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PASSIVE SOLAR HEATING - RESIDENTIAL

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Solar energy systems are generally divided into two categories, active and passive. An active solar space heating system collects the sun's energy outside the actual living area of the home. The sun's heat is then transported to point of use by mechanical devices and sophisticated control equipment. On the other hand, passive solar heating systems rely on the design and orientation of the house itself for the collection of solar heat. The building components (windows, walls, and floor) are designed to perform a particular function in the space heating system. A passive solar heating system uses few, if any, mechanical devices.

The use of passive solar design is not exclusive to new home construction. Many existing homes can be remodeled (often referred to as retrofit) for passive solar heating. The purpose of this pamphlet is to acquaint you with the basic principles of passive solar design and describe some passive design options.

CONSERVATION FIRST

When thinking of building a new solar home or retrofitting an existing home, you should be concerned with the overall energy efficiency of the home. Solar energy can make an effective contribution only in those instances where the home has been well insulated and air infiltration has been minimized. Your investment priority should be for a energy efficient building before proceeding with solar design options. Strong energy conserving construction practices from the foundation to the roof are the key to effective passive solar design. The home's interior should reflect the fact that it is solar heated. Concentrate those rooms in which you spend the most time on the south side of the home. These rooms will not only be warmer, but also will have more natural light. Concentrate storage areas, closets, or workrooms on the north side.

THE BASICS OF PASSIVE SOLAR

- Collection

The first important aspect of a passive solar design is collection of the sun's energy. This will require an unshaded southern exposure.

The south side of a structure will annually receive the predominant amount of sunlight, due to the fact that in the northern hemisphere the sun travels through the southern skyspace. South-facing windows therefore maximize solar gain. Shortwave radiation or light emitted by the sun is transmitted through the window area and is absorbed by objects inside the home. These objects reradiate that energy as long wave radiation or heat. The long wave radiation does not pass out through the windows as readily as the short wave radiation entered. This increases the temperature inside the structure. This phenomenon is known as the greenhouse

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effect and is familiar to anyone who has left car windows rolled up on a bright, sunny day.

The collection component in a passive solar home is the window area. The window area for solar transmission is commonly referred to as glazing. Most people typically think of glass, but plastic materials such as acrylic, polycarbonate, fiber reinforced plastic, and thin clear films are sometimes used as glazing material. The choice of glazing material you use will be determined by a number of factors. First, the material should transmit a large percentage of sunlight into the interior of the structure. A transmission of 75 - 95% of the available sunlight would be acceptable for solar gain applications. A second consideration is the ability of the glazing material to retard the flow of heat back out to the outside environment. Glass and rigid plastics perform better in this regard than do thin film plastics. A third factor influencing choice of glazing is the material's weatherability. For instance, glass is very resistant to surface abrasions but can be prone to breakage, while rigid plastics have just the opposite characteristics. Prolonged exposure to ultraviolet light can, in certain circumstances, cause yellowing and deterioration to some of the plastic materials. Thermal expansion, or the expansion of a material during temperature fluctuations, can also effect the life of the weatherseal of the glazing material. The final considerations for a glazing material are ease of handling and cost.

For space heating, the use of double glazing ensures a more efficient passive solar design. The second layer of glazing material separated by a dead air space gives greater insulating ability to the window area. While the added layer of material does reduce solar transmission, this loss is more than compensated for by the reduction in heat loss from the interior of the home. Double glazing will also reduce the chance of condensation forming on the windows. Triple glazing or double glazing with a high tech film suspended between the layers are both considerably more effective at reducing heat loss. Since both are substantially more expensive than standard double glazing, careful consideration must be given to cost versus insulation benefit.

- Storage

On a sunny day, a well-designed passive home will collect more solar energy than needed to maintain comfortable indoor temperatures. Thermal mass, such as water or masonry, can act as a flywheel, storing excess heat during the day and releasing that heat when temperatures drop during the night. While all materials have some capacity for heat storage, certain materials are primarily used due to their specific heat, high density, thermal conductivity, and relative low cost. Water and masonry exhibit good qualities in these regards with the capability to store significant amounts of heat over a small temperature range in a manageable volume. Thermal mass plays an important role in passive designs by moderating the high and low temperature extremes within the home. Masonry walls and floors or specially constructed water walls lessen daytime overheating problems by storing heat. Low nighttime temperatures are tempered by the release of this stored heat into the room. The location of thermal mass is an important design consideration for its effective performance. Mass which is located so that it is exposed to sunlight at least part of the day, and is dark in color, will be more effective at absorbing and storing the sun's energy.

Another heat storage approach used in passive solar designs is eutectic salt storage. Eutectic salts store large quantities of heat as they change phases from solid to liquid. This ability to store the heat of fusion allows a small volume of eutectic salts to store a large number of Btus. The eutectic salts return that stored energy back to the home when they re-solidify. The eutectic salts used in solar design in the last five years typically had melting points between 80 - 90°F. Some users of eutectic salts experienced problems with repeated melting and solidification of the salt. Newer salt solutions, however, are now able to achieve a variety of melting temperatures which makes them even more useful in passive solar design applications. Refinements in the salt solutions have also reduced the problems of resolidification of the salt.

DESIGN OPTIONS FOR THE HOMEOWNER

• Direct Gain

The direct gain home is the most straightforward approach to passive solar design. The window area is concentrated on the south side to allow sunlight into the interior of the home. This sunlight becomes heat as it is absorbed and reradiated by the interior of the structure.

The walls and/or floors in the direct gain design are masonry and serve as thermal mass. The design of the home, its orientation, depth, and length influence the location of thermal mass areas. In some cases, clerestories or skylights are used for directing sunlight to areas of thermal storage. Masonry fireplaces located on interior walls and exposed to the sun are sometimes employed to add additional mass to a direct gain design.

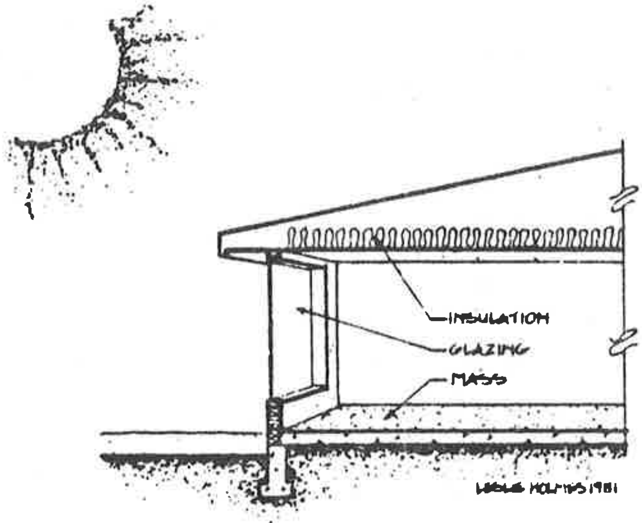

Figure 1. Direct Gain

The direct gain design is advantageous because the simplicity of its approach maximizes view potential, and provides excellent natural lighting. Utilizing the walls and floors of the home for heat storage means that the direct gain home needs little additional material for effective performance. This typically allows for lower construction costs. Some disadvantages of direct gain include glare from window area, ultraviolet light damage to household fabrics, and greater indoor temperature fluctuations than in other passive designs. Finally, when renovating existing homes for direct gain it can be difficult to obtain sufficient south-facing window area and thermal mass.

• Indirect Gain

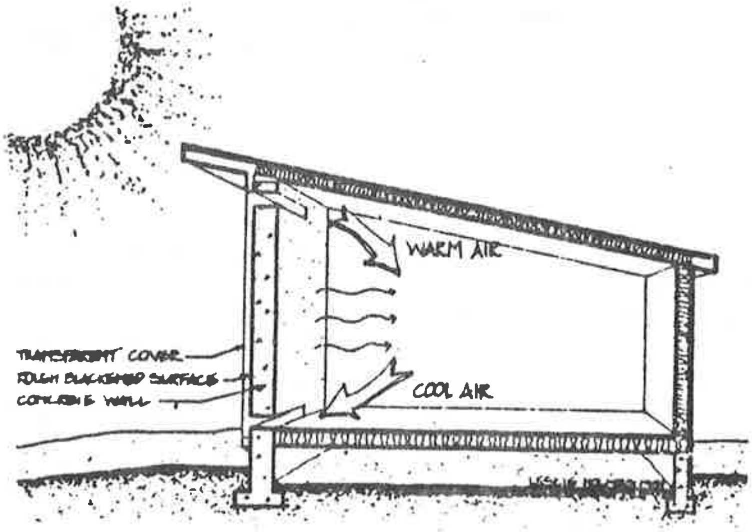

Figure 2. Indirect Gain

The indirect gain design places a wall of water or masonry directly behind the home's south-facing window area. The mass wall absorbs solar radiation that is transmitted through the glass. If the thermal storage wall is composed of masonry, it is often referred to as a trombe wall. The masonry material of the trombe wall absorbs sunlight throughout the day and conducts that heat through the wall. The heat is delivered to the interior of the structure by radiating from the living space side of the wall.

In some cases, small vent areas at the top and bottom of the wall are constructed to allow a natural convection air flow. During daylight hours, this air flow can bring warm air trapped between glazing and wall into the room. These vents are not necessary for efficient trombe wall performance.

The thermal storage wall design is attractive to some homeowners because it typically has less indoor temperature fluctuation than does direct gain. If the thermal storage wall is masonry it can be a structural component of the building shell. The rest of the home can then be wood frame construction. The trombe wall also tends to provide additional soundproofing for the home. Retrofitting existing homes is a possibility by adding water storage tubes behind southern windows. Uninsulated south-facing masonry walls make good candidates for trombe wall retrofits. Some of the disadvantages of thermal storage walls include restricting views to the home's south side and limited depth of space for radiant heat from the thermal storage wall. The cost of building a new thermal storage wall will vary depending on size and construction materials. The cost will typically be somewhat greater than a direct gain design home. Indirect gain systems tend to be more efficient in very sunny climates. In climates which have cloudy and partly cloudy conditions the indirect gain system will have limited practicality.

- Isolated Gain

Isolated gain is a term used to describe the solar greenhouse aspect of passive solar heating. The term isolated is used because the collection area, usually a greenhouse or sun space, is closed off or isolated from the rest of the house. This isolation prevents the greenhouse from becoming a source of heat loss during extended cloudy and cool periods.

The solar greenhouse is a popular passive design style because it offers the homeowner added living and gardening space as well as a source of supplemental solar heat. When attached or integrated into the south wall of the home, the greenhouse becomes a solar collector absorbing the sun's radiation. Temperatures inside the greenhouse increase so that excess heat can be transferred to the other areas of the home. This heat transfer process can be achieved by natural convection air flow through vents, doors, or windows. Other heat transfer options include using a fan to draw the greenhouse air into the home, heat transfer through a common masonry walls, or the use of a rock bin storage system.

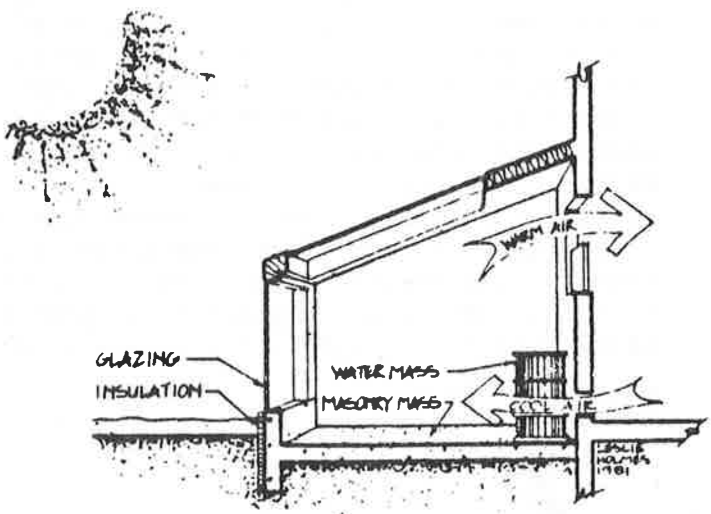

Figure 3. Isolated Gain

The solar greenhouse can be designed into new home construction or added on to the south wall of existing homes. Solar greenouses are sometimes owner-built additions. However, the attached solar greenhouse requires a large area for collection in order to provide a significant amount of supplemental heat for the home. The small greenhouse addition built over doors and windows of the home typically provides only a modest heat contribution to the home. The cost of a solar greenhouse can typically range from $1,000 - $25,000 depending on the size and quality of the greenhouse and whether you build it yourself or have it contractor installed.

• Thermosiphon Air Panels

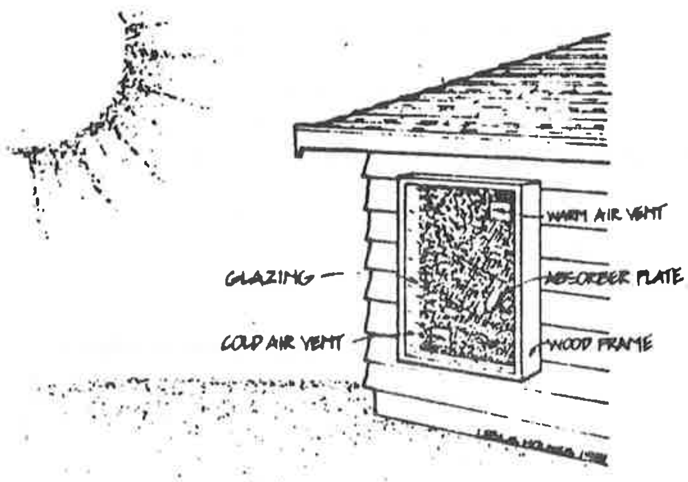

Figure 4. Thermosiphon Air Panels

The thermosiphon air panel (TAP) design is typically used for renovating the south wall of existing houses. The TAP systems resemble active flat plate collectors which are mounted vertically to the exterior wall of the home. The TAP system is designed with a metal absorber plate which is contained in an insulated frame. A glass or plastic glazing material transmits sunlight onto the absorber plate. Air is heated by the absorber plate and flows naturally to the top of the TAP panel. Vents at the top and bottom of the panel allow this warm air to circulate into the home. Backdraft dampers on the vents prevent warm air loss at night.

The thermosiphoning air panel is an inexpensive approach to retrofitting existing homes with solar energy. A minimum investment, generally under $500, allows for the addition of one or more panels to the south wall of homes with light frame construction. The disadvantages of TAP systems include the fact that there is not heat storage, making them useful only during sunny daytime hours. In addition, TAP panels will typically heat only those rooms directly adjacent to the panel. Finally, a large area of panels is required for a significant contribution to the home's heating needs. A commercially available variation of the TAP panel uses a fan to promote air circulation. Even with the addition of the fan, each wall collector can provide only a modest amount of room heat. Homeowners should always weigh the benefit of adding basic conservation items, before buying solar add-ons.

• Double Wall Envelope

The double wall envelope is a slightly different approach to passive solar design which became popular in the early 1980s. The performance of the envelope design relies heavily on the moderating effect of a constant ground temperature as well as solar gain. The home is designed with a continuous double wall construction on the south and north walls as well as in the ceiling and basement area. This construction allows for a continuous loop envelope around the home. A south-facing greenhouse serves as a solar collector feeding warm air into the loop circling the home. This solar heated air reduces the home's need for auxiliary heat. During times of little to no sunshine, ground source heat enters the loop from the basement and moderates temperatures within the double wall loop.

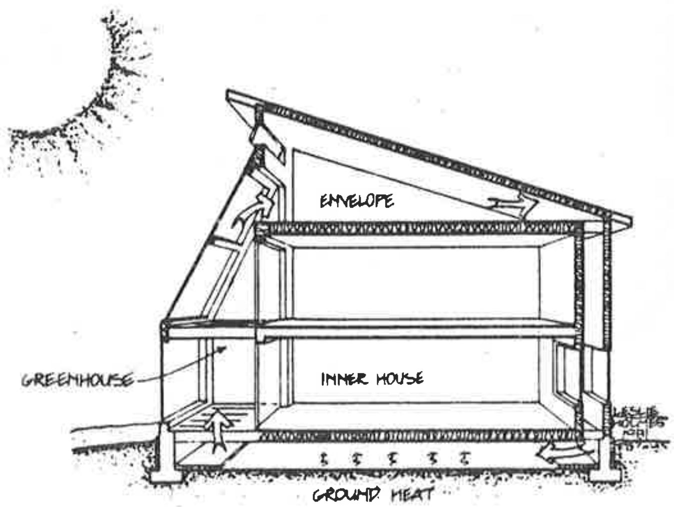

Figure 5. Double Wall Envelope

The envelope home's use of a solar greenhouse gives the design advantages similar to those of the attached greenhouse. The home's wall construction, two walls which are both insulated, and the buffering effect of the surrounding loop reduce significantly the home's heating needs. Owners of envelope homes report that little additional heat from conventional sources is needed during the winter. It should be noted, however, that construction costs of the envelope design will be higher than conventional construction due to increased material cost of the double wall design. Also precautions have to be taken to protect the double wall system from fire. In some cases either fire dampers or sprinkler systems have to be installed.

SUGGESTED READING

- Mazria, Edward. The Passive Solar Energy Book. Rodale Press. Emmaus, Pennsylvania. 1979.

  This book can be used as a primer on passive solar energy as well as a resource guide and workbook. Principles of solar energy are discussed clearly and illustrated in detail. Enough additional information is provided to apply those principles to individual cases.

- Carter, Joe. Solarizing Your Present Home. Rodale Press. Emmaus, Pennsylvania. 1981.

  This is a complete homeowners guide to energy conservation and solar projects for the home. Projects detailed range from plugging a house's heat leaks to building air collectors and solar greenhouses.

- Anderson, Bruce and Wells, M. Passive Solar Energy. Brick House Publishing. Andover, Massachusetts. 1981.

  This book is an excellent start for someone just getting acquainted with solar energy. It is neatly divided into four major sections: solar basics, passive solar heating, passive solar cooling, and a wrap-up which pulls it all together. An attractive color photo section and useful appendices are included.

This factsheet was written by Edwin L. Valbert. Illustrations provided by Leslie Holmes.