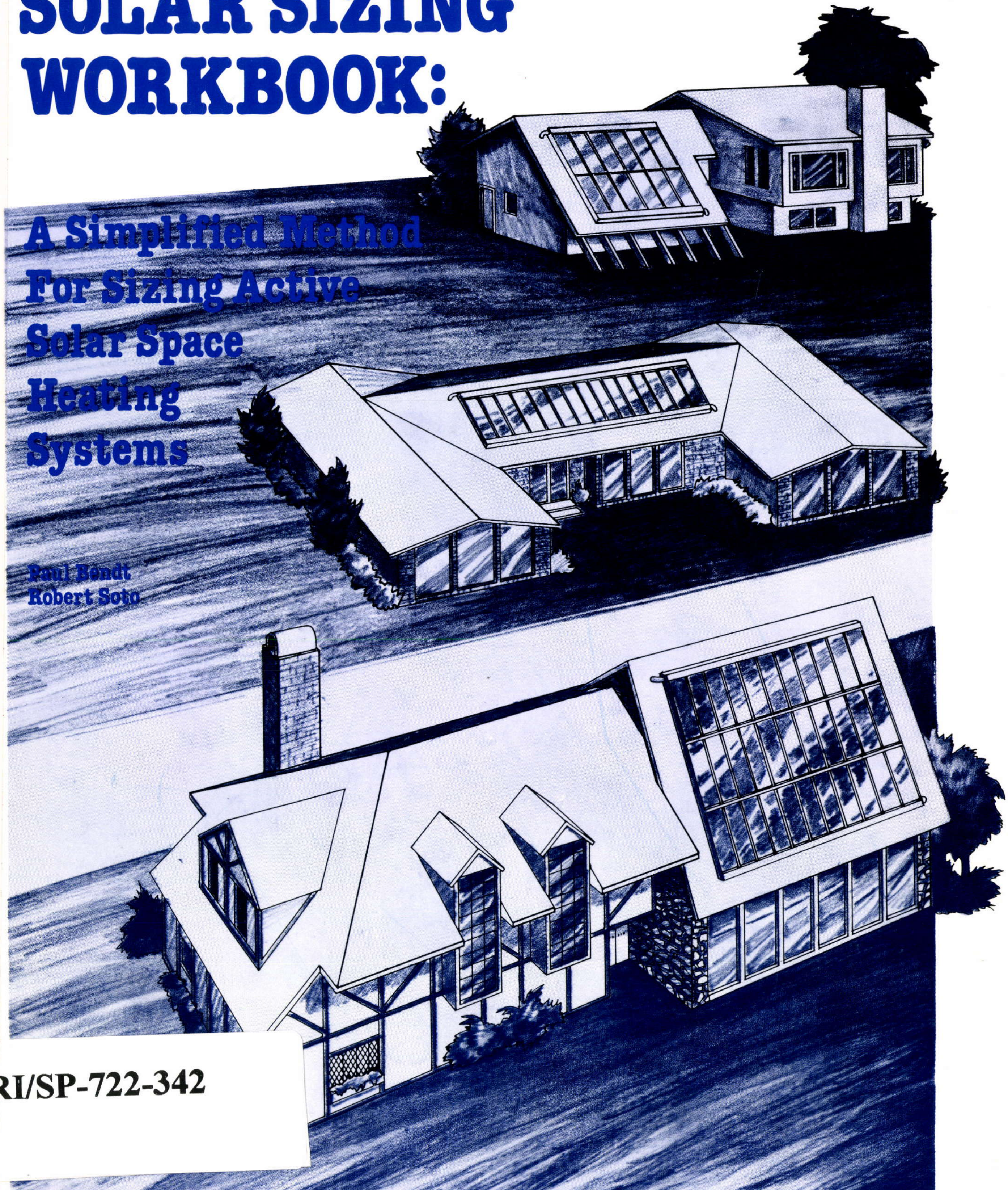
HOMEOWNER'S SOLAR SIZING WORKBOOK:

A Simplified Method For Sizing Active Solar Space Heating Systems

Paul Bendt
Robert Soto



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A Simplified Method For Sizing Active Solar Space Heating Systems

Solar Energy Research Institute

A Division of Midwest Research Institute

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Golden, Colorado 80401

INTRODUCTION

Determining the size of a solar heating system that is best for your home is an important process: you are sizing your initial investment as well as your future heating bills. Historically, the sizing process involved detailed, complex calculations which required computers, hand-held programmable calculators, or time-consuming hand calculations. Because of the complexity of these calculations and the need for computational equipment, most prospective solar buyers have shied away from sizing procedures and left them entirely to professional designers.

A Simplified Method for Sizing Active Solar Space Heating Systems was developed to help the prospective solar buyer by making the sizing process easier to understand and conduct without the aid of computational equipment (Bendt 1980). The method is presented in a single-page worksheet that requires only simple arithmetic and can be used by laypeople as well as professional designers, engineers, or architects. The method is based on F-CHART, a computer program used extensively in the solar design field for estimating collector size, long-term performance and costs, and how much heat a solar system will provide (Beckman, Duffie, and Kline 1977). The simplified method is, in essence, a correlation of thousands of F-CHART computer runs. Information pertinent to the sizing process has been analyzed, complex calculations conducted, and the results listed in three easy-to-use tables. You have to provide only specific information about your house, follow the worksheet instructions, and perform the simple arithmetic.

When the worksheet is completed, you will have determined three sizes of collector areas for heating your home and household water supply, an estimate of how much heat each size system will provide, and an indication of the recovery time of your investment plus interest.

A Word About Using This Workbook

This workbook is divided into three parts. Part I, Conservation and Solar Heating, briefly explains the advantages of practicing energy conservation in your home (solar heated or not) and gives information about the solar heating systems for which this sizing method is applicable. Potential heat-loss areas within a house are pointed out, together with recommendations that would reduce or eliminate these areas. Brief descriptions and illustrations of two types of active systems—air and liquid—are provided.* Many of the technical terms used in this section and throughout the workbook are printed in boldface, indicating they are further defined in the Glossary in Part III.

Part II, The Simplified Sizing Method, describes the method, explains how it differs from others, and discusses its limitations. You are told exactly what the method will help you determine. Also included are easy-to-follow worksheet instructions, a completed sample worksheet, blank worksheets, and Tables 1, 2, and 3. With the exception of specific information about your home (such as size, heating costs, and mortgage payment), this section provides the information necessary for you to complete the worksheet.

Study Your Options, Part III, is a follow-up section suggesting that after you complete the worksheet—but before you start making solar decisions—you seek the assistance of a professional solar designer/consultant, and obtain additional information about solar heating systems. Guidelines for purchasing a system and selecting an installation contractor are also given. Finally, a glossary and a bibliography are provided.

* The two types of systems described in this workbook are not the only types of active solar heating designs available. They are, however, the most common types of active systems used today and are the *only* ones for which this sizing method is applicable. For more information on other types of active components and systems, *see* the bibliography or contact the organizations listed in Part III.

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PART I: CONSERVATION AND SOLAR HEATING

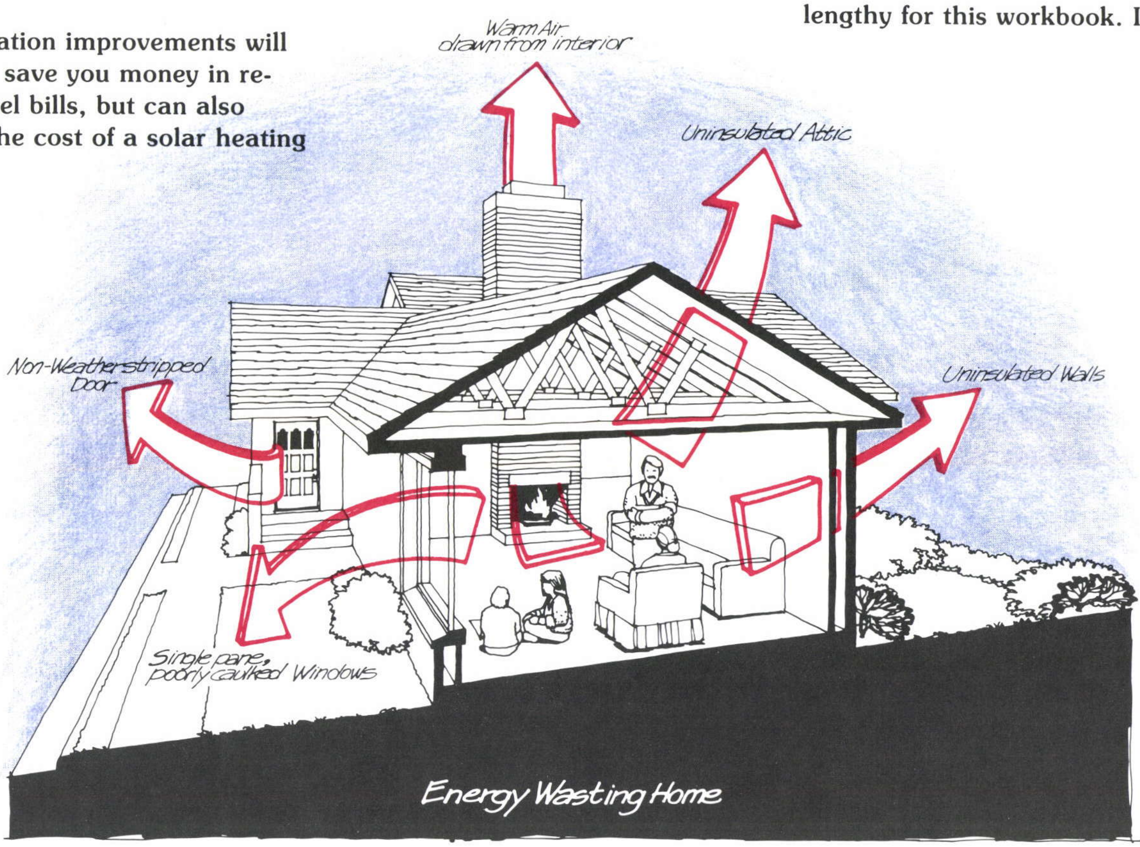
The Importance of Conservation

If you are considering a solar heating system to lower your heating costs and ease your dependence on expensive heating fuels, you should first consider energy conservation. Regardless of what type of heating system (solar or conventional) you are using or plan to use, taking measures to conserve energy is still the simplest, most economical energy strategy. At today's fuel prices, the amount you will save on your monthly fuel bills will soon pay for energy conservation improvements, especially if you take advantage of available federal and state tax credits (see page 42). If you decide not to use solar energy—or if the cost is prohibitive—energy conservation may be your only option.

Conservation improvements will not only save you money in reduced fuel bills, but can also reduce the cost of a solar heating system. By reducing the required amount of heat through energy conservation, you are also reducing the size of the solar heating system you will need, which in turn means a reduction in the initial cost of the system. Thus, conservation is *doubly* important for many people whose solar decision often depends entirely on the system's "up-front" cost.

There are many ways you can conserve energy in your home. Some require the purchase of inexpensive materials; others simply require actions on the part of the residents. In most cases, a combination of the two is the most beneficial. Actions by individual residents, however, can begin immediately, provide savings in a very short time, and set a pattern of energy-conscious behavior that will result in huge savings over the years. For example, it costs nothing to lower your thermostat a few degrees when you are away from home and a few more at night while you sleep. This conservation measure can easily reduce the amount of energy you use for space heating by as much as 20%— without any sacrifice in comfort. On the other hand, if you do not practice this energy conservation measure, the additional 20% capacity of a solar system needed to meet this demand would cost hundreds of additional dollars. It is wise to remember that it is always cheaper to conserve energy first rather than replace it by using *any* type of heating system.

A complete discussion of the many energy conservation measures available would be too lengthy for this workbook. In-



stead, this energy conservation section provides an overview of the most common areas in a home where energy is wasted and points out some simple conservation improvements. Many free or low-cost publications explaining energy conservation measures in more detail are available from the government or local bookstores (see Part III).

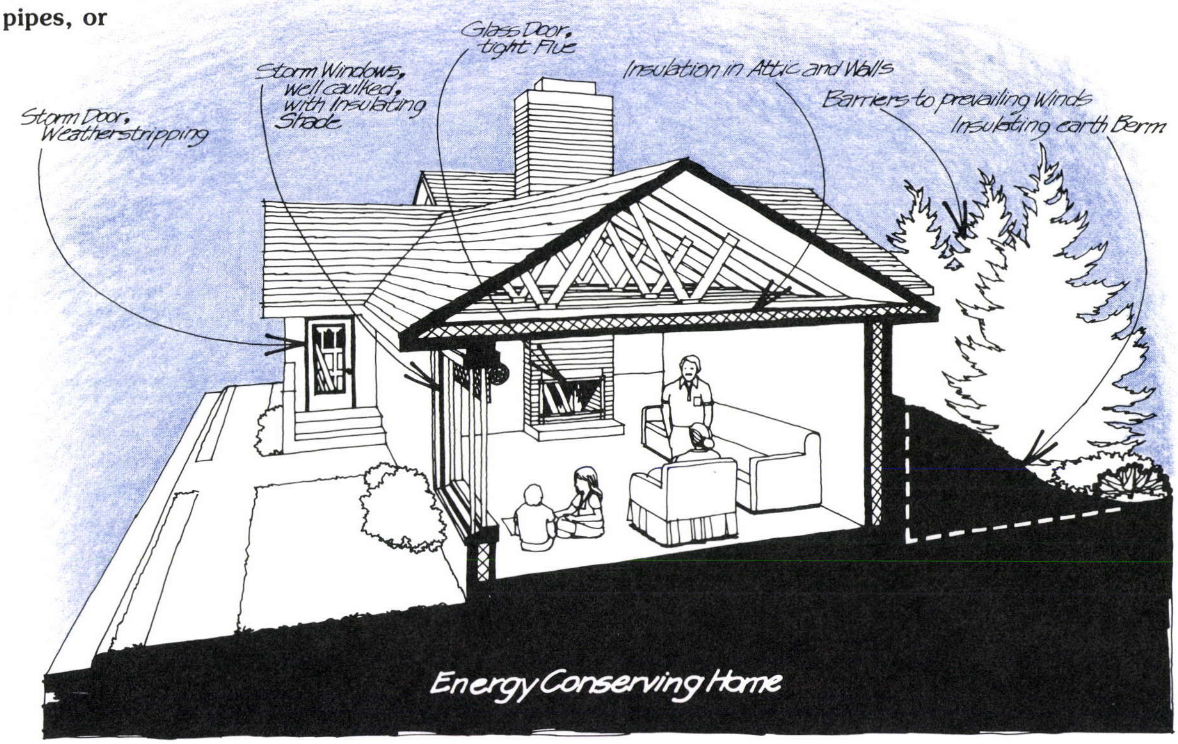
Lowering Heat Losses and Air Infiltration

Heat moves from warmer to colder areas, seeking to balance the temperatures. In any structure (your house included), there are many places where heat is lost to the outside during cold weather. If the walls, roof, and floors are uninsulated as shown in the illustration on the opposite page, your house is wasting a lot of energy. Heat not only moves through solid walls, but also seeks escape routes through vents, chimneys, uninsulated heating ducts, pipes, or electrical outlets, and through cracks around window and door frames. Even if there are no cracks around windows, heat can still be lost directly through the windows, especially if they consist of only a single pane of glass.

The same areas that allow heatloss also allow cold air to "infiltrate" a structure. Although a certain amount of air infiltration is needed to maintain comfort, too much infiltration means too much energy wasted trying to offset it. A good, inexpensive way to reduce heat losses and air infiltration is to add weatherstripping and caulking around your windows and doors or install storm windows and doors.

Properly insulated walls, floors, attic, and other heat-escape routes are necessary for conserving energy. Insulation is measured in R-values, which represent a material's ability to resist heat transmission. The higher the R-value of a particular material, the more resistant it is to heat loss. The amount of insulation you should install depends on your geographic location. Although colder climates may require more insulation, the minimum amounts generally recommended are R-11 in the walls, R-19 in the floor, and R-27 in the attic or roof. Movable insulation for covering windows is effective, especially in cold climates, and although the initial cost may seem high, movable insulation will add significantly to your energy savings.

Repairing or replacing chimney dampers that do not close properly, insulating hot water pipes and the hot water tank itself, and putting up fences and shrubbery against prevailing winds are other energy conservation improvements.



Energy Conserving Home

The energy conservation improvements mentioned above will become your house's barricades against heat loss, but even the best energy-conserving devices in the world won't be effective unless you take the necessary action to make them work. Many publications listed in the Bibliography in Part III include worksheets and simple instructions for you to estimate your energy use patterns and determine where energy conservation measures can mean the largest savings. It may be helpful for you to evaluate your energy use patterns and then write a thoughtful plan of the steps you will take not only to *conserve* energy but to *use* energy wisely. If you haven't gone through this type of exercise before, you will be amazed to see what energy conservation can mean in terms of actual dollars saved. *

Solar Heating

The two basic categories of solar heating systems are passive systems and active systems. This workbook and the sizing method it features, however, are applicable only to active systems and only to the two types discussed. In many instances, passive systems may be better suited, or a combination of both active and passive systems (called "hybrid") may be the best option. You should give all options full consideration before you embark on the purchase and installation of any heating system. ** The two types of active systems described here are believed to be the most applicable to most houses. Numerous buildings using these types of systems have performed well for several years, and the components are widely available. These types of systems will now be discussed in more detail.

Active Systems

Active systems rely on mechanical components to collect and deliver heat. Air or liquid is heated in a **solar collector** and then transported with the aid of fans or pumps powered by a small amount of electricity. Solar collectors, also referred to as collector panels, are usually mounted in rows on the roof or the south wall of a house. They can also be mounted on their own supporting structure entirely separate from the house, if necessary, for better exposure to the sun. For North American latitudes, where the winter sun is low in the southern sky, collectors should face south. However, a deviation of 20° or less from true south will not substantially reduce performance. Collectors should also be tilted toward the sun.

* By January 1981, a federal program is expected to be in effect requiring most large public utility companies to offer energy conservation and solar energy home audits for a minimal fee. Under this program, the utilities will make available on request, trained auditors who will examine a home for potential energy conservation improvements as well as potential solar energy applications, and will discuss such improvements with the homeowner.

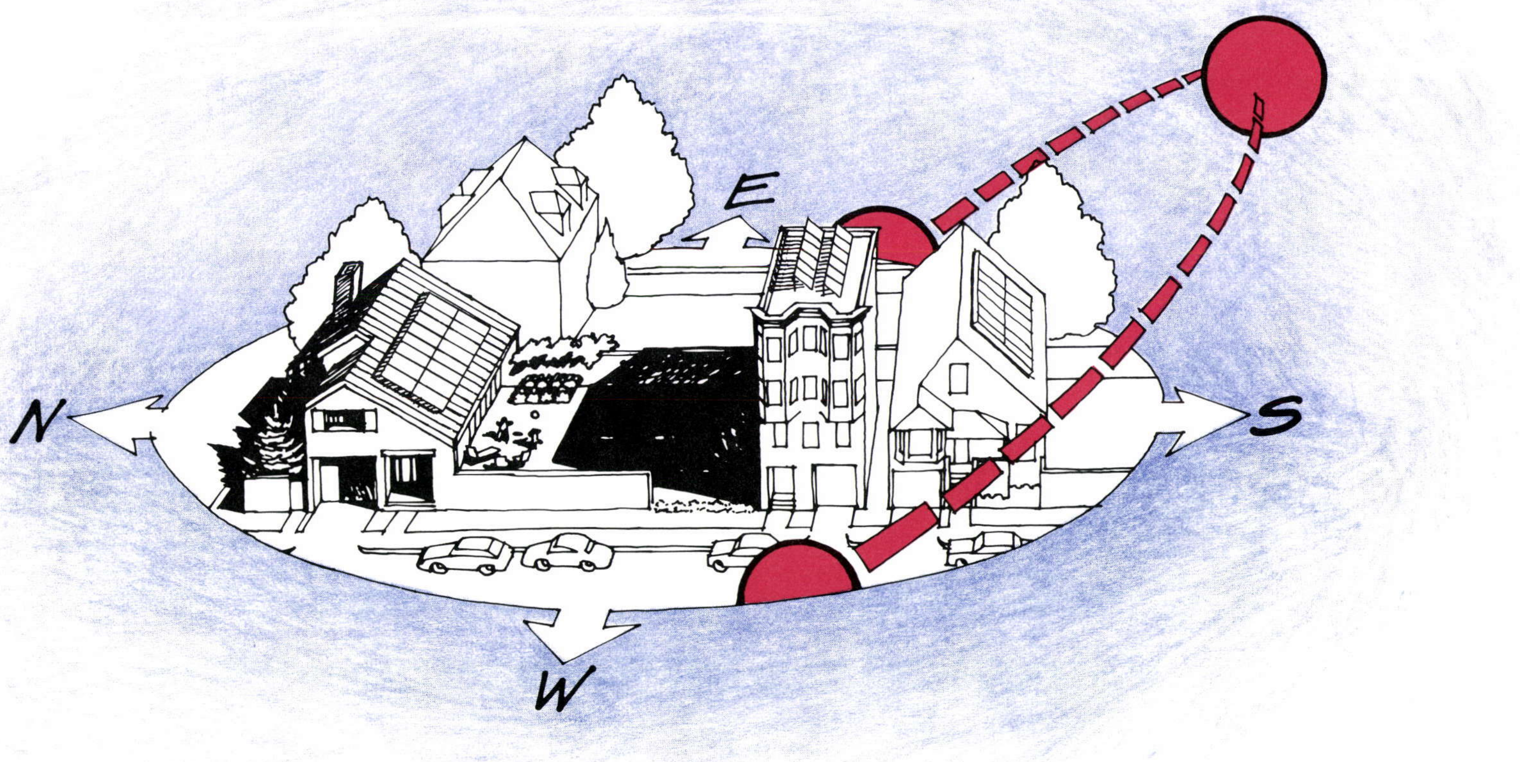
** For an introduction to passive design concepts see Snyder, Rachel. 1980. Passive Design: It's A Natural. Golden, Colo. Solar Energy Research Institute. (Also available from Superintendent of Government Documents, U.S. Government Printing Office, Washington, D.C. 20402. Stock Number 061-000-00401-7. $1.50.)

This combination—south facing and tilted toward the sun—allows the collectors to receive a maximum amount of solar radiation as shown in the illustration below.

The angle or tilt of the collectors toward the sun depends on the latitude of your location. A good rule of thumb for determining the best tilt angle is to add 12° to your latitude.* However, in some areas where snow covers the ground most of the winter, collectors mounted on the south wall of a structure can receive almost as much solar radiation as collectors mounted at the latitude plus 12° because of the high amount of radiation that can reflect off the snow and onto the collector surface.

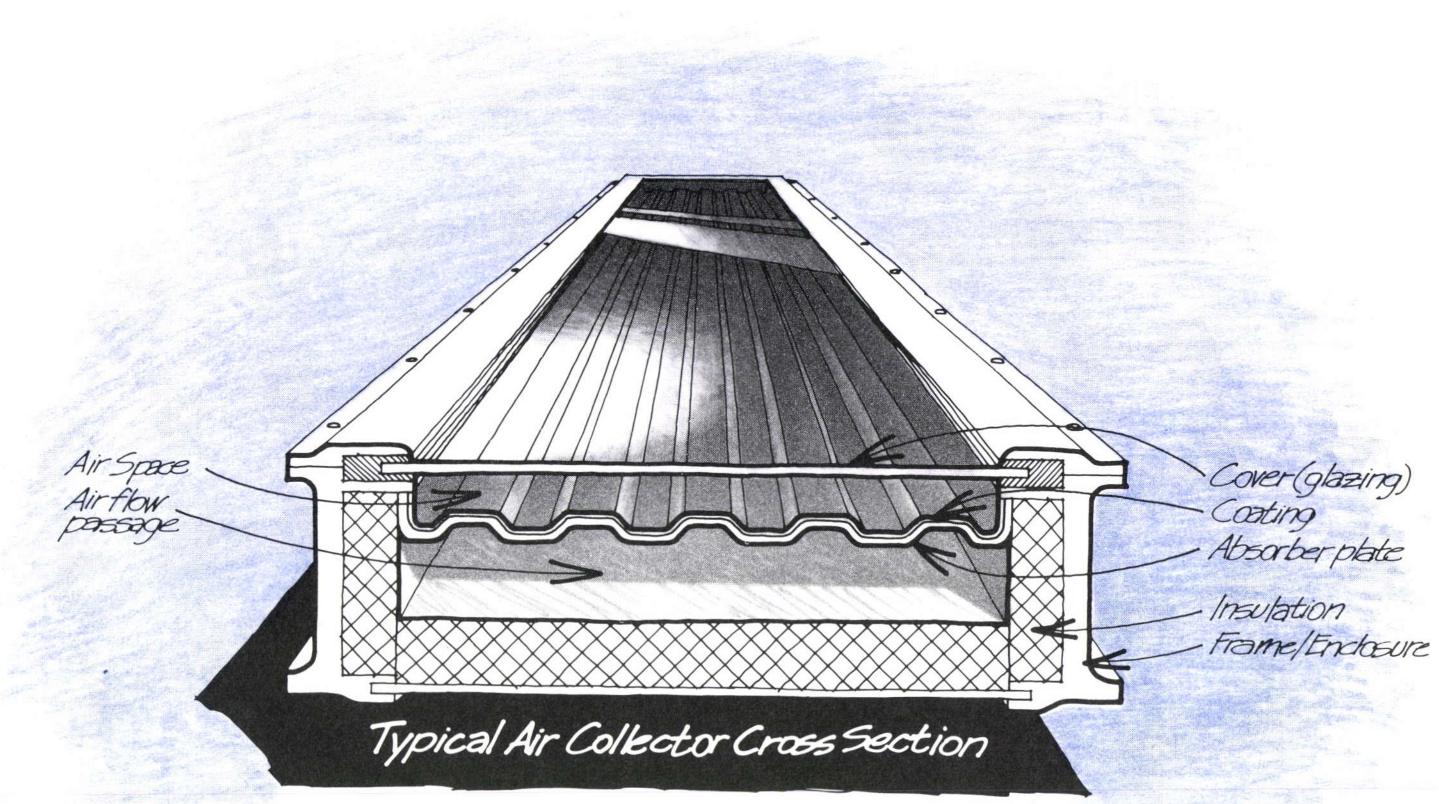
Wherever collectors are located, caution should be taken to make sure they are not shaded by trees, buildings, hills, or any other obstructions. If even a small part of the collector area is shaded, solar system performance will be reduced significantly.

In addition to solar collectors, other components used with active systems include a storage unit, backup heating unit, delivery system, and controls. Each of these components is discussed in more detail to help you understand how an active system works before you begin the sizing procedure.



* This simplified sizing method assumes the angle that allows collectors to intercept the greatest amount of solar radiation to be latitude + 12°.

For more specific information on passive solar home design see Mazria, Edward. 1979. The Passive Solar Energy Book. Emmaus, PA: Rodale Press, Inc.



Air Space
Air flow passage
Cover (glazing)
Coating
Absorber plate
Insulation
Frame/Enclosure
Typical Air Collector Cross Section

Air Space
Liquid flow passage
Cover (glazing)
Coating
Absorber plate, with flow tubes
Insulation
Frame/Enclosure
Typical Liquid Collector Cross Section

Solar Collectors

Of the many solar collectors currently available for space and household water heating, the **flat-plate collector** is most often used. Flat-plate collectors are categorized by the type of **heat-transfer fluid** used—air or liquid. Internal components may vary, but a typical flat-plate collector is a shallow rectangular box, covered with clear glass or plastic (**glazing**) to trap solar energy; an **absorber** plate usually made of steel, copper, or aluminum; an air pocket between the glazing and absorber; and a layer of insulation behind the absorber to retain the trapped solar energy within the collector box (see illustrations on opposite page). The absorber plate may be flat, corrugated, or grooved, and usually is either painted black to increase absorption or treated with a surface coating (**selective surface**) which absorbs more solar radiation and emits less thermal radiation than ordinary paints. Some collectors use two sheets of glass or plastic (double glazing) to further reduce heat loss from within the collector.

A solar collector works on a simple principle called the "greenhouse effect" which occurs, for example, when you leave your car parked in the sun with the windows closed. The window glass admits the sun's rays (shortwave radiation) into the car, where they strike the interior surfaces. These surfaces absorb the radiation, become warm, and lose this heat (longwave radiation) to the surrounding air. Because glass does not easily transmit longwave radiation, a large amount of heat is trapped inside the car.

The greenhouse effect also occurs inside a flat-plate collector: the sun's rays pass easily through the glass cover, strike the absorber plate, and are converted from sunlight to heat. The heat cannot easily escape because the glazing traps it within the collector box. The trapped heat is then absorbed by the air or liquid heat-transfer fluid as it passes by the absorber plate. Heat absorbed by the heat transfer fluid can then be delivered for immediate use within the house or to a storage unit for later use.

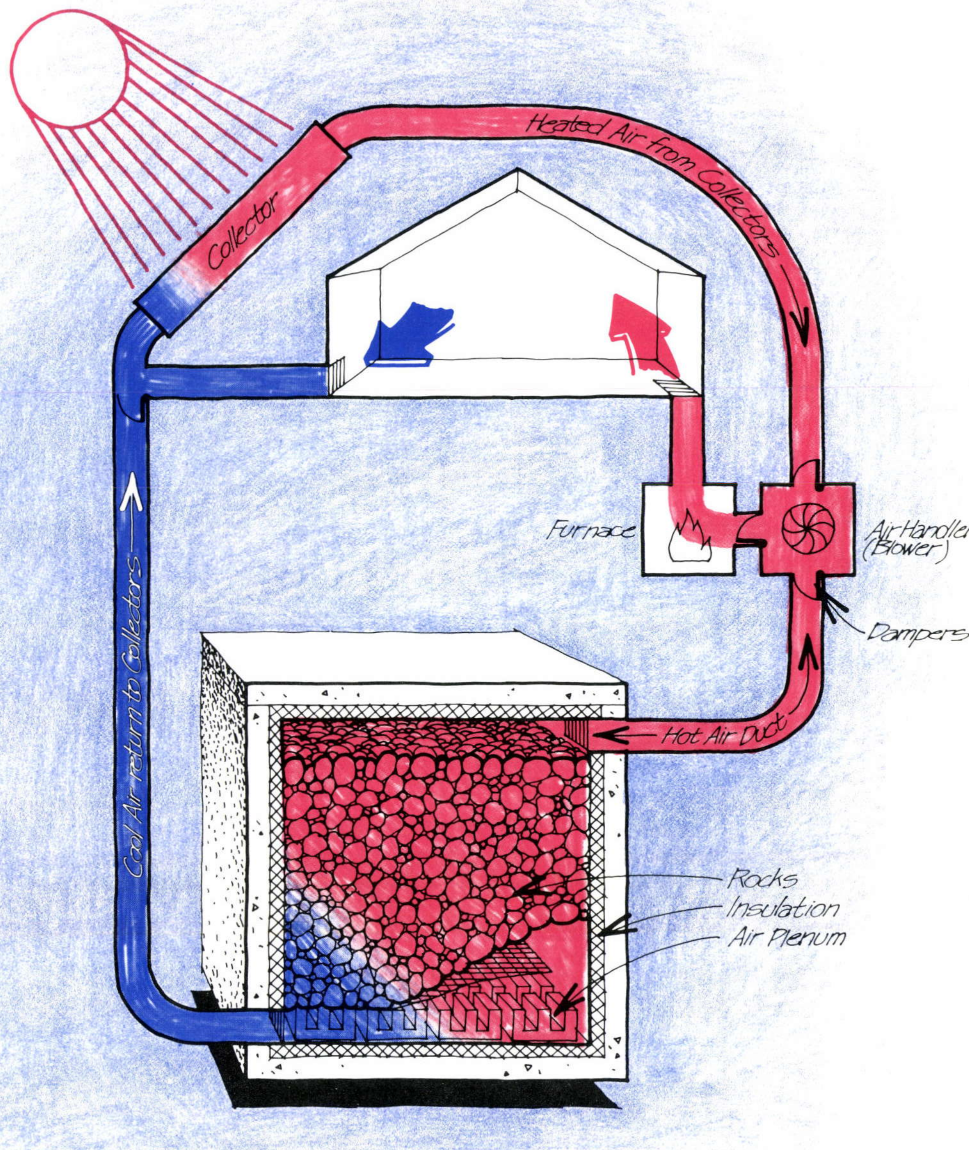
Characteristics of Air and Liquid Flat-Plate Collectors

Components	Uses/Functions	Important Considerations	Commonly Used Materials
Covers	• reduces energy losses from the collector • protects collector from outside environment	• optical properties • durability • strength • cost	• glass • plastic (acrylics, polycarbonates) • thin film (tedlar, mylar, and others)
Coatings	• increases energy absorption and protection of the absorber • selective coatings are used to reduce radiation losses as well	• absorptance • emittance • effect of high temperature • durability • cost • compatibility with absorber plate metal	• nonselective: black acrylic paint, flat black paint • selective: black chrome, ceramic enamel, black iron
Absorbers	• absorbs solar energy incident upon it and converts it to heat	• adjoining materials must be compatible • materials and transfer fluid must be compatible • thermal properties • fluid passage configuration • weight	• steel • copper • aluminum • plastic
Insulation	• reduces heat loss from the collector to outside environment	• proper R−value • compatibility with operating temperatures	• fiberglass • glass foam • foamed thermoplastics
Frame/Enclosure	• houses all the components • provides support for installation of collector on structure • protects components from the environment	• compatibility with adjoining materials • durability under given environmental conditions	• aluminum • steel • plastics • wood • fiberglass

Storage Units

Because solar radiation is intermittent, heat from solar collectors must be "stored" for use at night or during cloudy periods. Storage units commonly used with active solar heating systems contain either rocks or water.

A large bin or container filled with rocks is the best type of storage to use with air systems. The rocks absorb heat from collector-heated air blown into the storage bin by a small fan or blower. As it is needed, the stored heat can be blown from the storage unit through the delivery system ducts into the house. The illustration below shows how a typical rock storage bin operates within a solar heated-air system.

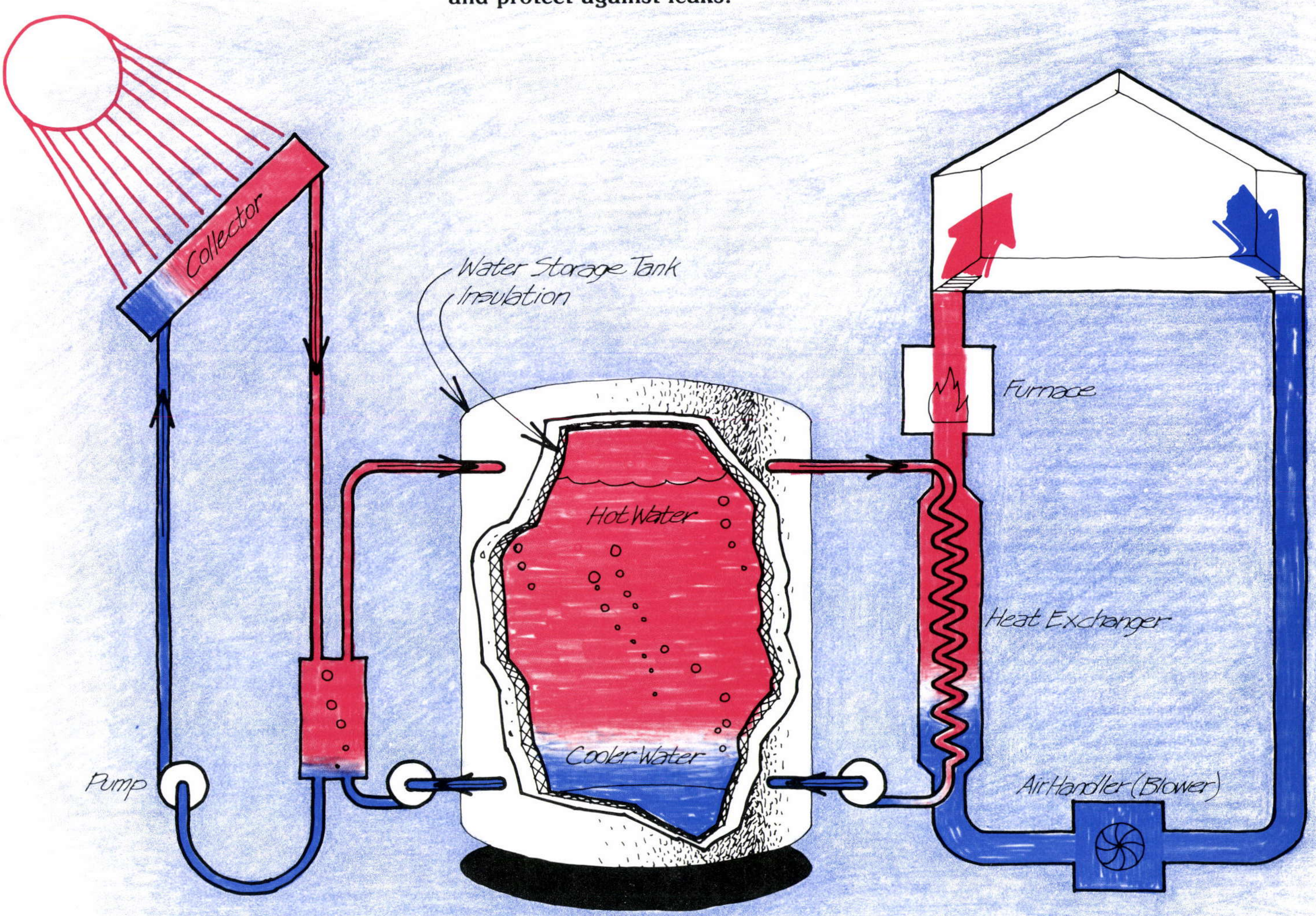


Rock Storage System

The rocks in a storage bin should range in size from 1/2 to 1-1/2 inch in diameter and should be washed to eliminate dust or other matter that may interrupt air flow. Rounded granite river rocks are excellent for use in a rock storage bin.

In liquid solar systems, a large insulated tank of water serves the same purpose as the rocks (see illustration below). Water, like rock, is inexpensive and can retain heat for long periods. Liquid storage tanks can be made of several different materials. Glass-lined steel tanks are probably the best but are also expensive. A concrete tank can be poured on-site; however, the tank must be lined with thick polyethylene plastic to resist high temperatures and protect against leaks.

Another type of tank that works well is a lightweight, noncorrosive fiberglass tank. Some fiberglass tanks are designed for solar heating systems but are slightly more expensive than other types. Whatever tank is used, it must be heavily insulated to reduce heat loss.



Liquid Storage System

Backup Heating

Most solar heating systems are designed to provide from 40% to 80% of a home's yearly heating needs (**solar fraction**), because it is less expensive to purchase a small amount of heat using a **backup heating system** than it is to build a solar system large enough to supply the total amount. A solar system sized to provide 100% of your heat would be very expensive and oversized; you would be paying to collect an unnecessarily large amount of heat throughout the year. Quite often, active systems are designed to provide less than 80% of yearly heating needs because money and space for collectors may be limited. However, the cost of a system that will supply less than 30-40% of yearly heating needs is seldom justified. (In most cases, the three sizes you will determine on the worksheet in Part II will have a solar fraction within the range of 30% to 90%.)

Many building codes and mortgage lenders require a solar heating system be accompanied by a backup heating system (**auxiliary**). Backup systems are usually conventionally fueled furnaces. However, depending on geographic location, local fuel costs, availability, and the amount of backup heat needed, fireplaces, woodburning stoves, electric or gas heaters, and coal or oil furnaces may be used. Regardless of which type of backup heating you select, its purchase will add to the cost of your solar project. In fact, having to pay for two heating systems is one of the major economic drawbacks of installing a solar heating system, especially in new home construction where initial costs may be a heavy burden if both are installed at the same time. With careful planning, however, you can reduce costs in both new construction and **retrofit** situations.

In new construction, the backup heater should be chosen with care, even though it will serve only part-time duty. The best choice of backup heater will vary according to economics, individual installation requirements, or personal preference. However, one advantage of new construction is the opportunity to select a backup heater that uses the most economical fuel available. Also, a common heat delivery system, shared by both solar and backup heating systems, can be included in the construction phase.

In retrofit situations, where a conventionally fueled furnace is already in place, there is little you can do about fuel choice. You can, however, maintain your furnace properly so that it operates at highest efficiency. In some cases, a common heat delivery system is possible, but this option should be investigated carefully (see Delivery System below).

For new construction or for retrofit, the backup heating system should operate automatically when needed (except for heaters fueled with wood or coal) and should be capable of supplying 100% of your home's heating load.

Delivery System

A **delivery system** is required in both solar and conventional heating systems. The materials used in solar delivery systems are much the same as those used with conventional delivery systems. Solar systems employing air as the heat-transfer fluid use well-insulated ducts and small blowers or fans to distribute heated air throughout the system. Liquid solar systems use conventional plumbing techniques and materials such as piping, valves, and small pumps to control and distribute heated liquid.

Solar heating systems operate more efficiently at lower temperatures than most conventional heating systems. As a result, the delivered heat is usually warm rather than hot. The most effective method for delivering warm air is with a forced-air delivery system. Air ducts used with forced-air delivery systems can deliver heat from either the solar system or a backup hot-air furnace. However, they must be larger than ducts used with conventional forced-air heating because a larger amount of solar-heated air must be delivered to make up for its lower temperature. Forced-air delivery is well-established, and factory-made units called air handlers are available for solar systems and contain everything needed except ducts.

When a **heat exchanger** is used to transfer heat from liquid to air, forced-air is also the most effective delivery system for liquid type systems. As shown in the illustration of a liquid storage system, page 8, the heat exchanger is installed in the return air duct to the furnace, allowing it to operate also as a preheater when the backup system is operating.

With liquid systems, it is also possible to use small heat exchangers for individual rooms if the backup system is also on a room-to-room basis (such as in a house equipped with electric baseboard heating). These small heat exchangers are available as standard plumbing units in various sizes and contain their own blowers. This type of heat delivery is often less expensive than central heating with ductwork and allows heat in unused rooms to be turned off—saving energy and money.

Before you choose a type of delivery system, remember to consider your existing or planned type of backup heating, its type of delivery system, and possible integration with the solar system.

System Controls

The **controls** for an active solar heating system are more complicated than a conventional system's controls because they analyze more signals, make more important decisions, and control more devices (including the conventional heating system). Modern solid-state electronic controls, however, can operate solar systems reliably and automatically.

Most solar system controls use sensors, switches, and motors to operate the system and to provide backup heating when the solar system cannot meet the requirements. Other controls are used to prevent extremely high temperatures or to protect against freezing.

A **differential thermostat** allows automatic operation by measuring the difference in temperature between the collectors and the storage unit. When the temperature in the collectors is sufficiently higher (a difference usually ranging from 10° to 20°F) than that in the storage unit, the thermostat will sense the temperature difference and turn on the pump or fan to circulate the heat.

System Operation

Generally, air systems operate in four distinct modes and liquid systems operate in three modes. Illustrated on page 13 and 14 are the four operating modes of an active air system. With the exception of the first mode, liquid systems operate much the same way. (Because liquid systems often require a heat exchanger in the delivery system, the direct heating mode is usually not possible.) The four operating modes for active air solar systems are commonly referred to as the direct heating mode, the charging mode, the discharging mode, and the backup heating mode.

A Comparison of Liquid and Air Systems

Liquid Systems

Because liquid heating by conventional means has been used for years and the technology is well developed, liquid solar systems have historically been preferred over air solar systems. Since liquid has a higher heat capacity than air, it is a compact storage material.

Where space is limited, liquid pipes have an inherent advantage over larger air ducts. The disadvantages of liquid systems include the expense of leak-proof storage facilities and piping, the dangers of freezing and boiling, and corrosion problems.

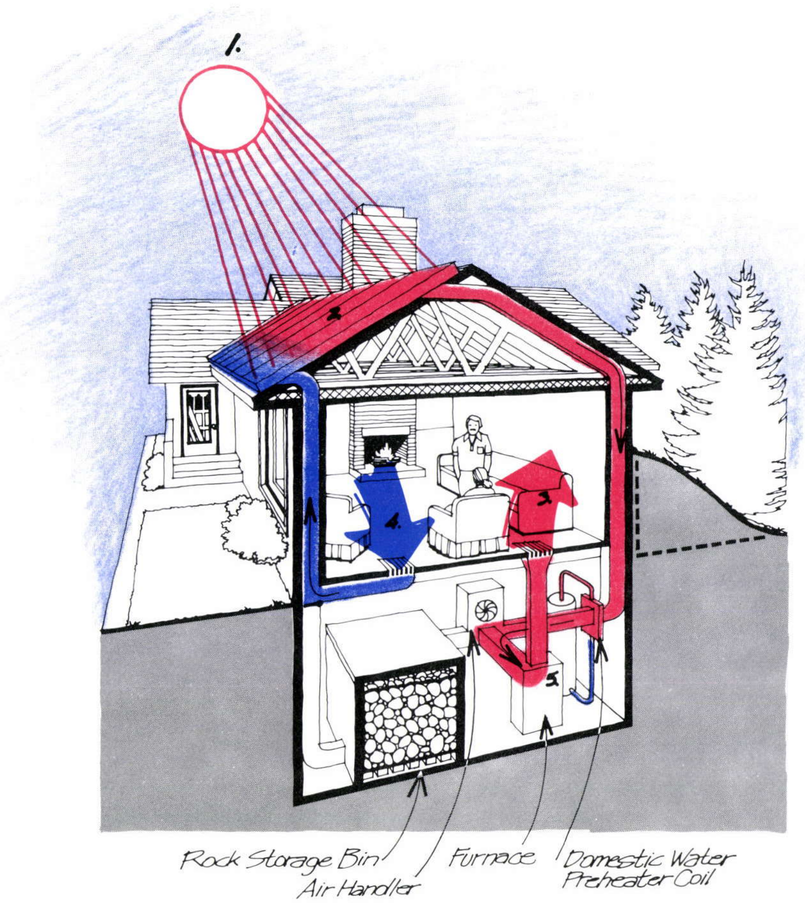
There are several ways to avoid freezing problems. Liquid systems used in cold climates can be designed so the collectors drain at night to isolate the liquid from freezing temperatures. In another design, a slow circulation rate through the collector system is maintained during freezing temperatures to prevent substantial ice formation. A third, more popular method, is to lower the freezing point of the liquid by adding antifreeze. However, most antifreezes break down and become corrosive if not replaced periodically. In addition, if the solar system also heats the household water supply, a heat exchanger must be used to keep the antifreeze from mixing with drinking or bath water.

Air Systems

An increasing number of homes today are successfully using air solar-heating systems. One advantage of air systems is the freedom from hazards associated with corrosion, freezing, boiling, and liquid leakage. Further, air is used in the collector-to-storage loop and the storage-to-rooms loop, allowing for some savings in component costs. Also, air systems have an additional operating mode: direct heat delivery from the collectors to the building without heat exchange or storage.

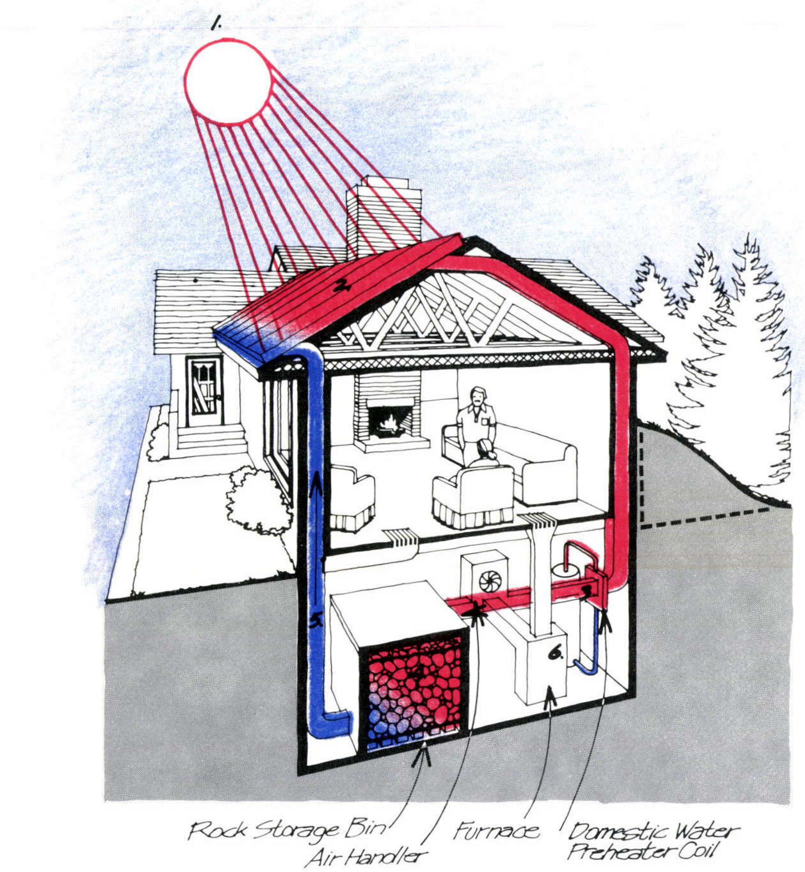
One disadvantage of air systems is the size of the ductwork and the storage units, which are often quite bulky. Flow noise and blowing air can also be a nuisance. In some cases, the power requirement for blowers or fans is higher than for pumps used with liquid systems. A common problem is leaky ductwork, which can seriously degrade performance, but is not easily detected. Even a small leak will allow cold air to mix with the warm air, making it cool—and useless.

The advantages and disadvantages of air and liquid solar heating systems, the subject of considerable discussion, often depend on site-specific considerations such as geographic location, storage space availability, and method of heat delivery. They also depend on material availability or personal preference, which are not necessarily related to the operational performance of either type of system.



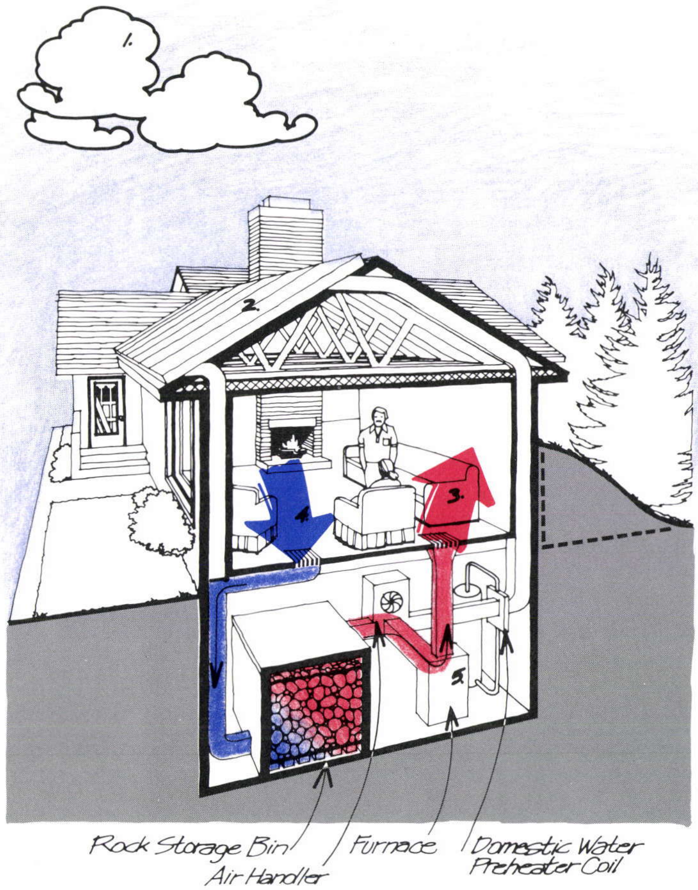
1. The "Direct Heating" Mode

1. Full Sun.
2. Collector (Air type) absorbing sun's rays.
3. Collector-heated Air distributed directly to rooms, by-passing Storage.
4. Cooler Air returning to Collector.
5. Furnace turned off.



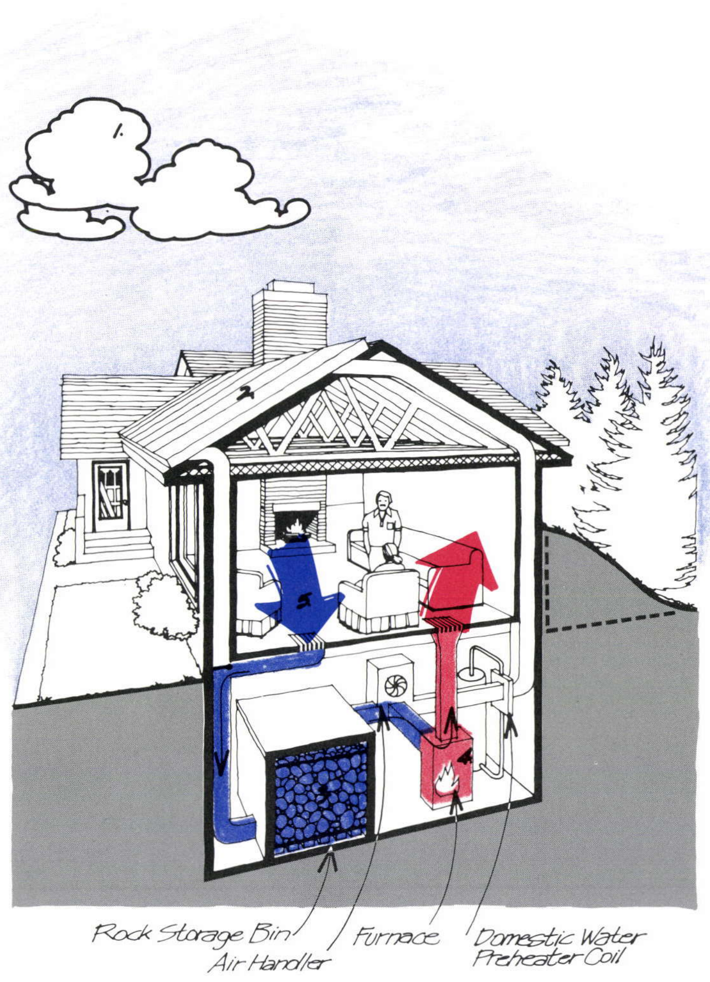
2. The "Charging" Mode

1. Full Sun.
2. Collector absorbing sun's rays.
3. Collector-heated Air distributed to Rock Storage Bin.
4. Rocks absorbing heat; heat being retained in Storage Bin.
5. Cooler Air in Storage returning to Collector.
6. Furnace turned off.



3. The "Discharging" Mode

1. Clouds blocking sun's rays.
2. Air circulation through collectors and ductwork turned off.
3. Heat from Storage distributed to rooms.
4. Cooler Air in rooms returning to Storage Bin.
5. Furnace turned off.



4. The "Backup" Heating Mode

1. Extended cloudy period blocking sun's rays.
2. Air circulation through collectors and ductwork turned off.
3. Temperature in Storage too low for distribution to rooms.
4. Furnace providing Heat to rooms.
5. Cooler Air returning to Storage.

PART II: THE SIMPLIFIED SIZING METHOD

Background

This method is a straightforward sizing procedure that differs from other methods in three ways. First, it is easier to use and does not require a computer, calculator, or complex hand calculations. Second, it is based on the concept that there is more than one appropriate size of solar system for a given house. Rather, there is a wide range of system sizes that will perform well, although the costs and solar fractions will vary. With this method you can compare different types of air or liquid systems for three different size ranges.

Finally, this method differs from others because it does not consider a detailed, long-term economic analysis as a major criterion in the sizing/decision-making process. The uncertainty of future fuel costs makes it risky to predict the economics of any size solar system over a long period. Even the best estimates of future fuel costs are only a matter of informed opinion, but they are often used as the only criterion for making a solar decision.

Instead, with this method, you will determine only the first-year savings for the different size systems. The first-year savings is represented on the worksheet by an economic indicator developed specifically for this method called RETURN.

RETURN is the number of cents saved on fuel bills in the first year per dollar invested in the system. The larger the RETURN, the sooner the system will pay for itself. However, it is not quite that simple. As you will see after completing the worksheet, large RETURNS usually accompany small systems because, compared to large systems, small systems are less expensive initially and require less time to pay for themselves. However, small systems ultimately save less fuel than large systems.

This is where a compromise must be made. One option is to aim for a short payback period but sacrifice large savings in the long run. Another option is to aim for a little longer payback period but benefit from larger savings in the long run. Near the bottom of the worksheet is a brief discussion of a good compromise. Remember though, that all long-term economic estimates contain uncertainties and must be dealt with carefully. The RETURN method used here is no exception.

ASSUMPTIONS

The amount of useful heat provided by a solar heating system depends on many factors that can be put into four broad categories: system design, occupant-use patterns, installation quality, and weather conditions. Of these four broad categories, the most unpredictable is generally the weather, but the other categories contain uncertainties as well. Therefore, some assumptions must be made about these categories when sizing a solar heating sytem. The results from the worksheet will depend upon the accuracy of these assumptions. The Simplified Solar Sizing Method assumes:

System Design: The system will be properly designed and well-functioning. You will select a qualified and experienced solar designer to help you choose the type of system best for you and to properly design the layout of the system's components. If you are designing the system yourself, you will still have a qualified solar designer thoroughly check your work.

Occupant Use Patterns: The assumed lifestyle is suburban American, which here means that the occupants of the house are accustomed to receiving hot water at the turn of the faucet, expect a constant room temperature, and generally do not want to make large sacrifices in their lifestyle in exchange for owning a solar heating system. In addition, insulating of homes is probably the extent of energy conservation of this lifestyle.

Installation Quality: All components of the system will be properly installed and adjusted, and all minor problems usually associated with any new mechanical system will be quickly ironed out.

Weather Conditions: The weather conditions for the first winter will fall somewhere between the coldest and warmest winters of the last 20 years. Predicting weather conditions for a particular day in the first winter is impossible, but a climate that is predictable over several years can be identified. This method uses average weather data from the last 20 years to predict probable climates for several locations. These climates are then used to predict system performances.

Variations from these assumptions will affect the results of this method. For example, family members may become more energy conscious after installing a solar heating system and might make several energy conservation improvements to the house, as well as altering their own energy use patterns. As a result, the decreased demand on the solar heating system will lead to an increase in solar system performance beyond that initially indicated on the worksheet. The reverse is also possible: a significant increase in demand on the solar heating system will result in lower solar system performance than originally predicted. If variations from these assumptions are minor, this method will provide a good prediction of system performance for the different types and sizes of systems described in this workbook.

Worksheet Instructions

Before you begin, it may be convenient to remove one of the worksheets and place it beside the instructions as you read. Extra worksheets are provided if you want to compare different collector types, orientations, tilt angles, and glazings. A completed sample worksheet is also given.

Section A: Background Information

The information required in this section must be as accurate as possible so that it can be used in the next section to estimate system performance.

Line 1 Enter the total square feet of heated space in your house, including the basement and attic if they are used as heated living spaces. With this sizing method, the amount of heat required for your house is estimated according to its size. For the method to be accurate, you must have taken the energy conservation measures mentioned in Part I. (Remember, it is to your benefit to take these measures whether or not you install a solar energy system.)

On the sample worksheet, the floor area of the building is 1500 square feet.

Line 2 Enter the amount you expect to pay for both heating and hot water in the next 12 months. This amount will not be used in designing your system; an estimate to the nearest $50 is sufficient. If you need help, your local utility company should be able to assist you. If you have not installed insulation but plan to do so, enter the amount which you expect to pay after insulation is installed. Estimates can usually be obtained from an insulation contractor or, in the case of new homes, from the architect or builder of the house.

On the sample worksheet, the owner expects to pay $365 in the next 12 months for space and water heating combined.

Line 3 To complete this line and the remainder of the worksheet, you must select a particular collector model (air or liquid), determine the orientation of the collector (south, southeast, etc.), and decide upon the collector tilt that is best for your particular situation. Table 1 (page 30) lists several typically used combinations. Select one from the table and enter the number value (COLLECTOR FACTOR) on Line 3. You may want to try different combinations on the extra worksheets. First, here is a review of the four properties of the collector and its mounting:

- The type of collector depends on the heat transfer fluid—air or liquid. (See **Solar Collectors,** page 6.)
- Some collectors have an absorber plate that has a special paint or coating called selective surface. If you are not using collectors that have a selective surface, then choose either single glazing or double glazing according to your plans. (It is not very common to use a selective surface with double glazing.) If you have a certain brand of collector in mind, the manufacturer of the absorber plate will know if a selective surface has been applied.

- Select the orientation closest to that which your collectors will have: South (S), Southeast (SE), etc.

- Determine the tilt angle of your collector area. Remember, your collector area should be tilted toward the sun to intercept a maximum amount of solar radiation for winter space heating (see page 4). A good rule-of-thumb for determining the best angle (known as the optimal angle) is to add 12° to your latitude. However, your collectors may be off a few degrees without much sacrifice in system performance. (This may be the case if you install them on a standard 4/12 pitch roof.) If the collectors can only be placed on a south-facing vertical wall, your system's performance will suffer considerably. However, if snow remains on the ground in front of this wall most of the winter, or if you add white gravel in front of it, the reflected solar radiation will increase the wall's sun intake so that a collector mounted here can be nearly as effective as one at the optimal angle. If you add a polished reflector such as foil, the vertical collector may be more effective than the collector at the optimal angle.

On the sample worksheet, the COLLECTOR FACTOR (8.5) entered on Line 3 corresponds to a liquid collector with a selective surface and a due south orientation, mounted on a standard 4/12 pitch roof.

Section B: Collector Sizing

In this section you will determine three sizes of solar collector areas—small, medium, and large—and their expected performances for your particular situation. Each step must be completed for each of the three columns. You will then be able to make comparisons and determine what size system is best.

Line 4 — Find in Table 2 the location where your system will be installed and enter the LOCATION FACTORS for small, medium, and large systems in the corresponding columns for Line 4. If your location is not listed, enter the LOCATION FACTORS for the climate most similar to that where your system will be installed.

For the sample worksheet, the LOCATION FACTORS that correspond to Boulder, Colo., are 4.4, 6.2, and 7.9, respectively, and are entered on Line 4.

Line 5 — Multiply the COLLECTOR FACTOR entered on Line 3 by each LOCATION FACTOR entered on Line 4 to get the solar fraction for each size range. The solar fraction is an estimate of the percentage of the total heating requirement that will be met by solar energy. In some cases, it is also the approximate percentage by which your fuel bills will be reduced.*

The sample worksheet shows that a small solar system will provide 37%, a medium 53%, and a large system 67% of the total heating requirements. These amounts are also a close estimate of how much the fuel bills will be reduced for the sample situation.

Line 6 — This line has been completed for you. The numbers entered represent the ratio of collector area to floor area as determined through extensive calculations.

*Because many utilities use a declining block-rate structure, savings may not be quite as large as this fraction in all cases. However, rate structures are being reformed under federal laws and should affect all cases the same in the future.

Line 7 Multiply the number entered on Line 1 by the numbers entered on Line 6 and enter the answers on Line 7.

Line 8 Since the cost of solar systems varies widely, you should contact the dealer who will install your system for an estimate of the total cost for each size on Line 7. This estimate should include installation costs but not applicable tax credits.

Lines 9 & 10 Similar to the energy conservation tax credits mentioned on page 4, the Federal Government currently provides a tax credit up to 40% of the cost of a solar energy system (with a maximum credit of $4000). (See Part III for organizations that can provide additional information on tax credits.) These two lines calculate how much you will be able to deduct from your federal income taxes for each size system, in the first year following system installation.

Line 11 In addition to federal tax credits, some states offer tax credits. If your state provides these additional tax credits, enter this amount on Line 11. Since these credits vary from state to state, no specific procedure can be given. Obtain details from your state department of revenue, state energy office, state solar energy association, or a solar consultant/contractor.

On the sample situation, the State of Colorado currently offers a tax credit up to 30% (maximum $3000) of the cost of a solar energy system including installation. This amounts to a deduction in state income taxes of $1890 for the small system, $2970 for the medium, and a maximum $3000 for the large system in the first year following system installation.

Line 12 Enter on this line the number you obtain by subtracting, in this order: Line 10 from Line 8; and then Line 11 from that answer. This figure represents the NET COST—the amount you actually spend on the solar system.

For example, the net cost for a medium size system for the sample situation would be approximately $2970.

Line 13 Multiply Line 2 by Line 5, divide that answer by Line 12, and enter the final answer on Line 13. This number is the RETURN indicator as explained on page 15 and on the worksheet.

On the sample worksheet, for every dollar invested in the medium system, 6.5 cents will be saved on the fuel bill in the first year. Thus $193.05 will be saved in the first year for the medium system (Line 12 × 13 = 19305 cents = $193.05). Since a RETURN of 6.5 is the closest to the desired figure of 6 (see worksheet, under RETURN), it appears to be the best size system for the sample situation as a compromise between a prompt payback and higher long-term savings.

Section C: Mortgage

This section is optional and is included only so that you can estimate your monthly mortgage payment.

Lines 14 & 15 — Enter the terms of your mortgage. If the solar system is being built together with a new home, use the terms of the new home mortgage.

The sample worksheet shows a 20-year mortgage at a 10% interest rate.

Line 16 — Find on Table 3 and enter on Line 16 the number that corresponds to your mortgage terms.

The correct corresponding number for a 20-year mortgage at a 10% interest rate is 104.

Line 17 — Enter the DOWN PAYMENT. If the mortgage covers the complete house, enter only the additional DOWN PAYMENT to be made because the system is included. (For example, if a DOWN PAYMENT of $20,000 is being made whether the house is purchased with or without a $10,000 solar system, then the DOWN PAYMENT doesn't change and 0 should be entered on Line 17.)

On the sample, an additional DOWN PAYMENT of $2,000 will be made if a large system is installed. However, if a small system is installed, no additional DOWN PAYMENT will be made.

Line 18 — Subtract Line 17 from Line 8, and enter the answer on Line 18. NOTE: The AMOUNT FINANCED will exceed the NET COST because your tax credits (Line 10 and 11) have not, at the time of financing, been applied to the GROSS COST (Line 8) of the system. This is because your tax credits will be taken in the form of deductions on your yearly federal and state income taxes.

For example, in the sample situation, a zero DOWN PAYMENT for a small system (Line 17) results in the GROSS COST of $6300 (Line 8) as the AMOUNT FINANCED (Line 18). At the time of financing, the owner does not have the $4410 ($2590 plus $1890) he will later be able to deduct from his federal and state income taxes, so it must be borrowed resulting in a total AMOUNT FINANCED of $6300.

If the owner were to apply the savings from both federal and state income tax deductions ($4410) toward the AMOUNT FINANCED ($6300), the amount owed would be closer to the NET COST of the system ($1890).

Line 19 — To approximate your monthly payment divide Line 18 by Line 16 and enter the answer on Line 19. In the case of a new home mortgage, this is the amount by which your monthly payments will be increased because of the solar system.

On the sample situation, if a small system is installed, the monthly mortgage payments will be increased by $60.58 per month.

The homeowner in this sample situation is considering the possibility of using liquid-type collectors coated with a selective surface and mounted on a 4/12 pitch roof with a due south orientation. The COLLECTOR FACTOR 8.5 taken from Table 1, represents this type of system.

The sample home is in Boulder, Colorado. These LOCATION FACTORS taken from Table 2, represent this location.

These three numbers represent the approximate collector area required in each size range.

The homeowner obtained these cost estimates by describing to a dealer the type of system being considered and asking for approximate costs of total systems with collector areas as indicated on line 7.

The NET COST is the approximate amount this homeowner would actually spend on each solar system after *deductions on Federal and State of Colorado Income Tax Forms.*

Evaluating the RETURN values here, the homeowner finds the medium size range offers the closest RETURN value to the desired 6. Therefore, it appears to be the size range that is best for this homeowner.

SIMPLIFIED SOLAR SIZING WORKSHEET

The instructions for this worksheet begin on page 17. If convenient, detach the worksheet and place next to instructions as you read. On the back side of the worksheet are Section C and some space where you can perform your calculations.

SAMPLE

SECTION A - Background Information

House Size Enter the floor area of house in square feet	(1)	1500 sq. ft.
Fuel Cost Enter current annual cost for heating and hot water combined	(2)	$ 365
Collector Factor Copy entry from Table 1 (page 30) which best describes collector type, orientation, etc.	(3)	8.5

SECTION B - Collector Sizing

		small	medium	large
Location Factor Copy entries from Table 2 (pages 31 to 37) for location	(4)	4.4	6.2	7.9
Solar Fraction Multiply: Line 3 x Line 4	(5)	37	53	67
Collector to floor area ratio (Do nothing on this line)	(6)	0.12	0.20	0.30
Collector Area Multiply: Line 1 x Line 6	(7)	180 sq. ft.	300 sq. ft.	450 sq. ft.
Gross Cost Enter cost of each size system	(8)	$ 6300	$ 9900	$ 14400
Tax Credit (calculation) Calculate: Line 8 x 0.40	(9)	$ 2520	$ 3960	$ 5760
Federal Tax Credit (actual) Enter Line 9 or $4000, whichever is less	(10)	$ 2520	$ 3960	$ 4000
State Tax Credit, if any Enter state tax credit, if any	(11)	$ 1890	$ 2970	$ 3000
Net Cost Subtract: Line 8 - Line 10 - Line 11	(12)	$ 1890	$ 2970	$ 7400

RETURN, as defined on page 15, is introduced so that you can roughly compare the economics of different size systems over a period of years. Calculations have indicated that a RETURN in the range of 3 and 10 will offer the best trade-off between a prompt payback and high long-term savings. The best compromise appears to be a system with a RETURN closest to 6 (using a fuel inflation rate of 12%). *

RETURN Calculate: Line 2 x Line 5 ÷ Line 12	(13)	7.0	6.5	3.3

* You can expect these results from a system with a RETURN of 6:

- Savings (in fuel bills) will accrue until the system has paid for itself in 9 years following installation; and
- Savings will pay for the system *Plus* 8% interest on investment in 13 years following installation. Everything following that is pure savings.

* Using a fuel inflation rate of 12%.

SIMPLIFIED SOLAR SIZING WORKSHEET
(Continued)

SECTION C - Mortgage Payments*

Term of Mortgage Enter the term of your mortgage in years			(14)	20 yrs.
Interest Rate Enter the interest rate of your mortgage as a percentage			(15)	10 %
Compound Interest Enter the corresponding number from Table 3 (page 38)			(16)	104
		small	medium	large
Down Payment Enter the down payment	(17)	$ 0	$ 500	$ 2000
Amount Financed Subtract: Line 8 - Line 17	(18)	$ 6300	$ 9400	$ 12400
Monthly Mortgage Payment Divide: Line 18 ÷ Line 16	(19)	$ 60.58	$ 90.38	$ 119.23

* This section does not include savings from any state or federal credit presently being offered for the installation of solar energy systems.

CALCULATIONS

SIMPLIFIED SOLAR SIZING WORKSHEET

The instructions for this worksheet begin on page 17. If convenient, detach the worksheet and place next to instructions as you read. On the back side of the worksheet are Section C and some space where you can perform your calculations.

SECTION A - Background Information

House Size Enter the floor area of house in square feet	(1)	sq. ft.
Fuel Cost Enter current annual cost for heating and hot water combined	(2)	$
Collector Factor Copy entry from Table 1 (page 30) which best describes collector type, orientation, etc.	(3)	

SECTION B - Collector Sizing

		small	medium	large
Location Factor Copy entries from Table 2 (pages 31 to 37) for location	(4)			
Solar Fraction Multiply: Line 3 x Line 4	(5)			
Collector to floor area ratio (Do nothing on this line)	(6)	**0.12**	**0.20**	**0.30**
Collector Area Multiply: Line 1 x Line 6	(7)	sq. ft.	sq. ft.	sq. ft.
Gross Cost Enter cost of each size system	(8)	$	$	$
Tax Credit (calculation) Calculate: Line 8 x 0.40	(9)	$	$	$
Federal Tax Credit (actual) Enter Line 9 or $4000, whichever is less	(10)	$	$	$
State Tax Credit, if any Enter state tax credit, if any	(11)	$	$	$
Net Cost Subtract: Line 8 - Line 10 - Line 11	(12)	$	$	$

RETURN, as defined on page 15, is introduced so that you can roughly compare the economics of different size systems over a period of years. Calculations have indicated that a RETURN in the range of 3 and 10 will offer the best trade-off between a prompt payback and high long-term savings. The best compromise appears to be a system with a RETURN closest to 6 (using a fuel inflation rate of 12%).*

RETURN Calculate: Line 2 x Line 5 ÷ Line 12	(13)			

* You can expect these results from a system with a RETURN of 6:

- Savings (in fuel bills) will accrue until the system has paid for itself in 9 years following installation; and
- Savings will pay for the system *Plus* 8% interest on investment in 13 years following installation. Everything following that is pure savings.

* Using a fuel inflation rate of 12%.

SIMPLIFIED SOLAR SIZING WORKSHEET
(Continued)

SECTION C - Mortgage Payments*

Term of Mortgage Enter the term of your mortgage in years			(14)	yrs.
Interest Rate Enter the interest rate of your mortgage as a percentage			(15)	%
Compound Interest Enter the corresponding number from Table 3 (page 38)			(16)	
		small	medium	large
Down Payment Enter the down payment	(17)	$	$	$
Amount Financed Subtract: Line 8 - Line 17	(18)	$	$	$
Monthly Mortgage Payment Divide: Line 18 ÷ Line 16	(19)	$	$	$

* This section does not include savings from any state or federal credit presently being offered for the installation of solar energy systems.

CALCULATIONS

SIMPLIFIED SOLAR SIZING WORKSHEET

The instructions for this worksheet begin on page 17. If convenient, detach the worksheet and place next to instructions as you read. On the back side of the worksheet are Section C and some space where you can perform your calculations.

SECTION A - Background Information

House Size Enter the floor area of house in square feet	(1)	sq. ft.
Fuel Cost Enter current annual cost for heating and hot water combined	(2)	$
Collector Factor Copy entry from Table 1 (page 30) which best describes collector type, orientation, etc.	(3)	

SECTION B - Collector Sizing

		small	medium	large
Location Factor Copy entries from Table 2 (pages 31 to 37) for location	(4)			
Solar Fraction Multiply: Line 3 x Line 4	(5)			
Collector to floor area ratio (Do nothing on this line)	(6)	**0.12**	**0.20**	**0.30**
Collector Area Multiply: Line 1 x Line 6	(7)	sq. ft.	sq. ft.	sq. ft.
Gross Cost Enter cost of each size system	(8)	$	$	$
Tax Credit (calculation) Calculate: Line 8 x 0.40	(9)	$	$	$
Federal Tax Credit (actual) Enter Line 9 or $4000, whichever is less	(10)	$	$	$
State Tax Credit, if any Enter state tax credit, if any	(11)	$	$	$
Net Cost Subtract: Line 8 - Line 10 - Line 11	(12)	$	$	$

RETURN, as defined on page 15, is introduced so that you can roughly compare the economics of different size systems over a period of years. Calculations have indicated that a RETURN in the range of 3 and 10 will offer the best trade-off between a prompt payback and high long-term savings. The best compromise appears to be a system with a RETURN closest to 6 (using a fuel inflation rate of 12%).*

RETURN Calculate: Line 2 x Line 5 ÷ Line 12	(13)			

* You can expect these results from a system with a RETURN of 6:

- Savings (in fuel bills) will accrue until the system has paid for itself in 9 years following installation; and
- Savings will pay for the system *Plus* 8% interest on investment in 13 years following installation. Everything following that is pure savings.

* Using a fuel inflation rate of 12%.

SIMPLIFIED SOLAR SIZING WORKSHEET
(Continued)

SECTION C - Mortgage Payments*

Term of Mortgage Enter the term of your mortgage in years	(14)	yrs.
Interest Rate Enter the interest rate of your mortgage as a percentage	(15)	%
Compound Interest Enter the corresponding number from Table 3 (page 38)	(16)	

		small	medium	large
Down Payment Enter the down payment	(17)	$	$	$
Amount Financed Subtract: Line 8 - Line 17	(18)	$	$	$
Monthly Mortgage Payment Divide: Line 18 ÷ Line 16	(19)	$	$	$

* This section does not include savings from any state or federal credit presently being offered for the installation of solar energy systems.

CALCULATIONS

SIMPLIFIED SOLAR SIZING WORKSHEET

The instructions for this worksheet begin on page 17. If convenient, detach the worksheet and place next to instructions as you read. On the back side of the worksheet are Section C and some space where you can perform your calculations.

SECTION A - Background Information

House Size Enter the floor area of house in square feet	(1)	sq. ft.
Fuel Cost Enter current annual cost for heating and hot water combined	(2)	$
Collector Factor Copy entry from Table 1 (page 30) which best describes collector type, orientation, etc.	(3)	

SECTION B - Collector Sizing

		small	medium	large
Location Factor Copy entries from Table 2 (pages 31 to 37) for location	(4)			
Solar Fraction Multiply: Line 3 x Line 4	(5)			
Collector to floor area ratio (Do nothing on this line)	(6)	**0.12**	**0.20**	**0.30**
Collector Area Multiply: Line 1 x Line 6	(7)	sq. ft.	sq. ft.	sq. ft.
Gross Cost Enter cost of each size system	(8)	$	$	$
Tax Credit (calculation) Calculate: Line 8 x 0.40	(9)	$	$	$
Federal Tax Credit (actual) Enter Line 9 or $4000, whichever is less	(10)	$	$	$
State Tax Credit, if any Enter state tax credit, if any	(11)	$	$	$
Net Cost Subtract: Line 8 - Line 10 - Line 11	(12)	$	$	$

RETURN, as defined on page 15, is introduced so that you can roughly compare the economics of different size systems over a period of years. Calculations have indicated that a RETURN in the range of 3 and 10 will offer the best trade-off between a prompt payback and high long-term savings. The best compromise appears to be a system with a RETURN closest to 6 (using a fuel inflation rate of 12%).*

RETURN Calculate: Line 2 x Line 5 ÷ Line 12	(13)			

* You can expect these results from a system with a RETURN of 6:

- Savings (in fuel bills) will accrue until the system has paid for itself in 9 years following installation; and
- Savings will pay for the system *Plus* 8% interest on investment in 13 years following installation. Everything following that is pure savings.

* Using a fuel inflation rate of 12%.

SIMPLIFIED SOLAR SIZING WORKSHEET
(Continued)

SECTION C - Mortgage Payments*

Term of Mortgage Enter the term of your mortgage in years	(14)		yrs.
Interest Rate Enter the interest rate of your mortgage as a percentage	(15)		%
Compound Interest Enter the corresponding number from Table 3 (page 38)	(16)		

		small	medium	large
Down Payment Enter the down payment	(17)	$	$	$
Amount Financed Subtract: Line 8 - Line 17	(18)	$	$	$
Monthly Mortgage Payment Divide: Line 18 ÷ Line 16	(19)	$	$	$

* This section does not include savings from any state or federal credit presently being offered for the installation of solar energy systems.

CALCULATIONS

Table 1. COLLECTOR FACTORS*

Collector Orientation	Collector Tilt Angle	COLLECTOR TYPE					
		Air			Liquid		
		Selective Surface	Single Glazing	Double Glazing	Selective Surface	Single Glazing	Double Glazing
South	Roof	7.4	6.6	6.8	8.5	7.7	7.8
	Optimal	8.2	7.3	7.5	9.3	8.6	8.6
	Wall	6.8	6.0	6.1	8.1	7.3	7.2
	Wall with Reflector	8.0	7.2	7.3	9.3	8.5	8.4
Southeast or Southwest	Roof	7.2	6.3	6.5	8.2	7.5	7.5
	Optimal	7.7	6.8	7.0	8.8	8.0	8.0
	Wall	6.3	5.5	5.6	7.5	6.6	6.6
	Wall with Reflector	7.5	6.7	6.8	8.7	7.9	7.9
East or West	Roof	6.5	5.7	5.9	7.5	6.7	6.8
	Optimal	6.4	5.6	5.8	7.4	6.6	6.7
	Wall	5.0	4.3	4.5	5.9	5.2	5.3
	Wall with Reflector	6.4	5.6	5.8	7.5	6.6	6.7

* COLLECTOR FACTORS and LOCATION FACTORS (Table 2) are numbers derived from computer simulated performance of approximately 30,000 solar heating systems. The results of these computer simulations indicate that performance depends mainly on (1) the amount of solar energy available together with local climatic conditions (LOCATION FACTOR), and (2) the collector's effectiveness for capturing that energy (COLLECTOR FACTOR). By combining these factors, you can estimate how much heat a given collector will provide in a given location.

Key Word Explanations:

Selective Surface	-Absorber plate treated with selective surface coating (see page 6) and single sheet of glazing
Single Glazing	-One sheet of glazing covering collector (no selective surface)
Double Glazing	-Two sheets of glazing covering collector (no selective surface)
Roof	-Standard 4/12 pitch roof
Optimal	-Latitude of location where collector array is to be installed plus 12° (latitude + 12°)
Wall	-Vertical wall (90°)
Wall with Reflector	-Vertical wall with attached horizontal polished reflector 90° to wall

TABLE 2. LOCATION FACTORS*

State	City	Small	Medium	Large
Alabama	Birmingham	5.7	7.2	6.7
	Mobile	7.8	9.7	11.1
	Montgomery	6.7	8.4	9.9
Alaska	Annette	2.3	3.5	4.7
	Homer	0.8	1.3	1.8
	Juneau	0.7	1.2	1.6
	King Salmon	0.7	1.1	1.5
	Kodiak	0.9	1.4	2.0
	Matanuska	1.9	2.9	3.9
	Yakutat	0.6	1.0	1.4
Arizona	Page	5.5	7.5	9.2
	Phoenix	9.6	11.7	12.7
	Prescott	6.2	8.3	10.1
	Tucson	9.6	11.6	12.7
	Winslow	5.7	7.7	9.5
	Yuma	11.5	12.9	13.4
Arkansas	Fort Smith	5.2	6.7	8.2
	Little Rock	5.2	6.7	8.1
California	Arcata	4.6	6.6	8.3
	Bakersfield	7.0	8.6	9.9
	China Lake	4.6	5.5	6.3
	Daggett	7.8	9.7	11.1
	Davis	6.1	7.7	9.1
	El Toro	9.2	11.3	12.5
	Fresno	6.6	8.3	9.6
	Inyokern	8.3	10.3	11.7
	Long Beach	9.6	11.7	12.7
	Los Angeles	9.5	11.7	12.7
	Mt. Shasta	4.2	5.7	7.2
	Needles	9.5	11.2	12.4
	Oakland	7.2	9.3	10.8
	Pasadena	9.6	11.7	12.7
	Point Muga	6.8	9.6	11.3
	Red Bluff	6.2	7.9	9.2
	Riverside	9.5	11.6	12.7
	Sacramento	6.3	7.9	9.3
	San Diego	10.1	12.1	13.0
	San Francisco	7.1	9.2	10.7
	San Jose	7.2	9.1	10.6
	Santa Maria	7.6	9.9	11.5
	Sunnyvale	7.5	9.5	11.0
Colorado	Boulder	4.4	6.2	7.9
	Colorado Springs	4.5	6.3	8.0
	Denver	4.6	6.4	8.1
	Eagle	3.6	5.2	6.6
	Grand Junction	4.6	6.2	7.7
	Grand Lake	3.1	4.7	6.3
	Pueblo	4.9	6.7	8.3
Connecticut	Hartford	2.7	3.7	4.7
Delaware	Wilmington	3.7	5.0	6.3

*See definitions of COLLECTOR FACTORS and LOCATION FACTORS on page 30.

Table 2. (continued)

	City	Small	Medium	Large
District of Columbia	Washington	3.6	4.8	6.0
Florida	Apalachicola	8.9	10.7	12.0
	Daytona Beach	10.7	12.3	13.1
	Gainesville	10.4	12.1	13.0
	Jacksonville	9.1	11.0	12.2
	Orlando	11.5	12.9	13.4
	Pensacola	8.5	10.5	11.8
	Tallahassee	8.4	10.3	11.6
	Tampa	11.6	12.9	13.4
Georgia	Atlanta	5.5	7.0	8.5
	Augusta	6.2	7.9	9.4
	Griffin	6.4	8.1	9.7
	Macon	6.7	8.4	10.0
	Savannah	7.3	9.1	10.6
Idaho	Boise	3.9	5.3	6.5
	Lewiston	2.1	2.7	3.1
	Pocatello	3.5	4.9	6.1
	Twin Falls	3.5	4.9	6.2
Illinois	Chicago	3.0	4.1	5.1
	Lemont	3.3	4.5	5.6
	Moline	3.0	4.1	5.2
	Peoria	3.4	4.6	5.7
	Springfield	3.5	4.6	5.8
Indiana	Evansville	3.8	5.0	6.2
	Fort Wayne	2.7	3.6	4.6
	Indianapolis	3.1	4.1	5.1
	South Bend	2.6	3.6	4.4
Iowa	Ames	3.2	4.4	5.7
	Burlington	2.0	2.5	3.0
	Des Moines	3.2	4.3	5.4
	Mason City	2.8	3.9	5.0
	Sioux City	3.1	4.2	5.4
Kansas	Dodge City	4.8	6.5	8.0
	Goodland	2.5	3.2	3.8
	Manhattan	4.2	5.6	7.0
	Topeka	4.1	5.5	6.8
	Wichita	4.7	6.3	7.8
Kentucky	Covington	3.0	3.9	4.7
	Lexington	3.6	4.8	5.9
	Louisville	3.7	4.8	6.0
Louisiana	Baton Rouge	7.8	9.6	11.0
	Lake Charles	7.9	9.6	11.0
	New Orleans	8.4	10.2	11.6
	Shreveport	6.9	8.6	10.1
Maine	Bangor	1.6	2.0	2.5
	Caribou	2.0	2.8	3.7
	Portland	2.5	3.5	4.5

Table 2. (continued)

State	City	Small	Medium	Large
Maryland	Annapolis	4.2	5.6	7.0
	Baltimore	3.6	4.8	5.9
	Patuxent River	4.2	5.7	7.1
	Silver Hill	4.5	6.0	7.4
Massachusetts	Amherst	2.8	3.9	5.0
	Blue Hill	3.1	4.3	5.5
	Boston	3.1	4.2	5.3
	Lynn	3.1	4.3	5.4
	Natick	3.3	4.5	5.7
Michigan	Alpena	2.1	3.0	3.8
	Detroit	2.6	3.5	4.4
	East Lansing	2.7	3.6	4.6
	Flint	2.4	3.2	4.1
	Grand Rapids	2.4	3.3	4.1
	Houghton	1.3	1.8	2.2
	Lansing	2.7	3.7	4.7
	Sault Ste. Marie	1.9	2.8	3.6
	Traverse City	2.2	3.0	3.8
Minnesota	Duluth	2.0	2.9	3.8
	International Falls	1.9	2.8	3.6
	Minneapolis	2.4	3.4	4.3
	Rochester	2.4	3.3	4.2
	St. Cloud	2.7	3.8	4.9
Mississippi	Jackson	6.5	8.2	9.7
	Meridian	6.4	8.0	9.5
Missouri	Columbia	3.7	5.0	6.2
	Kansas City	3.8	5.1	6.4
	St. Louis	4.0	5.3	6.5
	Springfield	4.2	5.6	7.0
Montana	Billings	3.3	4.7	6.0
	Cut Bank	1.6	2.1	2.6
	Dillon	2.9	4.2	5.4
	Glasgow	2.5	3.6	4.6
	Great Falls	2.9	4.2	5.3
	Helena	2.8	4.0	5.1
	Lewiston	2.7	3.9	5.1
	Miles City	2.9	4.0	5.1
	Missoula	2.4	3.3	4.2
	Summit	2.2	3.4	4.5
Nebraska	Grand Island	3.6	5.0	6.3
	Lincoln	3.9	5.3	6.7
	North Omaha	3.3	4.5	5.8
	North Platte	3.7	5.2	6.6
	Scotts Bluff	3.7	5.2	6.7

Table 2. (continued)

State	City	Small	Medium	Large
Nevada	Elko	3.8	5.3	6.7
	Ely	4.1	5.8	7.5
	Las Vegas	7.9	10.0	11.4
	Love Lock	4.9	6.7	8.3
	Reno	5.0	6.9	8.6
	Tonopah	5.1	7.0	8.8
	Winnemucca	4.3	5.9	7.5
	Yucca Flats	3.6	4.4	5.1
New Hampshire	Concord	2.4	3.4	4.3
New Jersey	Atlantic City	4.4	5.9	7.4
	Lakehurst	3.5	4.7	5.9
	Newark	3.5	4.8	6.0
	Trenton	4.0	5.5	6.8
New Mexico	Albuquerque	6.0	8.0	9.7
	Clayton	3.1	4.0	4.9
	Farmington	5.0	6.9	8.6
	Roswell	6.4	8.4	10.2
	Truth or Consequences	4.3	5.3	6.3
	Tucumcari	3.6	4.5	5.4
	Zuni	5.0	7.0	8.8
New York	Albany	2.5	3.4	4.3
	Binghampton	2.0	2.8	3.6
	Buffalo	2.2	3.0	3.8
	Ithaca	2.6	3.6	4.6
	Massena	2.2	3.1	4.0
	New York	3.4	4.5	5.6
	New York (La Guardia)	2.3	2.8	3.3
	Rochester	2.4	3.3	4.2
	Schenectady	2.5	3.5	4.5
	Syracuse	2.3	3.0	3.8
North Carolina	Asheville	4.6	6.2	7.7
	Cape Hatteras	5.6	7.1	8.5
	Charlotte	5.4	7.0	8.5
	Cherry Point	6.3	8.0	9.6
	Greensboro	4.9	6.5	7.9
	Raleigh	5.0	6.6	8.1
North Dakota	Bismarck	2.5	3.6	4.6
	Fargo	2.3	3.2	4.1
	Minot	2.4	3.3	4.3
Ohio	Akron	2.7	3.6	4.5
	Cincinnati	3.2	4.3	5.4
	Cleveland	2.5	3.4	4.2
	Columbus	2.8	3.8	4.7
	Dayton	3.0	4.0	4.9
	Put-In-Bay	2.9	3.9	4.8
	Toledo	2.7	3.6	4.5
	Youngstown	2.4	3.3	4.1

Table 2. (continued)

State	City	Small	Medium	Large
Oklahoma	Oklahoma City	5.3	6.9	8.4
	Stillwater	5.4	7.1	8.6
	Tulsa	5.0	6.5	8.0
Oregon	Astoria	3.4	4.9	6.2
	Burns	3.1	4.3	5.4
	Corvallis	4.2	5.8	7.3
	Medford	3.9	5.3	6.5
	North Bend	4.6	6.5	8.1
	Pendleton	3.8	5.0	6.2
	Portland	3.2	4.3	5.3
	Redmond	3.4	4.7	5.9
	Salem	3.3	4.5	5.5
Pennsylvania	Allentown	2.9	4.0	5.0
	Avoca	2.6	3.5	4.4
	Erie	2.3	3.2	4.0
	Harrisburg	3.3	4.4	5.5
	Philadelphia	3.6	4.8	6.0
	Pittsburgh	2.6	3.5	4.4
	Scranton	1.8	2.3	2.7
	State College	2.9	3.9	4.9
Rhode Island	Newport	3.6	4.9	6.3
	Providence	2.9	4.0	5.1
South Carolina	Charleston	6.9	8.7	10.2
	Columbia	6.3	8.0	9.6
	Greenville	5.6	7.2	8.7
South Dakota	Huron	2.7	3.8	4.8
	Pierre	3.1	4.2	5.4
	Rapid City	3.3	4.6	5.9
	Sioux Falls	2.9	4.0	5.1
Tennessee	Chattanooga	4.7	6.1	7.4
	Knoxville	4.7	6.1	7.4
	Memphis	5.2	6.6	8.0
	Nashville	4.4	5.6	6.8
	Oak Ridge	4.5	5.8	7.1
Texas	Abilene	7.0	8.9	10.5
	Amarillo	5.8	7.7	9.5
	Austin	7.8	9.6	11.1
	Big Springs	7.3	9.3	10.9
	Brownsville	11.1	12.5	13.2
	Corpus Christi	10.1	11.7	12.7
	Dallas	6.6	8.3	9.8
	Del Rio	6.3	7.4	8.3
	El Paso	7.8	10.0	11.5
	Fort Worth	6.7	8.4	10.0
	Houston	8.1	9.8	11.1
	Kingsville	9.8	11.4	12.5
	Laredo	8.2	9.4	10.4
	Lubbock	6.3	8.3	10.0
	Lufkin	7.3	9.2	10.7

Table 2. (continued)

	City	Small	Medium	Large
Texas	Midland	7.3	9.3	10.9
	Port Arthur	8.1	9.9	11.3
	San Angelo	7.5	9.4	11.0
	San Antonio	8.3	10.1	11.5
	Sherman	4.0	4.7	5.5
	Waco	7.4	9.2	10.7
	Wichita Falls	6.2	8.0	9.6
Utah	Bryce Canyon	2.7	3.7	4.6
	Cedar City	4.7	6.5	8.2
	Salt Lake City	4.2	5.7	7.1
Vermont	Burlington	2.0	2.8	3.5
Virginia	Mt. Weather	3.7	5.1	6.5
	Norfolk	5.1	6.7	8.1
	Richmond	4.5	5.9	7.3
	Roanoke	4.3	5.8	7.2
Washington	Olympia	2.8	4.0	4.9
	Prosser	4.0	5.3	6.4
	Pullman	3.5	4.8	5.9
	Richland	3.8	4.9	6.0
	Seattle	3.1	4.2	5.1
	Spokane	2.8	3.8	4.7
	Tacoma	3.2	4.3	5.3
	Whidbey Island	3.1	4.4	5.5
	Yakima	3.4	4.5	5.5
West Virginia	Charleston	3.3	4.4	5.4
	Huntington	2.5	3.0	3.5
	Parkersburg	3.4	4.5	5.5
Wisconsin	Eau Claire	2.3	3.2	4.1
	Green Bay	2.4	3.4	4.3
	La Crosse	2.6	3.5	4.4
	Madison	2.6	3.6	4.6
	Milwaukee	2.6	3.7	4.7
Wyoming	Casper	3.8	5.4	7.0
	Cheyenne	3.9	5.6	7.2
	Lander	4.1	5.9	7.6
	Laramie	3.5	5.2	6.8
	Rock Springs	3.7	5.3	6.9
	Sheridan	3.1	4.4	5.7
Canada				
Alberta	Calgary	1.4	2.0	2.5
	Edmonton	2.7	3.9	5.1
	Lethbridge	2.8	4.0	5.0
British Columbia	Vancouver	2.7	3.7	4.6
	Victoria	2.3	3.0	3.6

Manitoba	Churchill Winnipeg	1.7 2.1	2.7 3.1	3.8 4.0
New Brunswick	Moncton St. John	2.2 1.6	3.2 2.2	4.2 2.7
Newfoundland	St. John	1.9	2.8	3.8
Nova Scotia	Halifax	1.6	2.3	2.8
Ontario	Hamilton Kapuskasing London Ottawa Toronto Windsor	1.8 1.7 1.7 2.4 2.5 1.8	2.3 2.4 2.2 3.4 3.5 2.3	2.8 3.2 2.6 4.3 4.4 2.8
Quebec	Montreal Quebec City	2.1 1.4	3.0 1.9	3.8 2.3
Saskatchewan	Saskatoon	1.2	1.6	2.0

TABLE 3. COMPOUND INTEREST

Interest Rate %	Years									
	2	3	4	5	7	10	15	20	25	30
6	23	33	43	52	69	91	119	140	156	168
6.5	23	33	42	51	68	89	115	135	149	159
7	22	33	42	51	67	87	112	130	142	151
7.5	22	33	42	50	66	85	109	125	136	142
8	22	32	41	50	65	83	105	120	130	137
8.5	22	32	41	49	64	81	102	116	125	131
9	22	32	40	49	63	80	99	112	120	125
9.5	22	31	40	48	62	79	97	108	115	120
10	22	31	40	47	61	76	94	104	111	115
10.5	22	31	39	47	60	75	91	101	107	110
11	22	31	39	46	59	73	89	98	103	106
11.5	22	31	39	46	58	72	86	95	99	102
12	21	30	38	45	57	70	84	92	96	98
12.5	21	30	38	45	56	69	82	89	93	95
13	21	30	38	44	56	68	80	86	90	91
13.5	21	30	37	44	55	66	78	84	87	88
14	21	30	37	43	54	65	76	81	84	85
14.5	21	29	37	43	53	64	74	79	81	83
15	21	29	36	43	52	63	72	77	79	80
16	21	29	36	42	51	60	69	73	75	75
17	21	28	35	41	50	58	66	69	71	71
18	20	28	35	40	48	56	63	66	67	67
19	20	28	34	39	47	54	60	63	64	64
20	20	27	33	38	46	53	58	60	61	61

PART III: STUDY YOUR OPTIONS

WHAT NOW?

This workbook has provided basic information about active solar heating systems and a method to estimate the performances of different sizes of systems. However, this workbook is not a solar decision-making publication. You should not base your solar decision entirely on what you have learned here, especially if the results seem discouraging. You should investigate all possible options—active, passive, and hybrid— and the best way to get started is to first consult a qualified solar designer or consultant who can help you evaluate what is best for you.

Once you have made your decision you must then decide if you will design your own system or have someone do it for you. Designing a solar heating system—active or passive—is difficult. To do your own designing, you must prepare yourself with an in-depth understanding of solar heating systems far beyond what you have learned in this workbook. Your solar designer should be able to help you by recommending solar literature; courses in solar theory, design, and construction; and other solar homeowners with whom you can talk. If you decide to embark on the design yourself, you should still retain the assistance of your solar designer throughout the design process.

If you do not feel comfortable designing your own system, leave the process to your designer or hire a solar architect or engineer. The cost for the solar designer's services may account for as much as 10% of the total cost of your solar heating system, so choose carefully. Be sure to tell your solar designer your needs, preferences, and priorities early in the design process.

To find an expert in designing and installing solar systems, talk to people who have already had systems installed, go to meetings of the solar energy association in your state, or contact solar information centers and agencies such as your state solar energy office (if there is one in your state). There are many federal or state organizations that can provide valuable information.

The National Solar Heating and Cooling Information Center provides informative publications and specific answers to both technical and nontechnical questions. Write the center at P.O. Box 1607, Rockville MD 20850, or call toll free:

Telephone (800) 523-2929
From Pennsylvania (800) 462-4983
From Alaska, Hawaii (800) 523-4700.

Regional Solar Energy Centers also provide many services particularly related to their service areas. The four centers and their service areas are:

Western Solar Utilization Network
Pioneer Park Building
715 S.W. Morrison
Portland, OR 97205
(503) 241-1222

- Alaska
- Arizona
- California
- Colorado
- Hawaii
- Idaho
- Montana
- Nevada
- New Mexico
- Oregon
- Utah
- Washington
- Wyoming

Northeast Solar Energy Center
470 Atlantic Avenue
Boston, MA 02110
(617) 292-9250

- Connecticut
- Maine
- Massachusetts
- New Hampshire
- New Jersey
- New York
- Pennsylvania
- Rhode Island
- Vermont

Southern Solar Energy Center
61 Perimeter Park
Atlanta, GA 30341
(404) 458-8765

- Alabama
- Arkansas
- Delaware
- District of Columbia
- Florida
- Georgia
- Kentucky
- Louisiana
- Maryland
- Mississippi
- North Carolina
- Oklahoma
- Puerto Rico
- South Carolina
- Tennessee
- Texas
- Virginia
- West Virginia

Mid-American Solar Energy Complex
8140 26th Avenue, South
Bloomington, MN 55420
(612) 853-0400

- Illinois
- Indiana
- Iowa
- Kansas
- Michigan
- Minnesota
- Missouri
- Nebraska
- North Dakota
- Ohio
- South Dakota
- Wisconsin

Energy Extension Service (EES) Centers offer information services to people with questions on energy conservation, solar energy, and other renewable energy resources. State energy offices can give further information on specific EES programs.

Once your system is designed, you come to another round of careful decision making concerning its purchase and installation. You should now have confidence in your solar designer and may want to let him or her choose the components, select a reliable contractor, supervise the construction, and inspect the completed work. Remember, solar heating is a new and wide-open field and requires a sizable financial investment. Therefore, it is wise to know as much as possible about your particular system design and be involved in all aspects of your solar venture.

CONSIDERATIONS IN BUYING A SOLAR ENERGY SYSTEM

Here is a checklist that you and your solar designer should consider before you purchase and install a solar heating system.

- ☐ **Consult Several Contractors, Consultants, or Solar Companies.** Determine the highest quality equipment and work for the fairest price. Be sure to obtain free written estimates for a complete job.
- ☐ **If Possible, Deal Only with Licensed Contractors.** Ask to see a contractor's license if your state requires one. Licensed contractors carry a pocket certificate that must be produced upon request. Make sure it is up-to-date and not just a business license.
- ☐ **Know Your Contractor Before You Sign.** Avoid high pressure sales tactics and do not blindly consult the Yellow Pages. Take the time to check with the agencies in your state or local area to see whether the contractor has had any disciplinary actions. Check with the Better Business Bureau regarding the status and reputation of the business. Check to see if the firm's employees have heating, plumbing, or engineering experience. Find out whether anyone has had formal training from the manufacturer on how to install the solar system. If not, find out if the manufacturer will have any control over the installation process.
- ☐ **Investigate the Company's or Contractor's Record.** How many systems has the firm installed? Look at some of the company's jobs. Ask to speak to some former customers. You should be able to tell quality workmanship by examining the site, observing the equipment in operation, and talking to the owner.
- ☐ **Buy Local.** This may not always be possible because many reliable solar companies are just starting and may have only one office. When possible, choose local dealers and installers with the longest and soundest track records.
- ☐ **Check Addresses.** Beware of sellers whose only address is a post office box (except in rural areas where this is often necessary). Find out from the salesperson where the place of business is and how long it has operated. Although many legitimate businesses use box numbers, one tactic of the "fly-by-nighters" is to set up box numbers and move on.
- ☐ **Beware of Bargains, Specials, Deals.** Beware of swindles such as fantastic long- term guarantees, promises of care-free maintenance, offers to reduce costs by using your home as a model for advertising or by referral sales to friends. Because some legitimate sellers will have special sales, you need to examine advertising carefully.
- ☐ **Read Your Warranty.** Know what the limitations are. How long does the warranty last? Are parts, service, and labor covered? Who will provide the service and for how long?
- ☐ **Will the Equipment Perform as Promised?** Ask for proof in writing from an independent laboratory or university. Have a solar designer or an engineering consultant go over the written proof if you do not understand it.
- ☐ **Will It Actually Heat Your Home?** Remember that climate, trees, insulation, orientation of collectors, and your family's lifestyle will determine how well the system performs at your location.
- ☐ **Insist on a Written Contract.** A written contract will help avoid misunderstandings between you and your contractor. By defining the most important terms, it will reduce the risk of dispute. Read the contract carefully. It should include the name and address of the contractor; the contractor's license number; a detailed description of the work to be completed, including specifications of the brand names of equipment used; the total contract price; the approximate dates when the work will begin and be completed; and the financial arrangements, including information required by the Truth in Lending Act. Be sure to state an upper limit on the cost of the work!
- ☐ **Use Your Right to Cancel.** In most cases, you will receive a notice that you have a three-day right to cancel your contract. If you have any doubts about proceeding, cancel by written notice. Then, decide what is best for you.

RESIDENTIAL SOLAR ENERGY AND ENERGY CONSERVATION TAX INCENTIVES: AN OVERVIEW

Federal Tax Credits

Solar Energy:

The federal solar energy tax credit, (originally passed under the federal Energy Tax Act of 1978) was increased in 1980 by the U.S. Congress. Federal taxpayers can now subtract from their federal income taxes up to 40% of the cost of eligible solar, wind, or geothermal energy systems. Credits can be claimed for the first $10,000 expended, for a maximum allowable federal credit of $4,000.

The new federal credit became effective January 1, 1980, and runs through January 1, 1986. To claim the credit, the solar system must be installed in or on your principal residence, which can be owned or rented.

The federal tax is "non-refundable," which means the total credit can never exceed the total amount of income taxes due. If you do not pay income taxes, you cannot get additional money to cover the solar tax credit. However, unused credit can be carried forward through the 1985 tax year.

For example: a resident buys and installs a $6300 solar energy space heating system. Under the 40% federal tax credit, the resident can deduct $2520 of that cost from federal income taxes. If this person's federal income tax bill for the first year following installation was $2000, the resident would pay no federal tax income that year, and the following year's income tax bill would be reduced by $520. If necessary, to cover the allowable credit, this can be done on federal income taxes from year to year, up through the 1985 tax year.

The federal solar energy credit does not apply if the system was financed with a government low-interest or no-interest loan program.

Energy Conservation:

Taxpayers can subtract from their federal income taxes up to 15% of the cost of new energy conservation measures such as insulation, storm or thermal windows and doors, caulking and weatherstripping, automatic setback thermostats, furnace modifications to improve efficiency, and meters that display the cost of energy use. Credits can be claimed for the first $2000 spent on these items and their installation, for a maximum allowable federal credit of $300.

The federal energy conservation credits cover expenditures made between April 20, 1977, and December 31, 1985. The federal energy conservation tax credit is "nonrefundable," as explained above, and unused portions of the credit can also be carried forward from year to year, until the expiration date.

For more information on federal tax credits, contact the Internal Revenue Office in your area or the organizations listed in PART III of the workbook.

State Tax Credits

Many states offer tax credits for either solar energy systems, energy conservation improvements, or in some cases, both. In some states the federal credits can be claimed in conjunction with state credits—a substantial deduction.

Because state credits vary from state to state, a complete disscussion would be too lengthy for this workbook. For more information on state tax credits, solar and energy conservation, contact the energy office or energy extension service in your state, or the appropriate Regional Solar Energy Center (see page 40).

GLOSSARY

absorber	the blackened surface in a collector that absorbs solar radiation and converts it to heat energy; usually made of steel, copper, or aluminum
active system	a solar heating or cooling system that uses external power to drive pumps and fans which transport water or air from solar collector to storage or to the house for heating
air-type collector	a collector with air as the heat transfer fluid
auxiliary heat	the supplemental heat provided by a backup heating system or furnace for periods of cloudiness or extreme cold
backup heating system	some type of heating system, usually powered by a fossil fuel or electricity and often used with a solar water and/or space heating system (see "auxiliary heat")
collector	any of a wide variety of devices used to collect radiant solar energy and convert it to heat
conduction	heat transfer through a solid mass by passing from molecule to neighboring molecule, provided the two are touching
controls	device(s) used to regulate a system; usually automatically
convection	heat transfer through a fluid (such as air or liquid) by currents caused by the natural fall of heavier, cool fluid and the rise of lighter, warm fluid
delivery system	the heat transfer loop that provides warm air to storage and to the house when necessary
differential thermostat	an automatic electric control system using sensors (thermometers) to measure the temperature difference between two points
double-glazing	sheets of glass or other transparent material used to cover absorber plate in solar collectors (see "glazing")
flat-plate collector	a solar collector using a large, flat absorber sheet that faces the sun; a collector that does not use mirrors or lenses to focus sunlight on the absorber
glazing	glass or other transparent materials used to transmit sunlight and act as a barrier to the emittance of thermal radiation
heat exchanger	a device, such as a coiled copper tube immersed in a tank of water, that is used for moving heat between two isolated fluids (such as air or a liquid) without mixing the fluids themselves
heat transfer fluid	the substance(s) that carries heat from the collector to storage and from storage to the house. The medium is typically a fluid such as air, water, or a water-antifreeze solution.
heat transfer loop	the path followed by the heat transfer fluid as it moves heat between the collector, storage and the house
insulation	a material having a relatively high resistance to heat flow (R-value) that is used principally to retard the flow of heat
liquid-type collector	a collector with a liquid as the heat transfer fluid
passive system	a solar heating or cooling system which is usually an integral part of the building and requires little, if any, mechanical or external power to move the collected solar heat
retrofit	the process of adding to an existing building a solar heating or cooling system
selective surface	an absorber coating formulated to absorb the visible infrared sunlight while emitting very little thermal radiation

solar fraction — the percentage of a building's net heating load met by solar gain

solar radiation — radiant energy emitted by the sun in the wavelength range between 0.3 and 3.0 microns. Of the total solar radiation reaching the earth, approximately 3% is in the ultraviolet region, 44% in the visible region, and 53% in the near infrared region

thermal radiation — longwave electromagnetic radiation emitted by every warm surface

tilt angle — the angle that a flat-plate collector surface forms with a horizontal surface

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