DSM Pocket Guidebook

Volume 1: Residential Technologies

Western Area Power Administration

August 2007

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Foreword

The original series of demand-side management (DSM) guidebooks was published in the 1990s, when rising energy prices and mandates to conserve made DSM programs popular. Today, interest in energy efficiency and renewable energy technologies continues to grow.

As an increasing share of the nation's fuel supply is provided by other countries, energy efficiency and renewable energy technologies are seen as a way to improve the nation's energy independence. Concerns about global warming contribute to interest in reducing carbon emissions that result from combustion technologies.

Researchers and manufacturers have worked diligently over the past several decades to improve the performance of these efficiency and renewable technologies, to the point where many are cost competitive with conventional technologies.

This version of the Residential DSM booklet has been updated to cover these proven new technologies, which promise to help our nation meet its energy goals.

This series of guidebooks is intended as a tool for utility personnel involved in DSM programs and services. Both the novice and the DSM expert can benefit from the information provided.

Acknowledgements

This updated version of the Residential Technologies Demand-side Management Pocket Guidebook is the result of the hard work and expertise of a number of people on Western Area Power Administration's Energy Services Team and the National Renewable Energy Laboratory staff.

Introduction

In 2004, residential buildings accounted for 36% of U.S. electricity consumption. The typical U.S. family spends more than $1,600 per year on home utility bills. All too often, some of that energy is wasted. And electricity generated by fossil fuels for a single home puts more carbon dioxide into the air than two average cars.

Many opportunities are available to make homes more energy efficient. ENERGY STAR® qualified homes are at least 15% more energy efficient than homes built to the 2004 International Residential Code.

A building code can be understood not as the goal for a new or existing home, but as the minimum standard that a home should meet. There are many opportunities to exceed the building code with technologies that are cost effective and offer quick payback.

A Department of Energy program, Building America, conducts systems engineering research to produce homes on a community scale that use 30% to 90% less energy. By integrating onsite power systems, "zero-energy" homes that produce as much energy as they use will be designed by 2020.

These highly efficient homes can include a variety of energy-efficient features, such as effective insulation, high-performance windows, tight construction and ducts, efficient heating and cooling equipment, and ENERGY STAR-qualified lighting and appliances. These features contribute to improved home quality and comfort, and to lower energy demand and reduced air pollution.

Technology Selection

Utility DSM programs typically consist of several measures designed to modify the utility's load shape (for example, innovative rate structures, direct utility load control, promotion of energy efficiency technologies, and customer education). The coordinated implementation of such measures requires planning, analysis of options, engineering, marketing, monitoring, and other coordination activities. This guidebook addresses one facet of an overall DSM program: selection of end-use technologies by the electrical utility.

All facets of a utility's DSM program, including technology selection, must be planned with the utility's overall objectives in mind. Selected technologies must make the utility better able to serve its customers by providing low-cost reliable power. yet the utility must also be able to recover its fixed and operating costs. In practice, this usually means that the technology must provide the same or expanded cost-effective energy service to the customer, smooth out the utility's load curve, and delay the need for additional power plants. This guidebook directly addresses these requirements by providing formulas for estimating the simple payback (to the end user) for energy-efficient end-use technologies and their impacts on the utility's load curve.

A number of additional factors must be considered in technology selection. Primary among these are customer acceptance of different end-use technologies, the type of marketing effort required to promote each, and the potential impact on the utility's revenues. These factors are not addressed in this guidebook.

Intended Audience

This guidebook is intended to be a quick reference source for utility field representatives in their customer interactions and for utility planners in the early stages of developing a DSM program. It is designed to allow a quick screening of commercially available electric end-use technologies for the residential sector.

This guidebook is also directed primarily at small municipal utilities and rural electric cooperatives within the Western Area Power Administration service area. Large utilities with more staff resources may find the guidebook useful as a starting point. Their technology selection process will undoubtedly also include reviews of other source documents and detailed system and engineering analyses of the options.

How to Use This Booklet

Because of the condensed nature of this guidebook and our desire to keep it simple, we have provided only overviews of the technologies. The guidebook is not intended to substitute for detailed analysis, but rather to point the reader toward technologies that are most likely to benefit both the energy user and the utility. For more details, the reader should consult "For More Information" provided at the end of each technology brief. A wealth of information is provided on these technologies on the Web.

DOE Western Area Power Administration
www.wapa.gov

DOE Office of Energy Efficiency and Renewable Energy (EERE)
www.eere.energy.gov.

Many software programs and online calculators are available as well; search for "Calculators" on the EERE Web site.

Load Shifting
example: cool storage

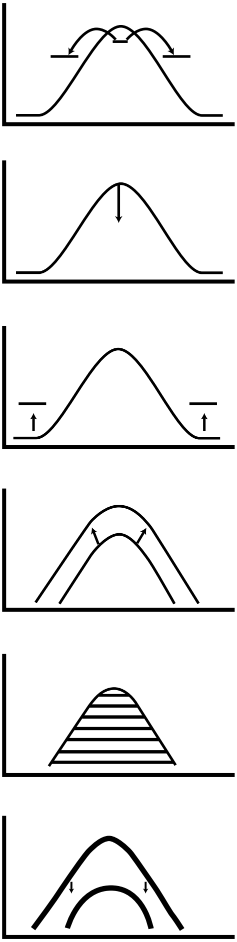
Peak Clipping
example: direct control of
air conditioning

Valley Filling
example: heat storage

Stragetic Load Growth
example: heat pumps

Flexible Load Shape
example: direct control
of water heaters

Stragetic Conservation
example: weatherization
and efficient appliances



Typical load shape changes resulting from selected demand-side management alternatives.

Adapted from Clark W. Gellings, highlights of a speech presented to the 1982 Executive Symposium of EEI Customer Service and Marketing Personnel.

Energy Use and Energy Audits

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An energy audit will pinpoint areas in a home that waste energy and money and suggest the most effective measures for cutting energy costs. A homeowner can conduct basic energy audits, contact the local utility, or hire an independent energy auditor for a more comprehensive examination.

A home energy audit is the first step to saving energy and money for a homeowner. After the homeowner has identified where the energy is being lost, he or she must then formulate a plan to correct the problem. Below are some questions that can help a homeowner to prepare an energy savings plan for the entire house:

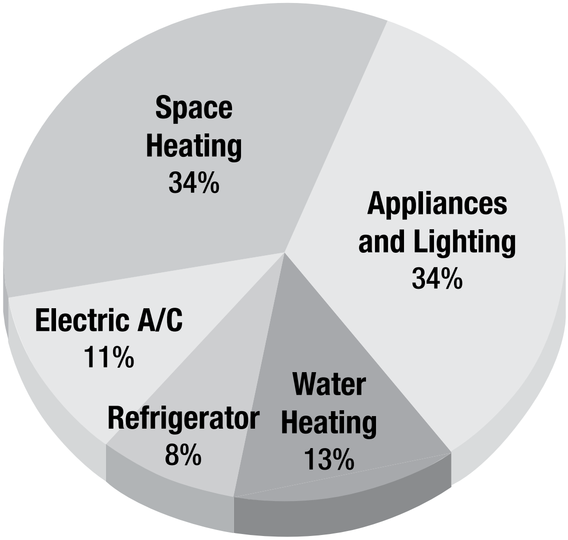
- What percentage of the household income is being spent on energy?
- How much money is spent on energy?
- Where are the greatest energy losses?
- How long will it take for an investment to pay for itself?
- Do the energy saving measures provide additional benefits (e.g., increased comfort)?
- How long does the homeowner plan to own the home?
- Can the job be done by the homeowner or is a contractor required?
- What is the budget for improving energy efficiency?
- How much time is available for maintenance and repair?
- What effect will identified improvements have on the resale value?
- How much of the identified improvements' costs can be recovered on resale?
- What is the remaining life expectancy of the home?

A good energy plan will maximize energy efficiency while saving the most money.

If a contractor is required, the homeowner should look for licensed, insured contractors with references. Another good idea is to obtain at least three bids for cost comparison.

Several factors determine how much energy is used in the home and the percentage of each energy use category. These factors include:

- Climate/location
- Building envelope efficiency
- HVAC, appliance, and lighting systems efficiency
- Home size.



How We Use Energy in Our Homes (U.S. Average)
Heating accounts for the biggest chunk of a typical utility bill.

Energy Audit

A home energy audit is the first step in assessing how much energy a home consumes and to evaluate the measures that are required to make it more energy efficient. An energy audit will reveal problems that, when corrected, can save homeowners significant amounts of money over time. An audit may also show homeowners ways to conserve hot water and electricity. Homeowners can perform a simple energy audit or hire a professional energy auditor to carry out a more thorough inspection. A professional auditor uses a variety of techniques and equipment including energy analysis computer software to determine the energy efficiency of a home. Thorough audits often use equipment such as blower doors, which measure the extent of leaks in the building envelope, and infrared cameras, which reveal hard-to-detect areas of air infiltration, and missing insulation.

Types

Simple Energy Audit – Homeowners can easily conduct a home energy audit with a simple, but diligent, walk-through of the home. Homeowners should keep a checklist of inspected areas and problems found. Below is a simple checklist of things to look for:

- Check for holes or cracks that leak air around walls, ceilings, windows, doors, lighting and plumping fixtures, switches, and electrical outlets.
- Check the insulation levels in the attic, exterior and basement walls, ceilings, floors, and crawl spaces.
- Check for open fireplace dampers.
- Check appliances and heating and cooling equipment to make sure they are working properly and are properly maintained.
- Replace standard light bulbs with compact fluorescent lights (CFLs).

- Look for ways to use lighting controls such as occupancy sensors, dimmers, or timers in high-use areas like living rooms and kitchens.

Professional Energy Audit – A professional energy auditor will examine energy loss in the home in great detail, including an examination of each room as well as past utility bills. Many professional energy audits will include a blower door test and thermographic scan. A less common technique is a PerFluorocarbon tracer gas (PFT) air infiltration scan. Before meeting with an energy auditor, homeowners should make a list of problems (e.g., drafty rooms) and request copies of their yearly utility bills from their local utility. A professional energy auditor will examine the outside of the home for size and features, occupant behavior, and use equipment to detect sources of energy loss such as blower doors, infrared cameras, furnace efficiency meters, and surface thermometers.

To find an authorized energy auditor, homeowners can contact their state or local government energy office, their local utility, or their local yellow pages under "Energy." Before contacting any energy auditor, they should speak to several references.

A good professional energy audit provides a roadmap for the homeowner to follow while making improvements to the home. It includes recommended measures, estimated costs for each measure, first year savings, and simple payback. This information allows homeowners to make wise decisions and considers available budget, return on investment, and other factors.

High energy prices and greater awareness of global warming have increased homeowners' interest in purchasing home renewable energy systems like photovoltaic (solar) panels. The interest in zero energy homes is also increasing. The term "zero energy home" indicates a home that both produces and uses energy; over the course of a year, the home offsets the energy used by the energy it produces, usually by generating electricity from photovoltaic panels. During certain times, electricity is sold to the utility and at other times, electricity is purchased from the utility.

Homeowners should be reminded that the first step to becoming a zero energy home is to obtain an energy audit and make the home as energy efficient as possible. Homeowners should also look into purchasing green power through the local utility or other provider. Purchasing green power means that the homeowner does not need to finance, purchase, and maintain renewable energy onsite. However, the homeowner still has the advantage of supplying the home's energy needs through renewable or green power. If the homeowner does decide to install renewable energy generation onsite, the renewable system can be sized smaller, thus saving money, if the home is highly energy efficient. See the graphic for more information on moving towards a zero energy home. Many homeowners can achieve their goals by completing steps 1 and 2.

Steps to Near Zero Energy for an Existing Home

Step 1	Step 2	Step 3
Contact Utility	Improve Energy Efficiency	Research Renewable Energy for Home
- request a home energy audit - ask about purchasing offsite green power	- air sealing - cooling - Energy Star appliances - heating - insulation - lighting - programmable thermostat - water heating - windows and doors - other measures identified in audit	- photovoltaics (solar electricity) - solar water heating - solar pool heating - wind energy - other technologies

Terms and definitions

Blower door test – A blower door is a powerful fan that mounts into the frame of an exterior door. The fan pulls air out of the house, lowering the air pressure inside. The higher outside air pressure then flows in through all unsealed cracks and openings. The auditor may use a smoke pencil to detect air leaks. These tests determine the air infiltration rate. Blower doors consist of a frame and flexible panel that can be placed in a doorway, a variable-speed fan, a pressure gauge to measure the pressure differences inside and outside the home, and an airflow manometer and hoses for measuring airflow. The auditor should use a calibrated blower door. Blower doors can also be used to measure duct leakage–Before and after treatment measurements are helpful.

Cooling Degree Day(s) (CDD)— A value used to estimate interior air cooling requirements (load) calculated as the number of degrees per day (over a specified period) that the daily average temperature is above 65 ˚F (or some other, specified base temperature). The daily average temperature is the mean of the maximum and minimum temperatures recorded for a specific location for a 24-hour period.

Heating Degree Day(s) (HDD) – The number of degrees per day that the daily average temperature (the mean of the maximum and minimum recorded temperatures) is below a base temperature, usually 65 ˚F, unless otherwise specified; used to determine indoor space heating requirements and heating system sizing. Total HDD is the cumulative total for the year/heating season. The higher the HDD for a location, the colder the daily average temperature(s).

*Home Heating Index (Btu / square footage * heating degree days)* – The home heating index is a way to compare homes' energy efficiency, comparable to comparing vehicles by miles per gallon. Each home's energy use is converted to British Thermal Units (Btus), which is divided by the home's square footage, multiplied by the heating degree days for the climate. Thus, a home in Denver and a home in Detroit could be compared to see which is more energy efficient, given the different square footage and climates.

PFT air infiltration measurement – A technique used to detect long-term air-infiltration problems in a home caused by changes in atmospheric pressure, weather, and wind velocity. The PFT technique uses two pencil-sized devices: an emitter, which gives off a small amount of colorless, odorless perfluorocarbon gas, and a receiver, which absorbs the gas. The higher the concentration of the gas absorbed, the tighter the building envelope. This technique is not common.

Thermographic scan – An energy auditor may use thermography—or infrared scanning—to detect air leaks in homes. The auditor uses an infrared video and/or still camera that records temperature variations in the form of different colors ranging from white for warm areas to black for cool regions. These images enable the auditor to see where leaks are occurring in the home, including how much heat is being lost through window glass and other building components. Thermograms also help the auditor to detect abnormally hot electrical connections or components and heat created by excessive friction in mechanical systems. Conditions like moisture differences, water leaks, and saturated roof insulation may also be detected.

Applicability

Climates: All
Building type: All
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Home Energy Audits
www.eere.energy.gov/consumer/your_home/energy_audits/index.cfm/mytopic=11160

DOE Building Technologies Program: Whole House Energy Checklist
www.eere.energy.gov/buildings/info/documents/pdfs/whole_house_energy_checklist-766.pdf

Building Structure

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Heating and cooling living areas account for the majority of the energy used in the average American home. A proper building structure can significantly reduce the amount of energy (and money) needed for heating and cooling. A structure or envelope encloses a building (walls, roofs, and foundations) and includes elements such as insulation, windows, air sealing, and passive solar design features such as brick flooring that provide a thermal barrier between the indoor and outdoor environments.

Most homes in the United States are not insulated to their best levels. Older homes are likely to use more energy than newer homes, leading to very high heating and air-conditioning bills. Adding insulation to new homes can save homeowners money in reduced utility bills and increase the resale value of their houses.

Many thermal improvements in building structure will reduce the required size of the building's heating and cooling systems. This potential reduction in equipment costs is generally not accounted for in the cost and payback calculations.

If a heating system cannot provide adequate comfort levels, the first recommended action is to improve the building envelope, which may eliminate the need to increase the heating or cooling unit's size.

Insulation

Inadequate insulation is the leading cause of energy waste in most homes. Proper insulation and air sealing techniques in walls, ceilings, and floors will not only reduce energy costs, but will make homes warmer in the winter and cooler in the summer. Insulation also absorbs sound, keeping noise levels down. For maximum energy efficiency, homes should be properly insulated from the roof to the foundation, including attic spaces and access doors; ducts; cathedral ceilings; exterior walls; and floors above unheated garages. Insulating materials can serve as thermal breaks, preventing the conduction of heat out of or into the home through highly conductive materials like metal frames. Foundation insulation includes basements, crawl spaces, and slab-on-grade floors. In addition, proper air sealing, moisture control, and ventilation strategies will improve the effectiveness of insulation.

Types of Insulation

Although insulation can be made from a variety of materials it usually comes in four main types; each type has different characteristics.

Rolls and batts – or blankets – These are flexible products made from mineral fibers, such as fiberglass and rock wool. They are available in widths suited to standard spacings of wall studs and attic or floor joists.

Loose-fill insulation – This is usually made of fiberglass, rock wool, or cellulose – it comes in shreds, granules, or nodules. These small particles should be blown into spaces with special pneumatic equipment. The blown-in material conforms readily to building cavities and attics. Therefore, loose-fill insulation is well suited for places where it is difficult to install other types of insulation.

Rigid foam insulation – This is typically more expensive than fiber insulation. But it's very effective in buildings with space limitations and where higher R-values are needed.

Foam-in-place insulation – This can be sprayed into walls and reduces air leakage.

Some new types of insulation fall into several categories (i.e., recycled cotton insulation can be a batt or foam-in-place insulation.)

In a warm climate, a radiant barrier (see definitions) may be installed along with the insulation.

Terms and Definitions

Heat transfer – When trying to prevent heat from leaving the home (winter) or entering the home (summer), it is important to understand how heat transfer occurs: conduction, convection, and radiation. Due to energy prices and environmental issues, all three must be considered in today's construction practices.

Conduction – The transfer of heat through a material by the transfer of kinetic energy from particle to particle; the flow of heat between two materials of different temperatures that are in direct physical contact.

Convection – The transfer of heat by means of air currents.

Radiation – The transfer of heat through matter or space by means of electromagnetic waves.

Radiant heat loss/gain – The transfer of heat through electromagnetic waves. To prevent radiant heat gain, the electromagnetic waves must be reflected rather than absorbed. Examples of this include radiant barriers installed in attics to reflect heat and spectrally selective coatings used on windows to reflect heat.

R-value – This measures insulation's resistance to heat flow. It can also be referred to as "thermal resistance." The higher the R-value, the greater the insulating power. All materials with the same R-value, regardless of type, thickness, or weight, are equal in insulating power. R-values are determined by material type, thickness, and installed weight per square foot, not by thickness alone. When calculating the R-value of a multilayered installation, add the R-values of the individual layers. An R-value's effectiveness also depends on how and where the insulation is installed.

DOE recommends ranges of R-values based on local heating and cooling costs and climate conditions in different areas of the nation. The map and chart below give the DOE recommendations for the United States. Note that the DOE recommended R-values may exceed state and local codes. The recommendations are based on cost effectiveness.

Radiant barriers – These are installed in homes—most commonly in attics—to reduce summer heat gain and winter heat loss, which help lower heating and cooling costs. The barriers consist of a highly reflective material that reflects radiant heat rather than absorbing it. They don't, however, reduce heat conduction like thermal insulation materials. Radiant barriers come in a variety of forms, including reflective foil, reflective paint coatings, reflective metal roof shingles, reflective laminated roof sheathing, and even reflective chips, which can be mixed with loose-fill insulation.

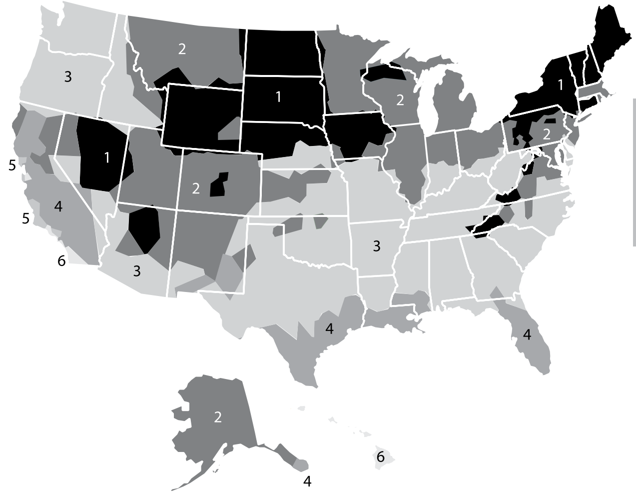
Applicability

Climates: All
Building type: All
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Insulation and Air Sealing
www.eere.energy.gov/consumer/your_home/insulation_airsealing/index.cfm/mytopic=11220

U.S. Department of Energy Recommended R-Values for New Houses in Six Climate Zones



Zone	Gas	Heat pump	Fuel oil	Electric furnace	Ceiling: Attic	Ceiling: Cathedral	Wall(A)	Floor	Crawl space(B)	Slab edge	Basement: Interior	Basement: Exterior
1	✔	✔	✔		R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
1				✔	R-49	R-60	R-28	R-25	R-19	R-8	R-19	R-15
2	✔	✔	✔		R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
2				✔	R-49	R-38	R-22	R-25	R-19	R-8	R-19	R-15
3	✔	✔	✔	✔	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
4	✔	✔	✔		R-38	R-38	R-13	R-13	R-19	R-4	R-11	R-4
4				✔	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
5	✔				R-38	R-30	R-13	R-11	R-13	R-4	R-11	R-4
5		✔	✔		R-38	R-38	R-13	R-13	R-19	R-4	R-11	R-4
5				✔	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
6	✔				R-22	R-22	R-11	R-11	R-11	(C)	R-11	R-4
6		✔	✔		R-38	R-30	R-13	R-11	R-13	R-4	R-11	R-4
6				✔	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10

(**A**) R-18, R-22, and R-28 exterior wall systems can be achieved by either cavity insulation or cavity insulation with insulating she
For 2 in. x 4 in. walls, use either 3-1/2-in. thick R-15 or 3-1/2-in. thick R-13 fiberglass insulation with insulating sheathing.
For 2 in. x 6 in. walls, use either 5-1/2-in. thick R-21 or 6-1/4-in. thick R-19 fiberglass insulation.

(**B**) Insulate crawl space walls only if the crawl space is dry all year, the floor above is not insulated, and all ventilation to the cra space is blocked. A vapor retarder (e.g., 4- or 6-mil polyethylene film) should be installed on the ground to reduce moisture n into the crawl space.

(**C**) No slab edge insulation is recommended.

Windows, Glass Doors, and Skylights

Replacing older windows and doors with newer energy-efficient models will lower a home's heating, cooling, and lighting costs. The National Fenestration Rating Council (NFRC) labels windows, glass doors, and skylights based on their energy performance ratings. An NFRC rating tells homeowners the product's potential for gaining and losing heat and air leakage, as well as transmitting sunlight. The NFRC label can be found on all ENERGY STAR-qualified window and skylight products, but ENERGY STAR provides only U-factor and solar heat gain coefficient (SHGC) ratings (see terms). Windows, glass doors, and skylights gain and lose heat by:

- Direct conduction through the glass or glazing
- Air leakage through and around them.

The energy efficiency of older windows, glass doors, and skylights can be improved by: 1) adding storm windows to reduce air leakage and heat loss; 2) caulking and weather-stripping to reduce air leakage; and 3) using treatments or coverings to reduce heat loss and/or gain. However, for homes with very old and/or inefficient windows, the benefits of new windows might be an investment worth considering.

New windows improve comfort and aesthetics, reduce noise, and are usually easier to operate than older ones. New windows take years to pay for themselves, through lower heating and cooling costs, and sometimes even lighting costs. New windows for a house should be selected based on climate, the home's condition, HVAC system, and window orientation.

Types of Windows

Cool/Cold Climates

To be effective in cold climates, windows must have an SHGC of 0.6 or higher and be southfacing to maximize solar heat gain in winter. Window overhangs or awnings can be used to block unwanted heat in summer. Windows in cooler climates should also have a U-factor of 0.35 or lower to reduce conductive heat transfer and a high visible transmittance (see terms) for good visible light transfer. In cold climates, reducing the size of east-facing, west-facing, and north-facing windows will prevent heat loss and allow for adequate daylight. These windows should have a low SHGC and/or be shaded. North-facing windows collect little solar heat, so they are used just to provide useful lighting. Low-emissivity (low-e) windows can help control solar heat gain and loss in heating climates. To improve the thermal performance of windows with insulated glazing, some manufacturers fill the space between the glass panes with gas.

For these gas fills, window manufacturers use inert gases—ones that do not react readily with other substances. Because these gases have a higher resistance to heat flow than air, they (rather than air) are sealed between the window panes to decrease a window's U-factor.

The most common types of gas used by window manufacturers include argon and krypton. Argon is inexpensive, nontoxic, nonreactive, clear, and odorless. Krypton is more expensive but has better thermal performance.

Warm/Hot Climates

In warmer climates, north-facing windows and generously shaded south-facing windows will lower utility bills and reduce the need for air conditioning. Windows with low SHGCs reduce cooling loads more effectively. The following types of glazing help lower a window's SHGC: low-e; tinted; reflective, and spectrally selective. Most of these glazing types, except for spectrally selective, also help lower a window's visible transmittance (VT).

Terms and Definitions

U-factor – measures how well a product prevents heat from escaping a home or building. U-factor ratings generally fall between 0.20 and 1.20.

The lower the U-factor, the better a product keeps heat inside. U-factor is the reciprocal of R-value.

Solar Heat Gain Coefficient (SHGC) – measures how well a window, glass door, or skylight blocks heat from the sun. SHGC is expressed as a number between 0 and 1. Windows with a low SHGC block more sunlight, which means they better block unwanted heat gain. Windows with a high SHGC collect more of the sun's heat during the winter.

Visible transmittance (VT) – measures how much light comes through a window, glass door, or skylight. VT ratings range between 0 and 1. A product with a higher VT transmits more visible light. The VT for a window, door, or skylight should be determined by a home's natural light requirements and/or whether interior glare needs to be reduced in a space. Studies have shown that increased use of natural light reduces energy use in buildings by replacing or reducing the need for artificial lighting and its associated heat.

Light-to-solar gain (LSG) – The ratio between the SHGC and VT. It provides a gauge of the relative efficiency of different glass or glazing types in transmitting daylight and blocks heat gains. The higher the number, the more light transmitted without adding excessive amounts of heat. This energy performance rating isn't always provided.

Spacer – A spacer keeps a window's glass panes the correct distance apart. Today's warm edge spacers, made of steel (with thermal breaks), foam, fiberglass, or vinyl, reduce thermal conductivity and prevent condensation. Seal failures could result in condensation between the panes, so look for a window manufacturer that provides a good warranty.

Applicability

Climates: All

Building type: All

Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Windows, Doors, and Skylights
www.eere.energy.gov/consumer/your_home/windows_doors_skylights/index.cfm/mytopic=13310

Air Sealing

Air sealing a home can significantly improve its energy efficiency. Air leakage occurs when outside air enters through cracks and openings. Proper air sealing can significantly reduce heating and cooling costs, improve building durability, and create a healthier indoor environment by controlling moisture and improving ventilation. The recommended strategy in new and old homes is to reduce air leakage as much as possible and to provide controlled ventilation as needed. The best time to seal a home is during initial construction, but older homes can also be air sealed.

Some simple steps to find leaks include turning off the furnace and all exhaust fans, shutting all doors and windows, and then passing a lighted incense stick around the edges of common leak sites such as windows and doors. Large cracks can be found by shining a flashlight at night over potential gaps while a partner observes the house from the outside. Large cracks will show up as light. Another test is to shut a door or window on a piece of paper. If the paper can be pulled out without tearing it, energy is being lost.

However, for a thorough and accurate measurement of air leakage in homes, a qualified technician must conduct an energy audit, particularly a blower door test. Such a test depressurizes a home and can reveal the location of many leaks. A complete energy audit will also help determine areas that need more insulation. For new homes, many of the air sealing techniques below can be incorporated. Air sealing alone can't replace the need for proper insulation.

Studies have shown airtight homes often consume one-third less energy compared to similar unsealed homes. However, for health reasons, a heat recovery ventilator or enthalpy recovery ventilator should be installed in an airtight home to ensure proper ventilation.

To ensure adequate ventilation, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. says that the living area of a home should be ventilated at a rate of 0.35 air changes per hour or 15 cubic feet per minute (cfm) per person, whichever is greater.

Air change is a measure of the rate at which the air in an interior space is replace by outside (or conditioned) air by ventilation and infiltration; usually measured in cubic feet per time interval (hour), divided by the volume of air in the room.

Air Sealing Types

Below are some of the most common techniques and materials to seal air leaks in the home:

- Air barriers such as drywall, decking, and sheathing
- Caulking
  - Household silicone (kitchens and baths)
  - Construction silicone (building materials such as wood and stone)
  - Polyurethane, expandable spray foam (large cracks indoors and outdoors)
  - Water-based foam sealant (windows and doors)
  - Butyl rubber (glass, metals, plastics, wood, and concrete)
  - Latex (bathrooms)
  - Oil or resin-based (building materials)
- Weatherstripping
  - Tension seal (windows and doors)
  - Felt (windows and doors)
  - Reinforced foam (windows and doors)
  - Tape (windows and doors)
  - Rolled or reinforced vinyl (windows and doors)
  - Door sweep (doors)
  - Magnetic (windows and doors)
  - Tubular rubber and vinyl (doors)
  - Reinforced silicone (doorjams or window stops)
  - Door shoe; bulb threshold; and frost-brake threshold (doors)

- Fin seal (aluminum windows and glass doors)
- Interlocking metal channels (doors)

Remember, a product with a low air leakage rating is tighter than one with a high air leakage rating.

Terms and Definitions

Air Barrier – Air barriers block air movement through building cavities. As a result, they help prevent air leakage in a home, which can account for 30% or more of a home's heating and cooling costs. A continuous air barrier is created by sealing all the holes and seams between any sheet goods with caulking, gaskets, or foam sealants. If house wrap is used, sealing all of its joints with "house wrap tape" is a good practice that improves the wrap's performance about 20%.

Airtight Drywall Approach (ADA) – An air sealing technique in which any seams and joints where the foundation, sill plate, floor joist header, and subfloor meet are sealed. The spaces between floors, the subfloor, rim joist, and plates are also sealed. Airtight electrical boxes complete the air barrier. ADA sealing is done during the construction process.

Simple Caulk and Seal (SCS) – A similar air sealing technique to ADA, but one that is done after the drywall is finished. Both ADA and SCS create an effective airtight wall by sealing the drywall to the building structure.

Applicability

Climates: All
Building type: All
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Insulation and Air Sealing
www.eere.energy.gov/consumer/your_home/insulation_airsealing/index.cfm/mytopic=11220

Passive Solar Design

The use of passive solar design techniques in a home can significantly improve its energy efficiency and reduce or eliminate heating, cooling, and lighting bills. Passive solar simply means to heat and light a home with building materials that store or disperse the sun's energy. Passive solar materials replace traditional mechanical systems that use natural gas or electricity to lower heating and lighting costs.

Passive solar homes range from those heated almost entirely by the sun to those with south-facing windows that provide some fraction of the heating load. The difference between a passive solar home and a conventional home is design. The key is designing a passive solar home to best take advantage of the local climate. For passive heating and cooling, the plan of the house, careful site selection and planning, construction materials, building features, and other aspects of the home are designed to collect, store, and distribute the sun's heat in winter and to block the sun's rays in summer. Passive solar houses can be built in any architectural style and in any part of the country.

Types

Below are the most common passive solar design techniques and materials:

Passive solar heating – Passive solar heating can reduce or eliminate the need for gas or electric heat in properly oriented and designed homes. The simplest passive solar heating technique—direct gain—allows sunlight to enter a house through south-facing windows or glass doors so that the brick or stone floors can capture the sun's heat. The masonry floors absorb and store the solar heat, then release it back into the room at night when the room cools. Sometimes a Trombe wall is placed between the south-facing windows and the living spaces. This approach, called indirect gain, consists of installing an 8 to 16 inch thick masonry wall on the south side of a house. A single or double layer of glass is mounted about 1 inch or less in front of the wall's surface.

Solar heat is absorbed by the wall's dark-colored outside surface and stored in the wall's mass, where it radiates into the living space. The Trombe wall distributes or releases heat into the home over a period of several hours.

Passive solar cooling – Passive solar cooling can reduce (or even eliminate) the need for air conditioning in homes. Passive cooling includes overhangs for south-facing windows, few windows on the west, shade trees, thermal mass, and cross ventilation. Because the sun's path and angle in the sky are different in summer than in winter, some of the same strategies that help to heat a home in the winter also cool it in the summer. For example, window overhangs will block the high summer sun but won't interfere with the low winter sun's ability to heat the home. Thermal mass, which stores heat in the winter to release in the evening, works in reverse in the summer. The mass cools down in the evening and retains that coolness the next day, moderating the effects of high daytime temperatures.

Passive solar lighting – Today's highly energy-efficient windows can reduce the need for artificial lighting during daylight hours without causing heating or cooling problems. The best way to incorporate daylighting in the home depends on the climate and the home's design. The sizes and locations of windows should be based on the cardinal directions rather than their on effect on the street-side appearance of the house. South-facing windows are most advantageous for daylighting and for moderating seasonal temperatures. They allow most winter sunlight into the home but little direct sun during the summer, especially when properly shaded. North-facing windows are also advantageous for daylighting. They admit relatively even, natural light, producing little glare and almost no unwanted summer heat gain. Although east- and west-facing windows provide good daylight penetration in the morning and evening, respectively, they should be limited. They may cause glare, admit a lot of heat during the summer when it is usually not wanted, and contribute little to solar heating during the winter.

Terms and Definitions

Aperture (Collector) – A large glass area, usually a window, through which sunlight enters a building. Typically, the aperture(s) should face within 30 degrees of true south and should not be shaded by other buildings or trees from 9:00 a.m. to 3:00 p.m. each day during the heating season.

Absorber – The dark surface of the storage element. This surface—which could be that of a masonry wall, floor, or partition (phase change material), or that of a water container—sits in the direct path of sunlight. Sunlight hits the surface and is absorbed as heat.

Thermal mass – The materials that retain or store the heat produced by sunlight. The difference between the absorber and thermal mass, although they often form the same wall or floor, is that the absorber is an exposed surface, whereas thermal mass is the material below or behind that surface.

Distribution – The method by which solar heat circulates from the collection and storage points to different areas of the house. A strictly passive design will use conduction, convection, and radiation exclusively. In some applications, however, fans, ducts, and blowers may help with the distribution of heat through the house.

Control – The elements that control under- and overheating, including electronic sensing devices, operable vents and dampers, low-emissivity blinds, and awnings.

Applicability

Climates: All
Building type: All
Demand management strategy: Strategic conservation

For More Information

DOE Building Technologies Program: Passive Solar Design
www.eere.energy.gov/buildings/info/documents/pdfs/29236.pdf

Heating and Cooling

■■■

Heating and cooling accounts for the largest energy use in a home—from 45% – 70% of a home's energy use. A wide variety of technologies are available for heating and cooling the home, and they achieve a wide range of efficiencies in converting their energy sources into useful heat or cool air. In addition, many heating and cooling systems have certain supporting equipment in common, such as thermostats and ducts, which provide opportunities for improved efficiency.

Programmable Thermostats

Homeowners can save around 10% a year on heating and cooling bills by simply turning the thermostat back 10°–15° for 8 hours. By installing an automatic setback or programmable thermostat, homeowners can do this automatically without sacrificing comfort.

Programmable thermostats can turn on the heating or air-conditioning according to a pre-set schedule. As a result, the equipment will run less when the occupants are asleep or when the house is not occupied.

Programmable thermostats can store and repeat multiple daily settings (six or more temperature settings per day) that can be overriden manually without affecting the rest of the daily or weekly program.

A common misconception associated with thermostats is that a furnace works harder than normal to warm the space to a comfortable temperature after the thermostat has been set back, resulting in little or no savings. This misconception has been dispelled by years of research and numerous studies. The fuel required to reheat a building to a comfortable temperature is roughly equal to the fuel saved as the building drops to the lower temperature. The homeowner saves fuel between the time that the temperature stabilizes at the lower level and the next time heat is needed. So, the longer the house remains at the lower temperature, the more energy the homeowner will save.

Specially designed programmable thermostats may be required for homes with heat pumps, electric resistance heating, steam heat, and radiant floor heating. Homeowners should consult with their HVAC professionals for assistance.

Applicability

Climate: All
Building type: Residential
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Thermostats and Control Systems
www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12720

Heat Pumps

For climates with moderate heating and cooling needs, heat pumps offer an energy-efficient alternative to furnaces and air conditioners. Like refrigerators, heat pumps use electricity to move heat from a cool space into a warm one, making the cool space cooler and the warm space warmer. During the heating season, heat pumps move heat from the cool outdoors into your warm house; during the cooling season, heat pumps move heat from your cool house into the warm outdoors. Because they move rather than generate heat, heat pumps can provide up to 6 times the amount of energy they consume.

Geothermal heat pumps (sometimes referred to as GeoExchange, earth-coupled, ground-source, or water-source heat pumps) have been in use since the late 1940s. Geothermal heat pumps use the constant temperature of the earth as the exchange medium instead of the outside air temperature. This allows the system to reach fairly high efficiencies (300%–600%) on the coldest of winter nights. Although they cost more to install, geothermal heat pumps have low operating costs because they take advantage of relatively constant ground or water temperatures. However, the installation potential depends on the size of the lot, the size of the system required, the subsoil makeup and type, the type of system being installed (horizontal loop, vertical loop, or open loop), and the landscape. Ground-source or water-source heat pumps can be used in more extreme climatic conditions than air-source heat pumps, and customer satisfaction with the systems is very high.

Many high-efficiency heat pumps are equipped with a desuperheater, which recovers waste heat from the heat pump's cooling mode and uses it to heat water. A desuperheater-equipped heat pump can heat water 2 to 3 times more efficiently than an ordinary electric water heater. The ability to combine heating, cooling, dehumidification, and water heating into one system, and the comparatively low energy demand and therefore low operating costs, and the potential to integrate this system with renewable energy technologies, all make this technology very attractive.

Another type of heat pump is the air-source heat pump, which transfers heat between the house and the outside air. If the home is heated with resistance electricity, an air-source heat pump can trim the amount of electricity used for resistance heating by as much as 30%–40%. High-efficiency heat pumps also dehumidify better than standard central air conditioners, resulting in less energy usage and more cooling comfort in summer months. However, the efficiency of most air-source heat pumps as a heat source drops dramatically at low temperatures (175%–250% for air-source heat pumps on cool days). These pumps are generally unsuitable for cold climates, although resistance electric and gas-fired add-on systems may overcome that problem.

For homes without ducts, air-source heat pumps are also available in a ductless version called a mini-split heat pump. In addition, a special type of air-source heat pump called a “reverse cycle chiller” generates hot and cold water rather than air, allowing it to be used with radiant floor heating systems in heating mode.

A new type of heat pump for residential systems is the absorption heat pump, also called a gas-fired heat pump. Absorption heat pumps use heat as their energy source, and can be driven with a wide variety of heat sources.

Terms and Definitions

Two-Speed Compressors – Unlike standard compressors that can operate only at full capacity, two-speed compressors allow heat pumps to operate close to the heating or cooling capacity that is needed at any particular moment. This saves large amounts of electrical energy.

Variable-Speed Motors – Some models of heat pumps are equipped with variable-speed or dual-speed motors on their indoor fans (blowers), outdoor fans, or both. The variable-speed controls for these fans attempt to keep the air moving at a comfortable velocity, minimizing cool drafts and maximizing electrical savings.

Desuperheater – A desuperheater uses waste heat from the heat pump's cooling mode to heat water.

Scroll Compressor – Another advance in heat pump technology is the scroll compressor, which consists of two spiral-shaped scrolls. One remains stationary, while the other orbits around it, compressing the refrigerant by forcing it into increasingly smaller areas. Compared to the typical piston compressors, scroll compressors have a longer operating life and are quieter. According to some reports, heat pumps with scroll compressors provide 10°–15°F (5.6°–8.3°C) warmer air when in the heating mode, compared to heat pumps with piston compressors.

BackUp Combustion Burners – Although most heat pumps use electric resistance heaters as a backup for cold weather, they can also be equipped with backup burners that help solve the problem of the heat pump delivering relatively cool air during cold weather and reduce its use of electricity. Since few heat pump manufacturers incorporate both types of heat supply in one box, these configurations are often two smaller, side-by-side, standard systems sharing the same ductwork. The combustion fuel half of the system could be propane, natural gas, oil, or even coal and wood.

Applicability

Climate: All
Building type: Residential
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Heat Pump Systems
www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12610

Heat Storage

Electric thermal storage is used to shift electricity used for space heating to off peak times. Heat storage is cost effective only under certain conditions: off-peak rates must be available from the electric utility and all available heating options should be considered, including oil, gas, and propane. Electric thermal storage units consist of electric resistance heating coils interwoven in a stack of ceramic bricks or crushed rocks inside an insulated cabinet. During off-peak hours—11:00 pm to 7:00 am—the bricks or rocks are changed by the heating coil. During the day, the heating coil is turned off and the bricks discharge their heat to the home. Central and zoned thermal storage systems are available for residential applications, although zoned systems are more widely available.

Applicability

Building type: Central systems are applicable for residences with low to high heating loads, adequate space for the unit, ductwork for delivery of heated or cooled air to individual rooms, and when it is desirable to evenly control temperatures in all rooms. Central systems come in many sizes and types and can be designed for any size home.

Climate: Cool climate
Demand management strategy: Load shifting, valley filling

For More Information

EERE Consumer's Guide: Electric Resistance Heating
www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12520

Zoned Heating

Zoned electric heating systems are composed of electric heaters and separate manual or programmable thermostats in each room to provide the desired level of heat. They use less energy than central systems because 1) thermostats can be turned down or off in rooms not in use during the day; and 2) they eliminate heat loss from ductwork where it runs through unheated spaces such as basements, garages, and crawl spaces. When radiant heat is used, the radiant energy effect allows for lower room temperatures and thus less heat loss to the outdoors. A zone heater can be added to a room to provide task heating in conjunction with a central system, or it can be used throughout a house instead of central heating. For new construction, a zoned system is more energy efficient than a central electric furnace and air conditioning.

Zoned heating can be combined with renewable sources of electricity, such as solar- or wind-generated electricity, to increase efficiencies even more.

Applicability

Building type: All
Climate: All
Demand management strategy: Strategic load growth, peak clipping

Duct Thermal Losses

Typical systems with ducts in attics or crawl spaces lose 25% to 40% of the heating or cooling energy that passes through them. Duct systems lose energy in two main ways: by air leakage through small cracks and seams and by conduction of heat through the duct wall. In addition, how the various systems and equipment interact has an effect on how well the ducts perform. Duct systems must also be sized properly to deliver the needed cubic feet of air to individual space and to not overwork the fan/motor system or compressor.

Air Leakage

Ducts lose energy when air leaks into or out of them. Sometimes this leakage is from holes in the ducts or from poorly connected duct joints. Even if the ducts are sealed, their operation can cause the house to leak more air because of differences in air pressure in various zones.

Heat Conduction

Duct systems also lose energy when the warm or cool air they contain heats or cools the duct walls, which in turn heat or cool the air outside the ducts. In winter, ducts that are in an attic or vented crawl space that is nearly as cold as the outdoors lose this heat completely through the duct wall. If the ducts are in a basement, some of this lost heat may be recaptured as it warms the basement ceiling enough to reduce heat loss from the house. In summer, ducts gain heat from warm surrounding spaces, detracting from the air conditioner’s ability to cool the house.

In the United States, ducted heating and cooling systems are installed in about 90% of new homes. In new construction, ducts can be placed within the conditioned space. If done in a manner that leaves no hidden leakage paths to the outside, duct efficiency of 100% is possible. In this case, all the heating or cooling provided by the equipment would reach the living space.

Terms and Definitions

Blower door – A large fan that is mounted in a doorway and used to pressurize and depressurize a space to determine air leaks. One way to determine leaks through ducts is to measure with a blower door the leakage with the registers and return first sealed, then open. The difference between the two readings is the amount of air leaking through the ducts.

Applicability

Climate: All
Building type: Residential and commercial
Demand management strategy: Peak clipping, strategic conservation

For More Information

DOE Building Technologies Program: Better Duct Systems for Home Heating and Cooling
www.nrel.gov/docs/fy05osti/30506.pdf

DOE Building Technologies Program: Air Distribution System Installation and Sealing
www.eere.energy.gov/buildings/info/documents/pdfs/air_dist_sys_install_seal-0783.pdf

Energy-Efficient Air Conditioning

Two-thirds of all homes in the United States have air conditioners. Air conditioners use about 5% of all the electricity produced in the United States, at a cost of more than $11 billion to homeowners. As a result, roughly 100 million tons of carbon dioxide are released into the air each year—an average of about 2 tons for each home with an air conditioner.

The adoption of high-efficiency air conditioners by homeowners could reduce this energy use by 20%–50%.

The two most common types of air conditioners are room air conditioners and central air conditioners. A compromise between the two types of systems is provided by ductless, mini-split air conditioners.

Central Air Conditioners

Central air conditioners circulate cool air through a system of supply and return ducts. Supply ducts and registers (i.e., openings in the walls, floors, or ceilings covered by grilles) carry cooled air from the air conditioner to the living space. This cooled air warms as it circulates through the home; then it flows back to the central air conditioner through return ducts and registers.
Central air conditioners are more efficient than room air conditioners. In addition, they are out of the way, quiet, and convenient to operate. To save energy and money, consumers should try to buy energy-efficient air conditioners and reduce the central air conditioner's energy use. In an average air-conditioned home, air conditioning consumes more than 2,000 kilowatt-hours of electricity per year, causing power plants to emit about 3,500 pounds of carbon dioxide and 31 pounds of sulfur dioxide.

Today's best air conditioners use 30%–50% less energy to produce the same amount of cooling as those made in the mid-1970s. Even if an air conditioner is only 10 years old, the homeowner may save 20%–40% on cooling energy costs by replacing it with a newer, more efficient model.

Proper sizing and installation are key elements in determining air conditioner efficiency. Too large a unit will not adequately remove humidity. Too small a unit will not be able to attain a comfortable temperature on the hottest days. Improper unit location, lack of insulation, and improper duct installation can greatly diminish efficiency. When buying an air conditioner, Homeowners should try to buy high-efficiency models.

Types

Split-System Unit

In a split-system central air conditioner, an outdoor metal cabinet contains the condenser and compressor, and an indoor cabinet contains the evaporator. In many split-system air conditioners, this indoor cabinet also contains a furnace or the indoor part of a heat pump. The air conditioner's evaporator coil is installed in the cabinet or main supply duct of this furnace or heat pump. If the home already has a furnace but no air conditioner, a split-system is the most economical central air conditioner to install.

Packaged Unit

In a packaged central air conditioner, the evaporator, condenser, and compressor are all located in one cabinet, which usually is placed on a roof or on a concrete slab next to the house's foundation. This type of air conditioner also is used in small commercial buildings. Air supply and return ducts come from indoors through the home's exterior wall or roof to connect with the packaged air conditioner, which is usually located outdoors. Packaged air conditioners often include electric heating coils or a natural gas furnace. This combination of air conditioner and central heater eliminates the need for a separate furnace indoors.

Terms and Definitions

SEER – Central air conditioners are rated according to their seasonal energy efficiency ratio (SEER). SEER indicates the relative amount of energy needed to provide a specific cooling output. Many older systems have SEER ratings of 6 or lower. The minimum SEER allowed today is

13. Air conditioners manufactured after January 23, 2006 must achieve a SEER of 13 or higher. SEER 13 is 30% more efficient than the previous minimum SEER of 10. The standard applies only to appliances manufactured after January 23, 2006. Equipment with a rating lower than SEER 13 manufactured before this date may still be sold and installed.

SEER is calculated by dividing the seasonal cooling output in Btu by the seasonal energy input in watt-hours for the average U.S. climate.

Ductless Mini-Split Air Conditioners

Ductless, mini split-system air-conditioners (mini splits) have numerous potential applications in residential, commercial, and institutional buildings. The most common applications are in multifamily housing or as retrofit add-ons to houses with "non-ducted" heating systems, such as hydronic (hot water heat), radiant panels, and space heaters (wood, kerosene, propane). They can also be a good choice for room additions and small apartments, where extending or installing distribution ductwork (for central air-conditioning or heating systems) is not feasible.

Like central systems, mini splits have two main components: an outdoor compressor/condenser, and an indoor air-handling unit. A conduit, which houses the power cable, refrigerant tubing, suction tubing, and a condensate drain, links the outdoor and indoor units.

The main advantages of mini splits are their small size and flexibility for zoning or heating and cooling individual rooms. Many models can have as many as four indoor air-handling units (for four zones or rooms) connected to one outdoor unit. The number depends on how much heating or cooling is required for the building or for each zone (which in turn is affected by how well the building is insulated). Since each zone will have a thermostat, the homeowner needs to condition that place only when someone is there. This will save energy and money.

Ductless mini split systems are also often easier to install than other types of space conditioning systems. Since mini splits have no ducts, they avoid the energy losses associated with ductwork of central forced air systems. Duct losses can account for more than 30% of energy consumption for space conditioning, especially if the ducts are in an unconditioned space such as an attic.

Room Air Conditioners

Room air conditioners range from window units designed to cool a single room to large-capacity, multi-room units for large homes. Most room air conditioners are less expensive to operate than central units, but their efficiency is generally lower than that of central air conditioners. The most efficient air conditioners on the market are up to 70% more efficient than the current average room air conditioner.

The required cooling capacity for a room air conditioner depends on the size of the room being cooled: Room air conditioners generally have cooling capacities that range from 5,500 Btu per hour to 14,000 Btu per hour.

A common rating term for air conditioning size is the "ton," which is 12,000 Btu per hour. Proper sizing is very important for efficient air conditioning. A bigger unit is not necessarily better because a unit that is too large will not cool an area uniformly. A small unit running for an extended period operates more efficiently and dehumidifies more effectively than a large unit that cycles on and off too frequently. Based on size alone, an air conditioner generally needs 20 Btu for each square foot of living space.

Types

Three types of room air conditioners are available:

Window models – Installed in most double-hung windows.

Casement window models – Used in narrow, vertical windows, usually requiring the removal of a window panel for installation.

Built-in models – Encased in a sleeve installed in the wall.

Sizing and Selecting a Room Air Conditioner

Other important factors to consider when selecting an air conditioner are room height, local climate, shading, and window size.

Terms and Definitions

EER – A room air conditioner's efficiency is measured by the energy efficiency ratio (EER). The EER is the ratio of the cooling capacity (in Btu per hour) to the power input (in watts). The higher the EER rating, the more efficient the air conditioner.

Applicability

Climates: All

Building type: All

Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Air Conditioning
www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12370

American Council for an Energy Efficient Economy (ACEEE)
www.aceee.org

Provides consumers with list of the latest energy-efficient appliances.

Air Conditioner Cycling Control

Air conditioner cycling involves direct, real-time utility control over the operation of residential air conditioners. The standards method of intentional cycling is to shut off the compressor for some fixed period, allow it to resume operation for some fixed period, and then shut it off again. A 25% cycling strategy—7.5 minutes off and 22.5 minutes on—is a typical cycle.

Applicability

Air conditioner cycling is generally implemented on central air conditioning systems or large through-the-wall air conditioners. Small window units are rarely cycled. Cycling significantly undersized units can result in excessive discomfort, and cycling oversized units can result in little or no load relief.

Climate: Warm climates
Building type: All residential
Demand management strategy: Peak clipping, flexible load shape
Other: Cycling may shorten the life of the compressor and other system components

Whole House and Ceiling Fans

Whole house ventilation using a whole house fan, also called an attic fan, can substitute for an air conditioner most of the year in most climates. Whole house fans combined with ceiling fans and other circulating fans provide acceptable summer comfort for many families, even in hot weather. In addition to whole house fans, the ducts of a central heating and cooling system can be modified to provide whole house ventilation.

The whole house fan pulls air in from open windows and exhausts it through the attic and roof. It provides good attic ventilation in addition to whole house ventilation. Whole house fans should provide 30–60 air changes per hour.

Circulating fans include ceiling fans, table fans, floor fans, and fans mounted to poles or walls. These fans create a wind chill effect that increases occupant comfort, even if the home is also cooled by natural ventilation or air conditioning. Ceiling fans are considered the most effective of these types of fans, since they effectively circulate the air to create a draft throughout the room and consume very little energy.

For homes with air conditioning, using a ceiling fan will allow the homeowner to raise the thermostat setting about 4°F with no reduction in comfort. In temperate climates, or during moderately hot weather, ceiling fans may allow the homeowner to avoid using the air conditioner altogether Ceiling fans are appropriate only in rooms with ceilings at least 8 feet high. Fans work best when the blades are 7–9 feet above the floor and 10–12 inches below the ceiling. Larger ceiling fans can move more air than smaller fans. A 36- or 44-inch diameter fan will cool rooms up to 225 square feet; fans that are 52 inches or larger should be used in larger rooms. Multiple fans work best in rooms longer than 18 feet. Small- and medium-sized fans will provide efficient cooling in a 4- to 6-foot diameter area; larger fans are effective up to 10 feet.

When buying window fans, homeowners should look for the ENERGY STAR label. Fans that earn the label move air 20% more efficiently, on average, than standard models.

Applicability

Climate: Whole house and ceiling fans are excellent alternatives to air conditioning for windless locations, densely developed neighborhoods, or townhouses with high cooling requirements.

Building type: Residential

Demand management strategy: Strategic conservation, peak clipping

Other: During winter or in summer when air conditioning is used, the whole house fan louvers should be sealed with an insulated and weatherstripped or gasketed panel to prevent air infiltration. Another alternative is to construct an airtight insulated cover or box and place it over the whole house fan in the attic.

For More Information

DOE Building Technologies Program: Installing and Using a Whole House Fan

www.eere.energy.gov/buildings/info/homes/wholehousefan.html

Sizing a Whole House Fan

Whole house fans are sized in cfm of ventilating power. To determine the size needed, first calculate the volume of the house in cubic feet. To do that, multiply the square footage of the floor area to be cooled by the height from floor to ceiling. Take that volume and multiply by 30 – 60 air changes per hour (depending on the power needed). Then, divide by 60 minutes to get the cfm of capacity the house requires.

[(Square feet______ x room height______) x 30 or 60/ 60 = cfm required _________.]

Evaporative Cooling

In low-humidity areas such as the southwestern United States, evaporating water into the air provides a natural and energy-efficient means of cooling. Evaporative coolers, also called swamp coolers, rely on this principle, cooling outdoor air by passing it over water-saturated pads, causing the water to evaporate into it. The 15°–40°F cooler air is then directed into the home, and pushes warmer air out through windows.

When an evaporative cooler is running, windows are opened partway to allow warm indoor air to escape as it is replaced by cooled air. Unlike central air-conditioning systems that recirculate the same air, evaporative coolers provide a steady stream of fresh air into the house.

Evaporative coolers cost about one-half as much to install as central air conditioners and use about one-quarter as much energy. However, they require more frequent maintenance than refrigerated air conditioners and they're suitable only for areas with low humidity.

The low-energy use of evaporative coolers makes them an attractive option for cutting peak demand in the summertime.

Types

Evaporative coolers are installed in one of two ways: the cooler blows air into a central location, or the cooler connects to ductwork, which distributes the air to different rooms. Central-location installations work well for compact houses that are open from room to room. Ducted systems are required for larger houses with hallways and multiple bedrooms.

Most people install down-flow evaporative coolers on the roofs of their houses. However, many experts prefer to install ground-mounted horizontal units, which feature easier maintenance and less risk of roof leaks.

Small horizontal-flow coolers are installed in windows to cool a room or a section of a home. These portable evaporative coolers work well in moderate climates, but may not be able to cool a room adequately in hot climates. Room evaporative coolers are becoming more popular in areas of the western United States with milder summer weather. They can reduce the temperature in a single room by 5°–15°F.

Small, portable evaporative coolers on wheels are now available as well. Although the units have the advantage of portability, their cooling ability is limited by the humidity within a home. Generally, these units will provide only a slight cooling effect.

Two-stage evaporative coolers are newer and even more efficient. They use a pre-cooler, more effective pads, and more efficient motors, and add less humidity to the home than single-stage evaporative coolers. Because of their added expense, they are most often used in areas where daytime temperatures frequently exceed 100°F.

Terms and Definitions

CFM – Evaporative coolers are rated by the cfm of air that they deliver to the house. Most models range from 3,000 to 25,000 cfm. Manufacturers recommend providing enough air-moving capacity for 20–40 air changes per hour, depending on climate.

Applicability

Climate: Evaporative cooling is best suited to hot dry climates.
Building type: All residential and many small commerical.
Demand management strategy: Peak clipping

For More Information

EERE Consumer's Guide: Evaporative Cooling
www.eere.energy.gov/consumer/your_home/space_heating_cooling/index.cfm/mytopic=12360

Distributed Photovoltaic Systems

A small solar electric or photovoltaic (PV) system can be a reliable and pollution-free producer of electricity for the home. And they're becoming more affordable all the time. Small PV systems also provide a cost-effective power supply in locations where sending electricity through conventional power lines is expensive or impossible.
The amount of power generated by a solar system at a particular site depends on how much of the sun's energy reaches it. Thus, PV systems, like all solar technologies, function most efficiently in the southwestern United States, which receives the greatest amount of solar energy. PV technology is also used for stand-alone applications like outdoor lighting. For information about the amount of available solar energy in a specific area, see the National Renewable Energy Laboratory's Solar Maps Web site at *www.nrel.gov/gis/solar.html.*

Applicability

Climate: Because PV technologies use both direct and scattered sunlight to create electricity, the solar resource across the United States is ample for small solar electric systems.
Building type: All residential, all building types
Demand management strategy: Peak clipping, strategic conservation

For More Information

EERE Consumer's Guide: Small Solar Electric Systems
www.eere.energy.gov/consumer/your_home/electricity/index.cfm/mytopic=10710

National Renewable Energy Laboratory's Solar Maps
www.nrel.gov/gis/solar.html

The Economics of a Small Solar Electric System

The economics of the small solar electric or PV system are determined by the capital and operating costs. Capital costs include the initial costs of designing and installing a PV system. Operating costs include the costs associated with maintaining and operating the PV system over its useful life.

The factors that affect capital and operating costs include:

- System components
- System size
- Whether a system is grid-connected or stands alone (off-grid)
- Solar resource at the location (amount of sunlight).

Electricity Consumption

Before selecting system components and sizing a PV system for a home, a homeowner should evaluate energy consumption patterns and try to reduce the home's electricity use. A simple load analysis includes these tasks:

- Looking at utility bills over the past year
- Calculating energy consumption
- Recognizing consumption trends.

By understanding "energy habits" and using energy more efficiently, the homeowner can reduce the size of the PV system that is needed, lowering the capital and operating costs. Investing in energy efficiency is a wise choice as it will reduce the size of the solar system, thereby reducing the investment in solar technology. Dollars spent on efficiency are almost always less expensive, per kilowatt-hour, than dollars spent on generating solar electricity.

A homeowner who is designing a new home should work with the builder and the solar professional to incorporate the PV system into the whole-house system design—an integrated approach for building an energy-efficient home.

PV Cost Considerations

The PV provider can estimate how much electricity the new PV system will produce per year (measured in kilowatt-hours). The homeowner can compare that number to the annual electricity usage (called demand) for an idea of how much will be saved. As a rule, the cost per kilowatt-hour decreases as the size of the system increases.

Compare the purchase price of utility-generated electricity to the higher costs of smaller PV systems. PV-generated electricity is usually more expensive than conventional, utility-supplied electricity. However, these costs will vary by geographic location and type of provider.

Solar rebate programs, subsidies, and other incentives can help make PV more affordable. Tax incentives may include a sales tax exemption on the PV system purchase, a property tax exemption, or state personal income tax credits, all of which provide an economic benefit to consumers by reducing capital costs.

Some solar rebate programs are capped at a certain dollar amount. Therefore, a solar electric system that matches this cap maximizes the benefit of the solar rebate.

Many homeowners use PV systems because other considerations—such as environmental benefits and energy independence—tip the balance in their favor.

Water Heating

Water heating accounts for about 13% of a typical home's energy bill. There are two key ways to reduce energy use for water heating: use less hot water, and heat the water that is used more efficiently. This section focuses on water heating technologies including:

- Conventional water heating
- Combination space and water heaters
- Demand water heaters
- Heat pump water heaters
- Solar water heaters

Conventional Water Heating

Conventional storage water heaters remain the most popular type of water heating system for the home. A single-family storage water heater offers a ready reservoir—20 – 80 gallons—of hot water. It operates by releasing hot water from the top of the tank when the hot water tap is turned on. To replace that hot water, cold water enters the bottom of the tank, ensuring that the tank is always full.

Types

Conventional storage water heater fuel sources include natural gas, propane, fuel oil, and electricity. Natural gas and propane water heaters basically operate the same. A gas burner under the tank heats the water. A thermostat opens the gas valve as the water temperature falls. The valve closes when the temperature rises to the thermostat's setpoint. Oil-fired water heaters operate similarly, but they have power burners that mix oil and air in a vaporizing mist, ignited by an electric spark. Electric water heaters have one or two electric elements, each with its own thermostat. With two electric elements, a standby element at the bottom of the tank maintains the minimum thermostat setting while the upper demand element provides hot water recovery when demand heightens. Because water is constantly heated in the tank, energy can be wasted even when a hot water tap isn't running. This is called *standby heat loss.* However, some storage water heater models have heavily insulated tanks, that significantly reduce standby heat losses and lowering annual operating costs. Look for models with tanks that have a thermal resistance (R-Value) of R-12 to R-25.

Gas and oil water heaters also have venting-related energy losses. Two types of water heaters—a fan-assisted gas water heater and an atmospheric sealed-combustion water heater—reduce these losses. The fan-assisted gas water heater uses a draft-induced fan that regulates the air that passes through the burner, which minimizes the excess air during combustion, increasing efficiency. The atmospheric sealed-combustion water heater uses a combustion and venting system that is totally sealed from the house.

Terms and Definitions

First hour rating – The first hour rating is the amount of hot water (in gallons) the heater can supply per hour (starting with a tank full of hot water). It depends on the tank capacity, source of heat (burner or element), and the size of the burner or element. The EnergyGuide Label lists the first hour rating in the top left corner as "Capacity (first hour rating)." The Federal Trade Commission requires an EnergyGuide Label on all new conventional storage water heaters

Energy factor – The energy factor (EF) is used to determine the energy efficiency of a water heater. The EF indicates a water heater's overall energy efficiency based on the amount of hot water produced per unit of fuel consumed over a typical day. The higher the EF, the more efficient the water heater. However, higher EF values don't always mean lower annual operating costs, especially when fuel sources are compared. Product literature from a manufacturer usually provides a water heater model's EF factor.

The EF indicates a water heater's overall energy efficiency based on the amount of hot water produced per unit of fuel consumed over a typical day. This includes the following:

- Recovery efficiency – how efficiently the heat from the energy source is transferred to the water
- Standby losses – the percentage of heat loss per hour from the stored water compared to the heat content of the water (water heaters with storage tanks)
- Cycling losses – the loss of heat as the water circulates through a water heater tank, and/or inlet and outlet pipes.

Applicability

Climate: All
Building type: All
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Conventional Storage Water Heaters
www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12980

Comparing Costs and Determining Payback for Storage, Demand, and Heat Pump Water Heaters

After identifying the purchase and annual operating costs of the water heating system, determine the costs associated with another water heating system under consideration and compare the two.

Calculating Annual Operating Cost

To estimate the annual operating cost of a storage, demand (tankless or instaneous), or heat pump (not geothermal heat pump) water heater, you need to know the following about the model:

- EF
- Fuel type and cost (your local utility can provide current rates)

Then, use the following calculations:

For gas and oil water heaters
Find the unit cost of fuel by Btu or therm.

(1 therm = 100,000 Btu)

365 x 41045/EF x Fuel Cost (Btu) = estimated annual cost of operation

OR

365 x 0.4105/EF x Fuel Cost (therm) = estimated annual cost of operation

Example: A natural gas water heater with an EF of .57 and a fuel cost of $0.00000619/Btu

365 x 41045/.57 x $0.00000619 = $163

For electric water heaters, including heat pump units
Find or convert the unit cost of electricity by kilowatt-hour (kWh).

365 x 12.03/EF x Electricity Cost by kWh = estimated annual cost of operation

Example: A heat pump water heater with an EF of 2.0 and a electricity cost of $0.0842/kWh

365 x 12.03/2.0 x $0.0842 = $185

Combination Space and Water Heaters

Combination or integrated water and space heating systems use a home's space heating system to heat water.

Types

The main types of combined systems are tankless coils, indirect water heaters, and advanced systems.

A tankless coil water heater uses a heating coil or heat exchanger installed in a main furnace or boiler. Whenever a hot water faucet is turned on, the water flows through the heat exchanger. These water heaters provide hot water on demand without a tank, like a demand water heater, but because they rely on the furnace or boiler to heat the water directly, they work most efficiently during cold months when the heating system is used regularly. That's why they can be an inefficient choice for many homes, especially in warmer climates.

Indirect water heaters offer a more efficient choice for most homes, even though they require a storage tank. An indirect water heater uses the main furnace or boiler to heat a fluid that's circulated through a heat exchanger in the storage tank. The energy stored by the water tank allows the furnace to turn off and on less often, which saves energy. Therefore, an indirect water heater that is used with a high-efficiency boiler and well-insulated tank can be the least expensive means of providing hot water.

Indirect systems can be fired by gas, oil, propane, electricity, solar energy, or a combination of any of these. Tankless coil systems are typically electricity or gas fired. Also, these integrated or combination water heating systems can work with forced air systems and with hydronic or radiant floor heating systems.

Advanced combination systems are available that heat water and air. These systems typically include a heating unit and an air unit. The units work together to produce hot water like a water heater and warm air like a furnace.

These advanced systems may operate more efficiently than standard furnaces and water heaters.

Integrated or combination water and space heating systems usually cost more than a separate water heater and furnace or boiler, but installation and maintenance costs may be lower. For example, the home won't need multiple utility hookups since there's one source of heat. There also are fewer moving parts to maintain. Some of these high efficiency systems may also provide lower utility costs.

Most combination water and space heating systems are designed for new construction. However, some retrofit units can work with an existing water heater.

When selecting a system, a homeowner should consider its size. The sizing of a combination system involves some different calculations than those used for sizing a separate water heating or space heating system. It's best left to a qualified plumbing and heating contractor.

Some types of heat pump water heaters provide hot water and space heating. See Heat Pump Water Heaters for more information.

Terms and Definitions

Combined Appliance Efficiency Rating – To determine the energy efficiency of a combination water and space heating system, use its combined appliance efficiency rating (CAE). The higher the number, the more energy efficient it is. Combination appliance efficiency ratings vary from 0.59 to 0.90.

Applicability

Climate: Tankless coil water heaters, cold climates. Other combined systems, all.

Building type: All
Demand management strategy: Strategic conservation

Demand Water Heaters

Demand (tankless or instantaneous) water heaters provide hot water only as it is needed. Because they don't store heated water, they don't produce the standby energy losses associated with storage water heaters, which can save energy and money.

Demand water heaters heat water directly without of a storage tank. Therefore, they avoid the standby heat losses associated with storage water heaters. When a hot water tap is turned on, cold water travels through a pipe into the unit. Either a gas burner or an electric element heats the water. As a result, demand water heaters deliver a constant supply of hot water. There is no need to wait for a storage tank to fill with enough hot water. However, a demand water heater's output limits the flow rate. Typically, demand water heaters provide hot water at a rate of 2–5 gallons (7.6–15.2 liters) per minute (gpm). (For comparison, showerheads manufactured today must have a flow rate of 2.5 gpm or lower.)

Types

Demand water heaters can be powered by gas or electricity. Gas-fired demand water heaters produce higher flow rates than electric ones. Sometimes, however, even the largest gas-fired model cannot supply enough hot water for simultaneous, multiple uses in large households. For example, taking a shower and running the dishwasher at the same time can stretch a demand water heater to its limit. To overcome this problem, a homeowner can install two or more demand water heaters, connected in parallel for simultaneous demands. Or, separate demand water heaters can be installed for appliances—such as a clothes washer or dishwasher—that use a lot of hot water.

Although gas-fired demand water heaters tend to have higher flow rates than electric ones, they can waste energy if they have a constantly burning pilot light. This can sometimes offset the elimination of standby energy losses compared to a storage water heater. In a gas-fired storage water heater, the pilot light heats the water in the tank so the energy isn't wasted. The cost of operating a pilot light in a demand water heater varies from model to model. Some models have an intermittent ignition device (IID) instead of a standing pilot light. This device resembles the spark ignition device on some gas ranges and ovens.

Demand (tankless or instantaneous) water heaters are rated by the maximum temperature rise possible at a given flow rate. Therefore, to size a demand water heater, you need to determine the flow rate and the temperature rise you'll need for its application (whole house or a remote application, such as just a bathroom).

Homeowners should be aware that using a demand heater may require them to change some habits. Demand heaters generally do not turn on until the flow is at least 0.5 to 0.8 gallons per minute (varies by product). Therefore, running a slow trickle of hot water for shaving, for instance, may not be possible. As with any product, homeowners should ask for references to get a better idea of performance.

Terms and Definitions

Flow rate – To determine the maximum flow rate, the homeowner should list the number of hot water devices expected to be in use at any one time. Then their flow rates (gpm) need to be summed. This is the desired flow rate for the demand water heater. For example, if the homeowner expects to simultaneously run a hot water faucet with a flow rate of 0.75 gpm and a shower head with a flow rate of 2.5 gpm, the flow rate through the demand water heater would need to be at least 3.25 gpm.

Temperature rise – To determine temperature rise, subtract the incoming water temperature from the desired output temperature. Unless you know otherwise, assume that the incoming water temperature is 50ºF. For most uses, the water should be heated to 120ºF. In this example, a demand water heater would need to produce a temperature rise of 70ºF for most uses. For dishwashers without internal heaters and other such applications, you might need the water to be heated to 140ºF. In that case, a temperature rise of 90ºF is needed.

Most demand water heaters are rated for a variety of inlet temperatures. Typically, a 70ºF water temperature rise is possible at a flow rate of 5 gpm through gas-fired demand water heaters and 2 gpm through electric ones. Faster flow rates or cooler inlet temperatures can sometimes reduce the water temperature at the most distant faucet. Some types of tankless water heaters are thermostatically controlled; they can vary their output temperatures according to the water flow rate and inlet temperature.

Applicability

Climate: All
Building type: All. May be especially well suited to homes with fewer occupants.
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Demand Water Heaters
www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12820

Calculating Costs and Payback
Please see page 54 for how to calculate costs and payback for a demand water heater and how to compare costs for different water heaters.

Heat Pump Water Heaters

Heat pump water heaters use electricity to move heat from one place to another instead of generating heat directly. Therefore, they can be 2 to 3 times more energy efficient than conventional electric resistance water heaters. To move the heat, heat pumps work like a refrigerator in reverse.

A refrigerator pulls heat from inside a box and dumps it into the surrounding room, and a stand-alone air-source heat pump water heater pulls heat from the surrounding air and dumps it—at a higher temperature—into a tank to heat water. A homeowner can purchase a stand-alone heat pump water heating system as an integrated unit with a built-in water storage tank and backup resistance heating elements. A homeowner can also retrofit a heat pump to work with a conventional storage water heater. They require installation in locations that remain in the 40º–90ºF range year-round and provide at least 1,000 cubic feet of air space around the water heater. Cool air can be exhausted to the room or outdoors.

They need to be installed in a space with excess heat, such as a furnace room. Heat pump water heaters will not operate efficiently in a cold space. They tend to cool the spaces they are in. A homeowner can also install an air-source heat pump system that combines heating, cooling, and water heating. These combination systems pull their heat indoors from the outdoor air in the winter and from the indoor air in the summer. Because they remove heat from the air, any type of air-source heat pump system works more efficiently in a warm climate.

Heat pump water heaters have a very small market share, so they may be costly to purchase and install. As with any product, homeowners should ask for references to get a better idea of heat pump performance and durability before investing.

Applicability

Building type: All

Climate: All. A heat recovery water heater is most attractive for use in warmer climates where air cooling is required throughout much of the year.

Demand management strategy: Strategic conservation, strategic growth, peak clipping.

For More Information

EERE Consumer's Guide: Heat Pump Water Heaters
www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12840

Calculating Costs and Payback

Please see page 54 for how to calculate costs and payback for a heat pump water heater and how to compare costs for different water heaters.

Solar Water Heaters

Solar water heaters—also called solar domestic hot water systems—can be a cost-effective way to generate hot water. They can be used in any climate, and the fuel they use—sunshine—is free.

Solar water heating systems include storage tanks and solar collectors. There are two types of solar water heating systems: active, which have circulating pumps and controls, and passive, which don't.

Most solar water heaters require a well-insulated storage tank. Solar storage tanks have an additional outlet and inlet connected to and from the collector. In two-tank systems, the solar water heater preheats water before it enters the conventional water heater. In one-tank systems, the backup heater is combined with the solar storage in one tank.

Types

Three types of solar collectors are used for residential applications:

- Flat-plate collector
- Integral collector-storage systems
- Evacuated-tube solar collectors.

There are two types of active solar water heating systems:

- Direct circulation systems

  Pumps circulate household water through the collectors and into the home. They work well in climates where the temperature rarely falls below freezing.

- Indirect circulation systems

  Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures.

Passive solar water heating systems are typically less expensive than active systems, but they're usually less efficient. However, passive systems can be more reliable and may last longer. There are two basic types of passive systems:

- Integral collector-storage passive systems

  These work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot water needs.

- Thermosiphon systems

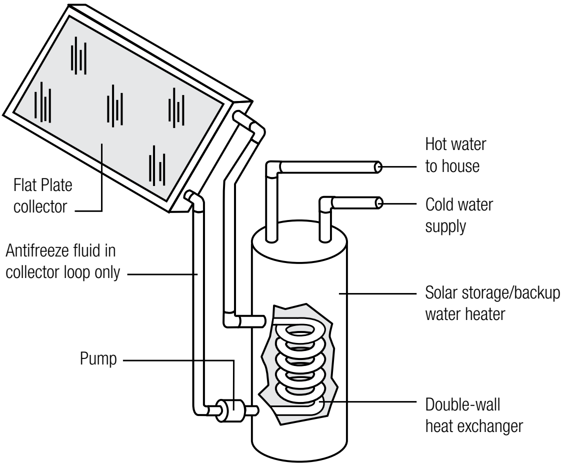
  Water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank. These systems are reliable, but contractors must pay careful attention to the roof design because of the heavy storage tank. They are usually more expensive than integral collector-storage passive systems.

Terms and Definitions

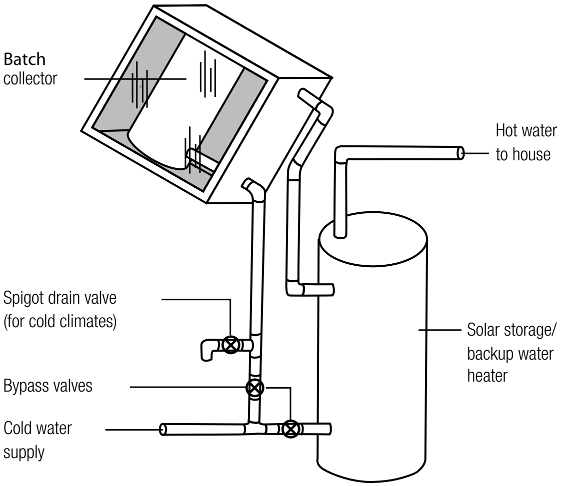
Solar energy factor – The energy delivered by the system divided by the electrical or gas energy put into the system. The higher the number, the more energy efficient. Solar energy factors (SEFs) range from 1.0 to 11. Systems with SEFs of 2 or 3 are the most common.

Solar fraction – The solar fraction is the portion of the total conventional hot water heating load (delivered energy and tank standby losses). The higher the solar fraction, the greater the solar contribution to water heating, which reduces the energy required by the backup water heater. The solar fraction varies from 0 to 1.0. Typical solar fractions are 0.5–0.75.

Active, Closed Loop Solar Water Heater



Passive, Batch Solar Water Heater



Applicability

Climate: All. ICS, recirculation, and thermosiphon systems are not recommended for cold climates.

Building type: All
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Solar Water Heaters
www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12850

Comparing Costs and Determining Payback

After identifying the purchase and annual operating costs of the solar water heating system, determine the costs associated with other water heating system under consideration and compare the two.

Calculating Annual Operating Cost

To estimate the annual operating cost of a solar water heating system, you need the following:

- The system's SEF
- The auxiliary tank fuel type (gas or electric) and rates

Gas auxiliary tank system:

365 × 41,045/SEF × Fuel Cost (Btu) = estimated annual operating cost

OR

365 × 0.4105/SEF × Fuel Cost (therm) = estimated annual operating cost

Example: Assuming the SEF is 1.1 and the gas costs $1.10/therm

365 × 0.4105/1.1 × $1.10 = $149.83

Electric auxiliary tank system:

365 × 12.03/SEF × Electricity Cost (kWh)= estimated annual operating cost

Example: Assuming the SEF is 2.0 and the electricity costs $0.08/kWh

365 X 12.03/2.0 X $0.08 = $175.64

Lighting

■■■

Artificial lighting consumes about 11% of a household's electricity use. Residential lighting encompasses all phases of lighting both inside and outside the home. Use of new lighting technologies can reduce lighting energy use in homes by 50%–75%. Further energy can be saved by installing lighting controls. Energy-efficient lighting can be designed into the house plans for new homes or addressed after construction for existing homes and remodeling projects. Proper installation and maintenance are also important. Another way to significantly reduce energy costs for lighting is to maximize the use of natural light through passive solar design and energy-efficient windows.

Incandescent Alternatives

Many homeowners still use incandescent light bulbs, even though more than 90% of the electricity they use is converted into heat rather than light. Not only do they waste energy, but they add to the electricity load by making air conditioners or other cooling technologies work harder to keep homes cool.

The new CFLs, cold cathode lamps, and LEDs (light-emitting diodes) are energy-efficient alternatives to incandescent lamps and they often last much longer. The CFLs will provide the same amount of light (or lumens) at a fraction of the electricity used.

Energy-efficient lighting begins with proper lighting design. Lighting design focuses on ways to improve the quality and efficiency of lighting.

When designing *indoor lighting* for energy efficiency, homeowners should consider:

- Using CFLs rather than incandescent bulbs in light fixtures.
- Using CFLs in portable lighting fixtures that are operated for more than 2 hours per day.
- Using ENERGY STAR-labeled lighting fixtures.
- Using occupancy sensors to turn lights on and off as needed.
- Painting walls and ceilings white to maximize natural light.
- Using airtight UL-approved fixtures for recessed ceiling lights with an uninsulated/unconditioned space above.

When designing *outdoor lighting* for energy efficiency, homeowners should consider:

- Security and utility lighting does not need to be bright to be effective.
- Using fluorescent, high-intensity discharge, or low-pressure sodium lights unless incandescent lights are automatically controlled to be on for just a few minutes each day.
- Using incandescent floodlights with combined photosensors and motion sensors in the place of other security lighting options.
- Using photosensors with fluorescent, high-intensity discharge, or low-pressure sodium lights.
- Using outdoor light fixtures with reflectors, deflectors, or covers to make more efficient use of the light source and help reduce light pollution.
- Using timers and other controls to turn decorative lighting on and off.
- Using outdoor solar lighting.

IES ILLUMINANCE CATEGORIES and VALUES - for GENERIC INDOOR ACTIVITIES

Activity	Footcandles
Public spaces	3
Simple orientation for short visits	5
Working spaces where simple visual tasks are performed	10
Performance of visual tasks of high contrast and large size	30
Performance of visual tasks of high contrast and small size, or visual tasks of low contrast and large size	50
Performance of visual tasks of low contrast and small size	100
Performance visual tasks near threshold	300-1000

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Types

Below are incandescent alternatives for use in homes.

Compact fluorescent lamp – the most commonly used lighting by homeowners. CFLs can replace incandescents that are roughly 3–4 times their wattage, saving up to 75% of the initial lighting energy. Although CFLs used to cost quite a bit more than comparable incandescent bulbs, the costs have dropped rapidly in recent years. Another advantage of CFLs is that they last 6–15 times as long (6,000–15,000 hours). Many new types of CFLs—three-ways, reflectors, globes, floods, dimmables, and decorative bulbs—are on the market. With the wide variety of CFLs on the market, consumers can purchase CFLs for use in most standard lighting fixtures.

Another option for consumers is to purchase or adapt fixtures to include built-in ballasts that are specifically designed for use with CFLs. The advantage of the built-in ballast is that the replacement cost is less, since they do not need ballasts. The other advantage of using a dedicated CFL fixture is that it requires a CFL, which ensures the energy-efficient use of the lamp throughout its lifetime.

Cold cathode fluorescent lamps – one of the latest technological advances in fluorescent technology. The "cold" in cold cathode means there is no heating filament in the lamp to heat the gas. This makes it more efficient. Also, since there's no filament to break, these lamps are ideal for use in rough service environments where regular lamps may fail. They are often used as backlights in LCD monitors and in exit signs.

High-intensity discharge lighting (HID) – provide the highest efficacy and longest service life of any lighting type. They can save 75%–90% compared to incandescent lighting. Because of the intense light they produce at a high efficacy, HID lamps are commonly used for outdoor lighting and in large indoor arenas where they stay on for hours at a time. They are not suitable for use with motion detectors. They are used for motor vehicle headlights and for high-end bicycle headlights, emitting a blue-tinted light.

Light emitting diode (LED) – An LED lamp is a type of solid state lighting (SSL) that utilizes LEDs as a source of illumination.

Low-pressure sodium – Low-pressure sodium lamps provide the most energy-efficient outdoor lighting compared to HID lighting, but the color is poor. Typical applications include security lighting where color isn't important. Low-pressure sodium lamps work somewhat like fluorescent lamps, but they require up to 10 minutes to start and have to cool before they can restart. Therefore, they are most suitable for applications where they stay on for hours at a time. They are not suitable for use with motion detectors.

Solar lighting – Many homeowners today are using outdoor solar lights because they are easy to install and virtually maintenance free. Best of all, they provide free electricity. Outdoor solar lighting systems use solar cells to convert sunlight into electricity. The electricity is stored in batteries for use at night. Outdoor solar lighting systems will work in most areas of the United States. However, it is important to consider geographic and site-specific variables when choosing a product.

Solid-state lighting – Unlike incandescent and fluorescent lamps, SSL creates light without producing heat. A semiconducting material converts electricity directly into light, which makes the light very energy efficient. SSL includes a variety of light producing semiconductor devices including LEDs and organic light-emitting diodes (OLEDs).

Until recently, LEDs—basically tiny light bulbs that fit easily into an electrical circuit—were used as simple indicator lamps in electronics and toys. But they can be as bright as incandescent lamps. And the cost of semiconductor material, which used to be quite expensive, has plummeted, making LEDs a more cost-effective lighting option.

Research shows that LEDs have great potential energy-efficient lighting for residential and even commercial building use. New uses for LEDs include small area lighting, such as task and under-shelf fixtures, decorative lighting, and pathway and step marking. As white LEDs become more powerful and effective, LEDs will be used in more general illumination applications, perhaps with entire walls and ceilings becoming the lighting system. They're already being used successfully in many general illumination applications, including traffic signals and exit signs.

OLEDs currently are used in very thin, flat display screens, such as those in portable televisions, some vehicle dashboard readouts, and in postage stamp-sized data screens built into pilots' helmet visors. Because OLEDs emit their own light and can be incorporated into arrays on very thin, flexible materials, they also could be used to fashion large, extremely thin panels for light sources in buildings.

Tungsten halogen lamps—a type of incandescent lighting—achieve better energy efficiency than standard incandescent light bulbs. Tungsten halogen lamps have a gas filling and an inner coating that reflect heat. Together, the filling and coating recycle heat to keep the filament hot with less electricity. These lamps provide excellent color rendition and are often used for specialty lighting uses like art displays. They also are considerably more expensive to buy than standard incandescent lamps, but are less expensive to operate because of their higher efficacy.

Terms and Definitions

Accent lighting – Draws attention to special features or enhances the aesthetic qualities of an indoor or outdoor environment.

Ambient lighting – Provides general illumination indoors for daily activities, and outdoors for safety and security.

Task lighting – Facilitates particular tasks that require more light than is needed for general illumination, such as under-counter kitchen lights, table lamps, or bathroom mirror lights.

Color temperature – The color of the light source. By convention, yellow-red colors (like the flames of a fire) are considered warm, and blue-green colors (like light from an overcast sky) are considered cool. Color temperature is measured in Kelvin (K) temperature. Higher Kelvin temperatures (3600–5500 K) are what we consider cool and lower color temperatures (2700–3000 K) are considered warm. Cool light is preferred for visual tasks because it produces higher contrast than warm light. Warm light is preferred for living spaces because it is more flattering to skin tones and clothing. A color temperature of 2700–3600 K is generally recommended for most indoor general and task lighting applications.

Color rendition – How colors appear when illuminated by a light source. Color rendition is generally considered to be a more important lighting quality than color temperature. Most objects are not a single color, but a combination of many colors. Light sources that are deficient in certain colors may change the apparent color of an object. The Color Rendition Index (CRI) is a 1–100 scale that measures a light source's ability to render colors the same way sunlight does. The top value of the CRI scale (100) is based on illumination by a 100-watt incandescent light bulb. A light source with a CRI of 80 or higher is considered acceptable for most indoor residential applications.

Lumen – A measurement of light emitted by a lamp. As reference, a 100-watt incandescent lamp emits about 1750 lumens.

Footcandle – A measurement of the intensity of illumination. A footcandle is the illumination produced by one lumen distributed over a 1-square-foot area. For most home and office work, 30–50 footcandles of illumination is sufficient. For detailed work, 200 footcandles of illumination or more allows more accuracy and less eyestrain. For simply finding one's way around at night, 2–10 footcandles may be sufficient.

Efficacy – The ratio of light produced to energy consumed. It's measured as the number of lumens produced divided by the rate of electricity consumption (lumens per watt).

Ambient lighting – Provides general illumination indoors for daily activities, and outdoors for safety and security.

Task lighting – Facilitates particular tasks that require more light than is needed for general illumination, such as under-counter kitchen lights, table lamps, or bathroom mirror lights.

Accent lighting – Draws attention to special features or enhances the aesthetic qualities of an indoor or outdoor environment.

CFLs and Incandescents: Comparable Wattage and Lumens

Incandescent Wattage	CFL Wattage	Lumens
25	7	300
40	11	450
60	15	950
75	20	1200
100	27	1750
150	42	2800

Source: Product literature

Applicability

Climates: All
Building type: All
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Lighting and Daylighting
www.eere.energy.gov/consumer/your_home/lighting_daylighting/index.cfm/mytopic=11970

DOE Building Technologies Program: Solid State Lighting
www.netl.doe.gov/ssl/

Lighting Controls

Despite advances in lighting technology, the most cost-effective means of saving energy for homeowners is still turning off the lights. Lighting controls help homeowners remember to turn off the lights. Lighting controls are more than switches and dimmers. An increasing number of new buildings are incorporating occupancy sensors, photosensors, and automatic systems that reduce electric load demand. These controls provide an easy means for cost savings and energy efficiency.

Automated lighting control systems may be hardwired or wireless. Hardwired systems involve a central control panel with low-voltage wiring to connect the components throughout the house. Wireless systems usually require central control components or can be built from combinations of switches, dimmers, and scene controllers, which are hardwired but communicate with each other wirelessly.

Home lighting automation is no longer exclusively a luxury item, but has become more of a lifestyle item due to declining costs and complexity, with controllers available for as little as $100.

Types

Dimmers – Provide variable indoor lighting. Dimming lamps reduces their wattage and output, which helps save energy. Off-the-shelf dimmers for incandescent fixtures are inexpensive and provide some energy savings when lights are used at a reduced level. Dimmers also increase the service life of incandescent lamps significantly. However, dimming incandescent lamps reduces their lumen output more than their wattage. This makes incandescent lamps less efficient as they are dimmed. Dimming fluorescents requires special dimming ballasts and lamp holders, but does not reduce their efficiency. Fluorescent dimmers are dedicated fixtures and bulbs that provide even greater energy savings than a regular fluorescent lamp.

Motion sensors — Motion sensors automatically turn outdoor lights on when they are needed (when motion is detected) and turn them off a short while later. They are very useful for outdoor security and utility lighting. Because utility lights and some security lights are needed only when it is dark and people are present, the best way to control might be a combination of motion sensor and photosensor. Incandescent floodlights with a photosensor and motion sensor may actually use less energy than pole-mounted high-intensity discharge or low-pressure sodium security lights controlled by a photosensor. Even though HID and low-pressure sodium lights are more efficient than incandescents, they are turned on for a much longer period of time than incandescents using these dual controls. When turned on, HID and low-pressure sodium lamps can also take up to 10 minutes to produce light. Therefore, they don't work well with just a motion sensor; central controls or timers would be better control options.

Occupancy sensors — Provide convenience by turning lights on automatically when someone enters a room. They reduce lighting energy use by turning lights off soon after the last occupant has left the room. Occupancy sensors must be located where they will detect occupants or occupant activity in all parts of the room. There are two types of occupancy sensors: ultrasonic and infrared. Ultrasonic sensors detect sound, infrared sensors detect heat and motion.

Photosensors — Prevent outdoor lighting from operating during the day. Photosensors sense ambient light conditions, making them useful for all types of outdoor lighting.

Timers — Timers can be used to turn on and off outdoor and indoor lights at specific times. Simple timers are not often used alone for outdoor lighting because they may have to be reset often with the seasonal variation in the length of night. However, they can be used effectively in combination with other controls. For example, the best combination for aesthetic (decorative) lighting may be a photosensor that turns lights on in the evening and a timer that turns the lights off at a certain hour of the night (e.g., 11:00 P.M.). For indoor lighting, timers are sometimes used to give unoccupied houses a lived-in look. However, they are an ineffective control for an occupied home because they do not respond to changes in occupant behavior.

Applicability

Climates: All
Building type: All
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Lighting Controls
www.eere.energy.gov/consumer/your_home/lighting_daylighting/index.cfm/mytopic=12180

Daylighting

Daylighting is the use of windows and skylights to bring sunlight into a home to replace electrical lighting. Today's energy-efficient windows, as well as advances in lighting design, allow efficient use of windows to reduce the need for artificial lighting during daylight hours without causing heating or cooling problems. The best way to incorporate daylighting into a home depends on climate and the home's design.

The sizes and locations of windows should be based on the cardinal directions rather than on their effect on the street-side appearance of the house. South-facing windows are most advantageous for daylighting and for moderating seasonal temperatures. They allow most winter sunlight into the home but little direct sun during the summer, especially when properly shaded. North-facing windows are also advantageous for daylighting. They admit relatively even, natural light, producing little glare and almost no unwanted summer heat gain. Although east- and west-facing windows provide good daylight penetration in the morning and evening, respectively, they should be limited. They may cause glare, admit a lot of heat during the summer when it is usually not wanted, and contribute little to solar heating during the winter.

Types

Of the many daylighting techniques, the most successful is known as "cool daylighting." Cool daylighting reduces the need for electric lighting and space cooling. Cool daylighting design looks at three key factors: light, heat, and glare. Most windowed buildings let in too much light, creating excessive heat and glare. Cool daylighting design carefully controls light entering the building, using several key techniques:

- *Window placement* – Too much light is uncomfortable. Ideal window design uses a clerestory to let in light high (where it can bounce off the ceiling) plus lower view windows to provide a view. The amount of glass increases with height, bringing more usable light into the room while cutting glare.

- *Brightness control*–The sun, clouds, sky, and reflected light can overwhelm the eyes. These bright sources must be controlled through the use of overhangs and window blinds. This is especially important for view windows.
- *Limited light transmission* – Even when direct light is controlled, the sky can supply an overwhelming amount of light. This leads to glare—one of the chief reasons that daylighting fails. To control glare, darker glass is used. Visible light transmittance is limited to 0.38 – 0.60 for clerestories and 0.18 – 0.25 for view windows (depending on design conditions).
- *Even light distribution* – The human eye does not like large visual contrasts. Direct–indirect lighting, sensors, and wall treatments help to distribute light more evenly.

Terms and Definitions

Daylighting – Daylighting uses natural light to illuminate homes and buildings. Daylighting can offset fluorescent lights or completely eliminate them during the day while reducing the cost of electric lights. Some studies have shown that natural light also improves occupant health and productivity.

Direct–indirect lighting – This type of fluorescent lighting provides direct downlighting and indirect light bounced off the ceiling.

Daylighting sensors – Sensors in the ceiling detect luminance levels and turn off lights as needed to keep light levels constant. Lights near the windows are dimmed, while lights near the back of the room are on more often. This prevents the "cave effect," where the back of the room appears poorly lit because the contrast between the back and front of the room is too great.

Wall treatments – Lighter colored paints are used for the ceiling and for the walls near the ceiling. Darker paints are used below. This helps create a bright canopy of light out of the field of view.

See also:

Building Structure

- Windows, Glass Doors, and Skylights
- Passive Solar Design

Applicability

Climates: All
Building type: All
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide: Daylighting
www.eere.energy.gov/consumer/your_home/lighting_daylighting/index.cfm/mytopic=12290

Appliances

■■■

Appliances and electronics are responsible for about 20% of the energy consumption in homes. These include stoves and microwaves; clothes washers and dryers; computers; dishwashers; home audio equipment; refrigerators and freezers; and televisions, DVD players, and VCRs.

Homeowners can significantly reduce their energy bills by using high-efficiency appliances. These may be more expensive to buy than comparable models with lower or average efficiency, but the reduced energy bills can save homeowners a significant amount of money long before the product wears out. Also, updated, efficient appliances like dishwashers and built-in microwaves are key selling points for homes. As energy costs rise, this return on investment grows.

When shopping for and comparing energy-efficient appliances and home electronics, homeowners should look for the EnergyGuide and ENERGY STAR labels that can help them determine energy cost savings. Major home appliances manufactured today must meet conservation standards set by DOE. Manufacturers use standard test procedures developed by industry and DOE to prove their products' energy use and efficiency and print the test results on the big yellow EnergyGuide labels. The yellow labels on appliances provide specific information about their yearly energy use so consumers can compare similar models. However, a yellow label on a product does not mean it's energy efficient. Products that have earned the ENERGY STAR label are exceptionally energy efficient and exceed federal standards. Typically, ENERGY STAR-qualified products use 10% – 50% less energy than standard products.

The American Council for an Energy-Efficient Economy (ACEEE) lists the most energy-efficient new refrigerators, freezers, dishwashers, and clothes washers on its Web site, summarizing energy use in an annual list of the most efficient products. Only the highest rated models are listed within each appliance category, making up fewer than 5% of all the different models currently available. Many appliances not listed on Web site are above average in efficiency, but this list is a good place to start.

Terms and Definitions

EnergyGuide Label – The Federal Trade Commission requires EnergyGuide labels on most home appliances (except stove ranges and ovens), but not home electronics, such as computers, televisions, and home audio equipment. EnergyGuide labels provide an estimate of the product's energy consumption or energy efficiency. They also show the highest and lowest energy consumption or efficiency estimates of similar appliance models.

ENERGY STAR Label – ENERGY STAR labels appear on appliances and home electronics that meet strict energy efficiency criteria established by DOE and the U.S. Environmental Protection Agency. The ENERGY STAR labeling program includes most home electronics and appliances except water heaters, stove ranges, ovens, and clothes dryers.

Highly efficient appliances—those at the top of the charts for efficiency—are available. See the ACEEE Web site for current lists.

For More Information

American Council for an Energy Efficient Economy (ACEEE) – Provides consumers with list of the most energy-efficient appliances.

www.aceee.org

ENERGY STAR – Provides consumers with energy savings calculators for appliances.

www.energystar.gov

EERE Consumers's Guide: Appliances and Home Electronics
www.eere.energy.gov/consumer/your_home/appliances/index.cfm/mytopic=10020

DOE Building Technologies Program: Energy Efficient Appliances
www.eere.energy.gov/buildings/info/documents/pdfs/26468.pdf

Formula for Estimating Energy Consumption

Use this formula to estimate an appliance's energy use:

(Wattage × Hours Used per Day ÷ 1000 = Daily Kilowatt-hour (kWh) consumption

(1 kilowatt (kW) = 1,000 Watts)

Multiply this by the number of days the appliance is used during the year for the annual consumption. Calculate the annual cost to run an appliance by multiplying the kilowatt-hours per year by the local utility's rate per kilowatt-hours consumed.

Note: To estimate the number of hours that a refrigerator actually operates at its maximum wattage, divide the total time the refrigerator is plugged in by 3. Refrigerators, although turned "on" all the time, actually cycle on and off as needed to maintain interior temperatures.

Examples
Window fan:
(200 Watts × 4 hours/day × 120 days/year) ÷ 1000
= 96 kWh × $0.085/kWh = $8.16/year

Personal Computer and Monitor:
(120 + 150 Watts × 4 hours/day × 365 days/year) ÷ 1000
= 394 kWh × $0.085/kWh = $33.51/year

Wattage

The wattage of most appliances is stamped on the bottom or back of the appliance, or on its nameplate. The wattage listed is the maximum power drawn by the appliance. Because many appliances have a range of settings (for example, the volume on a radio), the actual amount of power consumed depends on the setting used at any one time. If the wattage is not listed on the appliance, finding the current draw (in amperes) and multiply that by the voltage used by the appliance. Most appliances in the United States use 120 volts. Larger appliances, such as clothes dryers and electric cooktops, use 240 volts. The amperes might be stamped on the unit in place of the wattage.

Phantom Loads

Many appliances continue to draw a small amount of power when they are switched “off.” These “phantom loads” occur in most appliances that use electricity, such as VCRs, televisions, stereos, computers, and kitchen appliances. Most phantom loads will increase the appliance’s energy consumption a few watt-hours. These phantom loads can be avoided by unplugging the appliance or using a power strip.

Typical Wattages of Various Appliances

- Aquarium = 50–1210
- Clock radio = 10
- Coffee maker = 900–1200
- Clothes washer = 350–500
- Clothes dryer = 1800–5000
- Dishwasher = 1200–2400 (using the drying feature greatly increases energy consumption)
- Dehumidifier = 785
- Electric blanket — single/double = 60/100
- Fans
  - Ceiling = 65–175
  - Window = 55–250

- Furnace = 750
- Whole house = 240–750

- Hair dryer = 1200–1875
- Heater (portable) = 750–1500
- Clothes iron = 1000–1800
- Microwave oven = 750–1100
- Personal computer
  - CPU — awake /asleep = 120/30 or less
  - Monitor — awake /asleep = 150/30 or less
  - Laptop = 50
- Radio (stereo) = 70–400
- Refrigerator (frost-free, 16 cubic feet) = 725
- Televisions (color)
  - 19" = 65–110
  - 27" = 113
  - 36" = 133
  - 53"-61" Projection = 170
  - Flat screen = 120
  - Plasma = Up to 800
- Toaster = 800–1400
- Toaster oven = 1225
- VCR/DVD = 17–21 / 20–25
- Vacuum cleaner = 1000–1440
- Water heater (40 gallon) = 4500–5500
- Water pump (deep well) = 250–1100
- Waterbed (with heater, no cover) = 120–380

Energy-Efficient Refrigerators and Freezers

Nearly all households have at least one refrigerator and about 30% own two. Nearly 60% of households own a separate freezer. Refrigerators and freezers have become more efficient, spacious, and quiet. According to ACEEE, replacing a 20-year-old refrigerator with a new, energy-efficient model will save about 800 kWh annually and reduce a home's CO_2 contribution by about 1 ton—all while saving about $64 a year through reduced electric bills (assuming an electric rate of $0.08/kWh).

ENERGY STAR-qualified refrigerators require about half as much energy as models manufactured before 1993. These refrigerator models use high-efficiency compressors, improved insulation, and more precise temperature and defrost mechanisms to improve energy efficiency. Refrigerators must use at least 15% less energy than required by current federal standards and 4% less energy than the conventional models sold in 2001.

ENERGY STAR-qualified freezer models use at least 10% less energy than required by current federal standards.

APPLIANCES

Types of Refrigerators

Top-freezer refrigerator. Top-freezer refrigerators place the freezer compartment on top. They are usually the most energy-efficient design and make good use of space and perform well temperature-wise. They are also less expensive than other types and account for about half of refrigerators sold.

Bottom-freezer refrigerator. Bottom-freezer refrigerators place the fresh food compartment on the top and the frozen food compartment below. This appliance has the same advantages as top-freezer refrigerators.

Compact refrigerator. An inexpensive refrigerator that makes a good fit for apartments or small tight spaces.

Side-by-side refrigerator. Side-by-side refrigerators include two full-height doors that open from the center. The freezer compartment is on the left and tends to offer more storage space than other types. The wide-open design of this refrigerator gives a clear view of fresh and frozen food items and easy access to contents on the same level. Side-by-side refrigerators are a good choice for narrow kitchens where door clearance is an issue, but they are the most repair-prone type of refrigerator. Most have through-the-door ice and water dispensers, which are also repair prone.

French door refrigerator. French door models have two side-by-side refrigerator doors atop a pull-out freezer drawer. But unlike a side-by-side refrigerator, the interior shelving is the full width of the unit.

Under-the-counter refrigerator. This type is made to sit nearly flush with kitchen cabinets, mimicking a built-in look for less money than a true built-in.

Built-in refrigerator. This kind of refrigerator lies flush with cabinetry and can be fitted with matching fronts, a custom look that's very expensive.

Freezerless refrigerator. Some newer models now come without freezers to allow consumers to store a significant amount of fresh food. Some models feature an internal heater for installation in cooler environments, such as the garage or back porch.

Types of Freezers

Chest freezer. Chest freezers use less energy than uprights because very little cold air escapes when the top-mounted door is opened. Chest freezers take up more floor space than uprights, and experts say they're 10% – 25% more efficient because they're better insulated and air doesn't spill out when the door is opened (the weight of the door also helps seal the unit).

Upright freezers. Upright freezers are the best choice for consumers who buy smaller quantities of food more often.

Organizing their contents is easy, but bulky items may be harder to fit. They take less floor space than chest freezers, but the door placement makes them less energy efficient.

Applicability

Climates: All
Building type: All
Demand management strategy: Strategic conservation

For More information

EERE Consumer's Guide
www.eere.energy.gov/consumer/

American Council for an Energy Efficient Economy (ACEEE) – Provides consumers with list of latest energy efficient appliances.
www.aceee.org

EnergyStar – Provides consumers with energy savings calculators for appliances.
www.energystar.gov

Energy-Efficient Dishwashers

Depending on how they are used, dishwashers can save time, energy, and water. Dishwashers can use half the amount of water it takes to wash the same number of dishes by hand. Most of the energy required to wash dishes goes into heating the water, so dishwashers save energy by reducing the volume of water used for washing. Temperature boosters added to products allow consumers to set their hot water heaters to 120 ˚F and still all the heat needed for proper and effective cleaning.

Strong federal standards ensure that dishwashers are more energy efficient today than in the past. ENERGY STAR models use 25% less energy than the federal minimum standard.

Types

24-inch Built-In Dishwashers

Standard 24-inch built-in dishwashers are the most common type of dishwasher. They fit snugly beneath the kitchen counter and connect directly to their own water and power supplies. Since they are located out of the way of general traffic and come in a wide variety of styles, these units blend in nicely with various environments.

Portable Dishwashers

In situations where it is not feasible to install a built-in dishwasher due to space or budget restraints, the portable dishwasher offers the same functionality as a built-in unit but does not require dedicated water and electrical connections or expensive renovations and are conveniently mounted on rollers. Portable models provide the additional benefits of extra counter space and even storage options when not in use.

Compact Dishwashers

Compact dishwashers measure 18-inch across and are the ideal solution for small households or confined spaces. They are available in built-in and portable models. A compact machine can be highly beneficial, but it can use more energy if consumers wash multiple loads because it is too small.

Drawer Dishwashers

Drawer style dishwashers are new. These powerful units fit into the same space as a standard dishwasher, but they offer the functionality of two independent dishwashers. Each drawer operates as its own separate unit. This design provides consumers with the option of using only one drawer for smaller loads or both drawers for larger loads.

Applicability

Climates: All

Building type: All

Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide
www.eere.energy.gov/consumer/

Energy-Efficient Clothes Washers and Dryers

Energy-efficient washers offer attractive energy and water savings, which can be crucial in areas where water is scarce. There are basically two types of washers: top load and front load. The new front loading washers use much less water and energy because they spray the clothes wet rather than fill a tub with water. Using less hot water allows homeowners to save on water heating costs. An added benefit to using less water is that less wastewater, and fewer suds, are deposited into the sewer system. Front load washers also spin faster at the end, which means they remove more water from clothes so clothes require less drying time.

Some resource-efficient clothes washers are more expensive to purchase than conventional washers; however, their substantial energy and water savings translate into cash back for consumers. An ENERGY STAR-qualified clothes washer must use 50% less energy than standard washers and can save up to $110 per year on utility bills. Also, field studies have shown that efficient washers are gentler on clothes. Less dryer time also reduces wear and tear. With the average load of laundry valued up to $500, this can translate into substantial additional savings. A growing number of energy and water utilities around the country recognize the benefits of efficient clothes washers and are offering rebates to consumers who purchase qualifying machines.

ENERGY STAR does not label clothes dryers because most dryers use similar amounts of energy, which means there is little difference in the energy use between models.

Types

Conventional washers are loaded from the top and have an agitator in the basket. They use roughly 40 gallons of water for each cycle. High-efficiency washers save both energy and water (they use up to 67% less water than a conventional washer) and are always ENERGY STAR labeled. All high efficiency washers use a special type of detergent called HE (for high-efficiency). HE detergent is made specifically for low-water wash systems; it's concentrated and generates less suds. HE detergents are available in a wide array of brands and scents, and can be purchased at most places consumers shop.

Front load – Front load washers clean clothing by tumbling them in water. By cleaning via tumbling instead of agitation, front loaders are usually gentler on fabrics and cause less wear and tear on washables than conventional top-load washers. These machines can be opened from the front, just like machines found at a laundromat. Front loaders can often be more expensive to purchase, but they make up for it by almost always being less costly to run. Washer costs can be recouped in about 8 to 10 years.

Top load washers – Conventional top load washers fill the washer tub with water and agitate the clothing as the method of cleaning. ENERGY STAR models are similar, but will use lower water temperatures to save money while still providing great cleaning performance. High-efficiency models use nontraditional wash motions to move clothes through a slurry of concentrated detergent and water. These washers do not submerge the clothes, but use just the amount of water needed for cleaning. High-efficiency models often are priced higher, but like front-load washers, they offer a payback over time.

Terms and Definitions

Modified Energy Factor (MEF) – MEF measures the energy used during the washing process, including machine energy, water heating energy, and dryer energy. The higher the MEF, the more efficient the clothes washer.

Applicability

Climates: All

Building type: All

Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide

www.eere.energy.gov/consumer/

Home Offices and Home Electronics

According to the Consumer Electronics Association, the typical American owns 25 consumer electronics products and spends more than $1,200 a year buying them. The average home has roughly two TVs, a VCR, a DVD player, and three telephones. Home electronics products use energy when they're off to power features like clock displays and remote controls. Those that have earned the ENERGY STAR label use as much as 50% less energy to perform these functions, and provide the same performance at the same price as less-efficient models. Less energy means lower energy bills.

Home offices and home electronics are becoming increasingly important when it comes to energy savings. For many of these devices, no standards exist despite the fact that some televisions can use as much or more energy than a refrigerator. ENERGY STAR is the only monitor of energy performance today for home office equipment and electronics.

The challenge for ENERGY STAR is that, unlike other appliances, cheaper, less-efficient power supplies for home electronics translate into low-cost products. Because competition is fierce in this area, low cost is vital for manufacturers. However, ENERGY STAR continues to persuade to get manufacturers to use more energy efficient power supplies. On July 1, 2007, every new ENERGY STAR computer will come with a power supply that is 80% efficient. So it will be more efficient when it's in sleep mode or when it's surfing the Web or crunching numbers.

Types

They may be small, but when combined, all these electronics consume a great deal of energy.

Home Office – Computers, printers, fax machines, copiers, scanners, and telephones.

Home Electronics – Televisions, including large plasma screen TVs and home theaters; vacuum cleaners and floor cleaners; personal care products such as blow dryers and electric razors; DVD players and VCRs; radios and clocks; cell phone chargers and digital camera equipment; toasters and toaster ovens; blenders; electric mixers; countertop grills, waffle makers, sandwich makers, rice cookers, egg cookers, bread machines and crock pots; clothes steamers and irons; room air cleaners and humidifiers/dehumidifiers; portable air conditioners, electric fans, and electric heaters; coffee pots, expresso/cappuccino machines; and water coolers.

Applicability

Climates: All
Building type: All
Demand management strategy: Strategic conservation

For More Information

EERE Consumer's Guide
www.eere.energy.gov/consumer/

Ranges and Cooking Appliances

Most stoves and ranges today consume about the same amount of energy. Because of this, they don't require ENERGY STAR labels. When shopping, consumers should look at the type of stove being considered rather than the individual models. Here's a general guide for stove efficiency:

GOOD: Electric ceramic glass units with halogen elements deliver instant heat and respond quickly when the temperature setting is changed.

BETTER: Induction elements transfer the electromagnetic energy directly to the pan, leaving the cooktop cool.

BEST: Gas stove with an electronic ignition for both range and stove saves 50% more energy than electric and 30% more than gas with pilot lights.

Types

Electric Ranges

Electric ranges are the most popular because they are usually less expensive and electricity is more widely available. Electric ranges have constant, even heat, and no open flame. They allow cooks to maintain very low heat, which is not always possible on some gas models. Some elements, compared to gas range tops, heat and cool more slowly and it can be somewhat more difficult regulating temperature with an electric range than with a gas range.

Gas Ranges

Gas ranges allow cooks to select different levels of heat, cool or heat instantly, and offer precise temperature control. They hold very little heat when the burner is turned off, so cooking ceases soon thereafter. Many models come with an electric ignition, which is an automatic system that lights burners instantly.

Generally, gas models are more expensive than electric ranges due to their visible flames and flexibility of temperature settings.

Dual Fuel Gas and Electric Ranges

These combine the benefits of the instant response of gas burners and the even heating action of an electric oven. They are typically priced at the middle to higher end price ranges.

Small Cooking Appliances

Consumers should use small electric pans or toaster ovens rather than large oven for small meals. A toaster oven uses one-third to one-half as much energy as a full-sized oven.

Using pressure cookers and microwave ovens whenever convenient is also a good idea. They will save energy by significantly reducing cooking time.

Terms and Definitions

Btu – is a measure of the heat generated by a cooking appliance. The higher the number, the more powerful the burner, with burners generally ranging from 675 Btus (which is used for melting chocolate or simmering delicate sauces) to 17,000 or more Btus (which are used for boiling).

Dual Fuel – A cooking appliance with both gas and electric cooking elements (usually a gas cooktop and electric oven combination).

Electric Oven/Range – Thermal cooking is accomplished with electricity as the energy source.

Gas Oven/Range – Thermal cooking is accomplished with gas as the energy source.

Induction cooking – A smooth cooktop in which the cooking elements generate a magnetic field, transforming the pot or pan into the heat source. Stainless-steel, enamel-treated steel, and cast iron are usually the

Solar Pool Heating, Covers, and Pump Control

■■■

Heating a swimming pool can consume a lot of energy and result in high heating bills. Homeowners can improve their swimming pools' heating and energy efficiency by doing the following:

- Installing a high-efficiency or solar pool heater
- Using a pool cover/solar blanket
- Managing the water temperature
- Installing a smaller, energy-efficient pump and/or operating it less with a timer.

For More Information

Water and Energy Conservation Tips for Pool and Spa Users
www.theapsp.org/45/index.aspx

Solar Pool Heating

Homeowners can significantly reduce swimming pool heating costs by installing a solar pool heater. They're cost competitive with gas and heat pump pool heaters, and they have very low annual operating costs. Actually, solar pool heating is the most cost-effective use of solar energy in many climates.

Most solar pool heating systems include the following:

- A solar collector – the device through which pool water is circulated to be heated by the sun
- A filter – removes debris before water is pumped through the collector
- A pump – circulates water through the filter and collector and back to the pool
- A flow control valve – automatic or manual device that diverts pool water through the solar collector.

Pool water is pumped through the filter and then through the solar collector(s), where it is heated before it is returned to the pool. In hot climates, the collector(s) can also be used to cool the pool during peak summer months by circulating the water at night.

Some systems include sensors and an automatic or manual valve to divert water through the collector(s) when the collector temperature is sufficiently higher than the pool temperature. When the collector temperature is similar to the pool temperature, filtered water simply bypasses the collector(s) and is returned to the pool.

Solar pool collectors are made of different materials. The type needed depends on the climate and intended use. If using the pool only when temperatures are above freezing, probably only an unglazed collector system is needed. Unglazed collectors don't include a glass covering (glazing). They are generally made of heavy-duty rubber or plastic treated with an ultraviolet (UV) light inhibitor to extend the life of the panels. Because of their inexpensive parts and simple design, unglazed collectors are usually less expensive than glazed collectors. These unglazed systems can even work for indoor pools in cold climates if the system is designed to drain back to the pool when not in use. Even if the homeowner has to shut the system down during cold weather, unglazed collectors may be more cost effective than installing a more expensive glazed collector system. Both glazed and unglazed collector systems should include freeze protection if they'll be used in colder conditions.

Applicability

Climate: This is most applicable to warm climates with high use of residential swimming pools
Building type: All
Demand management strategy: Strategic conservation

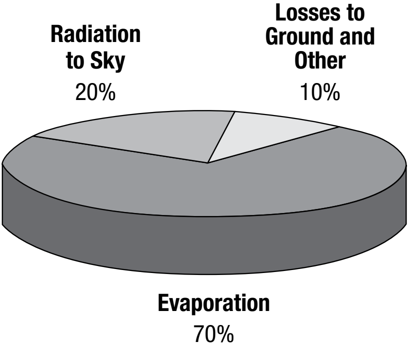
For More Information

EERE Consumer's Guide: Solar Swimming Pool Heaters
www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13230

Swimming Pool Covers

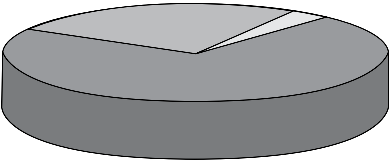
A homeowner can significantly reduce swimming pool heating costs by using a pool cover. Use of a pool cover also can help reduce the size of a solar pool heating system, which can save money. Swimming pools lose energy in a variety of ways, but evaporation is by far the largest source of energy loss. Evaporating water requires tremendous amounts of energy. It only takes 1 Btu to raise 1 pound of water 1 degree, but each pound of 80ºF water that evaporates takes a whopping 1,048 Btu of heat from the pool.

Outdoor Pool
Energy Loss Characteristics



The evaporation rate from an outdoor pool varies depending on the pool's temperature, air temperature and humidity, and the wind speed at the pool surface. The higher the pool temperature and wind speed and the lower the humidity, the greater the evaporation rate. In windy areas, homeowners can add a windbreak—trees, shrubs, or a fence—to reduce evaporation. The windbreak needs to be high enough and close enough to the pool that it doesn't create turbulence over the pool, which will increase evaporation. Indoor pools aren't subjected to the environment, but they still can lose a lot of energy from evaporation. They even require room ventilation to control indoor humidity caused by the large amount of evaporation. The ventilated air also must be conditioned, which adds to the energy costs.

Indoor Pool
Energy Loss Characteristics



Pool covers minimize evaporation from outdoor and indoor pools. Covering a pool when it is not in use is the single most effective means of reducing pool heating costs. Savings of 50%–70% are possible. Pool covers on indoor pools not only can reduce evaporation but also the need to ventilate indoor air and replace it with unconditioned outdoor air. A homeowner can also shut off exhaust fans when an indoor pool is covered, which saves even more energy.

Pool covers can also reduce chemical use, pump run time, cleaning time, heater use, and they can withstand the harsh chlorine-oxidizing environment.

Types

Technically, all that is really needed for a pool cover is a large sheet of plastic. Plastic meets the requirement of being a vapor barrier. But a large sheet of plastic from the lumber store is probably not the best choice. It will be very difficult to handle and store, it tears easily, and sunlight will deteriorate it rapidly. It's best to use a cover designed specifically for swimming pools that is made of special materials, such as UV-stabilized polyethylene, polypropylene, or vinyl. It can be transparent or opaque, and light or dark colored.

One of the lowest cost covers made specifically for swimming pools is the *bubble (or solar) cover.* Bubble covers are similar to bubble packing material except they use a thicker grade of plastic and have UV inhibitors.

Vinyl covers consist of a heavier material and have a longer life expectancy than bubble covers. Insulated vinyl covers are also available with a thin layer of flexible insulation sandwiched between two layers of vinyl.

Outdoor pools gain heat from the sun, absorbing 75%–85% of the solar energy striking the pool surface. This is an important contribution to the pool's heating needs. A pool cover will decrease the solar gain contribution to some extent, depending on the type used. A transparent bubble cover may reduce pool solar energy absorption by 5%–15%. A completely opaque cover will reduce it by 20%–40%. However, the benefits from reduced evaporation will likely outweight the decreased solar gian.

The following Web pages provide tables showing the costs of heating pools with and without pool covers in different U.S. cities:

EERE Consumer's Guide: Estimating Heat Pump Swimming Pool Heater Costs and Savings
www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13220

EERE Consumer's Guide: Estimating Swimming Pool Gas Heating Costs and Savings
www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13180

Applicability

Climate: This is most applicable to warm climates with high use of residential swimming pools
Building type: All
Demand management strategy: Strategic conservation

Pump Control

A homeowner can save energy and maintain a comfortable swimming pool temperature by using a smaller, higher efficiency pump and by operating it less.

In a study of 120 pools by the Center for Energy Conservation at Florida Atlantic University, some pool owners saved as much as 75% of their original pumping bill when they used these energy conservation measures (see table below).

Savings from Pump Conservation Measures			
Condition	Energy Use (kWh/year)	Cost of Energy ($/year)	Energy Savings
Original	**3000**	**240**	**----**
Pump replacement (downsizing)	**1800**	**140**	**40%**
Reduced time (60%)	**1200**	**100**	**60%**
Combination of above	**720**	**60**	**75%**

Applicability

Climate: This is most applicable to warm climates with high use of residential swimming pools

Building type: All

Demand management strategy: Load shifting, strategic conservation, peak clipping

For More Information

EERE Consumer's Guide: Installing and Operating a Swimming Pool Pump for Energy Efficiency
www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13290