machines, and lighting.

Efficient appliances are easily identified under the federal government’s ENERGYSTAR® program. The ENERGYSTAR® marked appliances have been tested to be the most efficient appliances available. Likewise, lighting provides another opportunity to extract large energy savings. Use of fluorescent fixtures or lamps are the best option today to save lighting energy. Newer technologies such as LED lighting are not yet widely available for general use in the home, but show promise for even more savings than fluorescent.

### 5.8.1 LIGHTS AND APPLIANCES – SEER CASE STUDY

The remodeler for this home made a bulk purchase of compact fluorescent replacement light bulbs that he will use in all the light fixtures of the home. Since he took advantage of special pricing on these units, his estimated cost increase over incandescent bulbs is approximately \$12 for all the fixtures in the

home. The appliances for the home are being chosen with an eye toward efficiency. The refrigerator, dishwasher, and clothes washer will all be ENERGYSTAR® rated. The estimated additional cost to provide these ENERGYSTAR® rated appliances is \$320.

## 5.9 ROOM ADDITIONS

A remodel project involving a complete addition is an excellent opportunity to include energy efficiency “from the ground-up.” Wall, roof, and foundation construction can be performed using new-construction methods that provide energy upgrades from normal practices. Many of these upgrades can be employed with little extra cost since the main work was already being performed. Also, some energy upgrades can actually result in contained costs – for example with the heating and cooling system. An efficient addition

may be able to be serviced from the existing HVAC system where a standard, less efficient addition might have required a separate heating and cooling system for the addition.

Many of these issues also pertain to room conversions, for example an attic or basement space. Use of more efficient methods and technologies can result in a more comfortable space, at a near equal cost, but with lower monthly bills.

### 5.9.1 ROOM ADDITIONS – SEER CASE STUDY

The addition is made from pre-manufactured structural EPS foam and steel tube panels and, therefore, does not require any additional structural supports. The floor of this addition is made of conventional solid wooden joists and plywood decking. The original design called for a conventionally framed



*Addition construction using foam panels*





*Ridge and eave supports for roof panels*



*Addition constructed in 6 hours*

addition with a vented attic. The choice to use structural panels allowed for the creation of a cathedral ceiling in the room and dramatically decreased the close-in time for the project. Once the conventional wooden deck had been built, it took the remodeler's crew of three, plus two support technicians from the panel manufacturer,

only 5 hours to construct the structure.

Mr. Asdal estimated that to construct this addition using conventional framing (2x4 walls) would have cost him \$3,000. The costs for the structural foam panel addition were \$5,700. While he saw the speed of the construction being an advantage

in some situations, in this case he thought the problems he had with scheduling the job with the supplier's crew countered any savings he had in the speed of construction.

## 5.10 RENEWABLE ENERGY SYSTEMS \_\_\_\_\_

Last, but not least, are those opportunities in the remodeling project to include renewable energy systems that can provide a portion of the home's energy needs. These systems tend to be more costly and require larger roof or ground areas, but also provide large amounts of energy that is, in its operation, pollution and waste free. The most prominent systems are solar photovoltaics that convert sunlight to electricity and wind generators that convert wind energy to electricity.

Solar thermal systems for hot water, briefly described above, are most often used to raise the efficiency of the hot water or heating system. Passive solar systems, such as sunrooms or trombe walls, also use solar energy to reduce the heating loads in the house.

Use of renewable energy systems not only reduce the consumption from non-renewable utility energy supplies, but provides a buffer against fluctuating costs of energy. When a renewable energy system is purchased and installed, a portion of the cost is considered as the "fuel" purchase. Unlike engine





*R-50 roof and R-30 wall panels*



*Ridge beam for roof support*

generators, for example, that can provide an alternative to utility energy supply, the engine systems still require regular purchase of fuel such as diesel or gasoline – that can change in price, sometimes dramatically and quickly.

Renewable energy systems typically have required the services of a solar system designer and installer and special attention to utility interconnections and metering.

### **5.10.1 RENEWABLE ENERGY SYSTEMS – SEER CASE STUDY**

An onsite photovoltaic (PV) solar system was investigated for the site. Since there was no significant shading, good roof orientation, and ample roof area, the home was deemed suitable for a PV array. The major factors that led to the decision to purchase a system were the significant financial incentives available and the simplified utility interconnection proce-

dures. There is a statewide residential grant program in place and operated by the Board of Public Utilities through the New Jersey Clean Energy Program (NJCEP). Through this program, the solar installer will receive an incentive worth up to \$5.50 per rated DC Watt of solar equipment that allows him or her to offer a substantially lower price to the homeowner for the installed system. This dealer is also handling the rebate application process and in turn, finances the rebate amount for the homeowner.

A 3.0-kW mono-crystalline system is located directly on the Cottage roof with a 4.2-kW system located on the garage roof also feeding into the building's utility service.



*PV system on Cottage home*



*Aerial view of PV system*



*Garage PV system for Cottage home*

The power-conditioning inverters are located inside both in the garage and basement of the home. The out-of-pocket expenses for the homeowner are approximately \$15,120. The NJCEP rebate paid for 70% of the system (\$35,280). The system is expected to produce approximately 9,000 kWh per year.



*PV system inverters*

# SUMMARY OF COST AND SAVINGS ESTIMATES

A summary of the energy efficiency feature costs is described in Table 2. The costs have been derived from a combination of construction cost estimates and actual bids from trade contractors and from the remodeler. The added costs (or savings) for the energy efficiency feature as described in the "Net" column represent a best estimate at adding the desired energy efficiency improvement in this home over standard practice.

Adding the energy features to the existing home (Base Retrofit) costs approximately \$23,000 over leaving the home "as-is" and performing only basic renovations to maintain the home, but including new appliances as part of the energy features. With the SEER project, additional upgrades to the energy efficiency features are included to significantly decrease the energy used in the

home. These additional features represent an additional cost of about \$14,000 or 60% more.

In conjunction with the additional energy efficiency features, a solar electric (photovoltaic) system is also included. The system's full price is about \$50,000, but within the NJ Clean Energy Program will cost the homeowner about \$15,000. Consequently, the total cost for the

**Table 2 – Energy Efficiency Cost Summary**

Technology	Base Retrofit	SEER Retrofit	Net Cost or Savings
Wall Insulation–Cavity	\$1,456 <sup>1</sup>	\$2,900	\$1,444
Wall Insulation–Continuous (w/ Siding)	\$2,848 <sup>2</sup>	\$3,656	\$808
Ceiling Insulation	\$375	\$672	\$297
Floor Insulation	\$470	\$798	\$328
Windows	\$2,420	\$2,820	\$400
Air Sealing	\$0	\$500	\$500
HVAC System	\$9,100	\$12,900	\$3,800 (inc. \$600 for excavation)
Water Heating System	\$700	\$4,400	\$3,700
Water Distribution System	\$2,700	\$2,200	-\$500
Lighting (bulbs only)	\$11	\$23	\$12
Fixed Appliances	\$1,630	\$1,950	\$320
Addition Framing and Insulation	\$3,000	\$5,700	\$2,700
Solar Electric System (PV)	\$0	\$15,120	\$15,120
<b>Total with PV<sup>3</sup></b>	<b>\$23,080</b>	<b>\$52,009</b>	<b>\$28,929</b>
<b>Total without PV<sup>3</sup></b>	<b>\$23,080</b>	<b>\$36,889</b>	<b>\$13,809</b>

<sup>1</sup> Includes \$733 for sheathing removal and disposal and \$723 for R-13 batt insulation.  
<sup>2</sup> Costs for uninsulated vinyl siding were used here to provide an accurate comparison.  
<sup>3</sup> Without added cost for new minimum-efficiency appliances.

SEER energy efficiency features and including a PV system is about \$54,000. For this cost, the home is expected to achieve a zero energy utility bill on an annual basis.

Based on energy simulations, estimates of energy use and savings for the SEER Case Study house have been developed and are summarized in Table 3.

For the base home remodel, the estimated energy costs (w/o service charges) show an annual energy savings of about \$500 over the existing (before) home, including the added energy cost for central air-conditioning. Central A/C would only be feasible given the minimal energy features included in the base retrofit. Had central A/C not been included, the annual savings would have been about \$665.

When considering the added costs for the energy features, including a new furnace and duct system and a new addition to replace the deteriorated existing addition, but not including replacement of the appliances, the total cost is estimated at \$23,080. Evaluating the added costs for the energy features only in terms of energy savings reveals a lengthy 46-year simple payback. However, this narrow approach ignores the added longevity of the home and the significant increase in comfort and durability based even on the modest energy efficiency upgrades.

However, when looking at the increase in the energy performance of the home from the

SEER energy efficiency approach, a much different picture emerges. Ignoring the solar electric (PV) system for the moment, the value of the energy savings for the SEER energy retrofit is about \$2,800 over the existing home's energy costs and about \$2,300 from the base case retrofit. This dramatic improvement results from an integrated (systems) design utilizing energy efficiency technologies that are selected based on the particular site characteristics and a knowledgeable remodeler and trades contractor. Even with the increased costs of 60% over the base energy efficiency retrofit, the simple payback approaches 13 years for the existing home and about 6 years over the base case.

When adding the PV system into the economic valuation of the SEER retrofit case, the resulting electricity costs go to zero<sup>12</sup>. The simple payback then is about 14 years from the existing home and 9 years from the base case. This approach values the PV system solely for its energy benefit, while adding no value for the reduction in pollution, security from rising energy costs, and reduced demand for fossil fuels.

Other economic valuations are possible. When considering a loan of about \$52,000 to pay for the full SEER energy efficiency remodel including the PV system, an interest rate of 6% over 30 years would show a monthly break-even cost based on the energy savings. And this assumes that the energy costs remain fixed over the term.

Still yet another approach is to consider the return on investment (ROI) of the savings when investing a similar amount as the energy efficiency upgrades. In this case, the ROI is over 7% when comparing the upgrades from the existing home and over 11% when considering the upgrades from the base case remodel. Again, this ROI assumes fixed utility rates over the useable lifetime of the energy efficiency systems. A summary of the economic analysis is shown on page 22.

<sup>12</sup> The actual benefit is a net-gain to the utility, but the economic value of the net-electricity fed back to the utility is not recoverable at this time.



Table 3 – Summary of SEER Case Study Energy Use<sup>1</sup> and Costs/Savings

Performance Characteristic	Before Retrofit	Base Retrofit	Base Savings Over Before	SEER Energy Efficient Retrofit	SEER Savings Over Base	SEER Savings Over Before
Heating Peak Load (Btuh)	65,400	45,400	31%	15,900	65%	76%
Cooling Peak Load (Btuh)	0	26,400	—	13,400	49%	—
Annual Heating Load Annual Cooling Load Totals (Million Btu)	134.3 0.0 134.3	71.0 12.7 83.8	47% — 38%	24.3 10.9 33.2	66% 14% 60%	82% — 75%
Heating Cost <sup>2</sup> Cooling Cost	\$2,660 \$0.0	\$1,794 \$163	33% —	\$179 \$61	90% —	93% —
Total Heating and Cooling Costs	\$2,660	\$1,957	26%	\$240	88%	91%
Water Heating Use (Million Btu) Appliance/Lighting Use (Million Btu)	30.5 19.6	27.4 19.6	10% 0%	5.6 13.3	80% 32%	82% 32%
Water Heating Cost- Oil/Propane/Elect	\$364/O	\$556/P	-53%	\$193/E	65%	47%
Appliances/Plug Loads	\$672	\$682	-1%	\$455	33%	32%
Estimated Annual Energy Costs	\$3,696	\$3,195		\$888		
Solar PV System (kWh) Value of kWh @ utility rates (\$)	0 \$0	0 \$0	—	8,899 \$1,043	—	—
Total Estimated Annual Energy Costs <sup>3</sup>	\$3,756	\$3,304	13.7%	\$-95(\$0) <sup>4</sup>	103%	103%
HERS Score	39.3	77.6	49%	93.1		
<p>Notes:  <sup>1</sup> Energy Use Estimates based on simulation software  <sup>2</sup> Electricity Rates: Applies to Before, Base and SEER energy estimates  Monthly Service Charge = \$5.00  Jun-Sep, 0-600 kWh @ \$0.1246/kWh  &gt; 600 kWh @ \$0.1508/kWh  Oct-May, 0-1000 kWh @ \$0.1134/kWh  &gt; 1000 kWh @ \$0.1107/kWh  Propane Rates: Applies to Base energy estimates for heating and water heating  Monthly Service Charge = \$4.00/month  Jan-Dec, @ \$1.85/gallon  Fuel Oil Rates: Applies to Before energy estimates for heating and water heating  Monthly Service Charge = \$0.00/month  Jan-Dec, @ \$1.69/gallon  <sup>3</sup> Including service charges and PV net-savings.  <sup>4</sup> Currently, there is no payment required by the utility for annual net-production.</p>						

### Summary of Economic Analysis Based on Energy Value Only

<b>Cost to add Base energy efficiency features to the Existing home remodel</b>	\$23,080
Annual Energy Savings (including the addition of A/C)	\$501
Annual Energy Savings (without the addition of A/C)	\$664
From existing-to-Base (with A/C) Retrofit - Simple payback	46 years
From existing-to-Base (without A/C) Retrofit - Simple payback	35 years
Return-On-Investment (with A/C)	2.2%
Return-On-Investment (without A/C)	2.9%
<b>Cost to add SEER energy efficiency features to the Existing home remodel (without PV)</b>	\$36,889
Annual Energy Savings	\$2,808
From Existing-to-SEER Retrofit – Simple payback	13 years
Return-On-Investment	7.6%
<b>Cost to add SEER features to the Base home remodel (without PV)</b>	\$13,809
Annual Energy Savings	\$2,307
From Base-to-SEER Retrofit - Simple payback	6 years
Return-On-Investment	16.7%
<b>Cost to add SEER energy efficiency features to the Existing home remodel (with PV)</b>	\$52,009
Annual Energy Savings	\$3,696
From Existing-to-SEER Retrofit – Simple payback	14 years
Return-On-Investment	7.1%
<b>Cost to add SEER features to the Base home remodel (with PV)</b>	\$28,929
Annual Energy Savings	\$3,195
From Base-to-SEER Retrofit - Simple payback	9 years
Return-On-Investment	11.0%
Loan Payment – SEER and PV system (7%, 15 years, \$28,929)	\$260.02
Monthly utility savings (\$3,195 annual cost)	\$266.25

# FIRST SEER REMODEL SITE - LEBANON, NEW JERSEY

## *Adapted from comments of the builder/remodeler, Bill Asdal*

The first SEER remodel site is in a rural setting. It is very typical of many of the houses throughout the countryside, not only here, but near and afar. The average age of housing in the country is 32 or 33 years. This one is 100+ years. Regionally, these averages can be as high as 55 or 60. And in the not too distant Pennsylvania and the Amish Country it gets up to 60 – 70 years, so there is a very large identifiable housing stock that is deficient in its energy efficiency and its mechanical systems. But quite frankly, houses of this vintage have very contemporary square footage and design attributes. For example, this one though it was built between 1898 and 1903 (about 100 years ago), has 10-foot ceilings on the first floor and 9-foot ceilings on the second floor. There are two homes on the site. One of which is very close to 4,000 sq. ft. The other, which we're calling the Cottage house, runs just shy of 1,500 sq. ft. So these are not unusual structures, but based on their age (unlike the post war homes of 1,100 or 1,200 sq. ft.) have the square footage that contemporary buyers are looking for. They are very much serviceable for another 100 years if kept dry. I think these attributes, in addition to the fact that we are completely gut rehabbing both houses, give us a good opportunity to be proactive and say that these houses should not be abandoned.

As an aside, the state of New Jersey led the country in introducing the rehab code in 1998, recognizing that neglected urban, mature suburban, and the old rural homes were three categories wherein you could find a large housing stock that not only need code upgrades, but are perfectly serviceable. In this project, we find the opportunity to look at energy conservation and use of renewables as a primary part of the home remodeling project. I think the combination of property and physical attributes lends itself well for a 2003 SEER project setting.

The construction approval process here, as in many other areas, is much constrained in the permitting of new homes. There is a tremendous demand on older homes to fill a need for new family or for move-up buyers who in can't get newly approved lots or when these new lots simply don't exist. We've gone from wetlands constraints to planning constraints to proximity to water constraints with the result that our new housing production is about 40% of its high, which was achieved almost 15 years ago. Again, there is lots of pressure on these old buildings to produce at today's standards and with a gut rehab I think we have a chance to show how to do just that. We have applied for an ENERGYSTAR® rating on the larger of the two homes and hope to do so on the cottage. For the larger home, we have had an evaluation and think

that with a couple of clever twists we will be able to achieve an 86 score, which will give us an ENERGYSTAR® home in the shell of a 100-year-old building. And that is very very exciting to know that these old homes could actually achieve that if you do a gut rehab.



# REPORT DOCUMENTATION PAGE

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## A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

## Research and Development of Buildings

Our nation's buildings consume more energy than any other sector of the U.S. economy, including transportation and industry. Fortunately, the opportunities to reduce building energy use—and the associated environmental impacts—are significant.

DOE's Building Technologies Program works to improve the energy efficiency of our nation's buildings through innovative new technologies and better building practices. The program focuses on two key areas:

- **Emerging Technologies**  
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