

## ENERGY FACT SHEET

AEES—10

### RESIDENTIAL SOLAR HEATING

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Heating a residence and the domestic water supply with solar energy is technically feasible in Kentucky. However, it is not feasible to provide 100 percent of the heat requirements. Some backup system is needed for continuous heat during cloudy weather and the cold part of winter. Both passive and active solar heating systems are technically feasible.

It is usually more costly to install solar heating for existing buildings since most existing buildings are not suitably oriented for passive or active solar heating. However, an active solar domestic water heater utilizes small collectors which can often be added to existing buildings. Therefore, heating domestic water supply may be technically feasible for existing buildings.

With respect to economics of solar heating, new residences should provide for partial heating with passive devices since the residence can be oriented and arranged to receive some heat at little or no additional construction cost. Domestic water heating with solar energy in new or existing residences may be economical today, particularly if electricity is the alternative fuel. The use of active collectors to provide 60 to 80 percent of the residential heat requirement is usually not economically justified at today's fuel costs. However, if fuel costs continue to rise solar energy will be more competitive. If there are rapid increases in fuel costs, then an investment now in solar heating could be a good investment for a new house. In addition, if some of the labor can be done by the owner and the tax credits for solar installations utilized, solar residential heating with active type collectors may be economically competitive in some cases.

If you are building a new residence, the following priority is suggested:

- \*ENERGY CONSERVATION.
- \*PASSIVE SOLAR HEATING.
- \*DOMESTIC SOLAR WATER HEATING.
- \*SLOPING THE ROOF NOW FOR INSTALLING AN ACTIVE SOLAR COLLECTOR IN THE FUTURE.
- \*INSTALL ACTIVE SOLAR HEATING NOW.

#### ENERGY CONSERVATION

Energy conservation is essential regardless of the fuel used, but particularly important if the fuel is rather

expensive. Heat from active solar heating systems costs as much or more than the most expensive fuels. Therefore, energy conservation is especially important if solar heat is to be used. Residential energy conservation should include the following:

1. Insulate the structure well. Consider R-40 or more for the ceiling; R-20 or more for the walls; limited window area on the north, east and west sides with any large windows in the south; and perimeter insulation for the top 2 feet of soil which is in contact with the outside wall.
2. Provide complete weatherstripping to decrease unnecessary infiltration of air and consider an air-lock entrance design which uses two doors to the outside with a small vestibule between the doors.
3. Consider placing as much of the house underground as is consistent with the desired living environment. The portion of a structure which is underground requires very little heating and contributes some cooling during the summer.

#### PASSIVE OR ACTIVE SOLAR HEATING SYSTEMS, WHAT'S THE DIFFERENCE?

Solar heating systems can be divided into two basic types: active and passive. The active system relies on a pump or blower to move heated air or liquid from the collector through pipes or ducts into the residence or from the collector to storage. Figure 1 illustrates an air

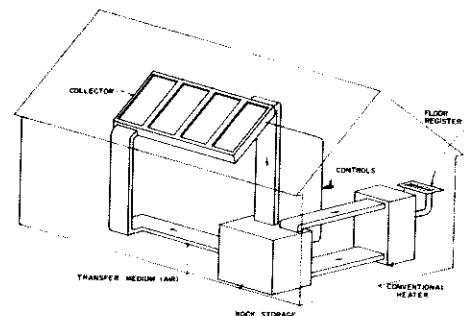


Figure 1.—Active solar heating system using air collectors and rock storage.

type active solar heating system which utilizes air to move the heat from the collector to a rock storage unit or directly to the residence if the heat is needed at the time it is collected. A second type of active system utilizes liquid in the collector. Generally, the liquid and air type systems are of approximately the same efficiency for heating a residence including domestic water, but the liquid type is preferred for water heating without residential heating.

A passive system uses natural forces of convection and gravity to transfer the heat. An effective passive heating system must include a transparent glazing, thermal storage and insulation. Most passive systems absorb the solar radiation within the space to be heated; if not, then a method for transferring the heat must be provided. Examples of heat storage include concrete floor, concrete block wall, water in tanks, etc. If a large glazed area admits sunlight to a space with little thermal mass for storage of the heat, the space will be overheated. Direct sunlight could be undesirable if the space is used for visual tasks or desirable if used for plant growth.

An example of passive heating is illustrated in Figure 2. The sunlight passes through a clear covering, a glazing, and is absorbed by the black-painted masonry. This warm storage wall then heats the living space. In some

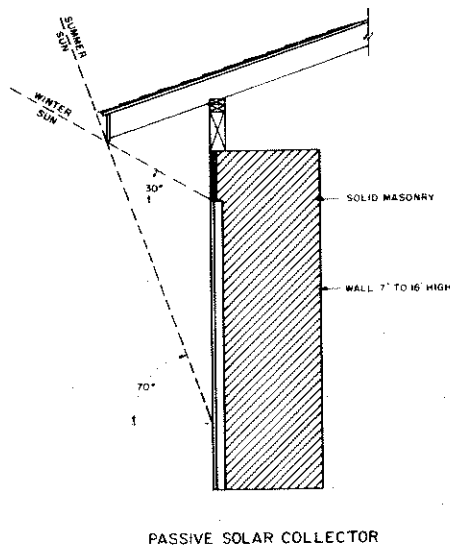


Figure 2.—Passive solar collector.

installations, air enters at the bottom of the wall, passes over the wall surface and picks up heat which is transferred back to the room by natural convection. A window facing south is also a good passive heater in that it allows the solar energy to enter directly into the space to be heated. Other types of passive systems include: a greenhouse attached to the southern side of a building or simply glazing an enclosure on the southern side of a building. All of these types require some type of insulation, preferably for the glazed area, if they are to be effective in capturing heat and retaining it. For instance,

the solar wall illustrated in Figure 2 would lose much of the absorbed heat unless some insulation is provided, which can be moved into place at night. Good passive design also requires a thermal mass, such as a concrete floor or wall, to store the heat. If no thermal mass is in the space, overheating may be a problem.

Although a passive heating system is simpler than the active, it usually requires more management. Insulating panels may need to be moved manually. Vents must be opened or closed according to the amount of solar radiation received and the needs of the living space. There are a number of different passive solar heating designs, varying from the simple concept of a well-insulated house with south windows to a complicated system of dampers, baffles and movable insulation. Many passive systems have been installed in sunny areas of relatively low heat requirements, such as in the southwest. Perhaps the most effective passive design is to use large insulating windows on the south wall, with a limited amount of window area on the other walls.

The active system can provide between 50 and 70 percent of the heat requirements of a house. Automatically controlled and involving a great deal of equipment, it may be expensive to install. Any solar heating system, passive or active, is dependent on the amount of solar radiation received. The remainder of this publication will discuss active systems in more detail and outline some suggestions for design.

## DOMESTIC WATER HEATING WITH SOLAR ENERGY

Solar water heating for residences should be more economical than space heating since the solar heating system is used 12 months of the year, whereas the system cost for space heating must be paid for by its use during the heating months. Solar water heating systems for residences are available in packaged units so they can be installed with standard plumbing and heating techniques. Generally these systems preheat the domestic water supply so that additional heat, when needed, can be added by the existing water heater. The approximate size of well-constructed solar collectors required for domestic water heating is 15 to 20 square feet per person. A residence will generally need from 80 to 120 square feet of collector area. Twenty square feet of collector surface per person, using a well-made commercial unit, should provide nearly all the domestic hot water required during the summer, and probably 30 to 40 percent during the coldest month. The decreased energy supply during cold weather is due to greater heat loss from the collector and less sunshine. It should be noted that collectors of the water heater size are insufficient for residential space heating.

## ACTIVE SOLAR SPACE HEATING

A solar space heating system for a residence generally includes heat for domestic water, since year-round use

can be made of the water heating part of the investment. Therefore, it is assumed that domestic water heating will be a part of all residential solar heating systems.

The installation of solar residential space heating on existing houses has limited potential because mounting the large collectors is usually difficult and costly. Only those structures which have a fairly large roof area sloped toward the south at an angle of 35 degrees or more should be considered as candidates for the installation of active solar collectors. If sufficient roof area is not available, or the roof does not face south, it is possible to install solar collectors separate from the house. However, the construction of a supporting frame for a rather large solar collector is highly doubtful from an economic standpoint, because solar heating systems are difficult to justify even on a new residence, where a proper size roof can be constructed at little additional cost. Also, solar units mounted separately from the structure have additional heat losses resulting in a less efficient system. SINCE THE ADDITION OF AN ACTIVE SOLAR HEATING SYSTEM REQUIRES CONSIDERABLE ROOF AREA SLOPED TOWARD THE SOUTH, ANY NEW CONSTRUCTION SHOULD CONSIDER PROVIDING A ROOF FOR FUTURE INSTALLATION OF AN ACTIVE SOLAR HEATING SYSTEM IF IT IS NOT INSTALLED DURING CONSTRUCTION.

The amount of collector area required depends on the heat loss from the structure. As a rough rule of thumb, from one-fourth to one-half of the floor area is considered to be the general range of desirable collector area for a well-insulated structure. However, the best design procedure for determining collector area is to utilize a computer program for designing the collector and estimating the percentage of heat load which the solar heating system will provide, as well as the quantity of water heating available with the specific design (see Computer Design).

Collector area may be estimated using a simplified system presented in the Kentucky Solar Energy Handbook\*. The method for estimating the collector area required should be adequate for sloping a roof for future installation of a solar collector but the computer design method would be recommended for design and installation. The roof for an active collector should slope due south with a slope angle of 45 to 50 degrees in Kentucky, although slopes as low as 35 degrees and orientations up to 30 degrees from south may be considered for solar heating design.

### PLANNING A SOLAR SYSTEM

The concept of solar heating is fairly simple. To collect solar heat, a dark surface absorbs the solar radiation, converts the radiation into heat and provides for transfer of the heat to a fluid (usually air or a liquid).

\*Available from the office of Continuing Education, College of Engineering, University of Kentucky, Lexington, Kentucky, 40546. Price \$7.50.

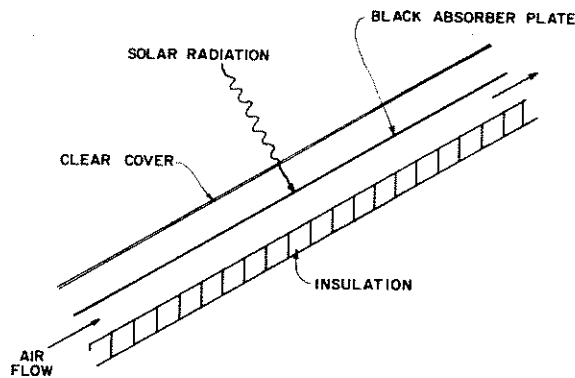


Figure 3.—Air heating solar collector.

which is moved across the surface of the absorber plate (see Figure 3). One or two transparent covers are placed over the absorber plate to decrease the amount of heat loss to the atmosphere. Two transparent covers and insulation underneath the absorber plate are needed for collectors which heat a domestic water supply or provide residential space heating. The heated fluid is directed to the living space or to a heat storage, depending on the heating needs at the time.

When planning a solar system consider the following items:

1. Energy conservation,
2. Selection of a collector type,
3. Energy storage,
4. Control of the system, and
5. Economics.

Energy conservation has been discussed previously. In selecting an air-type or a liquid-type solar system, consider efficiency of operation, maintenance and first cost. For residential space heating the air and liquid systems are equivalent in efficiency provided both are well constructed. However, the maintenance, freezing, corrosion and leak problems are greater with the liquid systems. An air system is usually easier to construct and less costly. However, leaks in an air system are difficult to detect and will adversely affect performance. All joints in the duct system should be filled with silicone caulk during assembly, fastened with screws and taped on the outside before applying insulation. The liquid system might be a good choice for a domestic water heating unit if the manufacturer provides a complete system which has been designed and constructed to avoid the previously noted problems. The liquid system may also be the best choice for combined residential and domestic water heating if hot water convectors are used for residential space heating. Generally, the air system is preferred for most other residential applications.

For either type of system the design of the solar absorber plate and the means of heat transfer from the absorber plate to the liquid or the air is of paramount importance in achieving an efficient unit.

A solar heating system is usually controlled by measuring the temperature in the collector and the

temperature of the storage unit and comparing these two temperatures. A differential thermostat is used so that the solar system will operate only when heat is available at a higher temperature than prevails in the storage unit. A commercial unit should be purchased for control.

The heat storage unit for a liquid system is usually a large water tank. The general rule is to provide 10 to 15 pounds of water (1.25 - 1.9 gallons) per square foot of collector surface for space heating including the heating of the domestic water supply. The water storage unit should prevent mixing of the heated water with the cold water in the tank to whatever degree is possible, and the tank should be insulated; otherwise, little storage design is necessary.

For the air type system, washed river gravel is generally recommended for heat storage; however, crushed rock may also be used. Design of the rock storage unit must include sizing the stone and determining the shape of the bed and the air velocity through the bed to achieve reasonable pumping pressures, good air distribution and effective heat transfer between the stone and the air. Persons considering the use of rock as a storage medium should secure additional information from the Agricultural Engineering Department of the University of Kentucky. The quantity of stone required is approximately 0.5 to 0.8 cubic feet per square foot of collector area. The stone selected should be the smallest size which will still provide a reasonable pressure head at the desired air flow rate.

Besides the solar heating system, there will need to be some type of wood, oil, gas, or electric-fired auxiliary heater. The purpose of the auxiliary unit is to provide heat at times when the solar heating unit cannot provide enough heat to meet the load. This would be during cloudy periods and cold nights. A well designed and constructed solar heating system will provide 50 to 70 percent of the home heating load during the heating season. To supply 100 percent of the heating requirements would be extremely costly with present design and construction knowledge.

## COMPUTER DESIGN

The completion of physical design and the economics of solar systems can best be accomplished by use of a computer program. Necessary analyses have been programmed on both large computers and hand-held pro-

grammable calculators. Computer design is recommended to achieve the completed design which will provide a reasonable prediction of system performance and economics for a selected collector size.

The Department of Agricultural Engineering at the University of Kentucky has a computer program, called the F-chart method, which will estimate the quantity of energy which can be provided by a given solar heating system and compute the economics. To operate the program it is necessary to have the performance curve for the collector, the construction plans of the building, cost of solar heating system, interest rates applicable, etc. Those interested in having a detailed analysis made for a particular building should contact the Agricultural Engineering Department, University of Kentucky, Lexington, Kentucky, 40546.

## READING LIST:

- Kreider, J. F., and F. Kreith (1975) Solar heating and cooling: engineering, practical design, and economics. Scripta Book Co., McGraw-Hill Book Co. 342 pp.
- Fundamentals of Solar Heating (correspondence course). January, 1978. HCP/M 4038-01. Available from: NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia, 22161.
- Kentucky Solar Energy Handbook. May, 1979. Available from: Office of Continuing Education and Extension, College of Engineering, University of Kentucky, Lexington, Kentucky, 40546. Price \$7.50.
- Introduction to Solar Heating and Cooling Design and Sizing. August, 1978. DOE/CS-0011. Available from: NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia, 22161. Price \$15.25.
- Mazria, Ed. The passive solar energy book. Rodale Press, Emmaus, Pennsylvania, 18049. Paperback—\$10.95.

## ADDITIONAL INFORMATION:

Federal Solar Energy Information, call toll free 1-800-523-2929 or contact Agricultural Engineering Department, University of Kentucky, Lexington, Kentucky, 40546.

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