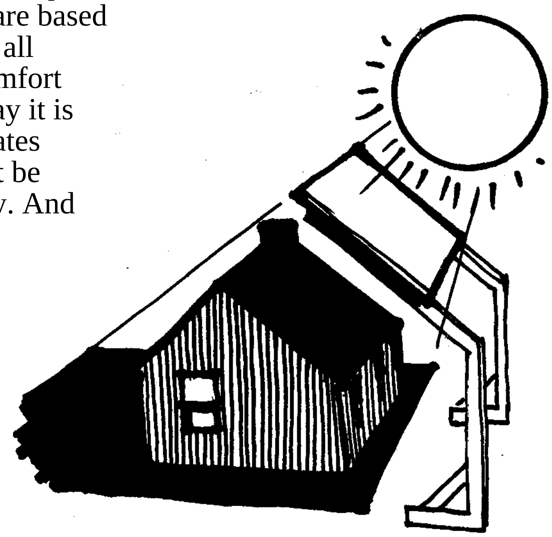
Chapter 8

How the Sun can Cool

"What do you mean *solar* cooling?" That's a good question. In fact, of the several passive solar cooling techniques discussed here, only one of them can be labeled strictly" solar," and even at that only if you stretch the definition. But all the techniques use passive, or natural, cooling that require no pumps or fans for their operation. Many of them are based on plain old common sense. Fortunately, in virtually all climates, houses can be designed to provide ideal comfort without mechanical air conditioning. This is not to say it is easy to do everywhere. In really hot and humid climates where electricity is still inexpensive, it just might not be worth the extra effort; not yet, but it may be someday. And it's at least nice to know such things are possible.



By far the first and most important step in cooling is to keep sunlight from falling on your house, so first we'll discuss "solar control." We'll also discuss natural cooling by ventilation, evaporation, sky radiation, and nesting of buildings into the earth.

Solar Control

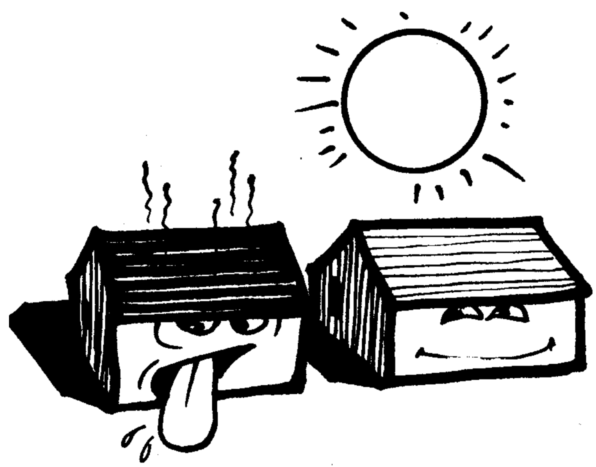
Usually the easiest, most inexpensive and effective way to "solar" cool your house is to shade it-keep the sun from hitting your windows, walls, and roof. In fact, where summer temperatures average less than 80°, shading may be all you need to stay cool.

Most of the things you do to reduce winter heat loss also reduce summer heat gain. For example, heavily insulated walls keep out summer heat, so shading them is not as important as if they were poorly insulated. Facing windows south to catch the winter sun and minimizing east and west windows to reduce heat loss are also important steps in solar control. South windows admit less sun in the summer than they do in the winter, while east and west windows can turn houses into ovens. A light-colored roof may be 60 to 80 degrees cooler than a dark roof because it reflects light.

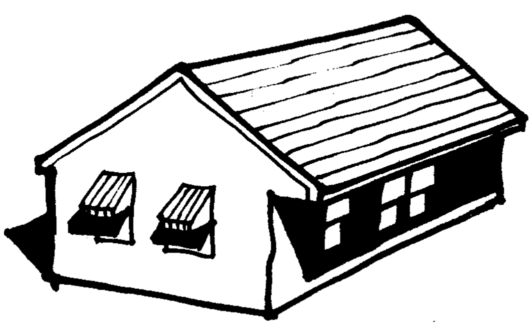
Reducing the Need for New Power Plants (No More Nukes)

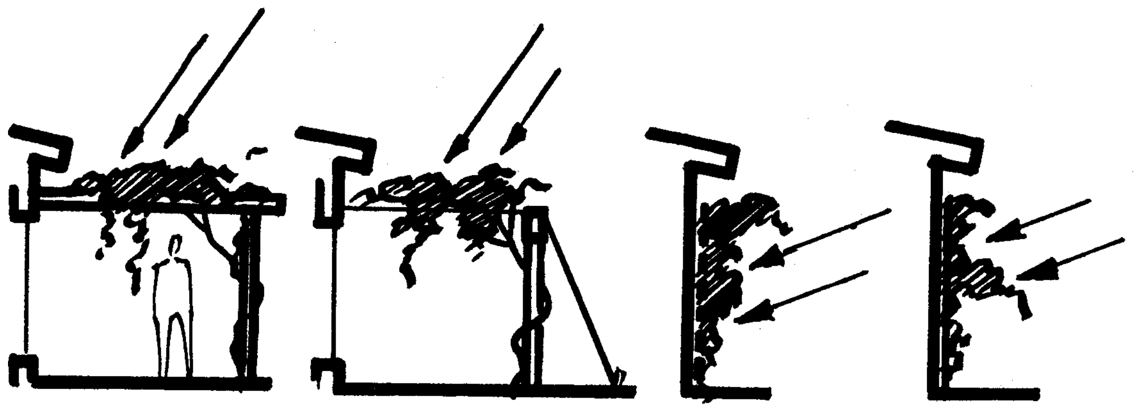
Natural cooling can significantly reduce peak cooling power loads. With natural cooling, the size and use of backup conventional electrical air conditioners is reduced. This means the demand for power is reduced and so is the need for new power plants. For example, approximately 50 square feet of west window unshaded from the sun needs a 1-ton air conditioner and approximately 2 kilowatts of electrical generating capacity costing $2500 or more to build. Shading the windows or facing them in other directions can reduce those peak power demands created during the summer months.

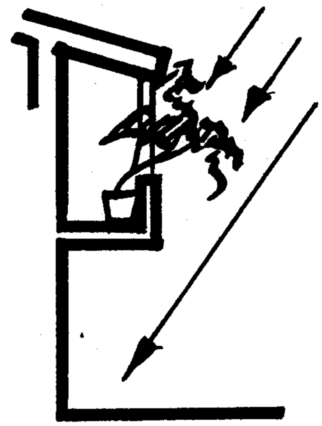
Thermal mass can absorb heat during the day, delaying the need for cooling until after peak demand hours. At that later time, the need will not be as great and the air conditioner can be smaller and cheaper to run.



In really hot climates, uninsulated walls and roofs should be shaded. But although this is important, shading windows is far more important. Overhangs and awnings work well. Unfortunately, fixed overhangs provide shading that coincides with the seasons of the *sun* rather than with the *climate.* The middle of the sun's summer is June 21-the longest day, when the sun is highest in the sky. But the hottest weather occurs in August, when the sun is lower in the sky. A fixed overhang designed for optimal shading on August 10, 50 days after June 21, also causes the same shading on May 3, 50 days before June 21. The overhang designed for optimal shading on September 21, when the weather is still somewhat warm and solar



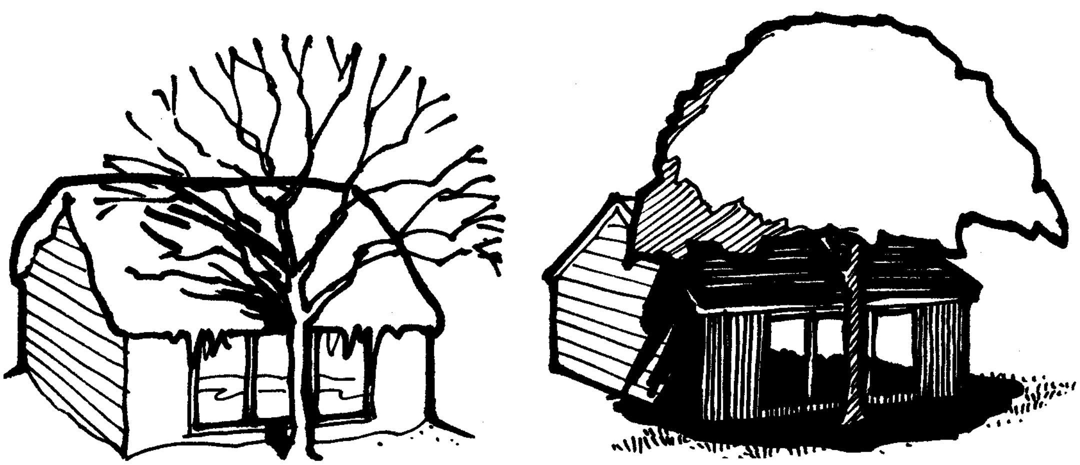




heat gain is unwelcome, also causes the same shading on March 21, when the weather is cooler and solar heat is welcomed.

Shading from deciduous vegetation more closely· follows the climatic seasons, and therefore, the energy needs of houses. On March 21, for example, there are no leaves on most plants in north temperate zones, and the bare branches readily let sunlight through. On September 21, however, those same plants are still in full leaf, providing needed shading.

Operable shades are even more versatile and adaptable to human comfort. The most effective shades are those mounted on the outside of a building. However, most exterior operable shades do not last very long. Nesting



The most significant sources of technical detail on shading can be found in the *ASHRAE Handbook of Fundamentals* by the American Society of Heating, Refrigerating, and Air Conditioning Engineers, New York, and in *Solar Control and Shading Devices* by Aladar and Victor Olgyay, Princeton University Press.

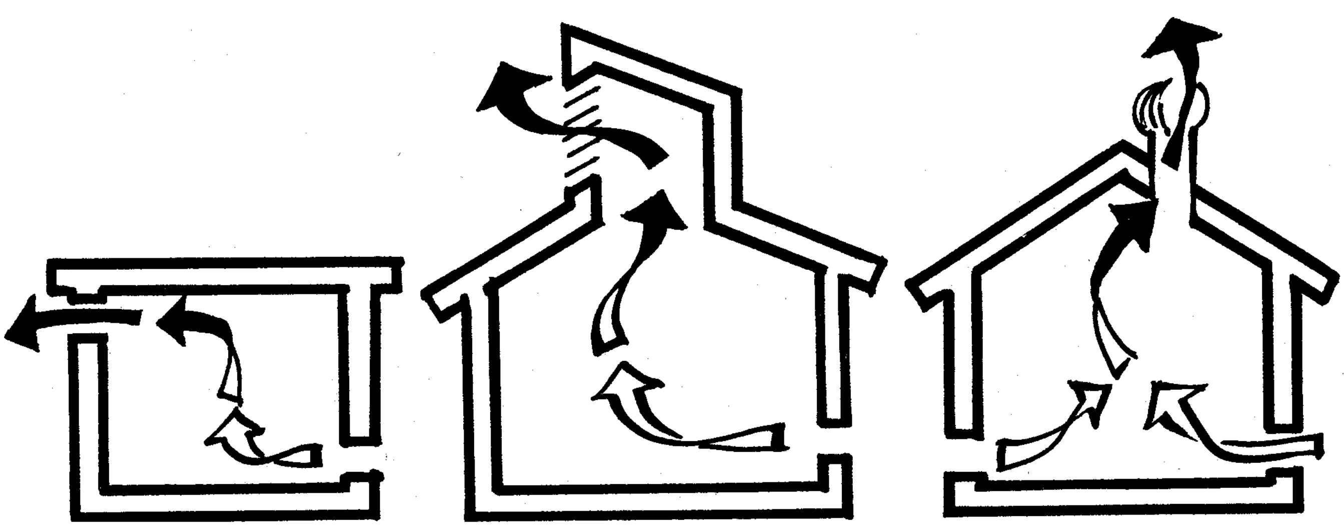
animals, climbing children, wind, and weather will see to that. Inside shades last longer, but few are as effective as outside shades. Once the sunlight hits the window glass, half the cooling battle is lost.

East and west glass is difficult to shade because the sun in the east and west is low in the sky in both summer and winter. Overhangs prevent the penetration of sunlight through east and west windows during the summer very little more than they do during the winter. Vertical louvers or other vertical extension of the building are the best means of shading such glass.

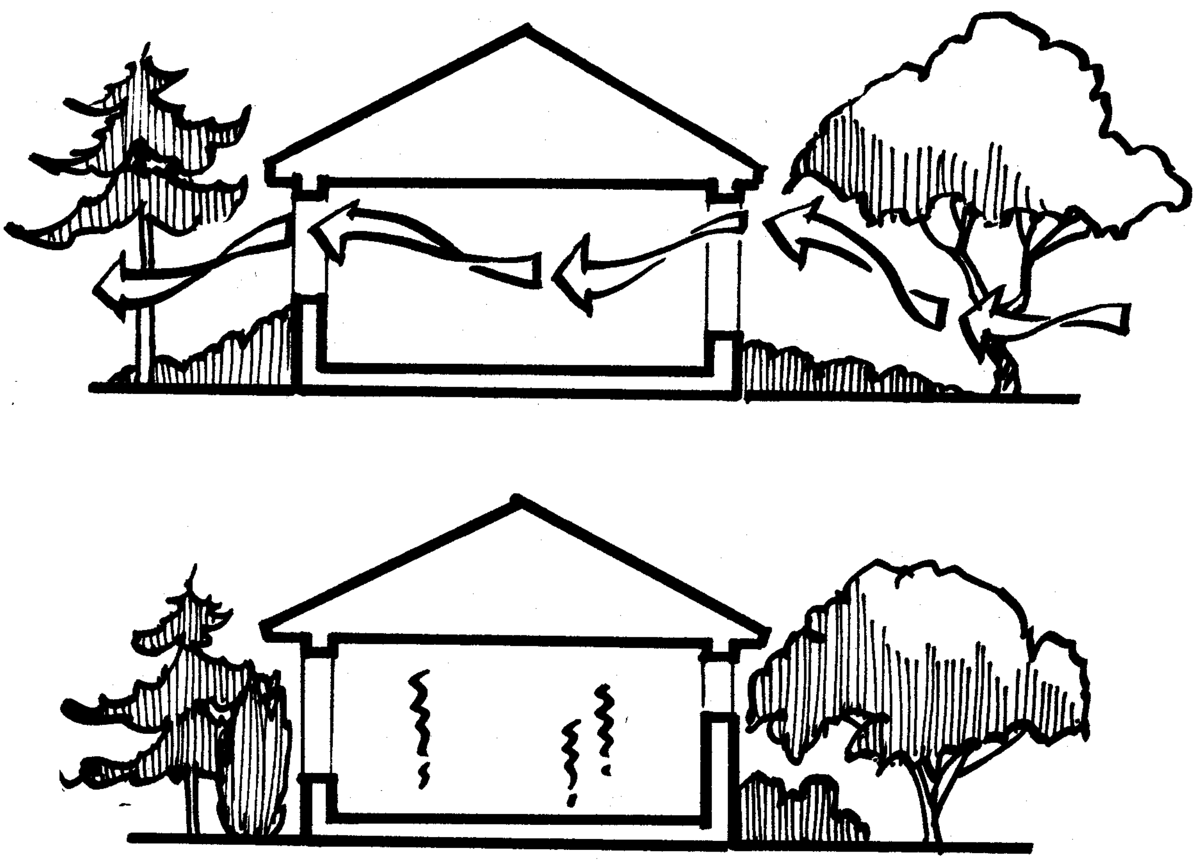
Ventilation

The movement of room temperature air, or even slightly warmer air across our skin causes a cooling sensation. This is because of the removal of body heat by convection currents and because of the evaporation of perspiration.

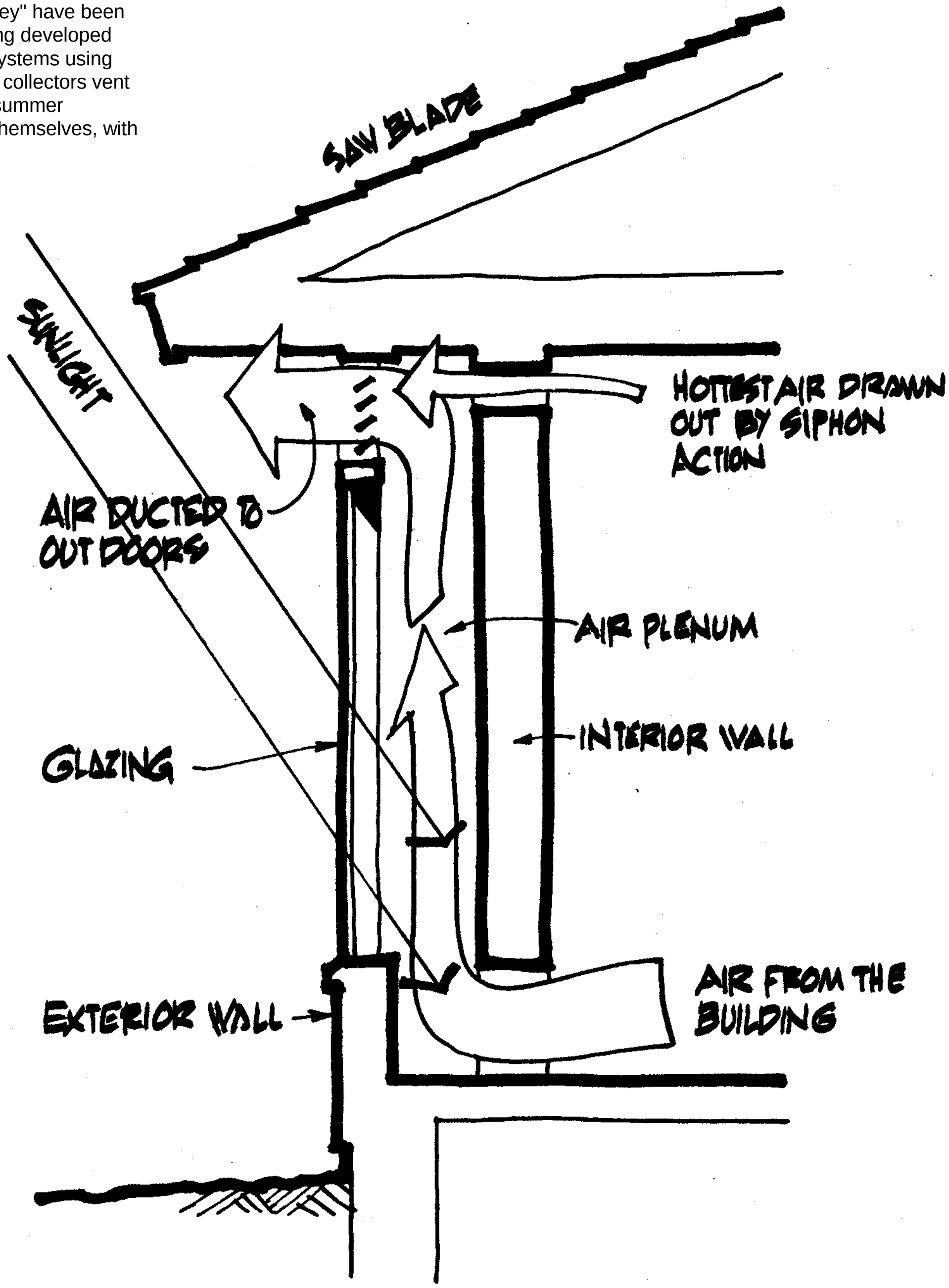
The most common way to cool a house with moving air without using mechanical power is to open windows and doors. Do not forget this simple concept-natural ventilation-and do not underestimate its cooling effect. Low, open windows that let air in result in air flow through



Natural ventilation can be affected by land planning. Natural breezes should not be blocked by trees, bushes, or other buildings. Shade trees should be selected so that branches and leaves are as high above the house as possible to allow a breeze to enter below them. The shape of your house, proper clustering of buildings, and other landscaping features such as bushes and fences can funnel and multiply natural breezes.



Here, a solar collector exhausts its hot air to the outdoors by natural convection and pulls house air through itself, providing ventilation. The solar collector is very similar to the solar chimney, convective loop collectors discussed in Chapter 4. Many variations of this "solar chimney" have been used widely in the past and are being developed again today. In some *active* solar systems using heated air (rather than a liquid), the collectors vent hot air to the outside during sunny summer weather, pulling house air through themselves, with or without the use of blowers.



the lower part of the room where people are, rather than near the ceiling. Houses that are narrow and face the wind, or that are T - or H -shaped, trap breezes and enhance cross ventilation through the house. When all else fails, open or screened porches, located at or near the comers of houses, can capture soft, elusive breezes as they glide around the house.

The "stack" or "chimney" effect can be used to induce ventilation even where there is no breeze. Warm air rises to the top of a tall space, where openings naturally exhaust the warm air. Openings at floor level let outdoor air in. Natural ventilation can be further induced by the use of cupolas, attic vents, belvederes, wind vanes, and wind scoops.

If your summer nights are a lot cooler than days, build your house of heavy materials. Cool the house at night by natural ventilation and the thermal mass will keep it cool during the day.

Determining Ventilation Air Flow

In stack-effect ventilation, air flow is maximized by the height of the stack and the temperature of air in the stack. Air flow is proportional to the inlet area and to the square root of the height times the average temperature difference, as follows:

$$Q = 540A\sqrt{h(T_1 - T_2)},$$

where

Q = the rate of air flow, in cubic feet per hour;

A = the area of the inlets, in square feet;

h = the height between inlets and outlets, in feet;

T_1 = the average temperature of the air in the "chimney," and

T_2 = the average temperature of the return air (normally just the outside temperature),

It is better to add heat (presumably using a passive air-heating collector) at the bottom of the chimney or stack than at the top. In this way the entire column of air in the chimney is hot, creating the desired bouyancy to cause the air to flow.

If outlet sizes are appreciably different from inlet sizes, the above expression must be adjusted according to the following ratios:

Area of Outlets / Area of Inlets	*Value to be substituted for 540 in above expression*
5	745
4	740
3	720
2	680
1	540
¾	455
½	340
¼	185

This information is from *Design with Climate* by Victor Olgyay, Princeton University Press.

Don't forget this one, either:

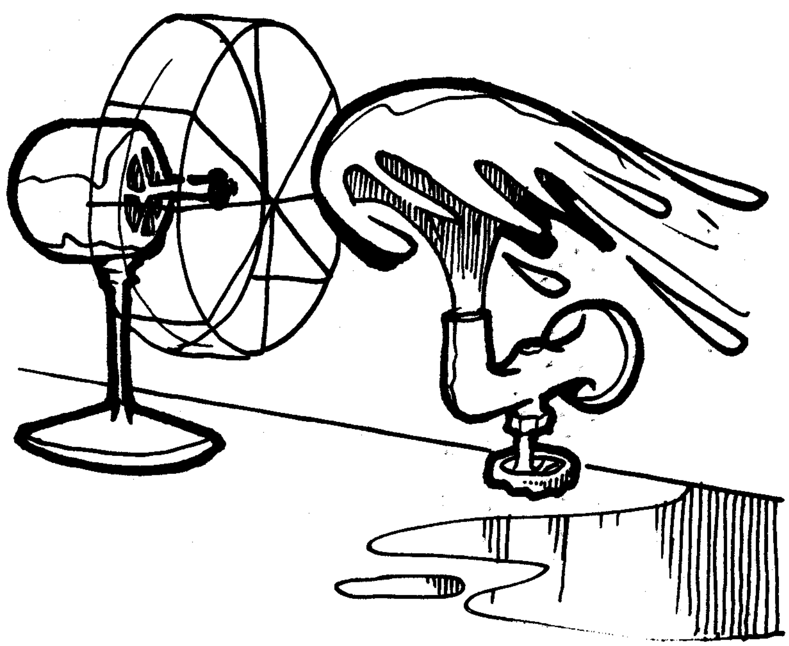
$Q = 540A\sqrt{h(T_1 - T_2)}$

Evaporation

Our skin feels cooler if it's wet when the wind hits it than when it's dry due to the evaporation of moisture. The same process can cool air effectively, especially in dry climates. There are many ways to evaporate water. The most effective are by having large water surfaces, and by agitating, spraying, or moving water in contact with the air for the greatest surface contact. For example, large shallow ponds provide this large surface contact. Moving streams and sprays from water fountains increase turbulence and, thus, surface contact.

Evaporative cooling can also keep roofs cool. Roof sprays and ponds have been used successfully in hot climates such as Arizona and Florida. Wind-flows across the roof ponds should be enhanced, if possible, to encourage evaporation. This can be done mechanically, but careful design of roof shapes can help speed the natural flow of air across the ponds.

The transpiration of indoor plants has a cooling effect. So do interior pools and fountains. Fans can add



enormously to the evaporative effect and have been used successfully in "swamp" coolers and other evaporative coolers.

If you live in a humid climate, however, do not expect evaporative cooling to help you very much. In fact, it is likely to make your humidity problems worse.

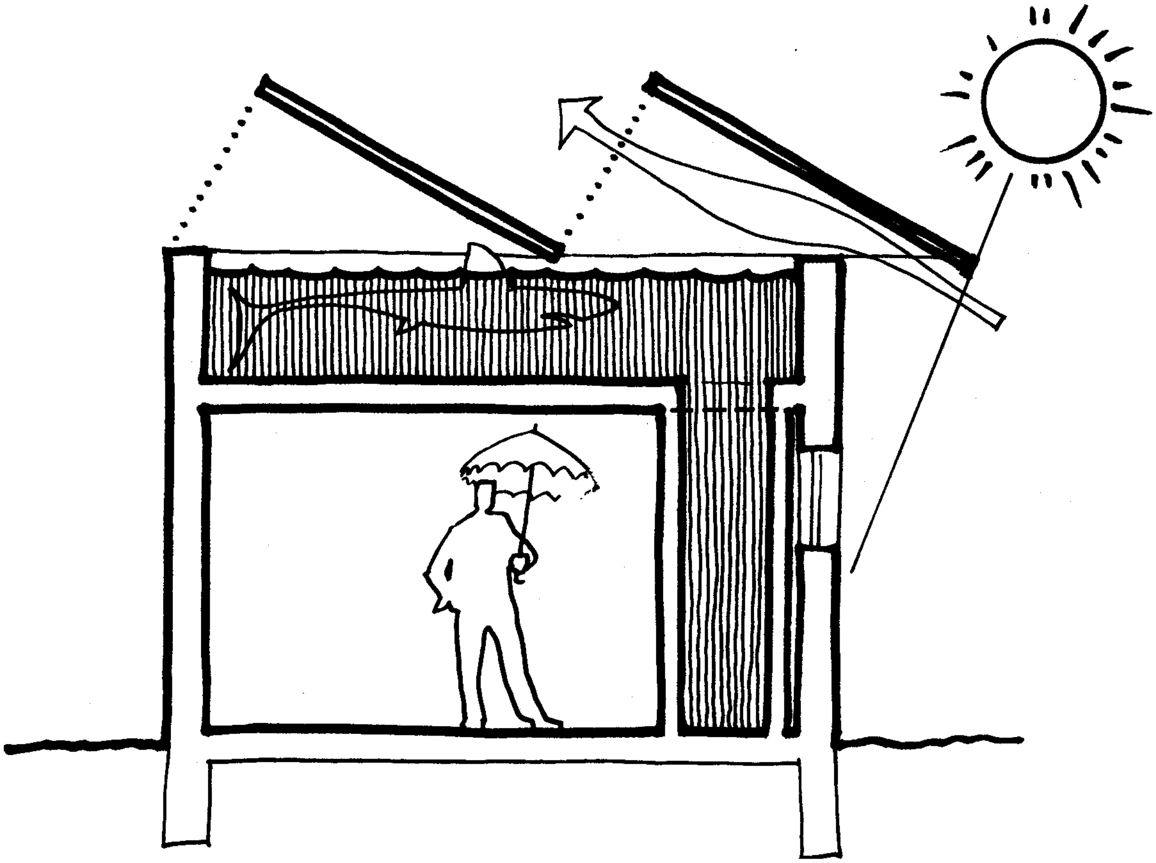
Radiational Cooling

Thermal energy is constantly being exchanged between objects that can "see" each other. More energy radiates from the warmer object to the cooler object. The sun radiates heat to the earth, and the earth radiates considerable heat to clear night skies, which, even during hot weather, are quite cool. The northern sky is often cool during the day.

Most sky radiation occurs at night. The amount varies greatly from one part of the sky to another, from 100 percent possible directly overhead to virtually none at the horizon. The most effective radiant cooling surface is horizontal, facing straight up. Obstructions such as trees and walls reduce night sky cooling. A vertical surface with no obstructions yields less than half of the radiant cooling of an unobstructed horizontal surface.

The classic sky radiation cooling concept is Harold Hay's "Skytherm" house in Atascadero, California. (Read Chapter 6 on Solar Roofs to learn more about this cooling effect.) To date, the use of sky radiation for cooling houses has been limited to climates with clear skies. Clouds and air with high moisture content significantly reduce the radiation of heat to the sky.

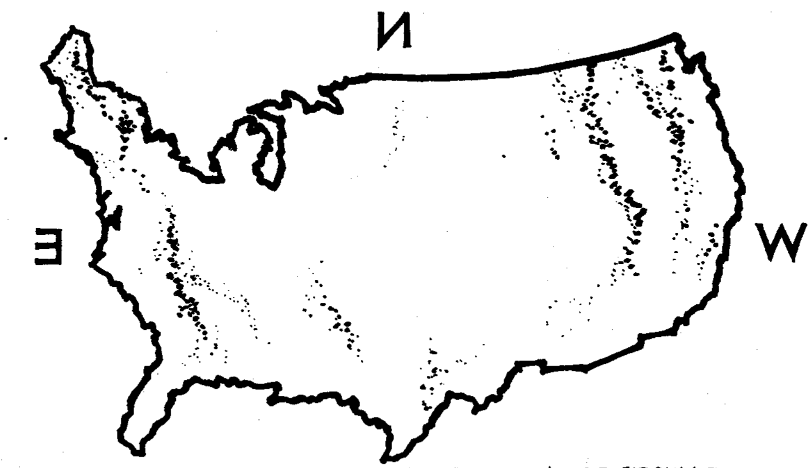
One of the best sources of engineering data and analyses of radiational cooling is "Atmospheric Radiation Near the Surface of the Ground: A summary for Engineers" by Raymond W. Bliss, *Solar Energy*, July/September 1961.



The "Cool Pool" concept is being developed and tested in Davis, Indio, and Sacramento, California, by Living Systems. The roof pond radiates its heat to the sky. The coolest water settles down into the radiant wall panel, cooling the house. The warmer water rises up into the pond where it radiates to the sky.

Ground Cooling

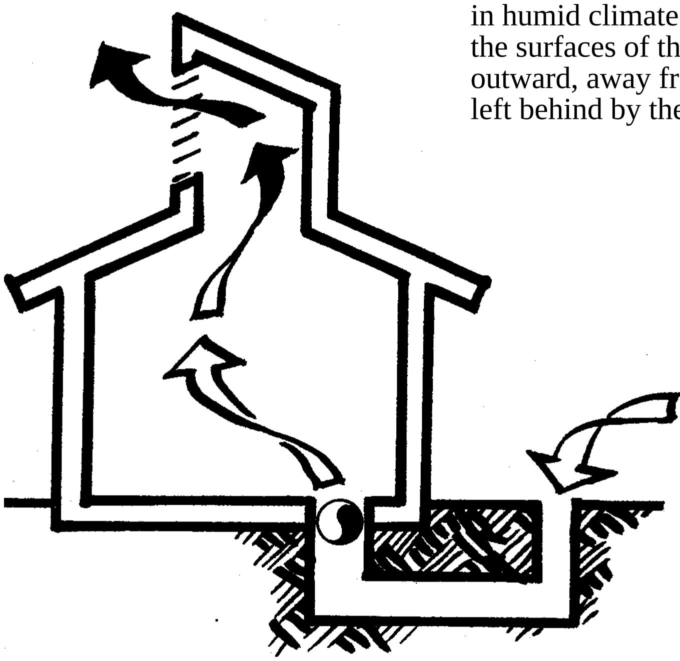
Since the ground is nearly always cooler than the air in the months when cooling is required, the more a house is in contact with the ground, the cooler it will be. Build your house below grade or into the side of a hill to obtain easy ground contact. You can also partially bank (berm) the earth around your house or even cover it. High levels of comfort and serene quiet usually accompany well designed underground housing. Just be careful to insulate the building in a way and to a degree that's appropriate to your region. In cold climates, insulate the walls well from the ground. In mild climates, use less insulation. In warm climates, no insulation is needed; the earth will keep the house cool. In humid climates, provide ventilation so that the surfaces in contact with the ground are kept dry.



THE UNITED STATES AS SEEN FROM UNDERGROUND
REMEMBER, YOU SAW IT FIRST RIGHT HERE.

Earth Pipes

Buildings built near natural caves have long used underground air masses to provide ventilation, needing only a little heating in most seasons. Earth pipes for the same purpose are just starting to be used. Earth-pipe systems have been designed to use pipe ranging in diameter from 4 to 12 inches. Forty to as many as 200 feet of pipe have been buried 3 to 6 feet below the earth. Metal culverts and plastic and metal waste pipe have been used. As house air is vented to the outside, either naturally or with a fan, outside air is drawn through the pipes and then into the house. During the winter, the air is warmed. During the summer, the air is cooled; and in humid climates, moisture condenses out of the air and onto the surfaces of the tubes. The pipes are sloped slightly outward, away from the house, to carry away the moisture left behind by the humid air.



The earth surrounding such pipes has in many cases been warmed (or cooled) too quickly to the temperature of the incoming summer (or winter) air, causing the pipes to lose their intended usefulness. Considerable research is being done in this area, however, and more detailed design and construction information will be available soon.