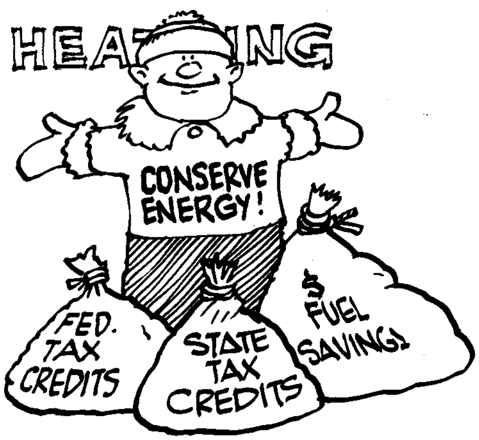
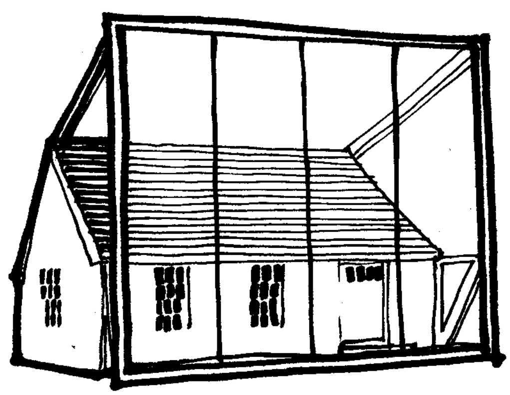
Chapter 2

Solar Building Design Basics



To most people, energy conservation lacks the glamour of solar energy, but it is always a winner in saving energy. In any climate where heating or cooling is a "big thing," solar design done in combination with energy conservation works best. Conservation always pays off in savings faster than any other energy strategy. The whole idea is simple.

A tight, energy-conserving, passive solar home may reduce energy costs by 5O to 90 percent depending on climate. As costs of conventional energy soar and fears of interrupted supplies heighten, your wise investment becomes more obvious to everyone: yourself, Your friends, and ... the next buyer of your home.

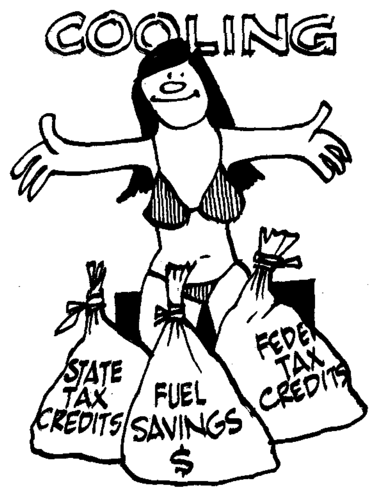


South glazing sized to heat a poorly-insulated house.

Much of the information in this section is based on *Solar Home Heating in New Hampshire* (available through the Governor's Council on Energy, 21/2 Beacon Street/Concord NH 033011

Federal tax credits of 15 percent make investments in conservation very attractive. I.R.S. publication No. 903 "Energy Credits for Individuals," will tell you how the government endorses your investment by giving a 15 percent "discount" that you can subtract directly from your tax bill.

Basking in the winter sun can be pleasant even though the temperature is below freezing. But you would never go out without "buttoning up" first. It should be just as obvious that it makes no sense to leave your house out in the cold without buttoning it up first. Most heat is lost through either conduction or infiltration. Conduction losses occur as heat escapes through the roof and walls. Infiltration means losing heat through warm air escaping and being replaced by cold air drafts seeping into the house through cracks around doors, windows, and around the foundation.



In climates where energy is used for cooling, conservation comes first, too! People do not sit in the hot sun for hours without shielding themselves. So also, shading, ventilating, and insulating to keep heat out and cool air in are important to summer cooling. These simple, economic measures lower both the size and cost of air conditioning equipment, reduce cooling bills, and improve comfort by lessening the often large differences felt between indoor and outdoor temperatures and humidity levels when air conditioning is used.

In terms of costs, energy conservation measures fall into three categories: Free, Cheap, and Economic. You just can't miss. Let's talk about some specific energy conservation measures, starting with the free ones.

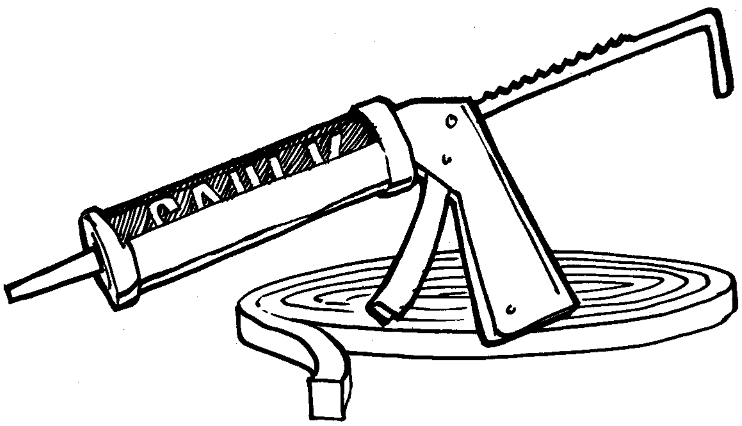
Free heating energy conservation measures include lowering thermostat settings to 68° or lower during the day and 55^0 or lower at night, reducing hot water tank temperatures to 120° (or 140° if dishwasher instructions require), adding water-saving shower heads, closing chimney dampers and blocking off unused fireplaces, shutting off unused rooms, turning off lights, and wearing heavier clothing. For cooling, get used to slightly warmer temperatures or turn the air conditioner off altogether and open windows. When these measures are used in combination, 20 percent savings is easily obtainable at no cost.

Among the "cheap" energy conservation measures are maintaining the efficiency of your heating system through servicing check-ups, caulking and weatherstripping windows and doors to seal infiltration cracks, installing a clock thermostat for automatic set-back, and adding sheets of plastic to windows that are the big heat losers. For cooling, shades, awnings,-and trellises with plant growth-block out the sun. Fans are much less expensive to run than air conditioners.

"Economic" energy conservation measures include adding extra insulation in attics and walls and around foundations, adding storm windows and doors or replacing older windows with tight new ones, covering windows with night insulation, and adding a vapor barrier wherever possible. Replacing an old inefficient burner or furnace can be economic. Consider a woodburning furnace or stove. Add an airtight entryway or plant a wind break of trees. (But don't block out south sunlight!) These measures do require an initial dollar investment, but they almost always make econornic sense, even if a bank loan is necessary to finance the investment.

So far, we have talked about the economics of energy conservation primarily for retrofitting existing homes. Planning energy conservation into new house design is a whole "new game" economically, one in which you stand to reduce energy bills even further. (Remember, energy conservation is the first step to efficient solar heating!) By planning before construction, many of the "economic" measures become "cheap" or "free." Extra insulation and a vapor barrier, for example, are very inexpensive in new construction as compared to retrofitting with the same materials. The small extra cost of "doing it right" may be offset by lower construction costs of other items, such as a smaller furnace, as well as by energy savings.

You are almost ready to do "something solar" to your home. But first, we want to elaborate upon some options. They are presented in their relative order of cost effectiveness.



Caulking and Weatherstripping

Caulking and weatherstripping reduce air infiltration by sealing cracks around windows, doors, wall outlets, and the foundation. These materials are inexpensive and easy to use. Caulkings include silicones, urethanes, and materials with an oil or latex base. Weatherstripping is made of felt, foambacked wood, and vinyl and steel strips. A supplier can inform you of types, costs, life expectancies, and uses of these materials. One- to-five year paybacks are usual, but sealing off big cracks may pay for itself in a matter of months.

Insulation

Insulating materials are assigned "R -values," a rating of how well each material resists the conduction of heat energy. The higher the R-value per inch thickness of material, the more effective the insulation.

Insulation types include fiberglass (which is available in a range of thicknesses), bags of loose cellulose, blow-in foams, and plastic foam sheets or boards. Check with reputable suppliers for possible fire or health hazards of these materials as well as for their comparative durability. Installers can recommend types and amounts of insulation best suited to your particular house.

Heavy insulation in the roof, exterior walls, and foundation reduces conduction losses. Recommended R -values of insulation for new construction in moderate climates are R-38 in attics and ceilings, R-19 in walls, R -19 in floors over crawl spaces, and R -11 around foundations. In severe climates, twice this much insulation should be used. These standards should be followed or exceeded in all new construction, but they may not be as easy to reach in existing houses. Generally, in older houses the more insulation the better, and the investment will be a good one.

Vapor Barriers

Vapor barriers protect wall and ceiling insulation from moisture. As warm house air seeps through walls and ceilings to the cold outside, it carries moisture with it into the insulation. If moisture condenses and is trapped, the insulation loses much of its effectiveness. In severe cases, moisture can cause wood to rot.

Adding vapor barriers to existing houses is difficult unless interior walls have been tom down. However, interior vapor barrier paints and vinyl wall papers are available for existing houses. Ridge and soffit vents for attic ventilation help carry away moisture. In humid climates, consult local builders since vapor barriers are not used in some parts of the country where moisture moves from the outside into walls during the summer.

Storm Windows and Doors

A window with a single pane of glass (called single glazed) can lose 10 times the heat of an R -11 wall (3 ½ " of fiberglass insulation) and 20 times the heat of an R-19 wall (6" fiberglass insulation). Adding a second layer of glazing can save one gallon of oil each winter per square foot of window area in cold climates. Adding two layers (resulting in triple glazing) can save nearly two gallons of oil per square foot of window area. At 1980 energy prices, added glazing can save $10 to $15 per window each year. Storm

Human Comfort

Regardless of how fuel bills are reduced, the primary purpose of energy consumption for heating and cooling is to keep people comfortable. Passive solar design is a natural strategy for accomplishing this.

Our bodies use three basic mechanisms for maintaining comfort: convection; evaporation/ respiration; and radiation. Air temperature, humidity, air speed, and mean radiant temperature all influence how we use our comfort control mechanisms.

Perhaps mean radiant temperature is least understood. Mean radiant temperature (mrt) refers to the average temperature we feel as a result of radiant energy emanating from all surfaces of a room: interior walls, windows, ceilings, floors, and furniture. It combines with the room air temperature to produce an overall comfort sensation, and different combinations of mean radiant temperature and room temperature can produce the same comfort sensation. For example, if the air temperature is 49° and the mean radiant temperature is 85°, you will feel as though it is actually about 70°. The same holds true for the combination of an air temperature of 84° plus a mean radiant temperature of 60°.

Many passive systems use warm surfaces to keep a house comfortable. The higher mean radiant temperatures provide comfort at lower air temperatures. Most people prefer this comfort balance to the more common comfort balance found in conventional houses where warm air is surrounded by cool or cold surfaces. In other words, because you are surrounded by warm surfaces, a passive house makes you "feel" warmer even with room temperatures several degrees lower than you might have in a conventional house.

Once you've become accustomed to passive warmth, conventionally-heated rooms feel cool and drafty, even at identical air temperatures. Interior surfaces of thickly insulated walls, floors, and roofs are warmer than those that are poorly insulated. The same holds true for muultipaned windows compared with single glazed. Thus, energy conservation enhances mean radiant temperature and is a good companion to passive solar in providing comfort.

Because lower house temperatures result in less heat loss, even more energy can be saved than what is normally calculated.

The combinations of temperatures in the following chart produce the common comfort sensation of 70°F:

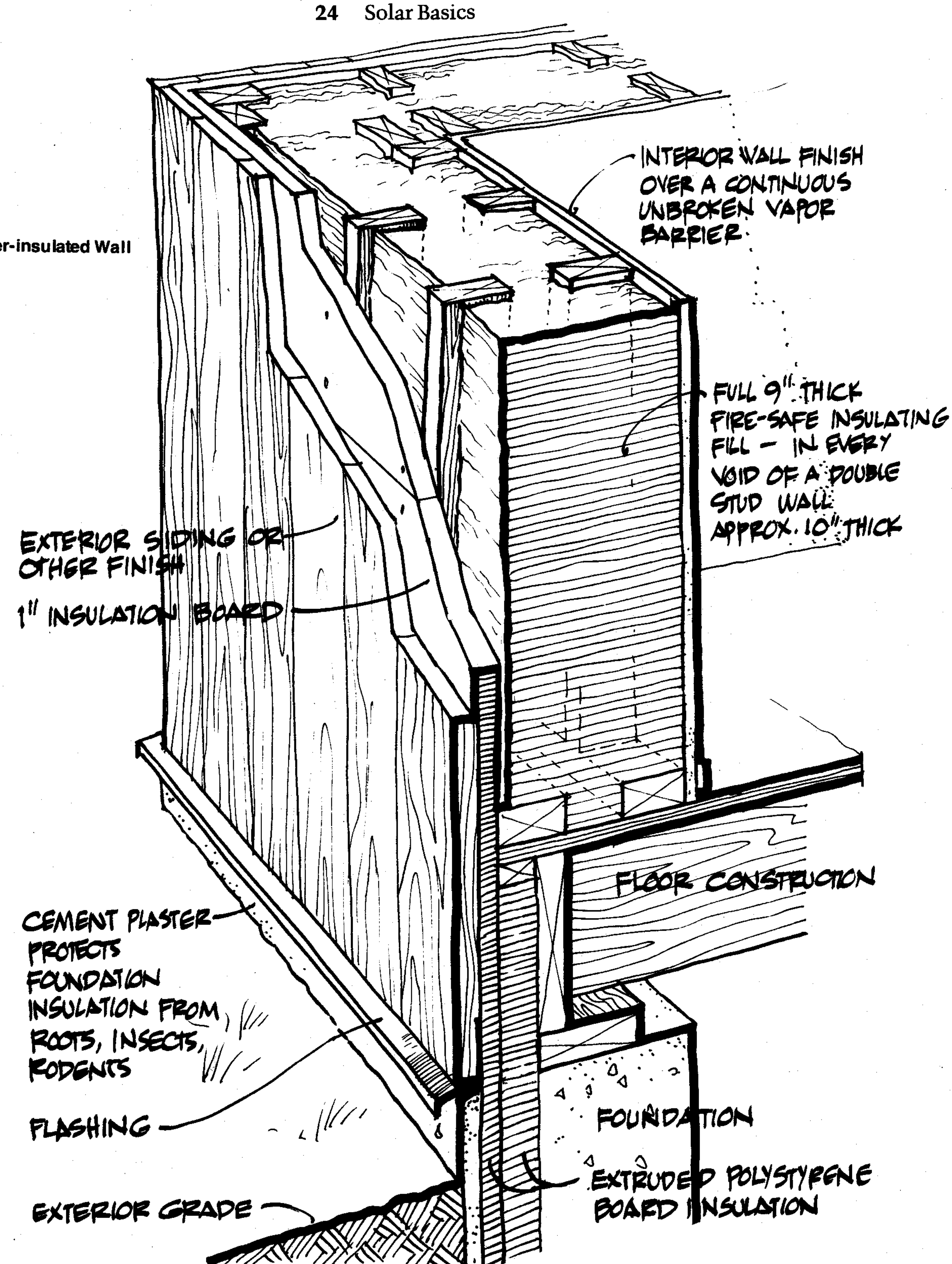
Mean Radiant Temperature:	85	80	75	70	65	60	55
Air Temperature:	49	56	64	70	77	84	91
Comfort Sensation:	70	70	70	70	70	70	70

windows are available with wood, aluminum or plastic sash. Aluminum insulates least and wood insulates best. Storm windows come with single or double panes of glass. Placing clear plastic sheets over windows is the least expensive solution.

Thermal Window Shades

Thermal shades, shutters, or heavy curtains can reduce heat loss through windows at night by up to 80 percent. Many types of night insulation can be hand-made. Others can be purchased and professionally installed. A snug fit and tight edges all around are important for high

A Super-insulated Wall



effectiveness. Combining night insulation with double or triple glazing will be the greatest deterrent to nighttime heat loss through windows.

Shades and Awnings

To stay cool during the summer, keep the sun out of the house during the day. Inexpensive interior shades from a hardware store are least effective but work well for the small investment. Exterior awnings are becoming popular again and do a good job of shading. Deciduous trees provide ideal summer shading and shed their leaves to allow winter sun in. Summer shading by whatever means is a "natural" first step in reducing cooling costs.

Taking Steps

Take time to get sound advice and to implement energy conservation measures properly. Although procedures are often simple, inadequate or faulty installations can reduce insulating effectiveness or even damage the house. But, without a doubt, energy conservation will pay you well for your effort in fuel savings.

Solar Retrofit

Suppose you already own a home and want to keep it, but are concerned about rising energy costs. Solar heating and cooling are not out of your reach. Solar retrofitting, or adding solar features to existing homes, is one of the most exciting challenges in the field.

There are a lot of existing homes and all of them use energy, often more than necessary. For many reasons, economic, historic, aesthetic or purely sentimental-we don't want to just discard older homes or other valuable buildings. Solar renovating or retrofitting is a viable option to consider.

All the passive solar choices we've talked about come in "retrofit sizes" too. Take time to compare options before choosing. Some solar retrofits will suit your existing structure better than others. But retrofit possibilities are not necessarily limited either. If you use your imagination and then carefully check out the most practical options, the results will be very satisfying. Some attractive and efficient solar retrofits are featured in the eight page photo spread on pp. 119-126.

Do button up first. Older homes, even those built five years ago, rarely have enough insulation or are tight enough to maximize the performance of any solar retrofit. Research for your solar retrofit starts very simply. Find south. Every home has a south-facing wall or comer at worst. If the compass does not yield a perfect long wall facing due south, don't give up. Orientation can be up to 30° off either to the east or west of south and still be effective for solar collection.

If, when looking in a southerly direction you don't find a high rise, you're in luck. Any obstruction which casts a shadow on the house in winter can reduce solar collection unless it can be removed or like a deciduous tree loses its leaves when you will need the winter sun. Summer shading from deciduous trees is a cooling advantage too. Solar orientation and shading factors are only the first steps in evaluating site suitability.

If the site checks out so far, think of the five passive solar options. Which ones make sense for you? It will depend upon the design of your home, its position on your lot, and the dollar investment you are prepared to make. For example, a solar room will make sense if you like gardening or want extra living space in addition to solar heat. If you want solar heat and privacy is needed because your south side faces a street, a solar chimney for a frame house or a solar wall for a masonry or frame house makes the most sense. Adding more south facing windows is a simple, efficient solution in many cases. If the only available south -facing surface is a roof, a solar attic may be a natural choice.

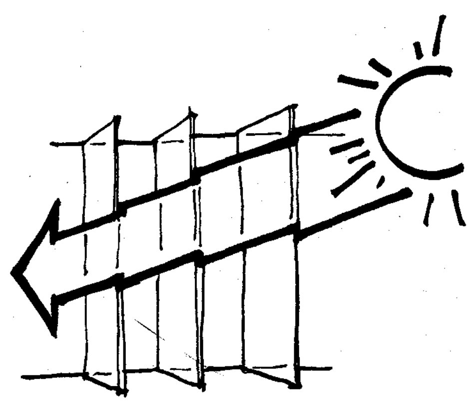
Cost is an important consideration in passive solar retrofits. (When building with a new passive home design, extra cost may be minimal when compared with a new conventional home.) A solar retrofit, like any remodeling work, will cost money, but compared to what? If you convert the home you have to solar instead of building a new one you could save a lot of money by comparison and substantially reduce heating and cooling cost as well.

Passive solar retrofits come in many "sizes," as well as "cost variations." A greenhouse solar room, for example, can vary from light lean-to framing covered with plastic glazing to one which is custom-built, with triple-glazed windows, built-in shutters, and water-wall heat storage. Both are appropriate for some uses and both function well. Cost is the variable, so you must decide what you want to spend.

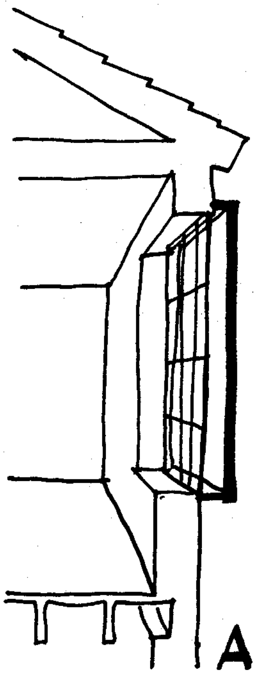
To help you make really informed retrofit decisions, each of the five passive heating options will be critically considered. However, one more bit of information you need is energy flow in and out of buildings. Heat and light flow through windows. Heat travels through walls also. The important point is that there are two primary flows of heat in and out of the house. One is solar radiation inward; the other is heat escaping from your house in cold weather and seeping in during hot. Both vary considerably depending on the time of day and the season of the year.

Adding transparent glazing to a house is the basic strategy in solar retrofitting. It is a way of taking advantage of needed energy flows in and reducing unwanted energy flows out. Solar retrofit strategy assumes that conservation measures have been taken first. When a second glazing layer is added to an existing window, A, it greatly reduces heat loss, but reduces solar heat gain only slightly. When glazing is added to the prepared wall surface of a house, B, it transforms the wall into a solar chimney collector. Adding a layer of glazing to an uninsulated masonry wall, C, significantly reduces heat loss and, in fact, produces considerable solar heat gain. Finally, a solar room results, D, when the space between the glazing and the wall is greatly enlarged. The space, in a sense, absorbs the shock of outdoor weather extremes, tempering their effect on the house while also providing solar heat.

The Ins and Outs of Energy Flow



If you understand how energy flows through windows and walls, you can more easily select the most suitable passive design for your house. There are two primary flows of heat in a house. One is solar radiation inward; the other is heat that escapes from your house in cold weather and seeps into your house during hot weather. Both types of flow vary considerably in amount depending on the time of day and the season of the year. Keep energy flow in mind as we look at the five basic passive solar options in a simple way.



All are variations of adding extra glass to let solar heat in and trap it to prevent heat losses back out.

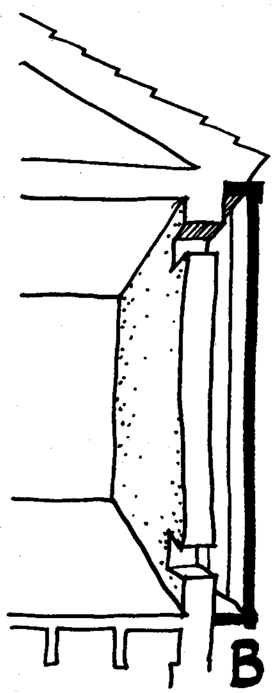
Transparent glazing can be added to south sides of houses in a number of ways to affect the amount of both solar radiation that enters into, and heat that escapes from, the house.

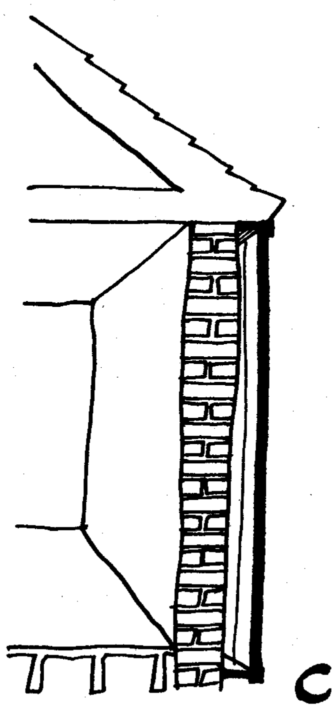
A. When glazing is added over an existing window, it greatly reduces heat loss but reduces solar gain only slightly.

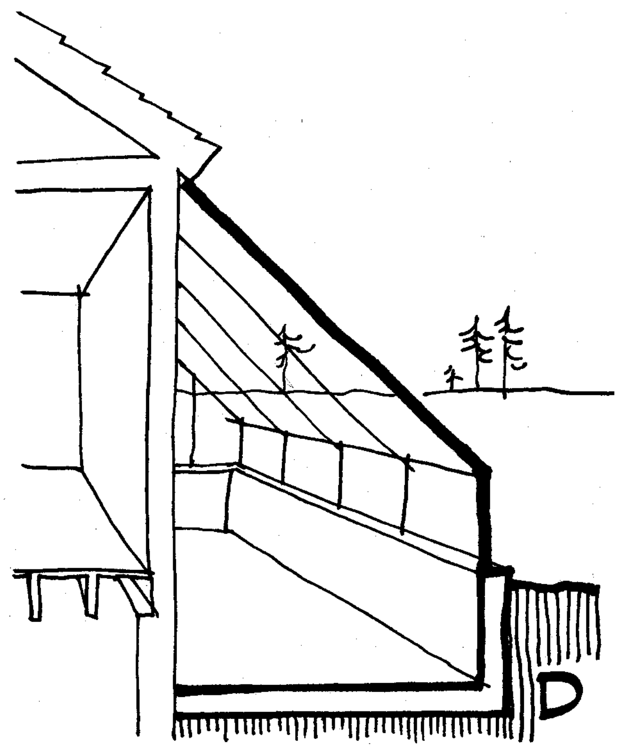
B. When glazing is added to the prepared wall surface of a house, it transforms the wall into a solar chimney collector.

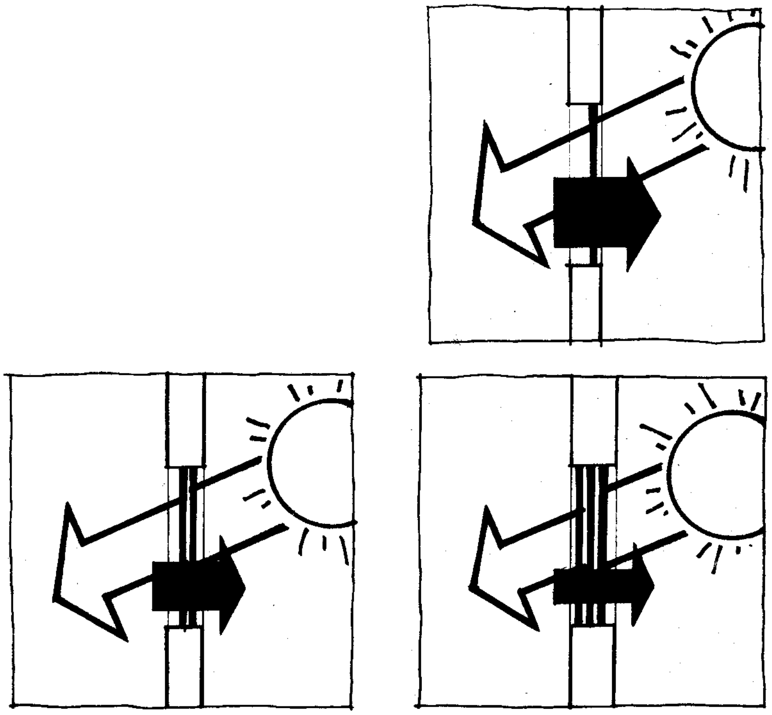
C. Adding a layer of glazing over an uninsulated masonry wall significantly reduces heat loss from that wall, and, in fact, produces considerable solar heat gain through the wall.

D. Finally, a solar room results when the space between the glazing and the wall is greatly enlarged. This space, in a sense, absorbs the shock of outdoor weather extremes, tempering their effect on the house while also providing solar heat.





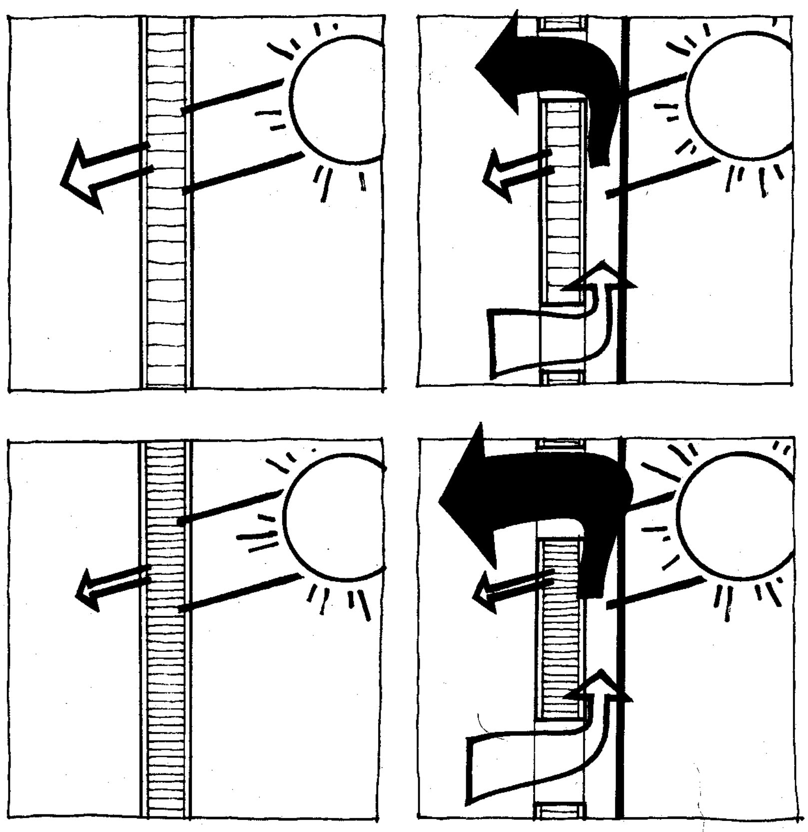




A. Solar Windows

Improving the Energy Performance of Existing Windows. Levels both of solar radiation "in" and of heat loss "out" are high through a single layer of glass. When the sun is shining, the house heats up quickly. Yet, when the temperature drops, heat loss increases quickly. A second layer of glass reduces solar gains by about 18%, but reduces heat loss by about 50%. A third layer of glass reduces solar heat gain by another 18%, but heat loss is reduced by an additional one-third. Therefore, a second, and even a third, layer of glazing is often cost effective. Movable insulation (to be discussed in Chapter 3) is most effective in reducing heat loss.

The same principles apply if you convert south-facing walls into windows, perhaps the simplest solar retrofit. Added glass area allows more heat in, but be sure to take steps to reduce heat loss. Be sure also to take steps to soak up the extra heat to keep the house comfortable during the day and to make the extra heat available at night. Make provisions for shading the glass during the summer.



B. Solar Chimneys

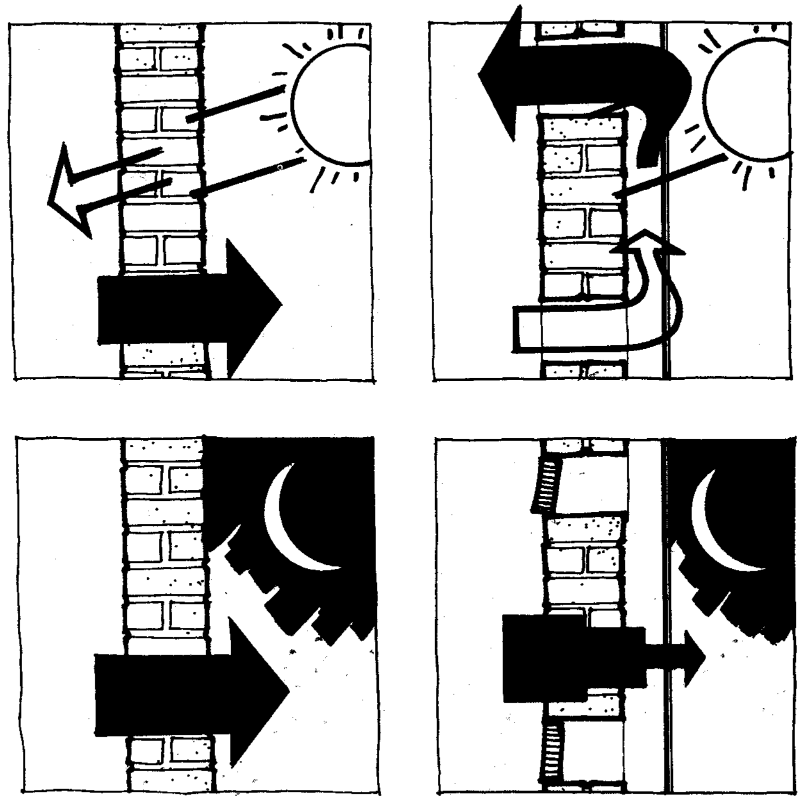
Converting Heat-losing Walls into Energy Producers. A poorly-insulated wall allows small amounts of solar heat gain. A well-insulated wall allows little or no solar gain. Whereas the poorly insulated wall has huge heat losses, the well insulated wall loses very little. When the outdoor temperature drops, heat loss through the walls increases quickly but not as quickly as it does through windows.

When the walls are covered by sheets of glass, and thereby are converted to solar chimney collectors, they increase considerably the amount of solar energy they provide to the house. They take a short time before they heat up and start producing heat, so they do not provide energy quite as quickly as windows do. Nor do they provide quite as much heat as windows do. However, the heat loss from the house through the walls is substantially less than through the windows (unless, of course, the windows are covered with insulation at night). The net result is that more energy is gained through solar chimneys than is lost. And, if properly constructed, solar chimneys can produce more energy than windows can.

C. Solar Walls

Brick 'n Mortar 'n Solar. Brick, stone, adobe, and concrete walls have high rates of heat loss, even if they are thick. If they face east, west, or north, insulate them, preferably with the insulation on the outside. But if they face south, cover them with sheets of glass or durable plastic and capture the sun's rays.

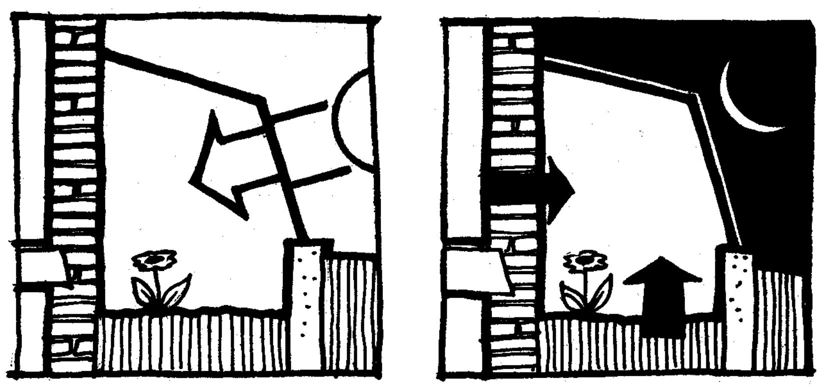
Much of the sun's heat is absorbed by the wall, delaying the time when the house receives the heat. Also, because the sun-warmed wall loses heat back to the outdoors, the net energy gain is not as great as it is through windows. But the solar heat enters the house slowly and over a long period of time, making overheating much less of a problem than with solar windows, and keeping the house warm well into the night.

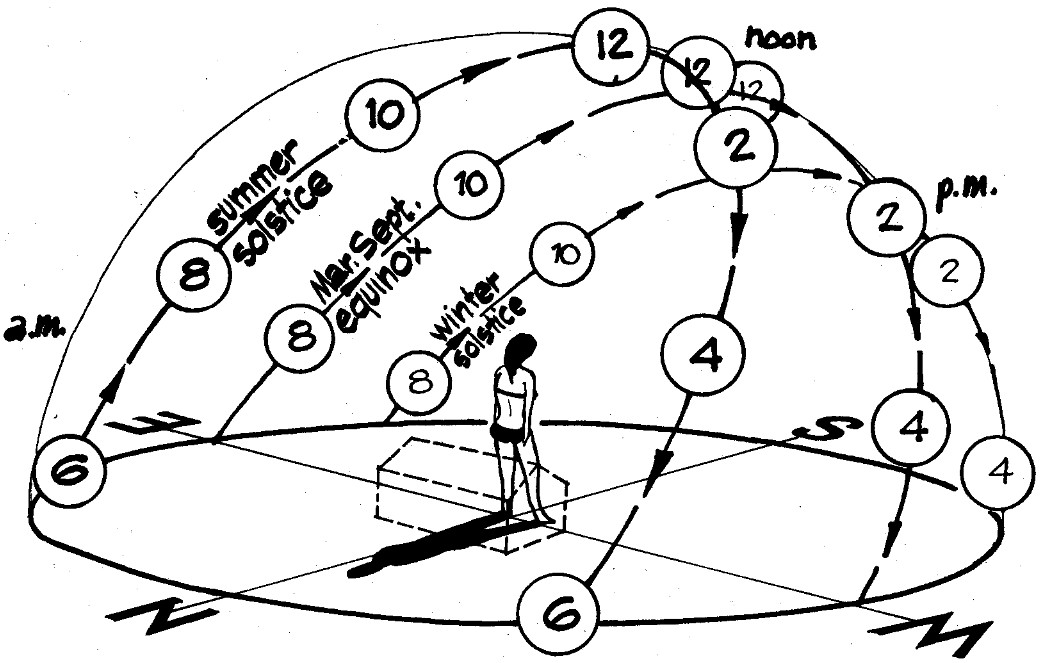


D. Solar Rooms

Going One Step Further-Solar Rooms. Vertical glazing offers only a small, dead air space over an exterior wall surface. If the glazing is installed instead in a lean-to fashion, the air space can become large and can be called a solar room. The heat loss from the house is no longer to the outdoors, but rather it is to this large air space, which is nearly always warmer than the outdoors. This makes the rate and amount of heat loss from the house much lower.

If the wall of the building is wood framed, a solar room is likely to experience wide temperature fluctuations. If the wall is of solid masonry, then the fluctuations will be much smaller. The thermal mass of masonry or earthen floors reduces temperature fluctuations, too.



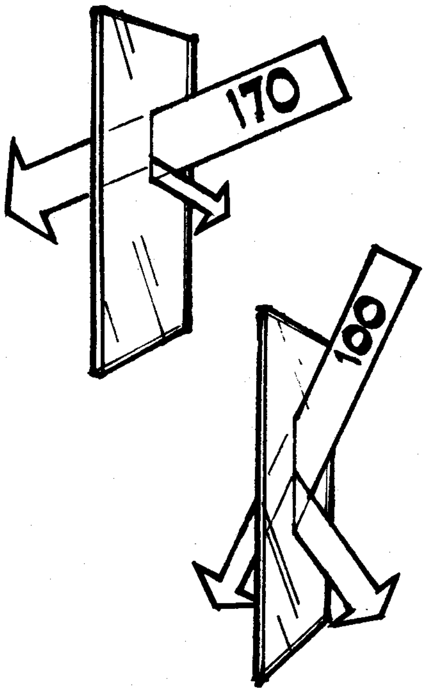


Instructions: Stand at the line of your proposed solar wall, face south, look at the numbered suns in the sky, wait there for 12 months until all 17 have appeared, then continue reading this book.

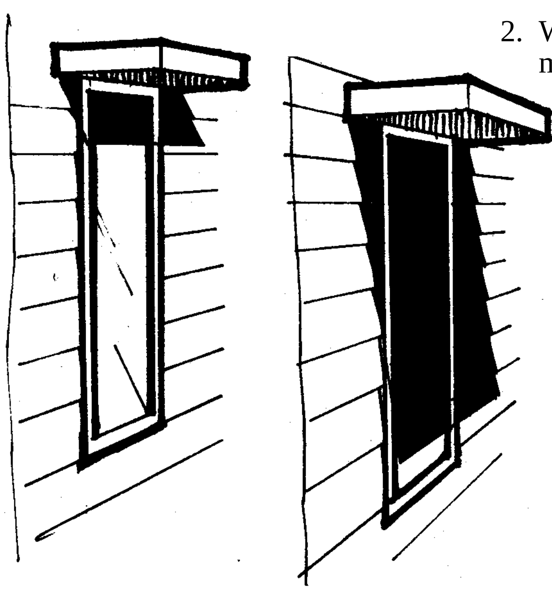
Solar Position

We all realize that the sun doesn't stay in one part of the sky all day and that its path varies from season to season and from state to state. Fortunately, its movements are completely predictable, widely published, and easy to understand. No guesswork is involved: from the sun chart for your latitude (see Appendix 1) you can find quite easily where the sun will be at any hour, at any season; and. from that information you can see how and where solar installations (and summer sunshades) must be placed in order to respond to the sun where you live.

Here's a nice surprise: the quantity of solar energy that penetrates a south-facing window on an average sunny day in the *winter* is greater than that through the same window on an average sunny day in the *summer*. Here are the reasons:

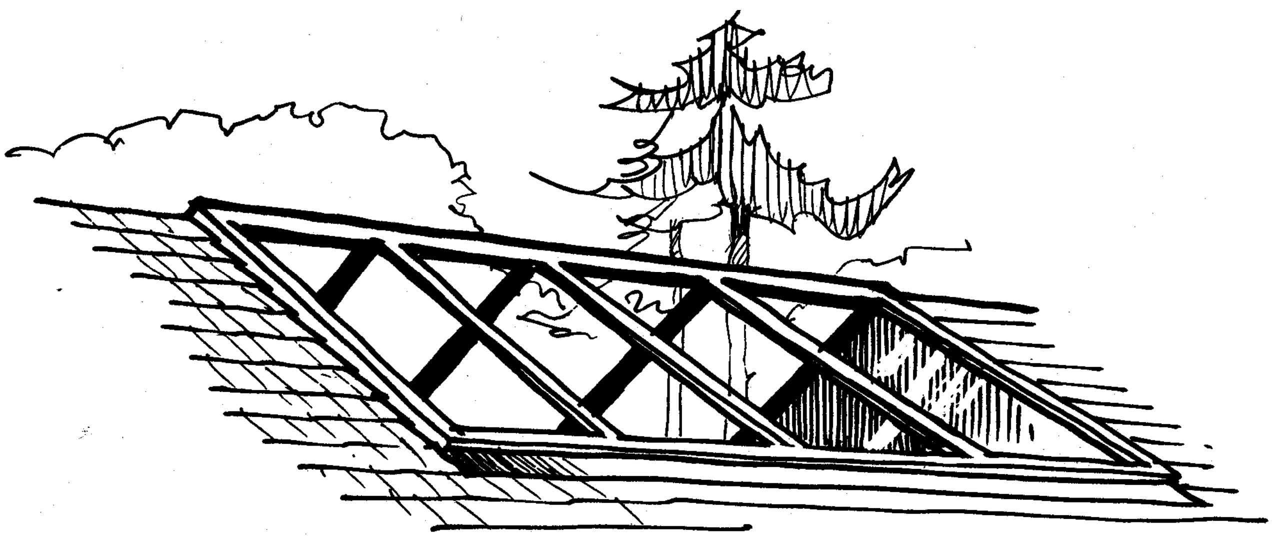


1. Although there are more daylight hours during the summer, there are more possible hours for sunshine to strike a south-facing window in winter. If you live at .35° north latitude, for example, there are fourteen hours of sunshine on June 21. But at that position the sun remains north of east until after 8 :30 A.M. and moves to north of west before 3 :30 P.M., so that direct sunshine occurs for only *seven hours* on the south-facing wall. On December 21, however, the sun shines on the south wall for the full *ten hours* of daylight.
2. The intensity of sunlight is approximately the same in summer as in winter. The slightly shorter distance between the earth and the sun during the winter than during the summer is offset by the extra distance that the rays must travel through the atmosphere in the winter when the sun is low in the sky.
2. In the winter, the lower sun strikes the windows more nearly head-on than in the summer when the sun is higher. At 35° north latitude, 170 Btus of energy may strike a square foot of window during an average winter hour, whereas only 100 strike on the average during the summer.
2. In winter, more sunlight passes through glass by hitting the window head-on. But in the summer, the high angle rays tend to reflect off the glass.
2. With proper shading, windows can be shielded from most of the direct summer radiation.



About twice as much solar radiation is transmitted through south-facing windows in the winter as in the summer. If the windows are summer-shaded, the difference is even greater.

In passive systems, tilted surfaces such as roofs are used less often than vertical surfaces. With reflective surfaces such as snow on the ground, a south-facing vertical surface actually receives more energy during the middle of the winter than a south-facing tilted one. Therefore, during the primary heating months there is little advantage to using tilted rather than vertical, south-facing surfaces. In fact, for more northern latitudes, the difference is insignificant.



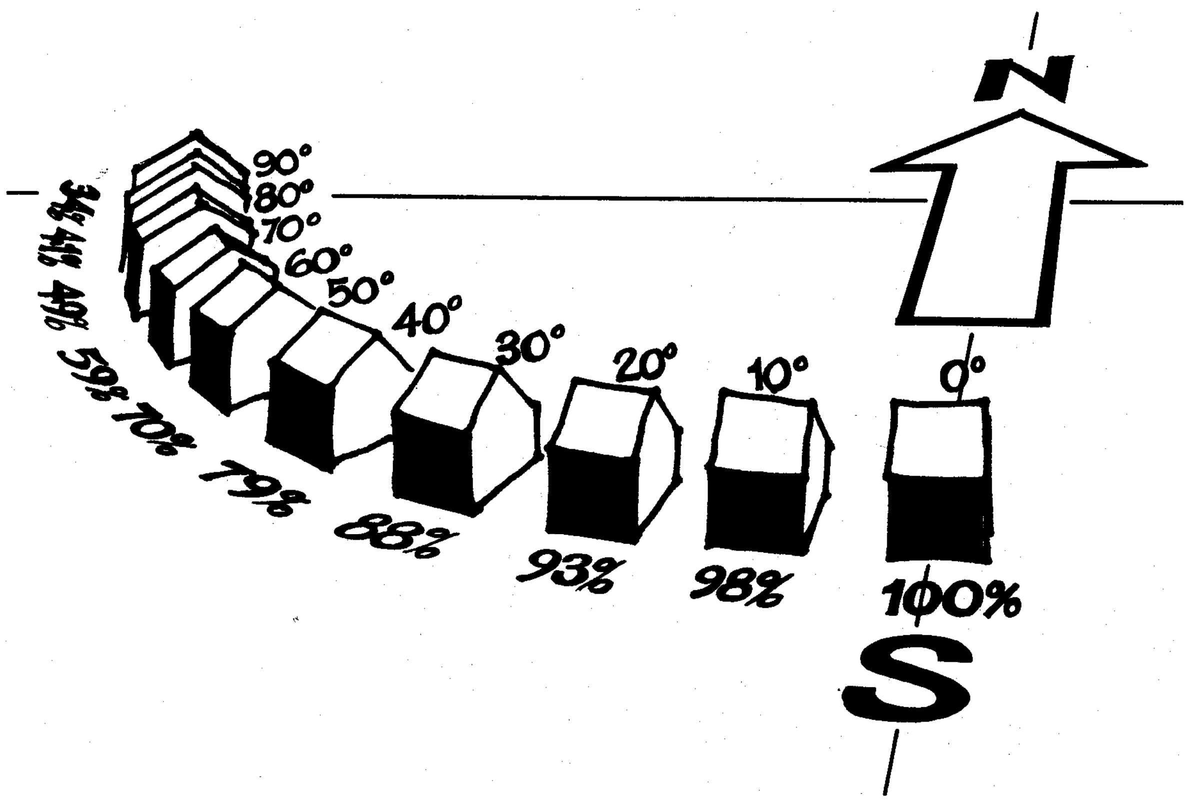
Tilted glazing, whether in collectors or skylights, tends to be more costly to build and more prone to leakage. It is also harder to shade and, if left unshaded, can more easily overheat the house in the summer than vertical glazing can. Roofs are less likely than walls to be shaded by trees or buildings during the winter, and they have large surfaces for collecting solar energy. Unfortunately, they are difficult to cover with insulation at night to reduce heat loss.

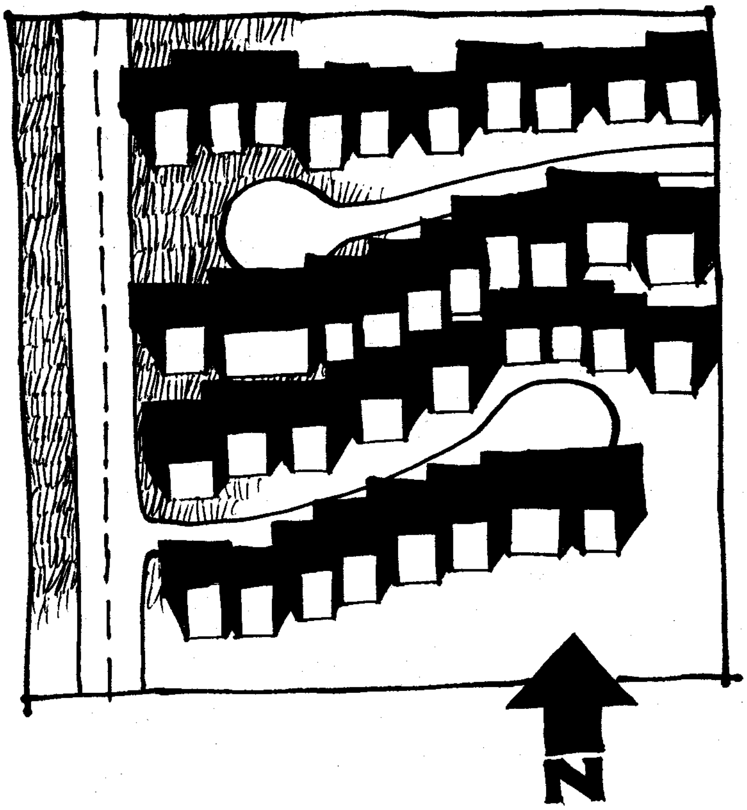
The Site

If your site does not have proper solar exposure because it slopes sharply north or is shaded darkly by evergreens or large buildings, a house designed for the site will have little chance of being solar heated. Here's what to watch for:

1. Lot Orientation

South-facing houses assure lower energy consumption, during both summer and winter. This does not mean that houses have to face rigidly southward. A designer who understands passive solar principles can devise dozens of practical solutions. The site or lot itself does not have to face south, as long as the building itself is oriented southward. A lot that slopes sharply north is, of course,

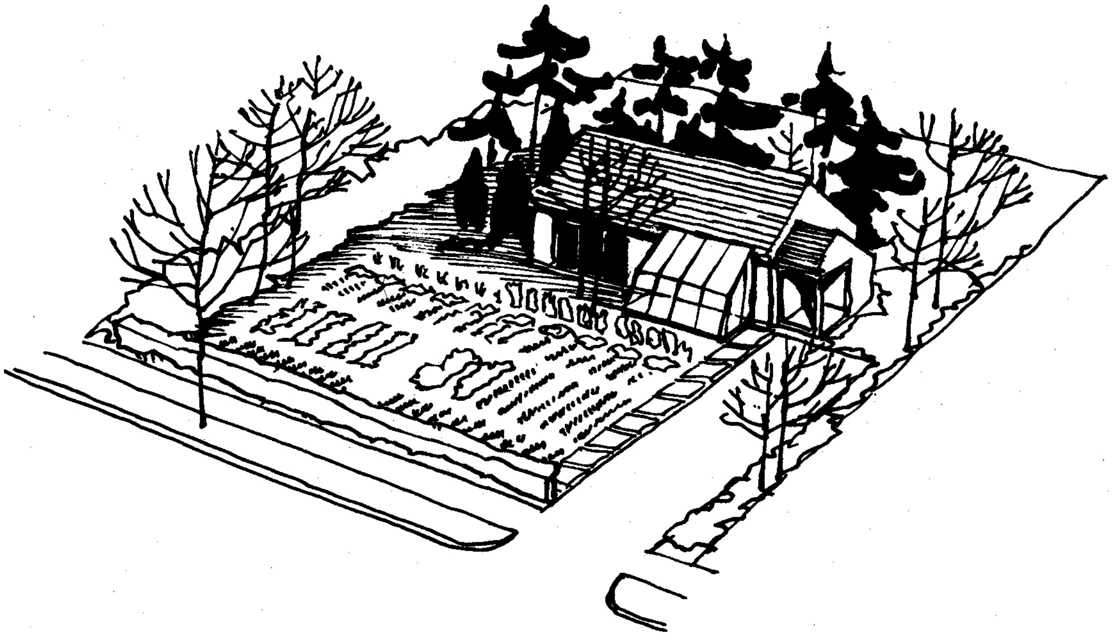




very difficult to work with, and south-sloping lots are preferred. Once land developers understand passive principles, they can plan for solar subdivisions with the cost approximately the same as for conventional subdivisions.

2. Setback Flexibility and Minimum Lot Size

Deep house lots which have narrow street frontage, reduce the surface area of summer heat-producing asphalt streets. Higher housing densities can reduce travel distances and times and subsequent energy use. Flexible zoning laws can permit houses to be located near the edges of their lots, thus minimizing the potential of shading from adjacent neighbors. Long-term, shade-free rights to the sun are necessary to guarantee adequate sunlight for the life of the house. Solar rights are slowly being acknowledged as legal precedents build up in the courts.



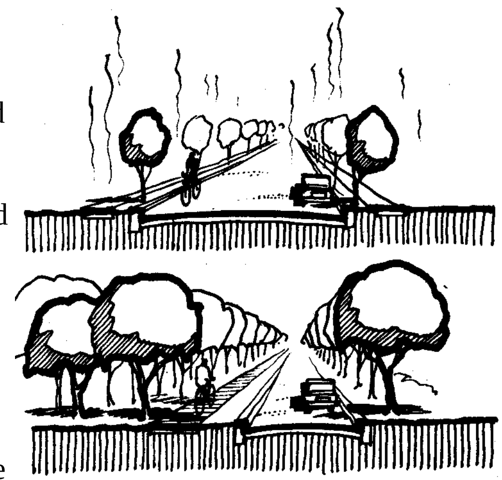
3. **Landscaping**

Proper landscaping can offer beauty as well as comfort and energy savings, both in winter and in summer. Evergreens can greatly slow arctic winds. For most of the country, these winds come from the west, north, and, northwest. Large deciduous trees appropriate to your region can provide shade and summer cooling. They are most effective on the east, west, and south sides of the house. Most, but not all, deciduous trees shed their leaves in the winter to let the warm sun in. Well-shaded and landscaped paving will often encourage people to walk or bicycle rather than ride in an energy-consuming car. Glaring, unshaded asphalt creates desert-like conditions, placing a higher air conditioning load on buildings. Pavings that are porous to rain and that do not absorb heat have a much less severe effect.

Landscape design that encourages home vegetable gardening saves energy in many ways. For each calorie of food produced by agriculture, ten calories of manufactured energy are expended. Home gardens do far better, offering not only more nutritional food, lower food bills, and richer soil, but also a more appropriate use for all the plant cuttings and food wastes so often discarded.

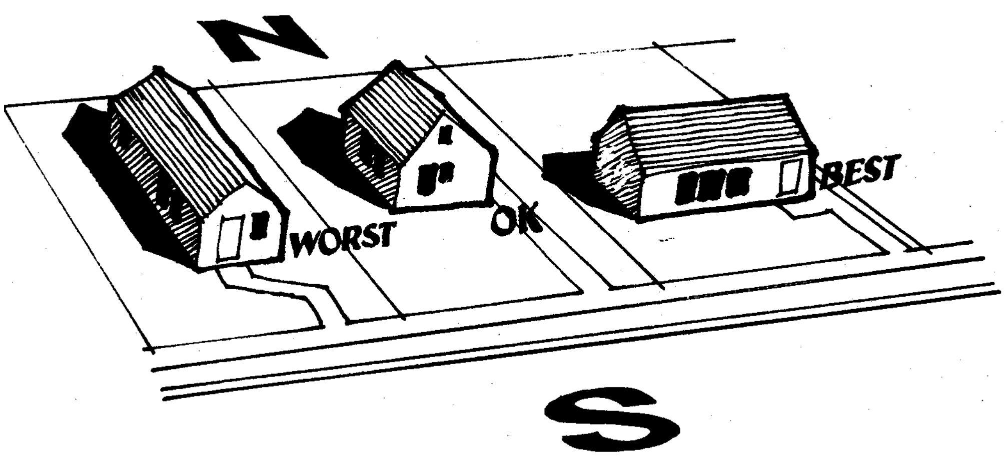
4. Street Widths

Narrow streets save valuable land and can be shaded more easily than wide ones. They are more pleasant than wide multilaned streets and are safer for bicyclists, pedestrians, and motorists. They reduce the heat load on people using them, and they also reduce traffic speeds. Parking bays, rather than on-street parking, can promote shading both over the bays and over the narrower streets. Pedestrian walks and bicycle paths are far more readily integrated into such plans.



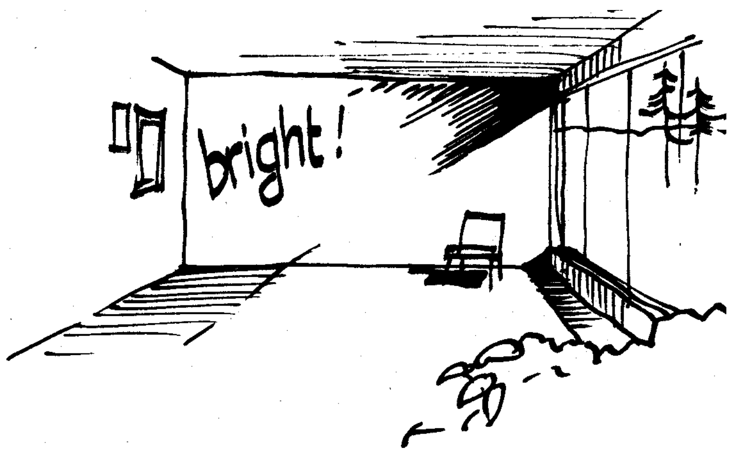
5. Length/Width Ratios

In the northern part of the country, south sides of houses receive nearly twice as much radiation in the winter as in the summer. This is because the sun is lower in the sky during the winter. In the summer, the sun is high in the sky, and the sun does not shine directly on south walls for a very long period of time. Houses in the south gain even more on south sides in the winter than in the summer.



East and west walls receive 2 ½ times more sunshine in the summer than in the winter. Therefore, the best houses are longer in the east/west direction, and the poorest are . longer in the north/south direction.

A square house is neither the best nor the worst. (Remember, however, that a square building is often the most efficient in terms of layout and economy of materials.) A poorly shaped house can be improved by covering the south wall with windows and other passive systems and minimizing windows facing other directions. If you pitch your roof south at a slope of 45° or so, you can add active solar collectors and/or photovoltaic (solar electric) cells. You may not want to do so now, but someday when energy prices have tripled, and then tripled again, everyone will envy your farsightedness. After all, this year's $150 heating bill of your cozy passive solar home will at that point be over $1,000 while everyone else's will be $5,000 to $10,000!



6. Natural Daylighting

Do not underestimate the bonus of natural daylighting, which passive solar designs can provide. In some big buildings, solar glazing may save more energy and money by reducing electric light bills than it saves by reducing fuel bills, and lighting engineers feel that properly located lighting from sidewalls can be two to three times as effective as artificial overhead lighting. For houses, the extra light from solar windows and solar rooms can add immeasurable pleasure and a living experience far surpassing any you've had before.