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ENERGY EFFICIENCY AND RENEWABLE ENERGY CLEARINGHOUSE

Elements of an Energy-Efficient House

You have much to consider when designing and building a new energy-efficient house, and it can be a challenge. However, recent technological improvements in building elements and construction techniques also allow most modern energy-saving ideas to be seamlessly integrated into house designs while improving comfort, health, or aesthetics. And even though some energy-efficient features are expensive, there are others that many home buyers can afford.

While design costs, options, and styles vary, most energy-efficient homes have some basic elements in common: a well-constructed and tightly sealed thermal envelope; controlled ventilation; properly sized, high-efficiency heating and cooling systems; and energy-efficient doors, windows, and appliances.

Thermal Envelope

A thermal envelope is everything about the house that serves to shield the living space from the outdoors. It includes the wall and roof assemblies, insulation, air/vapor retarders, windows, and weatherstripping and caulking.

Wall and Roof Assemblies

Most builders use traditional wood frame construction. Wood framing is a "tried and true" construction technique that uses a potentially renewable resource—wood—

Photo by Sara Farrar, NREL/PIX07134

This house in Illinois has many energy-efficient features, including advanced framing techniques, insulated sheathing, and an advanced ductwork system. It was built by Town and Country Homes as part of DOE's Building America Program.

to provide a structurally sound, long-lasting house. With proper construction and attention to details, the conventional wood-framed home can be very energy-efficient. It is now even possible to purchase a sustainably harvested wood.

Foundation walls and slabs should be as well insulated as the living space walls.

Some of the available and popular energy-efficient construction methods include the following:

Optimum Value Engineering (OVE). This method uses wood only where it is most effective, thus reducing costly wood use and saving space for insulation. The amount of lumber has been determined to be structurally sound through both laboratory and field tests. However, the builder must be familiar with this type of construction to ensure a structurally sound house.

Structural Insulated Panels (SIPs). These sheets are generally made of plywood or oriented-strand board (OSB) that is laminated to foam board. The foam may be 4 to 8 inches thick. Because the SIP acts as both the framing and the insulation, construction is much faster than OVE or stick framing. The quality of construction is often superior because there are fewer places for workers to make mistakes.

Photo by Craig Miller Productions, NREL/PIX02452

Workers install a structural insulated panel.

Insulating Concrete Forms (ICF). Houses constructed in this manner consist of two layers of extruded foam board (one inside the house and one outside the house) that act as the form for a steel-reinforced concrete center. It's the fastest technique and least likely to have construction mistakes. Such buildings are also very strong and easily exceed code requirements for areas prone to tornadoes or hurricanes.

Insulation

An energy-efficient house has much higher insulation R-values than required by most local building codes. An R-value is the ability of a material to resist heat transfer, and the lower the value, the faster the heat loss. For example, a typical house in New York might have insulation of R-11 in the exterior walls and R-19 in the ceiling, while the floors and foundation walls may not be insulated. A similar, but well-designed and constructed house will have insulation levels that range from R-20 to R-30 in the walls and from R-50 to R-70 in the ceilings. Carefully applied fiberglass batt or rolls, wet-spray cellulose, or foam insulation will fill wall cavities completely.

Foundation walls and slabs should be as well insulated as the living space walls. Poorly insulated foundations have a negative impact on home energy use and comfort, especially if the family uses the lower parts of the house as a living space. Also, appliances—such as domestic hot water heaters, washers, dryers, and freezers—that supply heat as a byproduct are often located in the basement. By carefully insulating the foundation walls and floor of the basement, these appliances can assist in heating the house.

While most new houses have good insulation levels, it is often poorly installed. In general, gaps and compaction of insulation reduce its effectiveness.

Air/Vapor Retarders

Water vapor condensation is a major threat to the structure of a house, no matter what the climate. In cold climates, pressure differences can drive warm, moist indoor air into exterior walls and

Photo by Sara Farrar, NREL/PIX08155

This house in Arizona features a passive solar design with overhangs above the south facing windows.

The best windows are awning and casement styles because these styles often close tighter than sliding types.

attics. The air condenses as it cools. The same can be said for southern climates, just in reverse. As the humid outdoor air enters the walls and encounters cooler wall cavities, it condenses into liquid water. This is the main reason why some buildings in the South have problems with mold and rotten wood after they're retrofitted with air conditioners.

A vapor retarder is a material or structural element that can be used to inhibit the movement of water vapor, while an air retarder can inhibit airflow, into and out of a house's envelope. How to design and install vapor retarders depends a great deal on the climate and on the chosen construction method. However, any water vapor that does manage to get into the walls or attics must be allowed to escape.

Regardless of climate, water vapor migration should be minimized by using a carefully designed thermal envelope and sound construction practices. Systems that control air and water vapor movement in homes rely on the nearly airtight installation of sheet materials on the interior as the main barrier.

The Airtight Drywall Approach (ADA) uses the drywall already being installed along with gaskets and caulking to create a continuous air retarder. In addition, seams where foundation, sill plate, floor joist header, and subfloor meet are also carefully sealed with appropriate caulk or gasket material.

Consult your local building codes official on the best vapor retarder method to use in your area.

Windows

The typical home loses more than 25 percent of its heat through windows. Even modern windows insulate less than a wall. Therefore, an energy-efficient house in a heating-dominated climate should, in general, have few windows on its northern, eastern, and western sides. Total window area should also not exceed 8 to 9 percent of the floor area for those rooms, unless the designer is experienced in passive solar techniques. If this is the case, then increasing window area on the southern side of the house to about 12 percent of the floor area is recommended. This is often called solar tempering.

A properly designed roof overhang for south-facing windows will help prevent overheating in the summer. North, east,

and west windows should have low Solar Heat Gain Coefficients (SHGC). South windows with properly sized overhangs should have a high SHGC to allow winter sun (and heat) to enter the house. The overhang blocks the high summer sun (and heat). If properly sized overhangs are not possible, a low SHGC glass should be selected for the south windows.

At the very least, you should use windows (and doors) with an Energy Star® label, which are twice as energy efficient as those produced 10 years ago, according to regional, climatic guidelines (note: houses with any kind of solar tempering have other guidelines). The best windows are awning and casement styles because these often close tighter than sliding types. In all climates, window glass facing south without overhangs can cause a problem on the cooling side that far exceeds the benefit from the winter solar gains.

Good air sealing alone may reduce utility costs by as much as 50 percent.

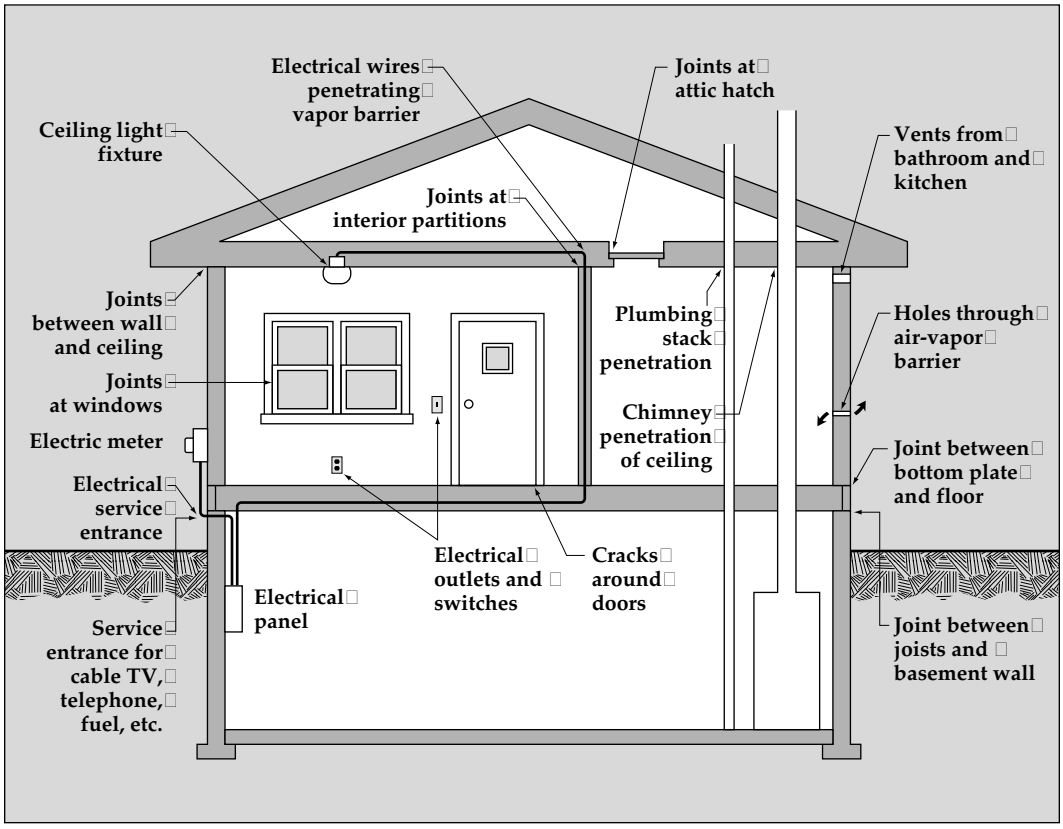
Weatherstripping and Caulking

You should seal air leaks everywhere in a home's thermal envelope to reduce energy loss. Good air sealing *alone* may reduce utility costs by as much as 50 percent when compared to other houses of the same type and age. You can accomplish most air sealing by using two materials: caulking and weatherstripping. Caulking can be used to seal areas of potential air leakage into or out of a house. And weatherstripping can be used to seal gaps around windows and exterior doors.

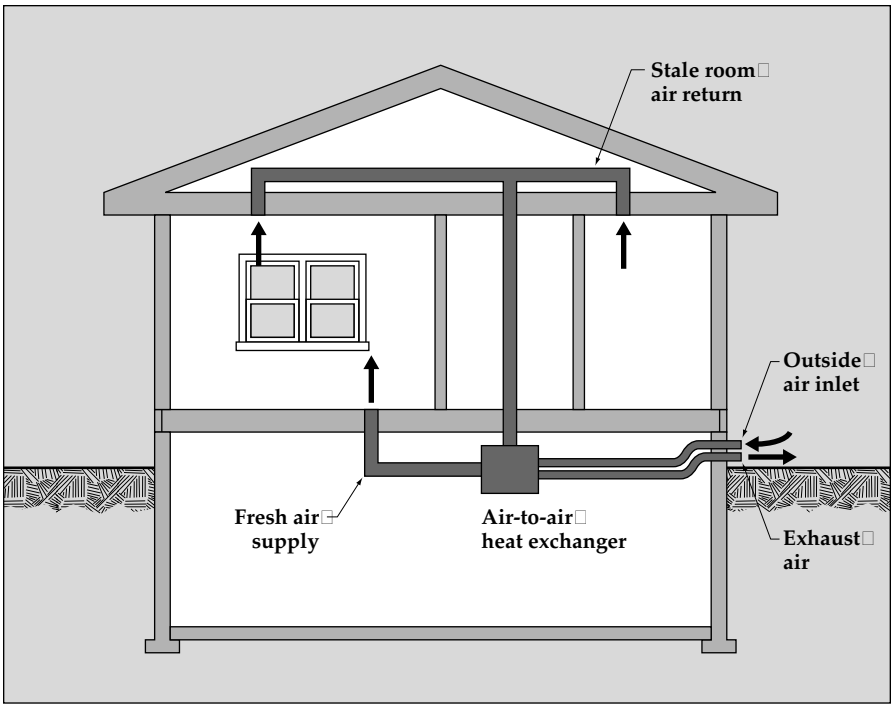
Controlled Ventilation

Since an energy-efficient house is tightly sealed, it needs to be ventilated in a controlled manner. Controlled, mechanical ventilation prevents health risks from indoor air pollution, promotes a more comfortable atmosphere, and reduces air moisture infiltration, thus reducing the likelihood of structural damage.

Furnaces, water heaters, clothes dryers, and bathroom and kitchen exhaust fans expel air from the house, making it easier to depressurize an airtight house if all else is ignored. But natural-draft appliances may be back-drafted by exhaust fans, which can lead to a lethal buildup of toxic



Air leakage can occur in many places throughout a home.



Heat recovery ventilation.

gases in the house. For this reason, sealed-combustion heating appliances, which use only outside air for combustion and vent combustion gases directly to the outdoors, are very important for ventilation energy efficiency and safety.

Heat recovery ventilators (HRV) or energy recovery ventilators (ERV) are growing in use for controlled ventilation in airtight homes. These ventilators can salvage about 70 percent of the energy from the stale exhaust air and transfer that energy to the fresh air entering by way of a heat exchanger inside the device. They can be attached to the central forced air system or may have their own duct system.

Generally, energy-efficient homes require relatively small heating systems.

Other ventilation devices, such as through-the-wall or "trickle" vents, may be used in conjunction with an exhaust fan. They are, however, more expensive to operate and possibly more uncomfortable to use because they have no energy recovery features to precondition the incoming air. Uncomfortable incoming air can be a serious problem in northern climates and can create moisture problems in humid climates. Therefore, this ventilation strategy is only for arid climates. Other systems pull outside air in with a small outside duct on the return side of the furnace.

Heating and Cooling Systems

Specifying the correct sizes for heating and cooling systems in airtight, energy-efficient homes can be tricky. Rule-of-thumb sizing is often inaccurate, resulting in wasteful operation. Conscientious builders and heating, ventilation, and air-conditioning contractors size heating and cooling equipment based on careful consideration of the thermal envelope characteristics.

Generally, energy-efficient homes require relatively small heating systems, typically less than 50,000 Btu/hour even for very cold climates. Some require nothing more than sunshine as the primary source of heat along with auxiliary heat from radiant in-floor heating, a standard gas-fired water heater, a small boiler, a furnace, or electric heat pump. Any common appliance that gives off "waste" heat can also contribute significantly to the heating requirements for such houses.

If an air conditioner is required, it's often a small unit and sufficient for all but the warmest climates. Sometimes only a large fan and the cooler evening air are needed to make the house comfortable. The house is closed up in the morning and stays cool until the next evening.

Smaller-capacity heating and cooling systems are usually less expensive to buy and operate. This helps recover the costs of purchasing more insulation, and other energy-efficient products, such as windows and appliances. Always look for the EnergyGuide label on heating and cooling equipment. The label will rate how efficient it is as compared to others available on the market.

In climates where summer cooling requirements dominate, light-colored materials and coatings (paint) on the exterior siding and roof can help reduce cooling requirements by up to 15 percent. Carefully selected and placed vegetation in any climate also contributes to reduced cooling and heating loads.

Higher efficiency appliances provide a measure of insurance against energy prices and emit less air pollution.

Energy-Efficient Appliances

Appliances with relatively high operating efficiencies are usually more expensive to purchase. However, higher efficiency appliances provide a measure of insurance against increases in energy prices, emit less air pollution, and are attractive selling points when the home is resold.

Home buyers should invest in high-efficiency appliances—such as water heaters, clothes washers and dryers, dishwashers, and refrigerators—especially if these appliances will be used a great deal. Because all major appliances must have an EnergyGuide label, read the label carefully to make sure you buy the most efficient appliance. To help you choose wisely, major appliances with an Energy Star® label exceed the federal government's minimum efficiency standards by a large percentage.

Energy-efficient lighting helps keep energy bills down by producing less heat and reducing cooling requirements. Fluorescent lighting, both conventional tube and compact, is generally the most energy-efficient for most home applications.

The building site and its climate should be carefully evaluated to determine the optimum design.

Advantages and Disadvantages

Houses that incorporate all of the above elements of energy efficiency have many advantages. They feel more comfortable because the additional insulation keeps the interior wall at a more comfortable and stable temperature. The indoor humidity is also better controlled, and drafts are reduced. A tightly sealed air/vapor retarder reduces the likelihood of moisture and air seeping through the walls. They are also very quiet because the extra insulation and tight construction helps to keep exterior noise out better.

But these houses also have some potential disadvantages. They may cost more and take longer to build than a conventional home if there's a lack of builder familiarity with new construction techniques and products available on the market. Even though the house's structure may differ only slightly from conventional homes, the builder and contractors may be unwilling to deviate from what they've always done before. They may need more training if they have no experience with these systems.

Building and Buying

Before you start a home-building project, the building site and its climate should be carefully evaluated to determine the optimum design and orientation for the house. There are energy-related computer software programs that can help with these evaluations. The design should accommodate appropriate insulation levels, moisture dynamics, and aesthetics. Decisions regarding appropriate windows, doors, and heating, cooling and ventilating appliances are central to an efficient design. Also the cost, ease of construction, the builder's limitations, and local building code compliance should be competently evaluated. Some plans are relatively simple and inexpensive to construct, while others can be extremely complex and, thus, expensive.

An increasing number of builders are participating in the federal government's Building America and Energy Star® Homes programs, as well as local home energy rating programs, all of which promote the construction of energy-efficient houses. Many of these builders construct energy-efficient homes to differentiate themselves from their competitors. Construction costs can vary significantly depending on the materials, construction techniques, contractor profit margin, experience, and the type of heating, cooling, and ventilation system chosen.

Because energy-efficient homes require less money to operate, many lenders now offer energy-efficient mortgages (EEMs). EEMs typically have lower points and allow for the stretching of debt-to-income ratios. State and local government energy offices can be contacted for information on region-specific financing.

In the end, your energy-efficient house will provide you with superior comfort and lower operating costs, not to mention a higher real estate market value.

Resources

The following are sources of additional information on energy-efficient houses:

The Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048
Merrifield, VA 22116
1-800-DOE-EREC (1-800-363-3732)
E-mail: doe.erec@nciinc.com
Web site: http://www.eren.doe.gov/consumerinfo/

EREC provides free general and technical information to the public on many topics and technologies pertaining to energy efficiency and renewable energy.

Organizations

American Solar Energy Society, Inc. (ASES)
2400 Central Avenue, G-1
Boulder, CO 80301
Phone: (303) 443-3130; Fax: (303) 443-3212
E-mail: ases@ases.org
Web site: http://www.ases.org

A national advocacy organization dedicated to the use of solar energy in buildings.

Building America
U.S. Department of Energy
Office of Building Systems, EE-41
1000 Independence Avenue, SW
Washington, D.C. 20585-0121
Web site: http://www.eren.doe.gov/buildings/building_america/

Works with the home building industry to produce quality homes that use up to 50 percent less energy without costing more to build.

Efficient Windows Collaborative
Alliance to Save Energy
1200 18th Street NW, Suite 900
Washington, D.C. 20036
Phone: (202) 857-0666; Fax: (202) 331-9588
E-mail: award@ase.org
Web site: http://www.efficientwindows.org/

Provides unbiased information on the benefits of energy-efficient windows, descriptions of how they work, and recommendations for their selection and use.

Energy Star®
U.S. Department of Energy and U.S. Environmental Protection Agency
Phone: (888) STAR-YES (1-888-782-7937)
E-mail: info@energystar.gov
Web site: http://www.energystar.gov/

Provides lists of Energy Star®-qualified products, including appliances and windows, as well as information on its energy-efficient homes program.

Lawrence Berkeley National Laboratory
Building Technologies Department
MS 90-3111
Berkeley, CA 94720 USA
Phone: (510) 486-6845; Fax: (510) 486-4089
Web site: http://eetd.lbl.gov/btp/btp.html

Provides information on past and current research in buildings energy efficiency.

National Renewable Energy Laboratory
The Center for Buildings and Thermal Systems
1617 Cole Blvd.
Golden, CO 80401
Web site: http://www.nrel.gov/buildings_thermal

Provides information on energy-efficient buildings.

Oak Ridge National Laboratory (ORNL)
Buildings Technology Center
P.O. Box 2008, MS-6070
Oak Ridge, Tennessee 37831-6070
Phone: (865) 574-5206; Fax Number: (865) 574-5227
Web site: http://www.ornl.gov/ORNL/BTC/

Provides information on research in buildings energy efficiency.

Sustainable Buildings Industry Council (SBIC)
1331 H Street, NW, Suite 1000
Washington, DC 20005-4706
Phone: (202) 628-7400; Fax: (202) 393-5043
E-mail: sbic@sbicouncil.org
Web site: http://www.sbicouncil.org

Promotes the use of energy-efficient and passive solar building design and construction.

Web Sites

Building Energy Software Tools
U.S. Department of Energy
Office of Building Technology, State and Community Programs
Web site: http://www.eren.doe.gov/buildings/tools_directory/

Describes many energy-related software tools for buildings, with an emphasis on renewable energy, and energy efficiency.

Cool Roof Materials Database
Lawrence Berkeley National Laboratory
Web site: http://eetd.lbl.gov/coolroof/

Assists with the selection of roofing materials that reflect instead of absorb the sun's radiant energy.

Green Buildings
Center of Excellence for Sustainable Development
Web site: http://www.sustainable.doe.gov/buildings/gbintro.htm

Provides information and links on energy-efficient buildings.

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The Residential Energy Efficiency Database
Web site: http://www.its-canada.com/reed/

Provides a wide-range of information on energy-efficient houses, including house plans.

Zip Code Insulation Database
Oak Ridge National Laboratory
Web site:
http://www.ornl.gov/~roofs/Zip/ZipHome.html

Provides information by zip code on the most economic insulation levels for new or existing homes.

Reading List

The following publications provide further information about energy-efficient home elements. The list is not exhaustive, nor does the mention of any publication constitute a recommendation or endorsement.

Books, Pamphlets, and Reports

Buildings for a Sustainable America Case Studies, B. Miller, ASES, 1997. Available from ASES or SBIC (see Resources).

Building Green in a Black & White World, D. Johnston, Home Builder Press, 2000; Phone: (800) 223-2665; http://www.builderbooks.com.

Consumer Guide to Home Energy Savings, A. Wilson and J. Morrill, American Council for an Energy-Efficient Economy, 2000; Phone: (510) 549-9914; http://aceee.org/.

The Efficient House Sourcebook, R. Sardinsky, Rocky Mountain Institute. Available from SBIC (see Resources).

Energy Savers: Tips on Saving Energy and Money at Home, U.S. Department of Energy. Available in PDF and HTML at http://www.eren.doe.gov/consumerinfo/energy_savers/ or print version from EREC (see Resources).

Fine Homebuilding: Energy-Efficient Houses, Fine Homebuilding magazine. Available from SBIC (see Resources).

Moisture Control Handbook: Principals and Practices for Residential and Small Commercial Buildings, J. Lstiburek and J. Carmody, Van Nostrand Reinhold Co., 1993. Available from the Building Science Corporation at (978) 589-5100 (phone); (978) 589-5103 (fax); or http://www.buildingscience.com.

The Passive Solar Design and Construction Handbook, M. Crosbie (ed), J. Wiley, 1997. Available for purchase from ASES (see Resources).

Residential Windows: A Guide to New Technology and Energy Performance, J. Carmody, S. Selkowitz, and L. Herschong, Norton Professional Books, 1996. Phone: 1-800-233-4830; http://www.wwnorton.com/npb/.

Insulation Fact Sheet, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, 1997. Available from ORNL in PDF and HTML at http://www.ornl.gov/roofs+walls/insulation/. Print version is available from EREC (see Resources).

Periodicals

Energy Design Update. Published by Cutter Information Corporation, 37 Broadway, Arlington, MA 02474-5552; Phone: (800) 964-5118 or (781) 648-8700; Web site: http://www.cutter.com. This monthly newsletter contains information for professionals interested in energy-efficient building technologies. Product reviews appear regularly.

Environmental Building News. 28 Birge Street, Brattleboro, VT 05301; Phone: (802) 257-7300; Web site: http://www.BuildingGreen.com. This bimonthly newsletter covers a wide variety of topics.

The Journal of Light Construction. Published by Builderburg Partners, Ltd., 932 West Main Street, Richmond, VT 05477; Phone: (800) 375-5981. This monthly journal often features articles on energy conservation techniques for the home builder.

Home Energy Magazine. 2124 Kittredge Street, #95, Berkeley, CA 94704; Phone: (510) 524-5405; E-mail: contact@homeenergy.org,; Web site: http://www.homeenergy.org/. It's a source of information on reducing energy consumption in the home.

Solpan Review. Published by Drawing-Room Graphic Services, Ltd., P.O. Box 86627, North Vancouver, BC V71 412 , Canada; Phone (604) 689-1841. This bimonthly newsletter features articles on energy conservation for the building industry, including information on new products and energy-efficient practices in residential construction.