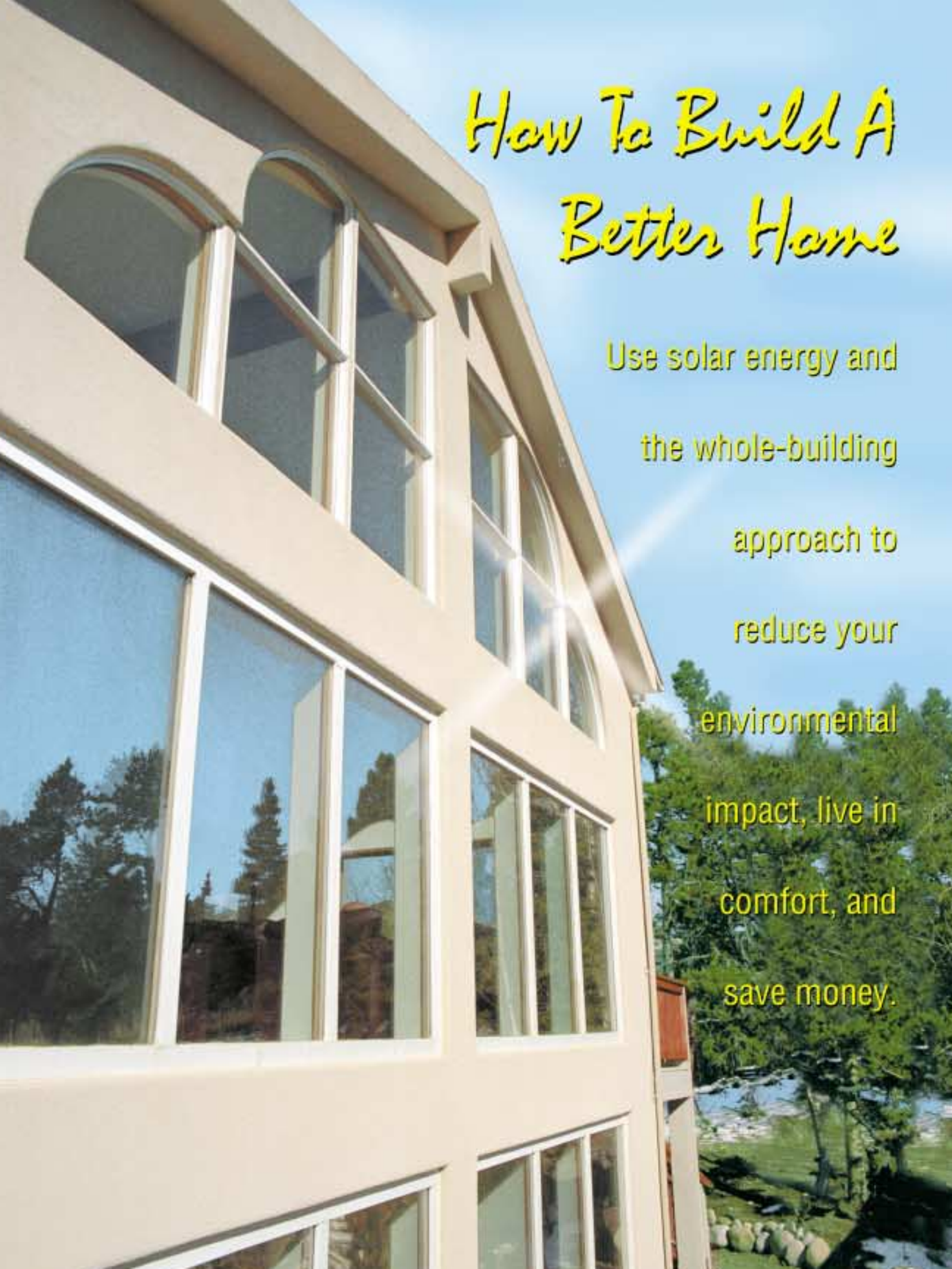


How To Build A Better Home

Use solar energy and the whole-building approach to reduce your environmental impact, live in comfort, and save money.

Welcome to the Whole-Building Approach!

Did you know the building decisions you make today will affect the environment and your wallet for years to come? That's why you should consider your home's total environmental and energy-saving potential before you build or buy.

If you're considering building a solar house or retrofitting an existing home with solar features, you may have started your project by reading a few books or articles about solar homes, only to find yourself overwhelmed by all the information. Many people are surprised when they discover building a solar home isn't as simple as adding some solar panels to the roof, but must be approached from a "whole-building" perspective. What is the whole-building approach? It's an approach that brings together building design, energy efficiency, and today's solar technologies to boost your energy savings and make the most of all your building elements. It reduces the amount of energy required to operate your solar home compared to conventional houses. It improves the comfort of your home. It uses pleasing architectural designs to brighten up living areas using sunlight rather than electricity. It allows your architect or builder to integrate today's advanced building materials and solar technologies into your home's design. Finally, it will increase the value of your home's solar systems because they will meet a greater portion of its energy needs. Building a solar home using the whole-building approach is cost-effective because each individual component will perform optimally, complementing the entire structure. Your home is more environmentally friendly to operate because it reduces the burning of fossil fuels in distant power plants and in your furnace that pollute the atmosphere. Other possible benefits are a "grid-free" lifestyle with no connection to a utility power line. Some people like the increased energy security of not being completely dependent on their utility company. But the most important reason to build your solar home using the whole-building approach is so that you can take advantage of today's enlightened possibilities. Don't worry about being on unfamiliar turf —let's tour your solar home together.

A Winning Combination—Design, Efficiency, and Solar Technology

DESIGN—a crucial part of the whole-building approach is design. Building design can make a big difference in energy savings. Low-energy design creates bright, beautiful interiors that use the sun's energy to heat the home in the winter and design to cool it in the summer. Most basic is a design that lets sunlight in through large south-facing windows. But designs do more than bring sunlight into the home—they also block it. Window overhangs reduce cooling costs by shading rooms from too much heat in the summer when the sun is higher in the sky. During the winter, when the sun is lower in the sky, more sunlight and heat will enter your home because the sun won't be blocked by the window overhang. Another energy-saving design feature is landscaping that shades your house from scorching summer heat and icy winter winds. Put low shrubs and plants on the south side. Situating rooms in strategic locations saves energy too, such as putting the most heat-producing room in the home, the kitchen, on the north or coolest side of the home. The north is also a good place to put storage and other low occupancy areas such as utility rooms and bathrooms. A well-designed home will not only lower your energy bills, it will provide an attractive floor plan with large windows for views and sunny interiors. With less noise from heating and cooling systems, it will also be quieter.

EFFICIENCY—now that your home is designed, let's look at its efficiency. It allows you to make the most of your building design and solar technologies. The typical house—with items such as lights, a dishwasher, a refrigerator, and other appliances—consumes considerable energy. Check energy-guide labels on appliances and try to choose those that require less energy to operate, not the ones with the lowest price tag. It may cost more up front, but it will save you money over the long term. For example, front-loading washing machines use half the energy of traditional machines. The new compact fluorescent lights use one-fourth the energy of incandescent bulbs, last longer, and are virtually indistinguishable from traditional lighting. Energy efficiency also applies to building materials. For example, windows now exist with added coatings that reduce heat loss. In the wall, loose-fill insulation and expansive foams can be used to fill irregularly shaped voids to seal air-leakage spots. Don't forget about energy conservation. Sealing air leaks around doors and windows with caulking and weatherstripping is a great place to start. Using programmable thermostats to regulate your home's temperature and turning down your water heater will also conserve energy. Energy conservation and efficiency measures will lower your home's energy demand and allow you to use smaller, more cost-effective solar-based systems.

SOLAR TECHNOLOGY—In the last 20 years, solar technology has made giant strides. As a result, a variety of solar technologies can now be combined with conventional architecture to address your home's heating, cooling, and electrical needs. For heating and cooling, heavy building materials such as brick or tile can be incorporated into the interior design of your home to store energy—something referred to as "thermal mass." Thermal mass is typically part of a "passive solar" system, in which solar energy enters through south-facing glass and is stored in the thermal mass to heat the home after the sun goes down. This same thermal mass helps keep the house cool in the summer by moderating the temperatures. For water heating, a solar thermal collector can be placed on a home's rooftop to heat water circulated to the roof by pumps from storage tanks, usually found in the basement. For electricity, you will need a solar electric or photovoltaic (PV) system that converts sunlight directly into electricity. Although many types of PV systems are on the market today, they all typically consist of three main items: modules that convert sunlight into electricity; inverters that convert that electricity into alternating current (AC); and batteries that store excess electricity produced by the system. The remainder of the system comprises equipment such as wiring, circuit breakers, and a meter. Many consumers may not be aware that the solar modules available today are more efficient and versatile than ever before. Today's modules can be built into glass skylights and walls—or merged with traditional roof shingles, such as the thin-film PV shingles used as a background for this page. In many locations, you can connect your solar electric system to a local utility grid and get credit from the utility for the excess power. The cost of a PV system varies with system size. In general, a 2-kW system will meet 80% of the electrical load needed by the average residential house. Be aware, however, that the rated capacity of the PV panel is for ideal conditions—practical experience shows actual measured outputs are about 30% below the rated value in most climates. Generally, you will pay between $6 to $10 per watt, with the average home system ranging from 1 to 6 kilowatts. This is one reason why reducing energy consumption first is so important—the less energy you need to operate your home, the fewer kilowatts you will have to generate or purchase to meet its energy needs. Today's solar technologies can provide you with clean, renewable energy, but the wise homeowner will combine these technologies with energy-efficient features and designs. There's no point in collecting solar energy with state-of-the-art solar technologies if it is immediately lost through energy-guzzling appliances, leaky windows and walls, and poor architectural design.

The Foundation—Planning

Planning before you build your home is important—it determines how efficiently your home will use the sun's energy. Planning involves four things: positioning your home to make the most of the sun's energy, taking inventory of your energy needs, deciding who will design and install your solar systems, and discovering your financing options.

Start by planning for site orientation. How much your house benefits from the sun will depend on how many hours per day your home is exposed to sunlight. Find out which house orientation on your lot makes the most of your southern exposure to sunlight. A home's design is often climate dependent. For example, in northern climates where heating the home is important, use windows and shading elements that maximize solar gain in the winter, but avoid overheating in the summer. In warm and hot climates, the shading elements in windows must be designed to reject solar heat most of the year. In all climates, the best designs have long south and north exposures with a pitched-roof suitable for solar panels. For solar panels, shadows affect performance dramatically. Keep these items in full sun as much as possible. Next, determine your energy needs. Estimate how warm you want your home to be in the winter, how cool in the summer, and how much electricity you will need to power lights, appliances, and other devices such as computers, televisions, and stereos. But remember, energy needs and energy efficiency are two sides of the same coin. Combine energy needs with proper appliances, solar systems, insulation, weatherization, and thermostat settings, and you can cut your energy bills and your pollution output in half. Hire a professional to install your solar systems—it's safer and can save you time, especially if you plan on installing a solar electric system. Check your local Yellow Pages under solar power. Don't forget about the Internet with its numerous websites on solar energy. We also have Web sites listed in back to get you started. Short on capital? Finance your solar home. Federal mortgage loan programs such as "Fannie Mae" are available to finance a wide variety of residential energy efficiency improvements, including low-energy appliance purchases. A number of banks also provide mortgage incentives for energy efficient homes. Many states offer rebates and buy-down grants for the purchase of PV systems to help defray costs. Property and sales tax incentives are available that may include exemption of property and sales tax on the purchase of a solar home or system. State personal income-tax credits may be granted for the purchase of a PV system or passive-solar addition to your existing home. Many states also encourage net metering, which allows customers to pay only for their "net" electricity, or the amount of power consumed from their utility minus the power generated by their PV system. We included Web sites on the back about this, too. If you start building your home with a strong planning foundation, followed by measures to reduce energy consumption, and energy enhancing designs and technologies, you can enjoy a clean-energy lifestyle at an affordable price.

The shingles in this photo generate electricity

How Low-Energy Design and High-Performance Power Work Together

APPLIANCES

Appliances account for about 20% of your household's energy consumption, with refrigerators and clothes dryers at the top of the consumption list. Look for the ENERGY STAR® label when shopping for appliances for long-term energy savings. Select front-loading washers and install low-flow water fixtures to reduce your demand for hot water.

Insulating your hot-water tank and the first six feet of both the inlet and outlet pipes will prevent heat loss and conserve energy.

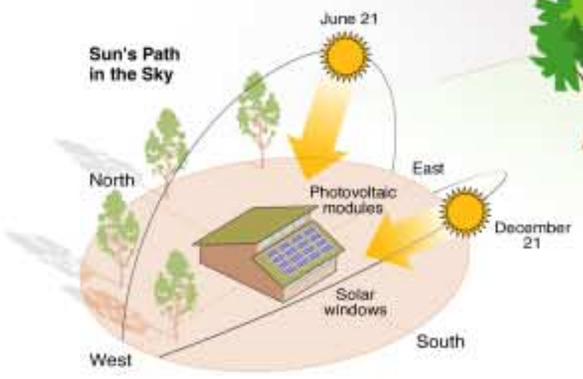
If natural gas is available, use it for cooking and heating.

LIGHTING

Compact fluorescent lamps are more energy efficient than incandescent and halogen lamps. They cost more initially, but last up to 10 times as long and can save up to 75% on energy costs, resulting in a better value over time.

ORIENTATION

Make the most of the sun's energy—choose south-facing solar systems and windows. Too much summer sun can increase your cooling costs, so be sure to shade windows with overhangs in the summertime.

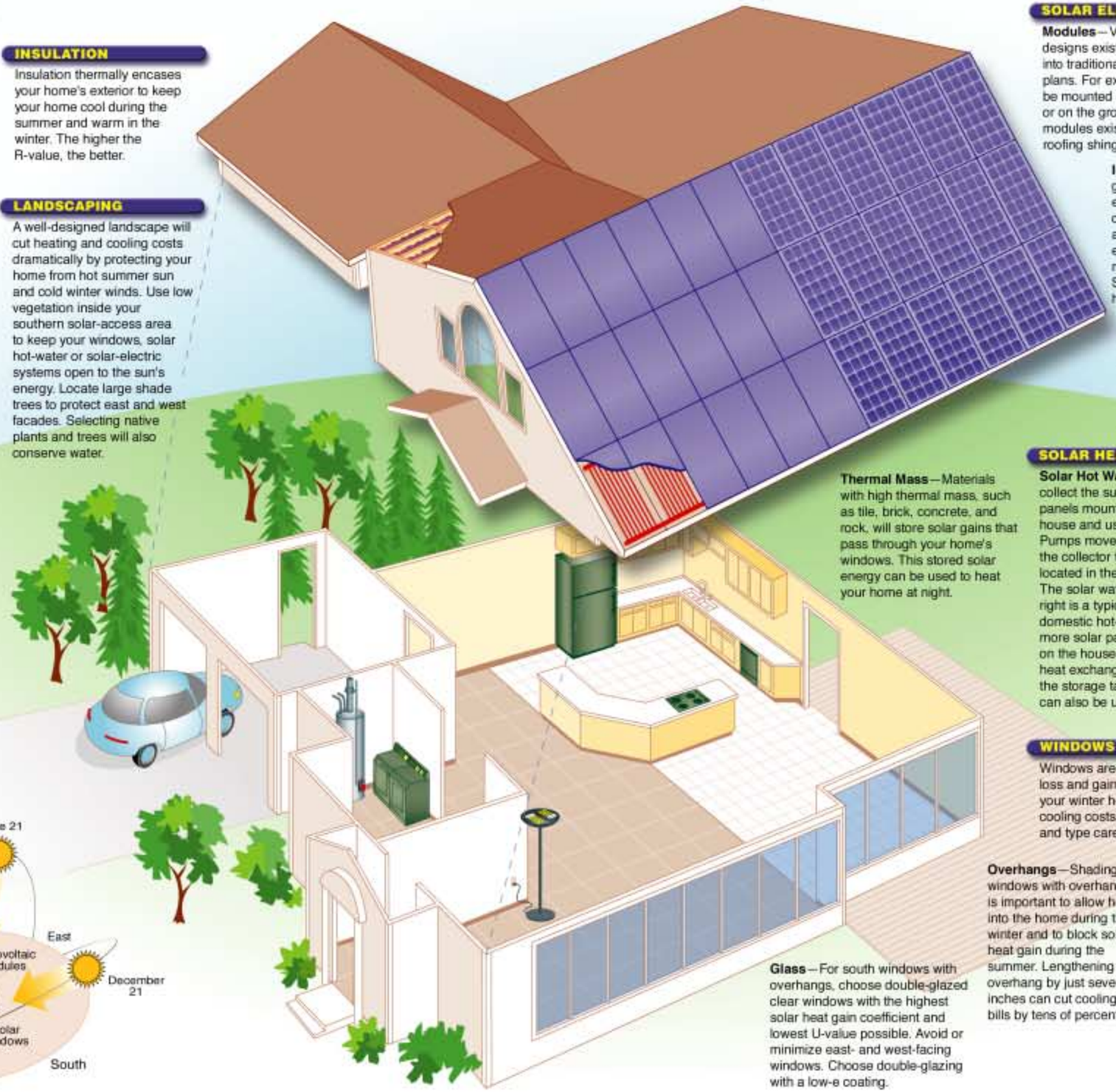


INSULATION

Insulation thermally encases your home's exterior to keep your home cool during the summer and warm in the winter. The higher the R-value, the better.

LANDSCAPING

A well-designed landscape will cut heating and cooling costs dramatically by protecting your home from hot summer sun and cold winter winds. Use low vegetation inside your southern solar-access area to keep your windows, solar hot-water or solar-electric systems open to the sun's energy. Locate large shade trees to protect east and west facades. Selecting native plants and trees will also conserve water.



Thermal Mass—Materials with high thermal mass, such as tile, brick, concrete, and rock, will store solar gains that pass through your home's windows. This stored solar energy can be used to heat your home at night.

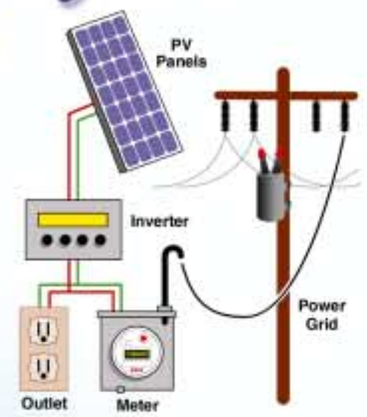
Glass—For south windows with overhangs, choose double-glazed clear windows with the highest solar heat gain coefficient and lowest U-value possible. Avoid or minimize east- and west-facing windows. Choose double-glazing with a low-e coating.

SOLAR ELECTRIC

Modules—Various solar modules and designs exist that can be integrated into traditional residential architectural plans. For example, rigid modules can be mounted either directly on the roof or on the ground. Thin, flexible solar modules exist that resemble traditional roofing shingles.

Inverters—Solar modules generate direct-current (DC) electricity. An inverter converts DC electricity into alternating-current (AC) electricity that can be used by most standard appliances. Some new solar modules have built-in inverters.

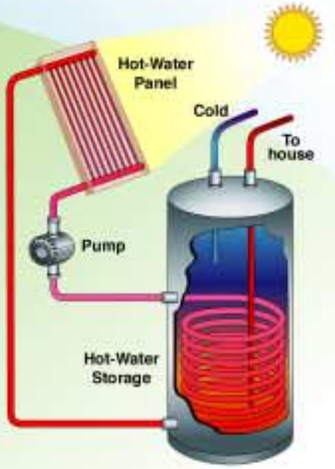
Batteries—Batteries are important if you want to store electricity, but you can eliminate them if you are connected to your local electrical utility power grid.



Net Metering: *Solar electric systems sometimes produce more electricity than your home needs. This extra electricity is either stored in batteries or fed into the utility grid. In some cases, the utility can provide a meter that runs backward when excess power is generated. Homeowners are given credit by their local power companies for the electricity produced at their homes through "net metering" programs.*

SOLAR HEAT

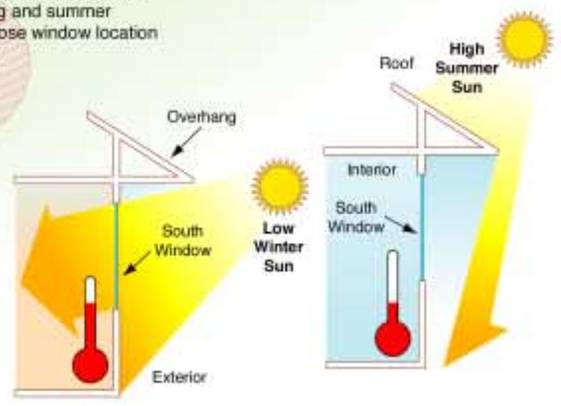
Solar Hot Water—Solar water heaters collect the sun's thermal energy in panels mounted on the roof of your house and use it to heat water. Pumps move the heated water from the collector to a storage tank, usually located in the basement or utility room. The solar water system shown to the right is a typical configuration for domestic hot-water heating. By adding more solar panels (such as is shown on the house to the left) and a second heat exchanger (usually located near the storage tank), solar-heated water can also be used for space heating.



WINDOWS

Windows are a major source of heat loss and gain. To significantly reduce your winter heating and summer cooling costs, choose window location and type carefully.

Overhangs—Shading windows with overhangs is important to allow heat into the home during the winter and to block solar heat gain during the summer. Lengthening the overhang by just several inches can cut cooling bills by tens of percent.



Another Solar Option: Factory-Built Homes

If you want to hire someone who will make sure your new home is energy efficient and uses today's solar technologies, an alternative to finding a good architect could be a high-quality, factory-built solar home. Showcased on this page is a home built for the Cahill family.

Jim Cahill, an engineer and experienced builder himself, decided to buy a factory-built home after visiting the manufacturer's factory. "I was skeptical at first, but what I witnessed was better quality control and more efficient construction than I ever see in the field," he said. "That's what sold me." Cahill was impressed with the modern building techniques, such as "computer-cut" lumber and screw-and-glue assembly. The framing wood is dry; walls, ceilings, and floors are square and level; and the homes are "over built," according to Jim, because they have to travel long distances to their sites. Cahill also found, after looking at the available designs, that passive solar had become what he calls "more visually digestible." This was important because the Cahills like the look of a traditional colonial design and wanted to be sure their home would harmonize visually with other moderate- to high-priced custom homes in their area.

Jim and Janice Cahill moved into their beautiful new 2-story, 4-bedroom, factory-built colonial home in Massachusetts for about $35,000 less than it would have cost to build a similar-quality conventional custom home in their neighborhood. The Cahills spend about $110 per year on heating, cooling, and electricity, while their neighbors will be paying utility bills of more than 10 times that much.

Lyle Rawlings/First

Large south-facing windows provide direct solar gain to the interior of the home, while dark-colored tile absorbs and holds heat from the sun.

Lyle Rawlings/First

Solar energy meets 78% of this home's heating needs. The 16 PV modules, which can be factory-installed or site-mounted on the roof, provide virtually all of the home's electricity. (Manufacturer: AvisAmerica homes.)

CAHILL HOME

- Location: Massachusetts
- Size: 2-story, 4-bedroom (factory-built main portion only), 2530 ft² (235 m²)
- Selling price (including dealer/builder mark-up): $185,000 (including PV system)
- Year completed: 1995
- Heating Degree Days: 5804
- Cooling Degree Days: 430

SOLAR FEATURES

- South-facing glass: 419 ft² (39 m²)
- South-facing interior thermal storage walls in direct sunlight: 168 ft² (16 m²)
- Overhangs on all south-facing windows
- Thermal mass integrated into the floor and 900 ft² (84 m²) ceramic tile adjacent to south-facing windows
- No west windows, minimal east and north windows
- PV system: 1920-watt, stand-alone-capable, grid-connected

ENERGY EFFICIENCY FEATURES

- R-38 ceiling — 2-in x 12-in (5.1-cm x 30.5-cm) construction with fiberglass batts
- R-27 walls — 2-in x 6-in (5.1-cm x 15.2-cm) construction with fiberglass batts and 1-inch (2.5 cm) foil-faced polyisocyanurate
- Factory sealing package (0.25 air-change per hour)
- Double-glazed windows, low-e on north and east; double-glazed clear windows on south
- Earth-tube system for controlled ventilation and cooling
- Window overhangs

ENVIRONMENTAL/HEALTH FEATURES

- Controlled ventilation for continuous fresh air
- Comfort achieved without air conditioning by home's advanced design

ESTIMATED ANNUAL ENERGY COST COMPARISON*

(not including domestic hot water)

	Reference case	Cahill home	Savings
Heating	$ 660	$110	$ 550
Cooling	$ 300	$ 0	$ 300
Electric	$ 410	$ 0	$ 410
Totals	$1370	$110	$1260

* Based on actual data from the Cahill home compared with the same home without solar or energy-efficient features.

Information on Buildings, Department of Energy:

This brochure is available electronically: www.nrel.gov/buildings/pv

- Consumer Energy Information: www.eren.doe.gov/consumerinfo
- National PV Program: www.eren.doe.gov/pv
- National Center for Photovoltaics at the National Renewable Energy Laboratory: www.nrel.gov/ncpv
- Office of Building Technology: www.eren.doe.gov/buildings
- Solar Buildings Program: www.eren.doe.gov/solarbuildings
- Home Energy Saver Tips online: www.eren.doe.gov/consumerinfo/energy_savers
- Consumer's Guide to Buying a Solar Electric System: www.nrel.gov/ncpv/pdfs/26591.pdf
- Consumer Guide to Home Energy Savings: www.aceee.org/consumer-guide/index.htm
- NREL High-Performance Buildings: www.nrel.gov/buildings/highperformance

Federal and State Incentive and Financing Information:

- Million Solar Roofs Program: www.millionsolarroofs.org
- National Database of State Incentives for Renewable Energy (DSIRE): www-solar.mck.ncsu.edu/dsire.htm
- The Borrower's Guide to Financing Solar Energy Systems: www.nrel.gov/ncpv/pdfs/26242.pdf
- State Energy Alternatives: www.eren.doe.gov/state_energy

Solar Organizations online

- American Solar Energy Society: www.ases.org
- Solar Energy Industries Association: www.seia.org
- Sustainable Buildings Industry Council: www.sbicouncil.org
- American Council for an Energy-Efficient Economy: www.aceee.org
- Alliance to Save Energy: www.ase.org

Cover photo: The Van Geet house, located near Idaho Springs, CO, is a 3400-ft^2 home powered by passive solar, solar hot-water, and photovoltaics. It is located in a development with no public utilities.

NREL
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