MASTER

BUILDING WITH PASSIVE SOLAR

**AN APPLICATION GUIDE
FOR THE
SOUTHERN BUILDER**

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AN APPLICATION GUIDE FOR THE
SOUTHERN HOMEOWNER & BUILDER

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SOUTHERN SOLAR ENERGY CENTER

A REGIONAL CENTER OPERATED FOR THE U.S. DEPARTMENT OF ENERGY
61 PERIMETER PARK ATLANTA, GEORGIA 30341

FOREWORD

This material was prepared by the staff of the Southern Solar Energy Center for use in the instruction of builders, home designers and others interested in the practical application of passive solar design methods. It was originally used during the summer of 1980 during training workshops with several groups of builders. The format involves considerable use of illustrations, charts, and "key point summary statements" in a manner which permits the use of viewgraph techniques by an instructor. This permits the written copy to parallel the instructor's charts with sufficient space to make individual notes.

The basic design information is universal and is not limited to any geographic constraints; however, some of the charts and maps are only pertinent to the southern area of the United States. Thus, some additional information should be obtained from competent professionals or other appropriate sources when working on applications in other areas.

DONALD W. ABRAMS
RICHARD E. SEEDORF

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SPECIAL CREDITS

Illustrations: Robert Wright

Technical Assistance: Dave Marlatt
Jon Rubel
Greg Winkler

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SUSTAINABLE

INTRODUCTION

1

INTRODUCTION

Energy crisis. Energy shortage. Energy problem. Regardless of the name you use, America is faced with an important challenge - the petroleum and natural gas supplies we depend on for transportation and heating and cooling our homes are dwindling. Prices have recently surged upward in response to diminishing supplies, higher production costs and the collective pricing actions of the OPEC cartel. The economic, social and political implications are being felt throughout the country and the world. As individuals and as a society, we must respond by developing new energy sources and by becoming more efficient consumers of energy.

The next two decades will be a time of transition, a time of discovery and change. America has successfully met similar challenges several times in our history. Transportation has moved from animal and wind power to coal power and finally to the petroleum driven internal combustion engine. Building heating energy sources have shifted from wood to coal and on to petroleum and natural gas. In each case, the transition provided a more easily usable and powerful energy source. However, the current transition is being driven by depletion; it will not be easy.

INTRODUCTION

There is a great deal of disagreement on the question of which new energy sources should be developed most aggressively. Advocates variously promote coal, ocean thermal systems, shale oil, fission, fusion, geothermal sources, orbiting photovoltaics, alcohol and biomass. One point is clear: during the next century, no single energy source will meet all of our needs. A combination of existing and new sources must be used.

The intelligent and efficient use of our existing energy supplies is equally as important as the development of new sources. Here individuals are the key - designers, builders, homeowners and building occupants - in transportation, careful trip planning and fuel-efficient vehicles are two tactics. In housing, energy conserving construction, careful operation and use of environmental forces provide opportunities.

Efficient use will allow us to stretch our petroleum and natural gas resources until new sources are available. The ultimate demand on those new sources will be reduced; the research and development job will be easier. Also the economic, social and political impact of the price/supply forces will be minimized.

PAST EXPERIENCE

In the South, there is a rich heritage of recognition and utilization of environmental forces in building design and construction. For years, nature provided the only air-conditioning in the South, and houses were designed to make use of whatever cooling was available. Broad-leaved magnolia trees and wide verandas were more than picturesque - they offered shade from the hot summer sun. Inside, high ceilings allowed warmer air to rise above the living area, open hallways and doors permitted maximum cross-ventilation.

The "dogtrot" plan allowed each room to ventilate on at least three sides. Breezeways, porches, patios and balconies allowed people to move outdoors to enjoy mild springs and autumns. By combining these historical concepts with new technologies, construction techniques and materials, new homes can be built that use less than one fourth of the heating and cooling energy of a typical Southern house. This book focuses on the practical design and construction of passive solar houses which conserve heating and cooling energy and draw on the sun, the wind, the earth and landscaping to provide comfortable, affordable homes for their owners.

*HEAT

*MASS

*SPECIFIC HEAT

*DELTA T

*ENERGY EQUATION

*TEMPERATURE

*HEAT TRANSFER

*HEATING DEGREE DAY

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*MEAN RADIANT TEMPERATURE

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FUNDAMENTALS

2

HEAT

HEAT is a basic form of energy, usually designated by the letter Q.

Heat is usually measured in British Thermal Units or BTUs. One BTU is approximately equal to the heat given off by one match.

HEAT = Q

Technically, it is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

ΔT , pronounced "Delta T" is an abbreviation for temperature change. As water is heated from 72°F to 73°F it undergoes a ΔT of one degree Fahrenheit.

Usually as the amount of heat energy stored in an object changes, the temperature also changes. The greater the change in stored heat energy, the greater the change in temperature. Temperature provides a convenient indication of the level of stored heat energy.

$$\Delta T = 73 - 72 = 1^\circ \text{ F.}$$

MASS

Mass is a measure of the amount of material in an object. The strict definition of mass involves consideration of gravity, falling apples and confusing forces; however, matters may be simplified somewhat by confining the discussion to the planet Earth. For most purposes, mass is the equivalent of weight. The heavier the object - the higher the mass.

As shown, one cubic foot of water has the same mass as 821 ft.³ of air at room temperature. Although the mass of these two samples is the same, there is obviously something different - their volume. 62.4 pounds of water will fit into a one cubic foot space. An equivalent mass of air requires 821 cubic feet. This variation is described by the density of the material, abbreviated as "ρ".

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad \frac{\text{lbs.}}{\text{ft.}^3}$$

$$\text{Density of Water} = \frac{62.4 \text{ lbs.}}{\text{ft.}^3}$$

$$\text{Density of Air (room temperature)} = \frac{62.4 \text{ lbs.}}{821 \text{ ft.}^3} = \frac{.076 \text{ lb.}}{\text{ft.}^3}$$

The amount of mass in a sample is influenced by the volume of the sample, V, in ft.³, and the density of the material, ρ in lb./ft.³.

$$M = \rho v \quad \text{lbs.}$$

MASS =

SPECIFIC HEAT

SPECIFIC HEAT describes how a material's temperature changes when heat is added.

Specific heat is abbreviated as C_p . Its units are BTU/lb°F.

The formal definition of specific heat is: the amount of heat required to raise the temperature of one pound of the material by one degree Fahrenheit.

A material with a high specific heat can absorb a large amount of energy with a small increase in temperature. On the other hand, an equal amount of a material with a low specific heat undergoes a much greater increase in temperature when heat is added.

MATERIAL		C_p Btu/lb °F
water :	1.00
air :	.24
rock :	.19
concrete :	.21
wood :	.33

THE EQUATION

Heat, mass, specific heat and temperature change can be related with a simple equation.

$$Q = MC_p\Delta T$$

WHERE:

- Q** = AMOUNT OF HEAT, (BTU)
M = MASS OF OBJECT, (lbs)
C_p = SPECIFIC HEAT, (BTU/lb°F)
ΔT = CHANGE IN TEMP., (°F)

For example, how much heat is required to raise the temperature of 1000 lbs. of concrete from 60°F to 80°F?

$$Q = ?$$

$$M = 1000 \text{ lbs.}$$

$$C_p = .20 \text{ BTU/lb°F (for concrete)}$$

$$\Delta T = 80^\circ\text{F} - 60^\circ\text{F} = 20^\circ\text{F}$$

$$Q = 1000 \text{ lbs.} (.20 \text{ BTU/lb°F}) (20^\circ\text{F})$$

$$Q = 4000 \text{ BTU}$$

TEMPERATURE

Temperature also provides an indication of how useful a particular heat source is for a certain application. Utilizing a heat source is easiest when the temperature of the source is much higher than the temperature required by the application.

When the temperature of the source is below the temperature required by the application, a special problem exists. Heat from the source will not flow uphill on the temperature scale to the application. However, like water, it can be pumped uphill - with mechanical equipment and the use of additional energy. Electric powered heat pumps "concentrate heat available in cool outside air and deliver it at a higher temperature to the interior of a house.

R - VALUE..... RESISTANCE VALUE

We frequently use insulation to reduce the rate of heat transfer. Insulation cannot stop the flow of heat. Even the best beverage cooler cannot keep canned drinks cold forever.

When we insulate a house, we are attempting to slow the rate at which the house loses or gains heat from its surroundings. The ability of insulation to slow heat flow is described by its R-value or resistance to thermal transfer. The higher the R-value, the better the insulating effect and the lower the rate of heat flow.

HEAT TRANSFER

Heat can be transferred by three basic means: conduction, convection and radiation.

Regardless of the process, heat always flows naturally from hot objects to cool objects - downhill on the temperature scale.

CONDUCTION

CONDUCTION is the flow of heat through a solid object. If you hold a poker in a fire, heat is conducted up the handle and into your hand. Heat flows through the wall of a house primarily by conduction.

RADIATION

RADIATION is the transfer of heat by electromagnetic waves. The earth receives heat from the sun by radiation. Radiant heat transfer to your body is quite apparent when you stand in front of a hot fire.

CONVECTION

Heat is transferred by moving gases and liquids by CONVECTION. Convection heat transfer is illustrated by the flow of hot air and smoke up a chimney.

TEMPERATURE DIFFERENCE THE DRIVING FORCE FOR HEAT TRANSFER

For all three heat transfer mechanisms, the rate of heat transfer depends upon the difference in the temperature of the object losing heat (hot object) and the object receiving heat (cool object). As the temperature difference, also abbreviated ΔT , increases, the rate of heat transfer increases. Temperature difference causes heat flow like pressure difference causes water flow in a pipe, or like voltage difference causes electric current flow in a wire.

Nature constantly tries to move heat from hot objects to cool objects, reducing temperature differences.

THERMODYNAMICS

Thermodynamics is the study of energy and its transformation from one form to another. It is a very complicated science which sometimes borders on philosophy in describing energy processes. The information below is an extreme simplification of some basic but quite important concepts.

1

First law - You don't get something for nothing. Regardless of what the little arrows on the drawings say, a Trombe wall cannot release more heat into a room than it receives from the sun.

2

Second law - You can never go back. Heat always flows from high temperature to low temperature.

A warm Trombe wall will lose heat to a cool room, but a cool room will never put heat into a warm Trombe wall. Don't expect heat to flow from the earth at 60°F into a basement at 65°F.

NOTE: Heat can be made to flow from a low temperature to a high temperature only if outside energy is used to force the process. The heat pump provides an example.

HEATING DEGREE DAY

The heating degree day (HDD) is used to describe the severity of the heating season in a particular locale. The higher the number of heating degree days, the "colder" the locale.

The heating degree day concept is based on the assumption that with an outside temperature of 65° or higher, the heat given off by people, lights, and appliances will maintain an indoor temperature of 72°F in a typical house, with no additional heat from mechanical or solar systems. HDDs are calculated by comparing the average outdoor temperature for the day to the 65°F base.

If the average outdoor temperature is 65°F or higher, there are no HDDs for that day. But with an average outdoor temperature of 20°F, there is a 45°F difference for one day, or 45 degree days.

$$(65^{\circ}\text{F} - 20^{\circ}\text{F}) \times 1 \text{ day} = 45 \text{ HDD}$$

45 HDD could also be accumulated over three days, each with an average outdoor temperature of 50°F.

$$(65^{\circ}\text{F} - 50^{\circ}\text{F}) \times 3 \text{ days} = 45 \text{ HDD}$$

In either case, the energy required to heat the house would be approximately equal.

Since modern houses are better insulated and weatherized than houses being built when the 65°F base was chosen, it is sometimes necessary to make degree day adjustments in energy calculations.

SAMPLE HDD

MOBILE, AL	1560
WILMINGTON, DL	4930
MIAMI BEACH, FL	141
ATLANTA, GA	2983
NEW ORLEANS, LA	1385
BALTIMORE, MD	4654
JACKSON, MS	2239
ASHVILLE, NC	4042
OKLAHOMA CITY, OK	3725
CHARLESTON, SC	2033
CHATTANOOGA, TN	3254
DALLAS, TX	2363
RICHMOND, VA	3865
CHARLESTON, WV	4476
SAN JUAN, PR	0

COOLING DEGREE DAY

Cooling degree days are also calculated using a 65°F base to describe the severity of a particular locale's cooling season. A higher number in this case means a "warmer" climate.

Three major factors contribute to a building's cooling load: heat generated inside the house, the outside air temperature; and heat from the sun. Since cooling degree day calculations consider only the outside air temperature, they do not provide an accurate measurement of seasonal cooling requirements. However, they do provide a convenient measure of the cooling load caused by outside air temperature.

(Average Daily
Outdoor Temp. - 65) x No. of days =
Number of Cooling Degree Days

SAMPLE CDD

MOBILE, AL	2577
WILMINGTON, DL	992
MIAMI BEACH, FL	4183
ATLANTA, GA	1589
NEW ORLEANS, LA	2706
BALTIMORE, MD	1491
JACKSON, MS	2321
ASHEVILLE, NC	872
OKLAHOMA CITY, OK	1876
CHARLESTON, SC	2354
CHATTANOOGA, TN	1636
DALLAS, TX	2755
RICHMOND, VA	1353
CHARLESTON, WV	1055
SAN JUAN, PR	4982

MEAN RADIANT TEMPERATURE

Mean Radiant Temperature, MRT, is one of the major determinants of human comfort. MRT is the area-weighted average of the temperatures of the surfaces around a body. For most purposes, these surfaces are the walls, ceiling and floor of a room. A person standing inside the room will lose or gain heat by radiant transfer to the walls, ceiling and floor. The rate of radiant transfer depends upon the temperature of the surfaces in the room. It is possible to be comfortable in a very cool room if the MRT is high. It is equally possible to be uncomfortable in a room where the air temperature is high, if the MRT is low - possibly as a result of poorly insulated walls. For heating purposes, it is usually possible to reduce the thermostat setting (air temperature) by 1.4°F for each one-degree increase in MRT.

Examples of the importance of MRT are plentiful. During winter a warm brick wall (Trombe wall or massive fireplace) will improve comfort by increasing the MRT. On the other hand, large expanses of single-glazed glass will be much closer to the outside temperature - leading to a low MRT and decreased comfort.

VOLUMETRIC HEAT CAPACITY $\text{BTU}/^{\circ}\text{f} \cdot \text{ft}^3$

Specific heat is not the only property which must be considered when selecting storage materials. Concrete and air have roughly the same specific heat, but since the density of air is so low, it is impractical for heat storage due to unreasonably large volumes which would be required.

Another way to consider heat storage capacity is the volumetric heat capacity - in $\text{BTU}/^{\circ}\text{F}$ per cubic foot of material, $\text{BTU}/^{\circ}\text{F} \cdot \text{ft}^3$.

Since space is a consideration in most designs, the volumetric storage capacity of a material is important.

VOLUMETRIC HEAT CAPACITY OF FOUR COMMON MATERIALS $\text{BTU}/^{\circ}\text{f} \cdot \text{ft}^3$				
	air	rock bed	concrete	water

ABSORPTANCE REFLECTANCE TRANSMITTANCE

When solar radiation strikes a surface, it is either absorbed, reflected or transmitted through the material. The fraction of the total energy that takes each path defines the absorptance, reflectance and transmittance of the material sample.

$$\text{ABSORPTANCE} = \frac{\text{Energy Absorbed}}{\text{Total Energy}}$$

$$\text{REFLECTANCE} = \frac{\text{Energy Reflected}}{\text{Total Energy}}$$

$$\text{TRANSMITTANCE} = \frac{\text{Energy Transmitted}}{\text{Total Energy}}$$

Absorptance and transmittance are particularly important properties to consider in designing passive systems. The surface of a thermal storage mass exposed to the sun should have a high absorptance value while glazing materials for heating applications should have high transmittance values.

Absorptance and transmittance values for common materials are shown in the tables on the next page. All values are for radiation which strikes the surface perpendicularly (incident angle = 0). As the incident angle becomes larger (radiation strikes at a greater angle), the absorptance and transmittance drop while the reflectance increases.

$$\begin{aligned} \text{Total Energy} = & \% \text{ Reflected} \\ & + \% \text{ Absorbed} \\ & + \% \text{ Transmitted} \end{aligned}$$

ABSORPTANCE REFLECTANCE TRANSMITTANCE TABLES

SOLAR ABSORPTANCE FOR VARIOUS MATERIALS *

Masonry

Uncolored concrete	.65
Brown concrete	.85
Black concrete	.91
Red bricks	.70
Moderately light buff bricks	.60
Stafford blue bricks	.89

Paints

White lacquer	.21
White gloss paint	.25
White semi-gloss paint	.30
Black lacquer	.92
Flat black paint	.95
Optional flat black paint	.98
Black oil paint	.90
Dark gray paint	.91
Light gray oil paint	.75
Dark blue-gray paint	.88
Dark blue lacquer	.91
Medium blue paint	.51
Azure blue or dark green lacquer	.88
Dark olive drab paint	.89
Medium dull green paint	.59
Medium kelly green paint	.51
Light green paint	.47
Brown or green lacquer	.79
Dark brown paint	.88
Medium brown paint	.84
Medium light brown paint	.80
Medium rust paint	.78
Red oil paint	.74
Medium orange paint	.58
Medium yellow paint	.57
Silver paint	.25

Miscellaneous

Polished aluminum reflector sheet	.12
Aluminized mylar film	.10
Laboratory vapor deposited coatings	.02

NOTES:

- 1). This table is meant to serve as a guide only. Variations in texture, tone, overcoats, pigments, binders, etc., can vary these values.
- 2). Reflectivity for a particular material equals $(1 - \text{Absorptance value.})$ For Opaque Surfaces

* Balcomb, J. Douglas, et al., Passive Solar Design Handbook, Volume Two: Passive Solar Design Analysis, Los Alamos Scientific Laboratory and University of California, January 1980, p.75.

SOLAR TRANSMISSION-GLAZING TYPES*

Glazing Type	Thickness	% Solar Transmission
Glass-Sunadex®	.125"	91
	.188"	92
Acrylic-Plexiglas®	.125"	89
	.250"	87
Acrylic-SOP®	.625"	83
Fiberglas-Sunlite®	.025"	85
Polyester-3M	.004"	96
-Flexiguard®	.007"	89
	.011"	91
Polycarbonate-Lexan®	.040"	85
	.250"	89
-Tuffak		
Twin-Wall	.220"	77
Fluorocarbon-Teflon®	.001"	96
Polyvinyl-Fluoride-Tedlar®	.004"	90

NOTE: This table only includes a sampling of glazing materials. A more complete list is available from the National Solar Center. Contact the manufacturer for more complete or current information.

*Adapted from: TELFON® FEP FILM AS INNER GLAZING IN FLAT PLATE SOLAR COLLECTORS, R. Ribbens, III; Proceedings of "Solar Glazing: 1979 Topical Conference", pp. B35-40.

ALTITUDE AND AZIMUTH ANGLE

Altitude and Azimuth Angles are used to define the sun's position at any time of the day for any month of the year. There are numerous charts and tables which give the sun's location in terms of these two angles.

In designing and locating passive solar buildings, it is critical that we know the sun's position with respect to our "collector area." The two important angles for this purpose are the ALTITUDE ANGLE and the AZIMUTH ANGLE.

When using the sun-angle charts, make certain that you use the latitude nearest where you will be building.

As one moves further north, say from Miami up to Louisville, the sun appears lower and lower in the sky (i.e. the ALTITUDE ANGLE becomes less and less.)

To find the Altitude Angle, face the sun and point a finger at it. The angle formed by your extended arm and a horizontal is the ALTITUDE ANGLE.

To find the Azimuth Angle, point due south with one hand and point towards the sun with the other. The angle between your arms is the AZIMUTH ANGLE.

RELATIVE HUMIDITY

Humidity plays a very important role in human comfort. In the southern United States, humidity combined with high temperatures often results in very unpleasant living conditions. In designing a passive house, it is important to understand the daily temperature and humidity relationships in order to determine when to open a building up to the outside air and when to isolate it.

The amount of moisture in the air is generally measured in relative humidity. Relative humidity, or RH, is the amount of humidity in the air relative to the maximum amount it can hold at a given temperature. Measured as a percentage, 0% indicates a total absence of humidity and 100% indicates that the air is fully saturated with moisture.

HUMAN COMFORT

In order to survive and be comfortable, the human body must maintain its inner organs within a very narrow temperature range. This is accomplished by three mechanisms: generating heat inside the body, losing heat to the surroundings and gaining heat from the surroundings. The body's automatic systems are constantly making small changes in its operations to control these three mechanisms and regulate the inner temperature. These automatic controls function twenty-four hours a day, responding to constantly changing activity levels and environmental conditions without any conscious input from the occupant of the body. When conditions become too severe and the inner temperature begins to drift, the body calls for help by telling the mind "we're uncomfortable!" The mind quickly checks the situation and responds by having the body loosen a collar, move into the shade, put on a sweater, move closer to the fire...and so on.

comfortable??

In addition, the body has a whole repertoire of responses that it uses without consulting the conscious mind. These include:

SHIVERING - Increased muscle activity, higher metabolic rate, more internal heat production.

SWEATING (perspiring, for proper gentlemen; glistening, for dainty ladies) - Moistened skin surface for evaporative cooling and increased heat loss to the surroundings.

MODIFYING BLOOD FLOW PATTERNS - Reduced flow to the feet, hands and skin surface to minimize heat loss to the surroundings (numb fingers and blue skin), or increased blood flow to the skin surface to increase heat loss (red, flushed skin).

GOOSE BUMPS - Fluffs up hair on the skin to provide better insulation and reduce heat loss. (The body doesn't realize that it evolved away most of its body hair thousands of years ago.)

Air temperature is the most significant ambient factor which affects our internal temperature and our level of comfort. But, it is not the only factor involved; air speed, humidity and mean radiant temperature must also be considered. Each of these four factors has a direct influence on the rate at which the body loses or gains heat to or from the surroundings.

AIR TEMPERATURE - Affects the ΔT or temperature difference between the body and the surroundings, consequently affecting the rate of heat loss or gain by convection.

AIR SPEED - Affects the rate at which the body loses heat by convection. The chill factor is one way to quantify the effects of air speed on heat loss. An air temperature of 35°F and a wind speed of 20 miles/hour combine to give a wind chill temperature of 11.2°F. This means that a body exposed to 35°F air and 20 mile/hour wind loses heat at the same rate as a body exposed to 11.2°F and no wind. Air speed is also very important during summer when the body is trying to lose heat to maintain comfort.

MEAN RADIANT TEMPERATURE (MRT) - MRT is the average of the surface temperature of the surroundings with which the body can exchange heat by radiant transfer. Radiant heat transfer to and from the body is quite apparent when sitting near a fireplace (high MRT) or large cold window area (low MRT).

HUMIDITY - Affects the rate at which the body loses heat by evaporation. During hot weather, high humidity increases discomfort by making it more difficult to evaporate perspiration into the air.

BIOCLIMATIC CHART

One convenient method of describing the impact of temperature, humidity, wind and MRT is the Bioclimatic Chart developed by V. Olgyay. Dry-bulb air temperature is plotted on the vertical axis and relative humidity (RH) on the horizontal axis. An oblong area near the center of the graph encloses the combination of temperature and humidity which most people would find comfortable during the summer.

TEMP & REL HUMIDITY

For example, 76°F and 40% RH would be considered comfortable by most people, while 76°F and 80% RH would not.

As the seasons change, our standard of comfort changes. The dashed line defines the winter comfort zone, indicating that we become somewhat acclimated to colder weather.

Clothing, activity, and other factors also have an effect on comfort.

BIOCLIMATIC CHART

Similarly, the impact of mean radiant temperature is shown by the two MRT scales on the left, above and below the comfort zone. The scale above the comfort zone represents the effect of surrounding surfaces which are cooler than the dry-bulb air temperature and the scale below shows the effect of warmer surfaces.

MRT & AIR SPEED

The effect of air speed is shown by the lines which lie above the comfort zone, roughly parallel to the upper edge. When the dry-bulb air temperature falls above the comfort zone, the air speed lines show the rate of air movement required to give comfort equivalent to a lower temperature in the comfort zone.

A cool concrete basement wall in the summer and a warm masonry fireplace in winter provide examples. Each of these two MRT scales shows the mean radiant temperature required to move a plotted set of temperature/humidity conditions back into the comfort zone.

BIOCLIMATIC CHART

COMPOSITE

The comfort zones shown on the chart assumes that the "average person" is in the shade. The impact of a fifth factor, solar radiation, may also be included in the chart. The roughly horizontal lines below the comfort zone show the level of solar radiation required on the body to bring the set of conditions back into the comfort zone.

The Olgyay Bioclimatic Chart is quite useful in understanding energy-conserving and passive solar design. The negative effect of drafts caused by leaky doors and windows is easily seen. Also, well-insulated walls reduce heat loss and provide warmer inside wall surfaces during winter and cooler surfaces during summer. The MRT scales show how this helps provide comfortable conditions. Looking at the solar radiation curves, the benefit from sunshine entering the building during winter is quite apparent. Finally, the outdoor climatic conditions for the building site can be plotted to illustrate when cooling, heating (solar or conventional) or just ventilation are needed.

Air temperature is not the only factor which has an impact on human comfort - air speed, humidity and mean radiant temperature are also important. As varied and wonderful as the body's automatic temperature controls are, they are not adequate by themselves. We must depend on shelter - our homes - to protect us from the sometimes hostile ambient conditions. A well-insulated and sealed passive solar house can provide comfort at lower thermostat settings than a conventional house, so...more energy savings.

*CLIMATE

*MICROCLIMATE

- Temperature
- Wind
- Humidity
- Solar Radiation

*SITE ANALYSIS AND SELECTION

- Winter Heating
- Summer Cooling

*SITE DESIGN FOR BOTH
HEATING AND COOLING

*PEOPLE CONSIDERATIONS

SITE & CLIMATE

3

INTRODUCTION

During the last seventy-five years we Americans have enjoyed a luxury no other society has ever known - the ability to neglect climate in the design of our homes. Comparatively low energy prices coupled with powerful heating and cooling systems have made it possible to build the same three bedroom ranch-style house in Buffalo or Tampa or Denver without concern for the sun, wind temperature or other climatic variables. The "luxury" is the fact that we could neglect these factors--and utilize energy consuming mechanical systems to maintain comfort.

But, the situation is changing, we are encountering supply interruptions and rapidly escalating prices. It's time to take a positive step back to design in accordance with the climate.

Designers, builders, and homeowners in the Southeast have the good fortune of dealing with one of the most moderate climatic regions in the world. Neither the winters nor the summers pose the extreme conditions found in other regions and the springs and falls are long and pleasant. But there is a rather unique problem-- the co-existence of significant heating loads and cooling loads. The only exceptions are Puerto Rico, the Virgin Islands and South Florida, which have virtually no heating load.

Throughout the majority of the South, heating is the more serious concern - both in terms of energy consumed and cost. But even the Gulf Coast consistently experiences sub-freezing winters, and cooling can't be neglected in the northern parts of the region. It's a two-faceted problem.

CLIMATE

In order to provide low-cost, year-round comfort, southeastern houses must be versatile, responding to both heating and cooling needs.

The magnitude and relative balance of heating and cooling needs vary somewhat within the region, in accordance with the climate. Climate can be discussed at several levels. While certain generalizations about climate and building design can be made at a regional or area level, the better low-energy designs demand a closer focus. Each individual building site has its own unique combination of climate forces and site features - its own microclimate. Sometimes the variations between the microclimates at individual sites in an area are quite small and may be safely neglected. But often, the presence of hills, buildings, paved areas, trees or lakes can significantly alter the climatic conditions at a specific site. The microclimate at the site may present a special opportunity or require additional effort to avoid a potential problem. The best way to assess a site's microclimate is to visit the site. Look it over, feel the breezes, talk to the neighbors.

REGION

STATE

CITY

SITE

MICROCLIMATE

The microclimate at a potential building site may be described by considering its four major elements: temperature, wind, humidity, and solar radiation. Long-term records of these four elements are published for hundreds of sites in the southeast by the National Oceanic and Atmospheric Administration. While this data provides an essential reference point, it may be somewhat misleading. A variety of features at or near the site can cause significant variations in each of these four elements.

NORMALS, MEANS AND EXTREMES
(Table Revised 1969. Base Period for Climatological Normals: 1951-1980)

Temperature °F										Normal Degree Days °F	
Normal					Extremes					Heating	Cooling
Month	Daily maximum	Daily minimum	Mean	Range	Year	Year	Year	Year	Year		
Jan	35.4	23.2	29.3	12-48	1974	1975	1976	1977	1978	701	290
Feb	38.1	26.0	32.1	15-51	1974	1975	1976	1977	1978	612	200
Mar	41.2	29.1	35.2	18-54	1974	1975	1976	1977	1978	523	110
Apr	44.3	32.0	38.2	21-57	1974	1975	1976	1977	1978	434	0
May	47.4	34.9	41.2	24-60	1974	1975	1976	1977	1978	345	0
Jun	50.5	37.8	44.2	27-63	1974	1975	1976	1977	1978	256	0
Jul	53.6	40.7	47.2	30-66	1974	1975	1976	1977	1978	167	0
Aug	56.7	43.6	50.2	33-69	1974	1975	1976	1977	1978	78	0
Sep	59.8	46.5	53.2	36-72	1974	1975	1976	1977	1978	0	0
Oct	56.9	43.6	50.3	33-69	1974	1975	1976	1977	1978	0	0
Nov	50.0	37.7	43.9	27-63	1974	1975	1976	1977	1978	0	0
Dec	38.1	26.0	32.1	15-51	1974	1975	1976	1977	1978	0	0

Mean number of days:
 0 or more days at or above 60°F: 197
 0 or more days at or below 32°F: 197
 0 or more days between 32°F and 60°F: 197

Relative humidity: 70% (1974-1978)
 70% (1951-1980)
 70% (1951-1980)

Precipitation: 47.4 (1974-1978)
 47.4 (1951-1980)
 47.4 (1951-1980)

Snow: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Ice: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Freezing: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Thawing: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Clouds: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Wind: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Thunderstorms: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with rain: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with snow: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with ice: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with fog: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with haze: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with drizzle: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with sleet: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with hail: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with rain or snow: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with rain or sleet: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with rain or hail: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with snow or sleet: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with snow or hail: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with rain, snow, or sleet: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with rain, snow, or hail: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with snow, sleet, or hail: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with rain, sleet, or hail: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Days with rain, snow, sleet, or hail: 0 (1974-1978)
 0 (1951-1980)
 0 (1951-1980)

Temperature is strongly influenced by the presence of large urban areas which collect and store heat. Suburban and rural areas are consistently several degrees cooler than urban areas; a recent study in Atlanta showed a twelve-degree increase from a wooded suburb to the downtown area. Also, average air temperatures normally decrease with increasing elevation at the rate of about three degrees per thousand feet. Large bodies of water tend to moderate extremes of temperatures. Finally, cooler air tends to flow like large rivers downhill into valleys and low-lying areas, creating cool areas.

MICROCLIMATE (cont.)

Local variations in winds are enormous, weather station data is useful only as a guide to prevailing conditions. Hills, trees, buildings and other features at the site frequently alter the larger wind systems. Wind may be slowed or blocked completely by site features or diverted to another direction or even funneled into smaller, faster streams. Paved areas, lakes, fields or woods which heat up at different rates than the terrain around them can actually create wind systems.

Winds throughout most of the Southeast are quite variable and undependable. A single generalization may be made - the coldest winter winds come from the Northwest.

Vegetation, bodies of water and temperature variations all have an effect on relative humidity. However, short of avoiding trees, water and cool air, there's not much that can be done.

Solar radiation data is more difficult to obtain, but fortunately, it may be generalized more easily than most other climatic factors. Although some local variations from site to site in available radiation do exist, they are relatively small. Microclimate concern about solar radiation availability centers around the presence of potential obstructions which might block or filter the sun.

SITE ANALYSIS

Traditionally, the selection of a home site has been governed by factors such as proximity to work, taxes, schools and neighborhoods. It is time to include another consideration--the quality of the microclimate. Passive solar houses will not work on every site. If you already own a heavily wooded lot and can't bear to cut the trees or own a lot on a north-facing slope, don't stop reading. Some passive features can be incorporated into a house in any location. But the house's potential thermal performance is governed directly by the site.

The two most critical microclimate factors involved in site selection are solar radiation and wind. These two factors and others must be considered in light of both winter heating and summer cooling needs.

A balanced site plan provides a good compromise between heating and cooling needs in the South. Its features are applicable to any house, conventional or solar.

Therefore, to achieve the maximum potential, you must analyze and understand your site before you design. If you have not yet bought a site, this analysis will help you learn what to look for.

SITE ANALYSIS - WINTER HEATING

There are two important questions you will want to answer during the analysis of your site for the winter heating season. They are:

1. Does the site get plenty of sunshine?
2. Does the site offer protection from the winter winds?

Any solar house, sun-tempered or totally solar heated, must have clear access to the radiant energy from the sun. There is more than enough solar radiation available anywhere in the South to allow a solar energy system to operate - it's not called the Sunbelt for nothing. Potential problems occur at the individual site, where the sun's rays may be blocked by trees, hills, or adjacent buildings. Both existing obstacles and future possibilities should be considered.

In the winter, since the early morning and late afternoon sun is comparatively weak, it is not important to have perfect exposure at those times. Due to the location of the standard time zones, solar time may vary as much as 45 minutes from standard time. Daylight savings time adds another hour to the confusion. The table contains a procedure to calculate solar time.

If actual observations of the sun's position are to be made, use the time correction or make sitings three hours before and after the sun reaches its highest point (solar noon).

$$ST = LST + ET + 4(LSM - LON)$$

ST = Solar Time

LST = Local Standard Time; not Local Daylight Savings Time

ET = Equation of Time

LSM = Local Standard Time Meridian;
75° for Eastern Time Zone;
90° for Central Time Zone

LON = Local Longitude

	JAN.	FEB.	MAR.	APR.	MAY	JUNE
ET	-11.2	-13.9	-7.5	+1.1	+3.3	-1.4
(min)						
	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
	-6.2	-2.4	+7.5	+15.4	+13.8	+1.6

SITE ANALYSIS- WINTER HEATING

If you don't feel inclined to make periodic observations of the sun's path over a full year, there are sun path diagrams and tables available from several sources that give azimuth and altitude angles. At the site, use a compass to locate the azimuth angle and a protractor to locate the altitude angle to check for exposure to winter sun and shading in summer. In this case there are no time problems since the tables and diagrams all use solar time rather than local or standard time.

For most site planning purposes the winter solstice angles - the sun's lowest path during the year - at 9:00 a.m., noon and 3:00 p.m. are adequate. The Appendix lists these angles for various latitudes in the SSEC region. Notice that the altitude and azimuth angles for 9:00 a.m. and 3:00 p.m. have the same values. The azimuth is east of south in the morning and west of south in the afternoon. The summer solstice angles - the sun's highest path - are also listed.

The sun's path may be visualized by standing at the site of the building and sitting along the appropriate angles. A single observation will not be sufficient; check for shading obstructions at both ends of the proposed solar collection area. And remember that you are making observations from eye level, a point about five feet above ground level. So, if you see an obstruction at that level, there would definitely be a shadow on a piece of glazing installed two feet above ground at the same point.

SITE ANALYSIS- WINTER HEATING

Ideally the sun should be unobstructed by both existing and future objects. If more than half of the total available winter sun is blocked, a large passive solar system is probably not justified.

For winter heating considerations, the goal is to design your site to maximize the house's exposure to the sun while at the same time minimizing its exposure to the wind. There are several basic concepts that can be used to achieve these goals. To maximize the sun, they are:

- Minimal shading
- Proper building orientation and placement

To minimize the effects of the wind, they are:

- Deflect the winds
- Create still air spaces as buffer zones

These concepts, when properly implemented, can drastically reduce your energy requirements. When minimizing the effects of shading, it is important to consider shade from the following:

- A. Neighboring buildings and houses
- B. Trees on the south side of the house
- C. Land forms
- D. Future tree growth or new construction

SITE ANALYSIS- WINTER HEATING

Other factors to consider to increase your exposure to the sun are:

- E. The optimum orientation of the solar elevation is within 15° east or west of south
- F. The optimum house placement is toward the north end of the site so that you have more control over potential shading problems.

Blocking the cold winter winds can also play a major role in reducing your energy usage by decreasing infiltration and conduction losses in your home. To minimize the effects of these winds,

- H. Locate your house on the leeward side of an existing evergreen tree stand or forest or create a wind break by adding trees and low bushes to block the wind.
- I. Create still air spaces that do not allow the wind to penetrate to the house by using evergreen vines, hedges and trees.

These concepts can help you to reduce the amount of energy required to comfortably heat your home in the winters to come.

SITE ANALYSIS- SUMMER COOLING

A site's summer cooling potential must also be considered. Again, sun and wind are the key points, but their desirability is reversed. Summer solar exposure is to be avoided, while winds are a blessing. The two major questions are:

1. Does the site offer protection from the sunshine?
2. Are there summer breezes across the site?

A major portion of a house's summer heat gain is a result of solar exposure. The high summer sun path exposes the east walls, roof and west walls of an unprotected house to severe heat gains. South walls receive less solar radiation and are readily shaded with fixed overhangs. A good building site would provide shade for the east and west sides of the house to reduce morning and afternoon heat gains. Due to the high sun angles, only those trees which are very close to a house or actually extend over the roof are effective in shading the roof.

Deciduous trees are a natural sun control device. Unlike evergreens, they lose their leaves in winter when the building needs solar heat and regrow them in spring when shading is required. This natural shading adjustment makes deciduous trees good candidates for use on the southern side of the house. However, very dense stands should be avoided, since even the bare trunks and branches block some of the sun's energy.

SITE ANALYSIS- SUMMER COOLING

Winds are a valuable summer feature at a site. On-site inspections are particularly valuable in analyzing summer winds. In addition to the direction, frequency and speed of the winds, their quality must be considered. Winds can pick up excess heat as they move across features near the site. A pleasant summer breeze may become a wave of hot air if it moves across a nearby parking lot. On the other hand, stands of trees block solar gains and cool the breezes that flow around and beneath them.

For summer cooling considerations, the goal is to design your site to maximize the shade on the house and, if possible, utilize the summer breezes for ventilation. Consider these steps:

- A. Shade the roof by placing the house just north of a large existing deciduous tree.
- B. Shade the east, west and north walls with small trees, bushes and vines. This can reduce the surface temperature of the walls by as much as 50 degrees.
- C. Shade paved areas such as driveways and patios so that air passing over these surfaces does not heat up.
- D. Reduce glare and reflected heat from water or paving with bushes, walls and vined trellises.

SITE ANALYSIS- SUMMER COOLING

If you determine that it is to your advantage to use the summer breezes and they meet the general requirements, it is important to:

- E. Shade air inlets to the house (windows, vents, etc.) to reduce air temperatures entering the house. Air temperature under the shade of a tree can be up to 20 degrees cooler than unshaded air.
- F. Allow breezes to flow freely across the site by minimizing planting under 10' in height or use hedges and trees to channel the breezes toward the air inlets on the house.

Having analyzed the site from the points of view of both heating and cooling, you will have a good understanding of its potential to assist you in developing a comfortable, low-energy home. The addition of shrubs, trees and other landscaping features can enhance the same natural assets or create new ones. SSEC's Solar Site Planning, A Guide to Residential Landscaping for Energy Efficiency provides additional information.

SITE DESIGN FOR BOTH HEATING & COOLING

Remember to balance heating and cooling needs in selecting and modifying a site. It is possible to avoid conflicts; the illustration below shows a site plan which would provide excellent results throughout the region.

- A. Deciduous or evergreen trees on the east and west sides to control summer heat gain.
- B. A dense evergreen windbreak on the northwest side to block cold winter winds.
- C. Good solar exposure within a 45° angle of the south wall for winter solar gains. A few deciduous are acceptable, but evergreens close enough to shade the house in winter should be avoided.
- D. Foundation plantings, shrubs, trellises and vines around the perimeter of the house to provide protection from cold winter winds and hot summer sun.
- E. Additional tree plantings which help shade and cool the site in summer but do not interfere with winter solar access.

PEOPLE CONSIDERATIONS

When discussing passive site and design issues it's altogether too easy to concentrate on temperatures and BTUs and to forget the people! A house must be designed as a thermal "machine" but it must also satisfy the needs of the occupants. The house must also provide opportunities for the occupants - opportunities to conserve energy and to improve the passive operations of the house, without compromising comfort.

The Southeast has a wonderful climate; throughout the entire region there are days in each month from April to October when outside conditions are perfectly comfortable. During the extreme winter and summer months, the house must provide some protection and isolation from the outdoor conditions. An equally important function is to allow the people inside to come in contact with the outdoors when conditions are good. The building site should be chosen carefully to complement this function. Pleasant views, birds, breezes, trees and shrubs lure people outside onto porches and decks and patios and encourage open windows. Traffic noises, gas fumes, glare and "plow it under" landscaping drive them indoors to isolate themselves, where mechanical comfort conditioning is required. We're not selling granola, but some back-to-nature concepts do save energy and improve lifestyles.

*FORM

*ROOM LOCATION

*INSULATION

- Floor Insulation
- Wall Insulation
- Ceiling Insulation

*WINDOWS

*INFILTRATION

*ROOF VENTILATION

*WHOLE HOUSE FANS

GREENSBUILDING

TECH

4

INTRODUCTION

The design and construction of the house are the keys to achieving comfortable, low-energy performance. Passive solar systems and landscaping can function successfully only in conjunction with a well insulated and weatherized building. Passive solar cannot act as a "bandage" for a poorly built, energy-wasting house.

During the construction of a new house, there are numerous opportunities to seal, caulk or insulate at low or moderate costs. Once the house is completed most of these opportunities are gone or are available only at much higher costs. For example, during construction a sill plate along an entire wall can be effectively sealed to the slab with a two-dollar tube of caulk and an extra ten minutes of labor. Once the wall is finished, the sill is inaccessible and an annoying and expensive infiltration path exists.

This chapter will consider two aspects of the building: design and construction. The items and concepts described here are only the essential basics. Consult the references listed in the appendix for detailed information.

FORM

Simplicity is the best guideline for the design of passive buildings. The building should provide the most living space with a minimum of surface area, joints, and corners. A spherical shape has the advantage of enclosing the maximum volume with a minimum of exterior surface area. Regrettably, or fortunately, depending on your point of view, most people do not wish to live in spheres.

The next most efficient form is the cube. Cube-like shapes provide high volume-to-wall-area ratio resulting in the use of fewer building materials and less wall area for heat loss and gain.

Since spheres and cubes are normally unacceptable, a good alternative is a rectangular shape elongated along the east-west axis. This form has two distinct advantages. One, it maximizes the area for solar collection along the south wall while reducing the east and west walls exposed to summer heat gains in the morning and afternoon. And two, it allows easy distribution of solar energy from the south side to the north side and facilitates natural cross ventilation.

As the building form becomes more complex, the relative amount of surface area increases. Also the number of joints, intersections and "wind traps" is increased. The consequences are higher construction costs, greater area for heat loss or gain and higher infiltration. A simple rectangle may not be acceptable in all cases, but remember, keep it simple.

ROOM LOCATION

One simple way to make a house less complex is to use a two-story plan. The first floor has no ceiling losses and the second floor has no floor losses. Although there is slightly more wall area, the net effect can be a reduction in heating and cooling costs.

In the same way that landscaping can be used to protect a house from harsh ambient conditions, parts of the house itself may perform a buffering or sheltering effect. A carport, storage room, or garage on the west side of the house will provide the house with both protection from cold northwest winter winds and shading from hot afternoon summer sun. Closets, laundry rooms, pantries, stairs, halls and bathrooms may be located on outside walls to reduce the heat loss and gain from frequently occupied rooms on the interior.

ROOM LOCATION (cont.)

In locating rooms in the house, consider the natural day/night and summer/winter cycles of nature. The floor plan should respond to these cycles and provide the owners with some flexibility to adjust to changing conditions. In general, during winter, daytime rooms should be on the south side and nighttime rooms should be in sheltered, protected areas. In summer, daytime rooms should provide protection from the sun while nighttime rooms should provide access to breezes and cooler outdoor temperatures. Some specific ideas are listed below:

- Locate kitchen and dining areas on the east side of the house. During winter, sunlight and heat are provided early in the morning while in summer the rooms are isolated from the afternoon sun.
- Locate bedrooms on second floor. In winter, warmer air tends to rise to upper floors. While the same effect occurs in the summer, the rooms are higher above ground to catch breezes.
- Locate patios and decks in shaded areas to help isolate them from summer heat.
- Locate storage rooms, laundry rooms and other infrequently occupied rooms on the west side to reduce summer heat gains.
- Plan family spaces - great rooms, dens, living rooms - so that they are open in a north-south direction. The south end can be favored in winter and the north end in summer.

INSULATION

The effect of insulation may be visualized in one of two ways: it slows the flow of heat, making it more difficult for heat to leak through the shell of the house. Alternatively, insulation makes it possible to use a smaller mechanical system to maintain comfortable temperatures. Adequate insulation allows the occupants of a house to maintain comfortable temperatures throughout the year with minimum energy usage. In building a new house, the amount of insulation to be used and the manner in which it is installed are equally important in assuring comfort and economical operation. New construction presents a one-time opportunity to install insulation with a minimum of effort and expense. Once construction is completed, walls, cathedral ceilings and slab floors are difficult if not almost impossible to insulate.

R-values are useful in specifying the amount of insulation to be installed. Most building codes now specify minimum R-values for homes. Code values should not be considered the optimum value; they usually represent only an absolute minimum acceptable level. The map shows the insulation levels commonly recommended by most manufacturers. Although these recommendations come from groups with an interest in selling insulation, they are quite reasonable.

A few of the fundamentals of insulating a house are discussed here. For more in-depth information, refer to Insulation Manual, Homes and Apartments from the National Association of Homebuilders Research Foundation, Inc.

RECOMMENDED R VALUES BY REGIONS			
REGION	WALLS	CEILING	FLOOR
A	19	30	19
B	19	26	13
C	13	26	11

FLOOR INSULATION

Three types of floors are commonly used in the South: slab, crawl space and basement. With the exception of south Florida and Texas and the Islands, insulation is appropriate throughout the region.

Almost all of the losses from a slab floor occur from the edges of the slab to the air. Only with heated slab systems where the slab will be used for thermal storage mass is below-slab insulation necessary. Rigid board insulation should be applied at the perimeter of the slab to break the shortest paths for heat loss.

It should extend 24" downward or 24" back under the edge of the slab. A water and rot resistant homogeneous insulation should be used. "Bead Board" material will absorb water and lose its insulating qualities, so it should not be used in below grade applications without adequate moisture protection. Optimum R-values range from R4 to R8, depending on climate.

Basement floors are normally not insulated unless they have a side at or near grade, such as a walk-in basement. In such cases, the exposed edge should be treated as a slab floor.

Floors over crawl spaces offer two alternatives for effective insulation. The most common approach is to install fiberglass batts between the floor joists, with the vapor barrier on the heated side. Support the batts with chicken wire, or wire lacing at the bottom of the joists or with heavy-gauge pointed wires made for the purpose-wedged between the joists. The objective is to hold the insulation in place and prevent gaps through which air could move.

An alternative, insulating the inside of the foundation wall, may be used if the crawl space is to be unvented. Batts are installed as shown to cover the band joist, the foundation wall and lap onto the ground for about two feet inside the crawl space. A polyethylene vapor barrier is placed over the ground in the crawl space to help control moisture.

WALL INSULATION

For years, the standard wall construction has been 2 x 4 studs on sixteen-inch centers. Using this construction, good insulating qualities can be achieved by applying 3½" fiberglass batts and an insulating sheathing. Total R-values of fifteen to nineteen are possible without changes in normal framing and finishing practices. An alternate framing configuration that uses slightly less lumber and allows higher R-values is the use of 2 x 6s on twenty-four inch centers. An R19 batt may be substituted for the R11 batt. However, window and door framing is more difficult.

When installing batt insulation and insulated sheathing, the objective should be to provide a continuous shell of insulation. Gaps, cracks and uninsulated areas allow unwanted heat transfer and air infiltration. Points requiring special attention include:

- Insulate behind electrical boxes, wiring and plumbing in exterior walls.
- Cut batts to fit spaces around window and door frames and other odd-size framing openings.
- Use let-in bracing and insulating sheathing at corners rather than exterior plywood bracing.
- Be sure that batts butt snugly against the top plate, sill and other batts at joints.

Poured concrete walls, concrete block walls and other massive walls present an opportunity to incorporate thermal storage mass into the house. In order to be effective, the mass must be exposed to the living space and insulated on the outside. Rigid foam insulation materials, with high insulating properties in comparatively thin sections work well both above grade and below grade. Moisture resistant materials or some form of moisture protection must be provided in below-grade applications.

INSULATING WALLS

Batts/Blankets are most commonly made from fiberglass, 15" to 23" wide and may be purchased with or without a vapor barrier.

Loose fill may use fiberglass, rock wool, cellulose, or vermiculite.

Rigid boards are gaining in popularity and are usually made from fiberglass, urethane or extruded polystyrene in 4' x 8' sizes.

TYPE	CATEGORY	R-VALUE/INCH	COST *
"Thermax," "High-R," "Climate Guard," "Tuff-R."	Rigid	7.2	3.6
Styrofoam	Rigid	5.41	4.9
Beadboard, "Supersheath" "Super-R Plus"	Rigid	4.25	
"Fiberglas"	Rigid	4.4	1.66
Cellulose	Loose Fill	3.7	.88
Rock Wool, Glass Fiber	Batts	3.2	1
Perlite and Vermiculite	Loose Fill	2.6	2.1-2.4
Fiberboard Sheathing	Rigid	2.6	5.88
Rock Wool	Loose Fill	2.5	1.22
Glass Fiber	Loose Fill	2.2	1

*NOTE: Cost are relative, where fiberglass batts equal 1.
Based on cost per s.f. per R-value.

CEILING INSULATION

A variety of alternatives may be employed in insulating ceilings below an attic. Either batts or blankets of insulation or loose-fill insulation may be used. Batts and blankets are available to fit between joists on sixteen or twenty-four inch centers. Blown or poured loose-fill insulation may be more appropriate where nonstandard or irregular joist spacing is used. In any case, a continuous layer of insulation without gaps, cracks or air bypasses should be the objective. Where soffit vents are used, the insulation at the edge of the ceiling must not be allowed to contact the roof decking and block airflow from the soffit vents.

Points requiring special attention include:

- Be sure that batts or blankets butt tightly against framing and other batts or blankets.
- Cut batts or blankets to fit at framing joints to avoid buckling and gaps.

• Do not cover recessed light fixtures with insulation.

• Insulate and weatherstrip the attic access panel.

Vaulted or cathedral ceilings pose a potential problem in providing ventilation of the roof structure. Adequate ventilation is necessary to prevent moisture accumulation and excessive summer roof temperatures and heat gain. It is desirable to use rafters large enough to provide a flow path above the insulation from soffit vents to ridge or gable vents. Special care is required to avoid blocking the flow path during installation of the insulation.

Due to the necessity of protecting exterior insulation, massive walls are often insulated on the interior. Furred-out walls with rigid or batt insulation are normally used. However, this practice prevents the wall from acting as thermal storage mass (see Chapter 5).

WINDOWS

Windows provide light, views, ventilation and emergency exits for homes. When properly installed they can also provide significant amounts of heating energy to the house during winter. The solar aspects are discussed in the next chapter; Here, windows are considered only as potential energy losers.

In a typical house, windows account for about 20% of the total heat loss. Reasonable conservation measures can cut this loss in half. The first and most cost effective measure is the careful installation of the window. Frames should be carefully caulked and insulated to minimize infiltration. Second, with the possible exception of South Florida, double glazing is a good buy. A typical 3' x 4' double-glazed window loses as much heat by conduction as about 153 square feet of R20 wall. A single glazed window of the same size corresponds to more than 260 square feet of R20 wall. Similar improvements may be obtained by applying storm windows over single glazed windows. However, maintenance is increased and the storm window must be adjusted or removed to allow summer ventilation. Double glazing also improves the Mean Radiant Temperature inside the house, leading to greater comfort.

The window frame also plays a role in controlling conduction losses through the window assembly, typically as much as a 15% reduction. Wood frames perform best, followed by metal frames with a thermal break and then by plain metal frames. Unfortunately, initial costs are higher for wood frame windows and periodic painting may be required.

SLIDING

DOUBLE HUNG

AWNING

CASEMENT

SKYLIGHT

WINDOWS

The following information should help you analyze where windows should be placed in order to optimize their thermal performance.

Minimize window areas to reduce heat loss. Use small windows for daylighting and ventilation. Shading is not normally needed. Use normal clear glazing.

NORTH

Reduce window areas to reduce winter heat loss and morning heat gain during summer. Use small windows for ventilation. Windows in a kitchen or breakfast area provide pleasant morning light. Use vertical shading elements or vegetation for shading. Only very deep horizontal overhangs (porches, carports...) will provide effective shading.

EAST

WEST

Avoid large unshaded glass areas to reduce heat loss and gain. During the summer, afternoon heat gains may be a severe problem. Shade glass with vertical elements, vegetation or deep overhangs. Overhangs are less effective on east and west walls due to low morning and afternoon sun angles. Small, well shaded windows should be used for ventilation. Consider heat absorbing or reflective glazing.

SOUTH

Use south-facing glass for winter heat gain and summer ventilation. Shade glazing with properly sized horizontal overhangs. Glazed area must be matched to the house's thermal load and storage capacity. Use normal glazing or, where glare may be a problem, use diffusing glazing.

Use south-facing clerestory windows to admit light and winter heat into the house. Provide overhangs for summer shading.

GLAZING IMPACT

Glazing is usually thought of as a weak point in a building's insulated shell; an easy place for heat to leak in or out. In fact, some new energy codes have moved toward restricting the amount of glazing to the minimum required for lighting, ventilation and emergency exit. While glazing does offer relatively minimal insulating effect, it can be a powerful energy source for a home. In order to be effective, it must be properly oriented, installed, and shaded.

South-facing vertical glazing receives large amounts of solar radiation during winter, and yet, is easily shaded during summer. To illustrate the value of south-facing glazing, compare its thermal performance to that of an R20 wall. The glazing is assumed to be vertical, south-facing double glass with a fixed overhang.

The heat loss, heat gain and summer air conditioning load are considered separately. Heating credit is given for only the five coldest months of the heating season. An air conditioning coefficient of performance (COP) of 2.5 is used. The chart summarizes the results of calculations for Atlanta, Dallas/Ft. Worth and Washington, D.C.

In all cases, south-facing double glazing provides a significant net energy contribution for the year. The R20 wall constitutes a net loss. This is not an argument for glass houses, but it does point out the potential of properly designed sun-tempered and passive solar houses.

COMPARISON OF NET ENERGY GAIN BETWEEN A GLAZED WALL & AN R20 WALL

		DOUBLE GLAZED WALL	R20 WALL
ATLANTA			
SOLAR GAIN		108,400	—
HEAT LOSS		-38,500	-3,300
ADDED AC ENERGY		-8,700	-500
NET ENERGY GAIN		61,200	=3,800
DALLAS/FT WORTH			
SOLAR GAIN		115,800	—
HEAT LOSS		-30,800	-2,600
ADDED AC ENERGY		-12,300	-800
NET ENERGY GAIN		72,700	-3,400
WASHINGTON			
SOLAR GAIN		100,800	—
HEAT LOSS		-58,200	-5,000
ADDED AC ENERGY		-6,100	-400
NET ENERGY GAIN		36,500	-5,400
		Btu/sq.ft. per year	

INFILTRATION

Infiltration is the unwanted flow of outside air into a house and the resulting flow of indoor air to the outside. During winter, infiltration allows warm air inside the house to be replaced by cold outside air, increasing the rate of heat loss. Cold drafts lead to discomfort, cold feet, higher thermostat settings and greater energy consumption. During the summer, hot, humid air which infiltrates into the house increases sensible heat gain, and by bringing moisture with it, increases the latent cooling load. In a typical new home infiltration comprises about 40% of the total heating or cooling. Infiltration is normally measured in air changes per hour (ACH) - the number of times the building volume could be filled in an hour by the infiltration flow. In typical new houses, infiltration rates range from 1 to 2.5 ACH.

Infiltration takes place through any opening in the building skin - through open doors, through cracks around windows and doors, between sill plates and floors around electrical fixtures, wiring and plumbing, and through vent openings and flues. Without resorting to unreasonable measures, it would be impossible to eliminate infiltration. Also, a certain minimum level of infiltration is desirable to bring fresh air into the building and prevent the buildup of odors or potentially dangerous gases. Many carpets, furnishings and building materials give off harmful or irritating chemicals while cooking, bathing and human activity produce humidity and odors. While there has been some concern about a potential health hazard resulting from very well sealed buildings, there is little cause for concern at infiltration rates above 0.5 ACH. Where special infiltration control measures and care are used during construction, infiltration may be reduced to 0.5 to 1.0 ACH. The most extensive and diligent efforts seldom reduce infiltration below 0.3 ACH in test programs.

INFILTRATION (cont.)

So despite your best efforts, you are not likely to create a health hazard by making a building "too tight."

Reduction of infiltration is the simplest, least expensive tactic to reduce energy consumption in a house. During the construction of a new house a total expenditure of \$250 for materials and labor can easily reduce the infiltration rate by 30-50% and cut heating and cooling energy consumption by 20%. With low initial costs and one-to-two year payback, infiltration control alternates are excellent energy investments. And the improvement in comfort conditions alone could probably justify the cost.

The design of the house itself can also help to reduce infiltration. A smooth, simple exterior, like a streamlined car, has less wind resistance and lower infiltration. In addition to increasing labor costs, joints, intersections and corners provide additional leak points. To reduce infiltration through entrance doors, airlocks may be incorporated. An airlock is nothing more than the traditional entry vestibule or mud-room used in earlier homes to receive guests, provide storage for hats, boots and coats and to afford additional privacy for the main rooms. Both doors should be weather-stripped. The airlock effect may also be achieved by providing entrances through garages, storage rooms or attached greenhouses.

INFILTRATION (cont.)

Simple techniques for controlling infiltration include:

- **Sill Sealers** - Gaps between sill plates and the slab or foundation may account for as much as one third of the total infiltration into a house. Gaps may be sealed by applying a bead of caulking or a fiberglass roll product made for this purpose beneath the sill plate during construction.
- **Vapor Barriers** - Careful installation of Kraft paper-backed fiberglass batts or, preferably, a four to six mil polyethylene vapor barrier is very effective.
- **Fireplace Flue Dampers and Outside Combustion Air Sources** - Fireplaces should not be installed without a positive sealing damper. An outside combustion air source and glass doors allow the fire to draw outside air rather than heated inside air.
- **Vent Dampers** - Automatic (spring or gravity) dampers should be used on the exits of all dryer, kitchen and bathroom vents.
- **Windows and Doors** - Weatherstripping is a must. Gaps and cavities in the frames should be caulked and stuffed with fiberglass scraps.
- **Plumbing and Electrical Penetrations** - Any penetration of the building skin by plumbing or electrical lines or components should be caulked or sealed. Check hose bibs, service entrances, ceiling light fixtures, water and drain lines, switches and outlets.
- **Attic Access** - Attic doors or folding stairs should be weatherstripped - and insulated.
- **Whole House Fans** - All ventilation fans should have a positive method of blocking leaking during winter. The common louver sets do not seal well.
- **Landscaping and Site Design** - Infiltration increases as wind increases. Trees, shrubs, fences or other windbreaks can have a significant effect on winter infiltration.

Infiltration control is inexpensive, simple to implement and does not disrupt normal design and construction procedures. Benefits include quick payback, energy savings and improved comfort levels. Don't miss the opportunity to include infiltration control features during construction--it's much more difficult later on.

ROOF VENTILATION

Good roof ventilation is essential to control summer heat gains through ceilings and improve inside comfort conditions. As a result of the high sun angles, almost all residential roofs receive significant solar exposure during summer. This is good news for water heaters but bad news for cooling.

The intense solar radiation can drive unventilated roof and attic temperatures to 150°F, causing unwanted heat transfer through the ceilings and into the house. The resulting warm ceilings also contribute to occupant discomfort by increasing the mean radiant temperature inside the house. Good ventilation carries solar heat out of the roof structure or attic and prevents excessive temperature build-up. The result is lower cooling costs, greater comfort and longer roof shingle life.

A second vital function of roof ventilation is the removal of moisture during the winter. Water vapor diffuses through the ceilings into the cooler attic or roof cavity and may condense. Condensation leads to a reduction in insulation effects and, in extreme cases, to structural damage. Ventilation removes excess moisture before it can create a problem.

Effective roof ventilation requires both an air inlet and an exit. Inlets normally consist of vents at the roof soffits. Soffit vents should be generously sized; continuous vents are desirable. In the southern parts of the SSEC region, one square foot of free vent area should be provided for each 100 square feet of ceiling. This value may be reduced to 1 square foot per 200 square feet in the northern part of the region.

ROOF VENTILATION

Note that both of these vent areas are much higher than the F.H.A. minimum. Vents should be protected with screen to exclude birds and insects. Avoid extremely fine mesh screen, since it will reduce air flow.

Air exits may be provided in the form of peak vents, flash vents, ridge vents, gable vents or power vents. However, adequate roof ventilation can naturally be accomplished without the use of power vents, reducing operating costs.

Exit vents should be sized to provide an exit area equivalent to the inlet area at the soffit. The particular application will determine the type of vent to be used.

Equally important as inlets and exits is a free flow path between the two. Airflow must not be obstructed by insulation, blocking or structural members. The illustrations point out one potential problem area.

Vaulted or cathedral ceilings without an attic require particular attention in order to avoid excessive heat gains. An airspace between the roof decking and the insulation should be provided to allow for airflow from inlet to exit. Care must be taken to insure that insulation is installed properly and does not block the airspace. Framing must allow room for both the insulation and the airspace. The use of larger rafters to provide the airspace is often offset by the wider spacing which is possible.

Light colored shingles or reflective roofing material also provide a substantial reduction in attic temperatures. However, stains from leaves may be a problem.

WHOLE HOUSE FANS

Whole house fans, sometimes called ceiling fans, have been used for years, but have recently become more popular as an inexpensive and effective means of cooling and ventilating a home. A whole house fan system consists of a large propeller type fan (usually 2' - 3' in diameter) mounted in the attic above a ceiling opening in a central part of the house - preferably a hallway. The fan draws air through open windows, pulls it throughout the home and into the attic, where it is expelled out the vents.

Ceiling shutters with insulated vanes are installed below the fan to seal the opening when it is not operating. The fan can be controlled automatically by a thermostat or manually by a timer or switch.

Although whole house fans are an efficient means of cooling and ventilating a home, particularly the attic, there are some problems that homeowners should be aware of:

*There is no effective way to control humidity and air movement while the system is operating.

*A serious safety hazard would exist if the fan were to continue operating during a fire. For this reason, the system should incorporate a smoke detector, or other fire sensing device.

Sizing Whole House Fans

- Determine the volume of each space to be ventilated: Multiply length x width x height. Do not include closets, storage rooms, or the attic.
- Add the room totals to determine the total space to be ventilated in cubic feet.
- Select a fan with cubic foot per minute (CFM) air delivery rated at 0.10" static pressure (SP) on high speed which equals the cubic feet to be ventilated.

*PASSIVE SYSTEMS

- Introduction
- General Description

*DIRECT GAIN

*GLAZING IMPACT

*SUNTEMPERING

*THERMAL STORAGE WALL

*SUNSPACE

*ROOF PONDS, DOUBLE ENVELOPES, THERMAL
CEILINGS, CONVECTION LOOPS AND OTHERS

*WINDOW SHADING

*WINDOW INSULATION

- Interior
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*LOW-ENERGY COOLING

- Introduction
- Cooling Load Minimization
- Solar Gains Through Glazing

*INTERNAL GAINS

*COOLING TECHNIQUES

*VENTILATION

*DESIGN CONSIDERATIONS

PASSIVE

5

PASSIVE SYSTEMS INTRODUCTION

The most common definition of passive solar systems states that they are solar systems which operate through natural processes without pumps, fans or blowers. Active systems, on the other hand, utilize mechanical devices powered by an outside source of energy. While this definition provides two well-defined categories, it misses the true nature of passive systems. It is preferable to think of passive systems as systems which work with the natural surroundings rather than against them. We should also expand our definition beyond solar factors exclusively and encompass other potentially useful forces in the environment - particularly wind and natural temperature swings. A passive house, then, is one which reacts to the changing conditions around it - admitting sunlight in winter, excluding it in summer; sealing itself against cold winter air and opening itself to the pleasant breezes of spring, fall and summer. It interacts with nature to promote comfortable interior conditions. In contrast, most conventional houses isolate themselves from nature - during winter, during summer and even during the long and comfortable southern springs and falls. Mechanical heating and cooling systems are used to add or remove heat from the building.

PASSIVE SYSTEMS INTRODUCTION

Residential passive systems are available in a broad spectrum of complexity and performance. At one extreme, there are large, quite recognizable ("zoomy") systems which provide almost all of a house's heating requirements. At the opposite end of the spectrum there are houses which incorporate fundamental passive principles into conventional designs, reducing heating and cooling requirements by 10% to 30%. Prior to the advent of cheap and abundant energy in this country, designs of this sort were considered "just plain good sense."

Today, they still make good sense, although the name has been given some additional flair; low solar fraction passive designs or sun-tempered designs.

Almost any residential design on any site can benefit from the application of basic passive principles. Energy savings of 10% to 30% are generally achievable without significant cost increases or changes in the appearance of the house. Considering present energy prices, it is unreasonable to build without passive principles incorporated into the home. And as energy prices escalate, more complex passive heating and cooling systems will be called for. The days of cheap energy and the luxury of disregarding the building's surroundings are over.

\$\$\$SAVINGS\$

PASSIVE SYSTEMS INTRODUCTION

But what about comfort? If we define comfort as an interior temperature which never varies more than 30°F, passive systems alone can't match conventional heating and air conditioning equipment. And as yet, there are no practical passive techniques which can overcome the severe humidity problems in the South.

So, passive systems alone cannot provide the control over interior conditions offered by conventional fuel-consuming equipment. That is an undeniable fact. But no excuses or apologies from the pro-solar faction are necessary. Passive systems should not be considered a one-for-one, equivalent replacement for conventional systems.

Instead, they offer us two diverse alternatives:

- 1) Same level of comfort/lower energy consumption
- 2) Wider definition of comfort/much lower energy consumption

The first alternate is achieved by utilizing passive systems to reduce the heating and cooling loads which must be handled by the conventional systems. When the passive system can maintain the prescribed conditions, it does so - with little or no conventional energy. When outdoor conditions become more severe, the conventional system takes over, maintaining the interior conditions within the prescribed range.

The second, lower energy consumption alternate is realized by depending heavily upon the passive systems for heating and cooling. With the South's relatively mild climate, conventional comfort standards can be maintained for significant periods. And when the temperature wanders a bit, we have the option of realizing significant energy savings by simply adapting to the new conditions - putting on a sweater, opening a window....After all, we Americans are the only society on earth that expects to be kept at a constant temperature, oblivious of outdoor conditions - like melons in a supermarket cooler.

PASSIVE SYSTEMS

All passive solar heating systems must do three jobs: 1) capture solar energy, 2) store surplus heat, and 3) control the flow of heat for maximum comfort and economy. In this respect, passive solar systems are very similar to active solar systems. But rather than depending on separate collectors, storage tanks, rock bins, pumps, blowers, and electrical devices, passive systems utilize parts of the building itself. This approach allows greater simplicity and lower cost.

Passive solar heating systems use ordinary windows, glass doors, and skylights to capture the sun's radiant energy. Like a flat plate collector, the passive system operates on the greenhouse principle. Short wave radiation from the sun (very high temperature) passes through the glazing and strikes the interior of the building. When the short-wave radiation is absorbed, it is converted into heat, warming the interior of the building. Since the temperature of the building interior is comparatively low, only long-wave radiation is emitted. The glazing contains most of this long-wave radiation back within the building. Solar energy enters the building, changes form and is trapped - the greenhouse effect! A passive solar house is really a solar collector that people live in. That is why shading is essential during the warm months.

PASSIVE SYSTEMS

The amount of collection glazing used in a passive solar system must be balanced to the building's heat requirements and its heat storage capability. If too much energy is allowed to enter the building, overheating will occur--even in winter.

Extra solar energy may be stored in the structure of the building itself. Tile floors and masonry walls are excellent storage masses. Additional heat storage mass may be added by placing water-filled drums or tubes or other massive elements inside the building.

During the day, properly designed heat storage mass absorbs some of the solar heat and prevents over heating. Later, when the interior temperature drops, the storage mass releases heat to prevent under-heating. The heat storage mass slows the rate of temperature change in the building, moderating high and low temperatures. It acts as a "thermal flywheel" for the building, moderates changes in an engine's much like a mechanical flywheel moderates changes in an engine's speed and torque.

In order to be most effective, the storage mass must have large surface areas exposed to the sun and to the air inside the building.

PASSIVE SYSTEMS

The final element of a passive solar system is a method for heat distribution and control. Although passive systems are somewhat self regulating, their performance can be improved by the use of simple controls and heat distribution devices. Open plan designs, interior doors and transom vents allow natural circulation and even heat distribution. Drapes and shutters provide an easy way to regulate the flow of solar heat into the building. And nighttime heat losses can be reduced drastically by fitting collection areas with movable insulation panels or insulating curtains.

Passive solar systems range in complexity from simple sun-tempered buildings (little or no additional storage mass) to complex convection loop systems with intricate collector and duct systems. As the complexity increases, the need for careful design and balance between collection, storage, and distribution also increases.

The most commonly used passive solar heating systems are the direct gain system, the thermal storage wall and the sunspace. While several other families of systems exist, they have not been thoroughly researched or accepted. Only the three major systems will be discussed in detail. Notice that each one incorporates the basic collection, storage and distribution functions.

BLOWERS

DAMPERS

DUCTS

NIGHT INSULATION

DRAPES

TRANSOM VENT

WELL-INSULATED
AND WEATHERIZED

ADEQUATE
STORAGE
MASS

ORIENTATION WITHIN
15° OF SOUTH

USE OVERHANG OR OTHER
SUMMER HEAT GAIN CONTROL

DOUBLE
GLAZING

GENERAL PASSIVE DESIGN POINTS

PROVIDE SUMMER SHADING
FOR GLAZING, ESPECIALLY
INCLINED GLAZING.

MINIMIZE EAST/WEST
GLAZING

USE LANDSCAPING FOR
SUN AND WIND CONTROL

SOME NORTH GLAZING
FOR LIGHT, VENTILATION
AND CODE REQUIREMENTS

BALANCE BETWEEN
HEATING AND COOLING

PORCHES, DECKS
AND PATIOS

NATURAL
VENTILATION

DIRECT GAIN

The Direct Gain system is the most straightforward of all the passive systems. Solar radiation passes directly through south-facing glazing into the living space. The glazing itself forms part of the building skin. Thermal storage mass is entirely contained inside the living space.

As solar radiation strikes walls, ceilings, floors and objects in the room, it warms their surfaces. A portion of this heat flows into the object where it is temporarily stored. Another portion is convected away from the surface and warms the air inside the room. The fraction of heat which is stored depends mainly upon the absorptance, mass, and thermal conductivity of the objects the radiation strikes. Light colored surfaces reflect most of the energy which strikes them, while dark surfaces absorb most of it. Lightweight objects like a rug heat up quickly and release most of the heat to the air. Massive objects, like a brick wall have a much higher heat capacity and change temperature slowly, storing more heat and releasing less to the air.

DIRECT GAIN

Although the house itself and the furnishings provide some thermal storage mass, direct gain systems with significant glazing areas (more than about 10% of the floor area) require additional mass. This mass helps eliminate overheating the inside air during the day and stores heat for later use.

As the temperature of the air inside the living space drops below that of the storage mass, heat is transferred into the air. Stored solar energy is used rather than relying on a conventional source. The warm objects inside the room also increase the mean radiant temperature, offering greater comfort and further savings.

Heat is distributed inside the house by natural convection or through the use of small fans, perhaps the central backup system in the "fan only" mode. The amount of solar heat entering the house may be controlled with simple drapes, blinds or shades; overhangs and deciduous trees provide seasonal modulation. During mild weather, excess heat may be discharged by opening windows. Total system performance may be improved by the use of night insulation on the glazing to reduce heat loss.

30 Btu/° F = 3.5 gallons or 150 lbs.

DIRECT GAIN DESIGN POINTS

THERMAL STORAGE WALL

Masonry thermal storage walls were described in an American patent by F. Morse during the nineteenth century. However, they are often called Trombe walls after Dr. Felix Trombe who conducted pioneering research on their application during the 1950's. Water-filled containers may be substituted for masonry in thermal storage walls, providing slightly improved performance.

When first described, thermal storage walls are sometimes thought of as "strange looking" or "prison-like". In reality, they are difficult to distinguish from normal window glass from the outside. And inside the building, they look like a normal masonry wall. It is not necessary to make the wall continuous; windows for views, light and ventilation may be installed.

The impact of thermal storage walls on summer cooling loads is not yet fully understood. Good shading, and possibly some form of exterior vent should be used during summer.

Unless the wall also serves a structural function, its cost may be difficult to justify.

THERMAL STORAGE WALL

Thermal Storage wall passive solar systems utilize vertical south-facing glass and an adjacent massive wall to collect, store and distribute solar heat. The storage mass is located between the glazing and the living space rather than in the living space. A small air cavity is formed between the glazing and the mass wall. Solar radiation passes through the glazing and is absorbed by the dark surface of the mass wall, normally masonry. Heat is stored in the mass and slowly conducts through the wall to be radiated and convected into the living space several hours later. The use of high and low vents from the living space to the air cavity allows warm air to circulate into the house early in the day. Thermal storage walls with vents are used where heat is required during the day and at night. Backdraft dampers or operable dampers are used to stop circulation at night when the air cavity has cooled. Unvented or stagnating walls are used when daytime heating requirements are smaller, as in a bedroom.

30 Btu/° F = 3.5 gallons or 150 lbs.

THERMAL STORAGE WALL DESIGN POINTS

SUNSPACE/GREENHOUSE

The sunspace is a separate room, with large glazed areas and thermal storage mass, which acts as a solar collector. Sunspaces are typically attached to the south wall of the house; they may also be incorporated into the house as a room along the south side. In any case they must be constructed so that thermal isolation from the house is possible.

During the day, solar radiation passes through the glazing and strikes the storage mass and other objects inside. Again, a portion of the energy is stored in the mass and a portion is transferred to the air. Small fans, operable vents, windows or sliding glass doors may be used to transfer heat from the sunspace to the house. Storage mass inside the sunspace helps prevent daytime overheating while storing heat for transfer to the house in the early evening and for moderating sunspace temperatures throughout the night. Additional thermal storage mass inside the house helps improve overall performance.

Since the sunspace is not a part of the main living area, temperature control is not critical. During moderate weather, daytime temperatures can be allowed to climb, storing energy which would have been vented from an occupied direct gain space to reduce overheating. At night, auxiliary heat need not be added; sunspace temperatures can fall without causing discomfort inside the house.

SUNSPACE/GREENHOUSE

Sunspaces provide valuable benefits other than heating. Even at night and on overcast days, the sunspace acts as a buffer zone, protecting a portion of the building from severe outside temperatures and winds - a sort of overgrown storm window. For much of the year and for some period during the winter days, the sunspace will be quite comfortable and provides exciting additional living space. Finally, the sunspace can serve as a planting area, providing a warm place to start spring garden plants and a tempered growing area for winter crops.

Because sunspaces have large glazed areas and lack a conventional heating and cooling system, temperature swings will be greater than in conventional living spaces. Provision of adequate storage mass and night insulation systems can reduce winter extremes.

Due to the difficulty of providing summer shading, steeply sloped or roof glazing should be used judiciously. Large windows, vents or a power ventilator are necessary to reduce summer overheating.

30 Btu/°F = gallons or 150 lbs.

SUNSPACE DESIGN POINTS

SUNTEMPERING

Suntempering is a basic application of direct gain passive solar heating. A suntempered house is well insulated and weatherized and takes advantage of good orientation. More south glazing and less east, west and north glazing increases winter heat gains and reduces summer gains. Little or no additional thermal storage mass is provided. Since only the house and furnishings provide thermal storage, the amount of glazing must be limited to no more than ten to fifteen percent of the floor area throughout most of the South. Overhangs or other shading features must be used on all south glazing.

Almost every new house being designed and built today can utilize suntempering to reduce its energy consumption. Reductions in heating and cooling energy consumption of twenty to thirty percent are possible - without exotic technology and with little or no increased costs.

ROOF PONDS, DOUBLE ENVELOPES, THERMAL STORAGE CEILINGS, CONVECTION LOOPS AND OTHERS

A variety of other passive solar heating systems have been envisioned, designed and built. Roof ponds, double envelopes, thermal storage ceilings and convection loop systems are among them. These systems are not discussed here because they have not been well-developed or may not have been proven in the South. With further work, some may prove to be quite useful while others will be rejected.

While these systems may soon be developed or improved to the point that they are widely applicable for single-family houses, they have not yet been well accepted. However, the direct gain, thermal storage wall, and sunspace do provide the South with viable passive solar heating alternatives today.

WINDOW SHADING

Windows on the west, south and east sides of a building are subject to excessive solar gains during the cooling season. Without proper shading, a severe overheating problem may be created. Passive solar systems, with large south-facing glazed areas, call for special attention. Fortunately, south-facing glass is easily shaded by fixed horizontal overhangs. The following chapter contains a procedure for sizing fixed overhangs for shading.

If you examine the climatic data for your location, you will see that the most severe heating and cooling periods lag behind the low and high points in the sun's path (winter solstice and summer solstice). Any fixed overhang is a compromise between shading for the cooling season and exposure for the heating season. Note that identical solar angles are encountered in March and September—but the weather is quite different. For suntempered houses, this paradox does not pose a serious problem—fixed overhangs are adequate. But for passive solar systems designed to provide the majority of a house's heat, movable or adjustable shading devices should be considered. Hinged or jointed overhangs and awnings are two alternatives. Arbors or trellises covered with deciduous plants provide natural changes in shading in accordance with the weather rather than solar angles.

WINDOW INSULATION

During winter days, large glass areas in passive buildings allow solar radiation to pass directly into the interior - providing welcome heat and light. However, on long cold winter nights, even double glazed windows "leak" large amounts of precious heat from the interior to the night air. The use of night insulation over glazed areas is one method to reduce nighttime heat losses and improve passive system performance.

An effective night insulation system should first provide a good seal to the window or frame to minimize convection losses. If air is allowed to leak around the insulation, the resulting heat losses will severely reduce the value of the insulation system. Secondly, some insulation against conduction losses should be included. Good seals between the insulation device and the window are more important than high R-values. The best payback should occur with systems having a total R-value Figure of 3 to 4 and tight seals.

Common interior draperies are an example of simple night insulation. Although most draperies are installed for privacy and glare control, they do provide some insulation. Additionally, they protect the occupants from radiant heat loss to the cold glass surfaces and the resulting discomfort. Performance may be improved by using heavy quilted fabrics and sealing the draperies to the window frame at the sides, top and bottom. In the past, valances and weighted draperies have provided some top and bottom sealing.

WINDOW INSULATION

Roller shades are an inexpensive method of providing some control of heat loss. If sealed to the window frame, they have a reasonable insulating effect.

A variety of hinged or removable panel systems may be custom built by the builder or homeowner. Also, new night insulation products are becoming available on the commercial market, many of them operating on the roller shade principle. Velcro® seals or guide tracks provide an air seal, while insulating qualities are improved by incorporating several layers of fabric or film. The layers form air spaces for insulating. Manufacturers advertise R-values as high as eight. Attractive interior insulated shutter systems are being developed.

EXTERIOR SHELL

EFFECTIVENESS OF NIGHT INSULATION

INSULATION

Night insulation installed on the interior of a window has several advantages:

- Not necessary to protect from wind, rain, vandalism
- Convenient to adjust from inside the building
- Low maintenance

However, there are disadvantages which can tip the balance toward exterior insulation for some applications. The primary difficulty is the risk of excessive condensation on the inside surface of the glass. The presence of the insulation increases condensation by causing the glass temperature to drop and preventing inside air from moving across the glass and evaporating the moisture.

Several designers and builders have used custom-built interior night insulation systems with rigid foam insulation panels. Both hinged interior shutters and removable panel designs are being used.

Exterior insulation eliminates the condensation problem, but requires special attention to weathering and possible damage. Several passive houses built in the Southwest and the Rockies have utilized exterior, rigid insulation panels which are either hinged or installed on tracks similar to barn doors. Appearance, wind loads and storage are concerns. Reflectors may be incorporated into the panels to increase solar collection through the windows during the day.

Commercially available exterior insulation products are also beginning to emerge. Very attractive roll-down shutters made of interlocking wood, aluminum or PVC slats are available from several manufacturers.

EXTERIOR SHELL

The shutters roll down from a storage container above the window, guided by side tracks and provide a tight seal. Their insulating performance has not been quantified and costs are quite high.

Remember when shutters were made of wood and were actually hinged so that they could close over windows during severe weather? We're progressing back to that point!

LOW ENERGY COOLING

INTRODUCTION

The cooling of buildings includes two components: preventing heat buildup inside the building and removing heat from the building. The first component is concerned with preventing the interior temperature and humidity from climbing above outside levels. The second involves lowering and maintaining the interior temperature below the outside conditions. For many months during the year, the first tactic, sometimes called load minimization, is perfectly adequate when outdoor conditions are reasonable. But during the peak of the hot and humid southern summers, outdoor conditions are simply too harsh to maintain conventional standards of comfort without the use of mechanical air-conditioning. Cooling and dehumidification below outdoor conditions is normally accomplished with electric powered vapor compression air-conditioning units or heat pumps.

During the last two or three decades, low-cost electric power has allowed us to neglect the good design, conservation and common sense aspects of load minimization. The common approach has been to build any sort of house at all and then install an air-conditioner large enough to overcome all the problems - comfort at the touch of a switch. Today's higher electric rates have made this approach unreasonable. Prior to the advent of air-conditioning, the accepted approach was good design, conservation, common sense and..... a certain amount of perspiration. With modern materials, equipment, construction and design concepts, there are several new approaches which combine the best features of comfort, costs, and compromise.

- Absolute Comfort by conventional standards. Use air-conditioning to provide constant comfort conditions. Apply load minimization to reduce electric energy consumption.
- Lowest Costs. Do not use air-conditioning. Apply load minimization and low-energy cooling features to improve comfort conditions. Usually involves some discomfort by conventional standards.
- The Reasonable Compromise. Apply load minimization and low energy cooling features to provide comfort during most of the summer. Use air-conditioning to maintain comfort conditions only when required.

For most situations, the third alternate is most sensible. It offers a balance between comfort and costs and provides a great deal of flexibility.

LOW ENERGY COOLING (cont.)

COOLING LOAD MINIMIZATION

The cooling load on a house results from four sources of heat:

- 1) Solar gains through glazing
- 2) Conduction gains through the building skin
- 3) Infiltration gains
- 4) Internal gains from people, appliances, lighting, cooking and bathing

The third and fourth source include both sensible heat (associated with an increase in temperature) and latent heat (associated with an increase in humidity). In the following pages, methods of minimizing the effects of each heat source will be discussed.

SOLAR GAINS THROUGH GLAZING

Minimization of solar gains through glazing is quite simple - keep the sun out! Block it, reflect it, filter it; just keep it out of the building. Several strategies may be used: orientation, remote shading, exterior, shading, reflective glazing, filtering, and interior shading.

LOW ENERGY COOLING (cont.)

Like conduction heat loss, conduction heat gain occurs through the elements of the building envelope, the roof, walls, floor and doors. Conduction gains also occur through glazing, along with radiant heat gains.

However, during the cooling season there is another element - the radiant heat gains on the outside of the building. As the sun's rays strike the outside surface of the building, it becomes warmer, increasing the temperature difference and the heat flow rate through the wall or roof. Wall temperatures above 120° and roof temperatures above 140° are not common for dark-colored surfaces. The value of light-colored surfaces to reflect the sun's heat is obvious. Heat gains through ceilings may be greatly reduced by good attic ventilation.

Infiltration is the unwanted movement of outside air through a house. In the summer, infiltration brings in both heat and humidity. While the level of infiltration is normally lower in summer than in winter, due to lower windspeeds, it is still a major part of the load when the building is closed for air conditioning. The techniques for controlling winter infiltration also apply to summer infiltration control.

INTERNAL GAINS

Internal heat gains result mainly from people, appliances and lighting. In a well-insulated and shaded house, internal heat gains can comprise a significant portion of the total cooling load. For example, a large color television may create a heat load as great as that created by an R30 ceiling in a 1500 ft² house. Reduction of internal gains is largely a matter of common sense and conservation. Turn off unnecessary lights and appliances whenever possible. Use vent fans to remove excess heat and humidity from bathrooms and kitchens. Cook with covered pots to reduce heat requirements and limit escaping humidity. Vent clothes dryers to the outside. Install laundry equipment and water heaters in unconditioned areas. Substitute fluorescent lighting for incandescent lighting and get three times the light for the same power cost and heat output. By reducing natural gas and electricity consumption you save twice - once for the energy cost itself and once for the reduced cooling cost.

COOLING TECHNIQUES

The amount of heat gain through a glazed area varies with the orientation of the glazing. Horizontal or nearly horizontal glazing, such as a skylight, poses the greatest problem. For example, over the course of a clear August day in Atlanta, a horizontal surface will receive about 2000 BTU on each square foot of area. Peak values of heat gain will exceed 250 BTU/Hr. for each square foot. East-and west-facing vertical glazing is next with a day-long total of about 1100 BTU/Ft.² and peak values above 200 BTU/Hr. Ft.². Unshaded south-facing vertical glazing receives about the same total, with peak values of about 160 BTU/Hr. Ft.². Of course, most of this load could be eliminated through the use of fixed overhangs, although they are not effective for east and west glazing. For comparison, north glazing would receive about 350 BTU/Day ft.² with a peak value less than 40 BTU/Hr. Other orientations are described in the table below.

AUGUST SOLAR HEAT GAIN FACTORS FOR 32° NORTH LATITUDE--Daily Totals in BTU/ft²*

N	NNE/ NNW	NE/ SW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
342	463	706	935	1084	1121	1038	849	704	1198

*Total Solar Heat Gains for DS (0.125 in.) sheet glass

Adapted from the ASHRAE Handbook of Fundamentals-1977; p.26.21; table 21.

COOLING TECHNIQUES

Remote shading utilizes objects which are not part of the building to provide shade. Trees are an excellent example. For typical lots on east/west streets, the adjacent house often provides protection of east and west glazing. Some rare sites may even be protected by hills or mountains. Remote shades block the sun's direct rays and allow the heat to be dissipated away from the house. Some diffuse radiation will still be received.

COOLING TECHNIQUES

Exterior shades are a part of the building; overhangs, trellises, shutters, awnings, porches, and carports are examples. Simple fixed overhangs are quite effective on south glazing. A sizing chart is included in Chapter 6. Only very wide overhangs--a carport perhaps--are effective for east and west glazing. Non-south glazing usually requires some sort of solid or vertical element device.

Exterior shades may exclude almost all direct and diffuse radiation if located close to the glazing. Overhangs allow some diffuse radiation to strike the glazing. At the glazing itself, several opportunities are available. The use of double glazing reduces both solar gains and conduction gains. A variety of reflective and heat absorbing sun-control glazings are available which reduce solar gains by as much as 80%. Reflective or tinted films may be added to existing glazing.

In the extreme southern areas of the region, these alternates are reasonable for east, west and south glazing. In most cases the benefits are small for use on north glazing. For more northern locations with significant cooling loads - Dallas, Mobile and Charleston - reflective or absorbing glazing should not be used on south walls in residences since they would block the valuable winter heat gain. In locations where cooling loads are small, sun-control glazings may not be a good buy.

Sun-control glazing is effective in reducing both direct and diffuse solar gains. However, since it is attached directly to the glazing and absorbs some solar radiation, it does increase the conduction gain through the window slightly.

**EXTERIOR
ROLLDOWN SHUTTER**

COOLING TECHNIQUES

Interior shading provides an easily controlled last line of defense against unwanted solar gains. Blinds, shades and drapes all reflect a portion of the sun's radiant energy back through the glazing. Performance improves with dense, opaque materials and with lighter colors or reflective backings. Interior shading is not as effective as exterior shading, since some of the energy escapes into the house rather than being reflected to the outside.

Interior devices do provide flexibility - open in winter, closed in summer - and are quite effective when used in conjunction with an exterior device.

Heavy drapes or venetian blinds reduce heat gains by about 60% when compared to plain glass. That is quite an incentive to open and close them once a day during the cooling season.

COOLING TECHNIQUES

Cooling consists of removing heat that has entered the building. Load reduction means not allowing the heat to enter in the first place. This is accomplished by good insulation to reduce conduction heat gain, tighter construction to reduce infiltration heat gain, and solar control (by shade trees, overhangs, etc.) to reduce solar heat gain.

"Underground" houses, earth berming, and others are all examples of earth sheltering. The ground is typically cooler than the hot summer air, and hence will always reduce the conduction heat gains. In many locations, the ground is cool enough for heat to flow from the building to the ground--actually cooling the building rather than merely reducing the load. In addition, earth sheltering will reduce infiltration (load reduction), and often minimize temperature swings.

Although it is a seldom used technique in residences, evaporative roof cooling is becoming more common in commercial applications. In many climates, water can be sprayed over the roof, where it will evaporate and reduce the roof temperature. This can provide significant load reductions. In dry climates, air can be drawn into a building past a spray of water. As the water evaporates, it will cool the air, and thereby cool the building.

Natural ventilation is a particularly simple and appealing method of passive cooling. Any time you have opened a window to let in a cooling breeze, you have used natural ventilation. With careful attention to building orientation, window placement, site design, and the local microclimate, even the slightest breeze can be used to increase comfort in the home.

COOLING TECHNIQUES

Earth tubes use the cooler ground temperatures to cool air entering the building. Length, diameter, soil properties, and climate are critical factors in determining how effective an earth cooling tube will be. They are becoming increasingly popular with homeowners, leading to further efforts to study their characteristics with respect to moisture control, economics, and effectiveness.

Night sky radiation may be an effective cooling technique in many areas. Large amounts of thermal mass "see" the night sky and transfer heat to it by radiation, becoming cool. During the day this thermal mass soaks up heat from the building, helping to cool it. There is little doubt that this means of cooling can be very effective in clear arid climates. Structural support for the large mass required, and efficiency in humid climates are two sources of concern in the radiation cooling technique.

Everyone knows that hot air rises. A solar chimney is designed to get air very hot, thus causing it to rise rapidly up and out the top. The bottom of the solar chimney is connected to the house, and therefore creates a cooling breeze through the house. Particular care must be taken that the heat in the solar chimney is not conducted into the building. In addition, factors such as the direction in which the air exits from the chimney are important--since even a five mile-per-hour wind from the wrong direction may conceivably cause the hot air to flow back down the chimney and into the house!

Since hot air rises, the air near the top of the building is warmer than the air at the bottom. This is one reason why older homes in the South had high ceilings. So if a rather tall structure is vented at the top, and the warm air is allowed to escape, then ventilation will be caused, and the air below will be made cooler simply because it is moving.

VENTILATION

Throughout the Southeast there are significant periods of time when outdoor conditions are very pleasant. The building requires only ventilation to prevent a buildup of heat inside from solar gains and internal sources. Ventilation maintains temperatures near the outside levels and improves comfort conditions inside the building. With air motion, higher temperatures feel "cooler".

Ventilation may be driven by winds (natural ventilation), by thermal forces (stack effect ventilation) or by fans (forced ventilation). Natural ventilation may be adequate for most of the season in some sites, but is only as dependable as the wind. Stack effect ventilation requires only that the inside of the house be warmer than the outdoors in order to drive the flow. However, this condition is somewhat undesirable on hot days. Forced ventilation is the most powerful alternate and always available, but does consume electricity. A combination of these three ventilation alternates can provide excellent results in residences. Good building design and appropriate fans can maintain comfort conditions for most of the cooling season throughout the South. For those excessively hot and humid periods, the homeowner has the option of relying on air-conditioning or tolerating some discomfort to achieve even greater energy savings.

DESIGN CONSIDERATIONS

Natural ventilation and stack effect ventilation.

- Design openings for effective ventilation with all wind directions.
- Use roughly equal inlet and exit areas for maximum flow volume.
- Avoid short circuits between inlets and exits. Ventilation air must move through the space being cooled at the location and level where the people will be.
- Openings should be easily accessible for adjustment.
- Stack effect ventilation depends on large vertical separation between inlets and exits.
- Exits should not function as wind scoops which will force back flow conditions. Slight breezes will easily overcome normal thermal flow forces.

Avoid thinking of natural ventilation as wind flow through the building. It is not. The wind creates areas of high and low pressure around a house as illustrated. High pressure areas form where wind strikes the building and "backs up". Low pressure areas occur where velocities are high and where eddies form on the down-wind side. Air moves into the building through openings in the high pressure regions and exits at low pressure areas. The direction of internal flow does not always correspond to the wind direction.

- * HEAT LOSS
- * HEAT GAIN
- * DESIGN OF PASSIVE SYSTEMS
 - Collection Area
 - Storage Mass
 - Sun-Tempered Buildings
- * SIZING FIXED OVERHANGS

Solar 6

HEAT LOSS

Whenever the temperature inside a building is higher than the temperature outdoors, heat will flow from the building to its surroundings. To maintain a comfortable temperature for the occupants, this heat flow or heat loss must be made up by the building's heating system. Heat may be added by a conventional furnace, a passive solar system, or even by appliances and occupants. With certain information about the building's design and the weather conditions in the area, it is possible to make an accurate estimate of the rate of heat loss from the building. This estimate is essential to selecting the proper heating equipment and allows us to estimate the building's heating bills with reasonable accuracy.

The heat loss rate also provides a starting point for the detailed design of passive solar systems.

Heat is lost from a building through two major mechanisms - conduction heat loss and heat losses associated with the flow of cold air into the building (infiltration). Conduction losses occur as heat flows from the warm interior to the outside through walls, windows, doors, roof and floor. Infiltration takes place through the small cracks, around windows and doors and through porous building materials.

$$\begin{array}{c}
 \text{HEAT LOSS BY CONDUCTION} + \\
 \text{INFILTRATION} + \\
 \hline
 = \text{TOTAL HEAT LOSS (BTU/hr)}
 \end{array}$$

For both mechanisms, the amount of heat loss depends directly on the difference in temperature between the inside and outside of the building. As the temperature difference increases, the heat loss from the building increases. Heat loss calculations are normally made using an indoor temperature of 70° and an outdoor design temperature chosen for the particular location.

CONDUCTION

In order to calculate the conduction heat loss through a building's outer surfaces, it is necessary to have the details of the construction of each wall section, the floor, windows, doors, and the roof. Knowing the type and thickness of the materials used, the R-value of each exterior surface can be determined. R-values and supporting information are available in tables compiled by several sources, the most complete being the ASHRAE Handbook of Fundamentals. The R-value is the measure of resistance to the flow of heat, expressed in $\text{BTU}/\text{Ft}^2/^{\circ}\text{F}/\text{hr.}$ The higher the R-value, the more difficult it is for heat to flow through the object. The R-values for walls, floors and ceiling/roof combinations are normally the sum of the R-values of the materials included: siding, sheathing, insulation, wall board paneling, etc.

For the conduction loss calculation, the total R-values are converted into U-values, the overall coefficient of thermal conductivity, by dividing them into 1. $U = 1/R$.

The U-value describes how well a wall or other surface transmits heat. Higher U-values mean greater heat loss.

$$U = \frac{1}{R}$$

The heat loss through a building element (roof, wall...) is calculated by multiplying the U-value by the area of the element and the difference between the indoor temperature and the outdoor design temperature.

This process is repeated until all the exterior surfaces of the building are accounted for.

TYPICAL R-VALUES

Fiberglass, 3½"	11.0
Fiberglass, 5"	19.0
Wood, 1"	1.0
Common Brick, 4"	0.8
Cellulose, 3½"	13.0
Building Paper, Felt	0.06
Airspace, 4" vertical	0.94
Expanded Polystyrene, Beads, 1"	3.6
Window Glass	0.9
Double Pane Glass, ½" space	1.8
Plywood, ¾"	0.93

(See ASHRAE Fundamentals Handbook for detailed listing of R-values).

INFILTRATION

The infiltration losses, or heat loss due to cold air entering the building, may be estimated by one of two methods: the air change method or the crack method. The air change method assumes a number of air changes per hour in the building and calculates the resulting heat loss. This estimate is an educated guess based on the building type, construction details and quality of construction. The crack method estimates the heat loss by summing the total length of window and door perimeter and predicting the air infiltration rate based on tabulated values for various types of windows and doors. The results of either method are somewhat approximate.

In well-insulated buildings, the infiltration losses may be a major part, 40% or more, of the total heat loss. Tight construction, caulking, sealing and weatherstripping deserve careful attention.

Once the conduction heat loss and the infiltration heat loss are determined, the two are added together to obtain the total heat loss for the building. U-values are not typically used for estimating heat loss through slab floors or below-grade basement walls and floors. A different technique is applied which recognizes both the temperature and the insulating characteristics of the soil around the building:

The end result is a heat loss rate expressed in BTU/hr at stated design temperatures. For example, in Atlanta, a typical 2000 square foot house might have a heat loss of 40,000 BTU/hr at design conditions of 70°F indoors and 18°F outdoors.

This figure allows the selection of an appropriate heating system and selection of passive systems. In addition, several manipulations of the basic heat loss calculation results are sometimes useful.

Note: Infiltration rates below 1.0 air changes per hour require special care in both design and construction. Rates below 0.5 air changes per hour are very difficult to achieve.

ADJUST HEAT LOSS TO A DIFFERENT ΔT

CALCULATIONS

This calculation may be used to adjust the heat loss rate to a new outdoor design temperature or to find the design loss at any given temperature.

$$\text{HEAT LOSS IN BTU/HR.}_{\text{New } \Delta T} = (\text{Heat Loss})_{\text{Old } \Delta T} \times \frac{(\text{New } \Delta T)}{(\text{Old } \Delta T)}$$

CONVERT TO LOSS PER DEGREE DAY (BTU/ HDD)

This figure allows comparison of buildings located in different climates.

$$\text{HEAT LOSS in } \frac{\text{BTU}}{\text{HDD}} = \frac{\text{Heat Loss in BTU/hr} \times 24 \text{ hr/day}}{\text{Design } T \text{ in } ^\circ\text{F}}$$

CONVERT TO LOSS PER DEGREE DAY PER SQUARE FOOT (BTU/HDD $\cdot$ Ft²) =

THE BUILDING HEAT LOSS COEFFICIENT (BHLC)

Many thermal performance specifications are expressed in terms of a heat loss in BTU/Degree Day $\cdot$ ft².

$$\text{HEAT LOSS in } \frac{\text{BTU}}{\text{HDD ft}^2} = \frac{\text{Heat Loss in BTU/DD}}{\text{Living Area in ft}^2}$$

Note: The building heat loss coefficient is called the modified building loss coefficient in the Passive Solar Design Handbook, Volume II; Los Alamos Scientific Laboratory, 1980 (#DOE/CS-0127/2).

HEAT GAIN

A house gains sensible heat during the summer months from three sources: Hot outside air, internal heat sources (people, lights, appliances) and the sun.

The portion of the cooling load created by hot outside air is fairly simple to estimate. Heat moves into the building by conduction through the building shell and by infiltration. Insulation levels, temperature differences and areas are used to calculate conduction gains and the air change method allows the infiltration load to be estimated. It's much like a heat loss calculation in reverse.

Internal gains are much more variable and difficult to quantify. However, they are comparatively small and may be handled by simple assumptions when making equipment sizing calculations.

The final source of heat - solar gain - is the most difficult to quantify. The building receives solar heat indirectly through its walls, roof and doors. The sun strikes the outside surface and raises its temperature, causing increased heat conduction into the building. This effect can be estimated by using equivalent temperature differences (ETDs) in the conduction gain calculations. The ETDs include the effect of both hot outside air and solar gains on the building's shell.

Solar energy also passes directly into the building through windows, glass doors, and skylights. Due to the sun's high east to west summer path, glazing on east and west walls and horizontal surfaces presents particular problems.

The amount of solar heat transmitted through these surfaces can be minimized by the use of overhangs, trees, shrubs, blinds and draperies.

Since the sun's position, cloud cover, intensity of radiation, shading, and other factors change constantly, a detailed calculation would require the use of a computer. Fortunately, simplified techniques based on average conditions are available. The ASHRAE 1977 Fundamentals Handbook and Manual J provide two excellent references.

A heat gain calculation gives the capacity of the air-conditioning system required to cool the building during average design conditions. Cooling loads and air-conditioner capacities may be expressed in BTU/hr or tons of cooling capacity. A ton of cooling capacity is equal to 12,000 BTU/hr.

BTU/hr

DESIGN OF PASSIVE SYSTEMS

The difficulty involved in designing a passive solar system depends directly upon the fraction of heat to be provided by the system. As systems become larger and more complex, the number of potential problems increases, requiring more care in the design process. Low solar fraction passive systems, sun-tempered houses, are relatively simple to design using the guidelines in this publication and good common sense. However, the design of high solar fraction passive systems should not be attempted without the assistance of a competent professional with experience in passive solar design.

Like passive solar systems, design tools are available at various levels of complexity, ranging from rules-of-thumb to computer simulations of a building's thermal performance over a complete year. Acceptable rules-of-thumb are available for low fraction designs. But above that level, somewhat of a void exists. The complexity and cost of long term thermal simulations make them unacceptable for most residential design work. Simplified versions are being developed, but are not yet available. At an intermediate level, there are a variety of performance prediction procedures in use which are based on computer simulation work done at Los Alamos Scientific Laboratories. One basic version is presented later.

These techniques should be used with caution, since they are based on a set of assumed building construction and operating characteristics. The performance predictions obtained with these techniques will be quite accurate if the design being examined closely matches the assumptions. If significant deviations exist, particularly in the amount of thermal storage capacity, the accuracy of the predictions will suffer.

Programmable calculators and mini computers offer another array of passive design tools. Several commercially available programs allow simple simulations of a building's thermal performance, providing predictions of temperatures at key locations. These programs are most useful for assessing whether a particular design is subject to overheating on clear winter days or during summer.

RULE OF THUMB DESIGN

Rules-of-thumb provide a convenient approach to many design problems and are frequently utilized by designers and builders. However, a reliable set of rules-of-thumb for passive design have not yet been generated and tested in a large number of applications. Most of the rules-of-thumb and design tools now being used are based on the Los Alamos Scientific Laboratories computer simulations. And while some validation work has been done with Southwestern houses and test structures, there has been little input from actual experiences in the Southeast. So...these rule-of-thumb sizing procedures for collection glazing and thermal storage mass should be viewed as guidelines for initial design work. They are not foolproof.

RULE OF THUMB

SOLAR COLLECTOR AREA

A south-facing solar collection area of $\frac{\quad}{(R1)}\%$ to $\frac{\quad}{(R2)}\%$ of the floor area can be expected to reduce the annual heating load of a house in $\frac{\quad}{(location)}$ by $\frac{\quad}{(S1)}\%$ to $\frac{\quad}{(S2)}\%$.

If R4 night insulation is used, the heating load reduction will range from $\frac{\quad}{(S3)}\%$ to $\frac{\quad}{(S4)}\%$.

Values of R1, R2, and S1-S4 can be selected from the table for any of sixty-seven locations in the SSEC region.

*Adapted from
Passive Solar Design
Handbook, Volume Two,
Los Alamos Scientific
Laboratory, Table D-1,
p. 22.

SOLAR COLLECTOR AREA

CITY	R1	R2	S1	S2	S3	S4
Birmingham, Alabama	.09	.18	22	37	31	53
Mobile, Alabama	.06	.12	26	44	32	56
Montgomery, Alabama	.07	.15	24	41	32	55
Fort Smith, Arkansas	.10	.20	24	39	35	58
Little Rock, Arkansas	.10	.19	23	38	34	56
Wilmington, Delaware	.15	.29	19	30	34	55
Washington, D.C.	.12	.23	18	28	32	53
Apalachicola, Florida	.05	.10	28	47	34	58
Daytona Beach, Florida	.04	.08	30	51	35	60
Jacksonville, Florida	.05	.09	27	47	33	58
Miami, Florida	.01	.02	27	48	30	53
Orlando, Florida	.03	.06	30	52	35	60
Tallahassee, Florida	.05	.11	26	45	33	56
Tampa, Florida	.03	.06	30	52	35	60
West Palm Beach, Florida	.01	.03	30	51	33	57
Atlanta, Georgia	.08	.17	22	36	31	53
Augusta, Georgia	.08	.16	24	40	32	55
Macon, Georgia	.07	.15	25	41	33	55
Savannah, Georgia	.06	.13	25	43	33	56
Baltimore, Maryland	.14	.27	19	30	33	54
Lexington, Kentucky	.13	.27	17	26	31	50
Louisville, Kentucky	.13	.27	18	27	31	51
Baton Rouge, Louisiana	.06	.12	26	43	32	55
Lake Charles, Louisiana	.06	.11	24	41	30	53
New Orleans, Louisiana	.05	.11	27	46	33	57
Shreveport, Louisiana	.08	.15	26	43	34	57
Jackson, Mississippi	.08	.15	24	40	32	54
Meridian, Mississippi	.08	.15	23	39	31	53
Asheville, North Carolina	.10	.20	21	35	32	55
Cape Hatteras, North Carolina	.09	.17	24	40	33	55
Charlotte, North Carolina	.08	.17	23	38	33	55
Greensboro, North Carolina	.10	.20	23	37	34	57
Raleigh-Durham, North Carolina	.09	.19	22	37	33	55
Oklahoma City, Oklahoma	.11	.22	25	41	37	51
Tulsa, Oklahoma	.11	.22	24	38	36	58
Charleston, South Carolina	.07	.14	25	41	32	55
Columbia, South Carolina	.08	.17	25	41	33	56
Greenville-Spartanburg, SC	.08	.17	23	38	33	55
Chattanooga, Tennessee	.09	.19	19	32	30	50
Knoxville, Tennessee	.09	.18	20	33	30	50
Memphis, Tennessee	.09	.19	22	36	33	54
Nashville, Tennessee	.10	.21	19	30	30	49
Abilene, Texas	.09	.18	29	47	38	63
Amarillo, Texas	.11	.22	29	46	41	66
Austin, Texas	.06	.13	27	46	35	59
Brownsville, Texas	.03	.06	27	46	25	54
Corpus Christi, Texas	.05	.09	29	49	34	60
Dallas, Texas	.08	.17	27	44	35	59
Del Rio, Texas	.06	.12	30	50	37	62
El Paso, Texas	.09	.17	32	53	42	67
Fort Worth, Texas	.09	.17	26	44	35	59
Houston, Texas	.06	.11	25	43	32	55
Laredo, Texas	.05	.09	31	52	37	61
Lubbock, Texas	.09	.19	30	49	41	66
Lufkin, Texas	.07	.14	26	43	33	57
Midland-Odessa, Texas	.09	.18	32	52	41	67
Port Arthur, Texas	.06	.11	26	44	32	56
San Angelo, Texas	.08	.15	29	48	37	62
San Antonio, Texas	.06	.12	28	48	36	60
Sherman, Texas	.10	.20	25	41	35	58
Waco, Texas	.08	.15	27	45	35	59
Wichita Falls, Texas	.10	.20	27	45	38	62
Norfolk, Virginia	.09	.19	23	38	34	56
Richmond, Virginia	.11	.22	21	34	33	54
Roanoke, Virginia	.11	.23	21	34	33	54
Charleston, West Virginia	.13	.25	16	24	28	47
Huntington, West Virginia	.13	.25	17	27	30	50

ASSUMPTIONS

STOP!

Before you go any further, you should know what the fine print says. There are some conditions attached:

- Adequate thermal storage mass is assumed. (See the thermal storage mass rule-of-thumb.)
- The rule-of-thumb is valid for direct gain, Trombe wall and water wall systems.
- The upper limit is selected to prevent overheating on a clear January day with average outdoor temperatures.
- Double glazed windows are assumed.
- Internal heat gains are assumed to raise the interior temperature by 5°F.
- It is assumed that the house is well insulated; the heat loss rate varies according to the site climate. Assumed values of the Building Load Coefficient (BLC) are listed below. The BLC is the rate of heat loss from the house in BTU/DD · Ft² of floor space minus the heat loss through the south glazing.

Range of Heating Degree Days	Building Load Coefficient Exclusive of the Solar Wall -- Btu/DD sq. ft.	Building Load Coefficient for a Corresponding "Normal" Non-Solar Building -- Btu/DD sq. ft.
less than 1000	7.6	9
1000 - 3000	6.6	8
3000 - 5000	5.6	7
5000 - 7000	4.6	6
7000	3.6	5

EXAMPLE

If the actual Building Loss Coefficient is different, adjust the rule-of-thumb by multiplying the required south facing glazing areas (R1 and R2) by $\frac{\text{Actual BLC}}{\text{Reference BLC for the site}}$

EXAMPLE: Find the area of south-facing glazing required to provide a solar savings fraction of 18 to 27% in Louisville, Kentucky in a 1600 ft.² house with a design heat loss of 32,000 BTU/hr at 70°F indoors and 10°F outdoors.

FROM THE TABLE R1 = 13%
R2 = 27%
S1 = 18%
S2 = 27%

The reference value of the BLC for Louisville (4645 DD/Yr) is $7 \frac{\text{BTU}}{\text{DD} \cdot \text{ft.}^2}$

For this house:

$$\text{BLC} = \frac{32,000 \frac{\text{BTU}}{\text{Hr.}} \times \frac{24 \text{ Hr.}}{\text{Day}}}{(70-60)^{\circ}\text{F} \times 1600 \text{ ft.}^2} = 8 \frac{\text{BTU}}{\text{DD} \cdot \text{ft.}^2}$$

Adjust the values of R1 and R2 by multiplying by $\frac{8 \text{ BTU/DD} \cdot \text{ft.}^2}{7 \text{ BTU/DD} \cdot \text{ft.}^2}$

$$R1 = 13\% \times \frac{8}{7} = 14.9\%$$

$$R2 = 27\% \times \frac{8}{7} = 30.9\%$$

In this case, the rule-of-thumb is:

A south-facing solar collection area of 14.9% to 30.9% of the floor area can be expected to reduce the annual heating load of a house in Louisville by 18% to 27%.

The required glazing area is 238 to 494 ft.².

$$14.9\% \times 1600 \text{ ft.}^2 = 238 \text{ ft.}^2$$

$$30.9\% \times 1600 \text{ ft.}^2 = 494 \text{ ft.}^2$$

REWORK THIS EXAMPLE!

RULE OF THUMB

STORAGE MASS

The minimum thermal storage mass should be:

Water = $(0.072 \times \text{SSF} \times A_c)$ gallons
Storage

Masonry = $(3 \times \text{SSF} \times A_c)$ pounds of
Storage masonry

Where SSF = Solar savings fraction
in percent.

A_c = South-facing collection
area in ft.^2

This is equivalent to 6 BTU/lb°F of
storage capacitance $\times \text{SSF} \times A_c$.

WATER
(gallons)

$$[0.072 \times \text{SSF} \times A_c]$$

MASONRY
(pounds)

$$[3 \times \text{SSF} \times A_c]$$

ASSUMPTIONS

Assumptions:

- Mass is directly exposed to sunlight from 9:00 A.M. to 3:00 P.M.
or, for direct gain systems,
Mass is entirely within the direct gain space. Mass is not insulated from the space and the exposed surface area of the mass is 3 times the glazed area.
- Masonry storage is only effective to a depth of 4" to 6" (except Trombe walls.)
- If the storage mass is never exposed to direct sunlight, multiply the storage requirement by 4.

A typical frame house with normal furnishings provides approximately 4.5 BTU/lb°F of storage capacitance per square foot of floor area. This storage capacitance may be counted as part of the total requirement. Use only the floor area of the space in which the collection glazing is located.

DESIGNING SUN-TEMPERED BUILDINGS

A SUMMARY

Most of this publication concerns itself with the design of sun-tempered houses--houses that receive up to about one fourth of their heating energy needs from the sun. A summary of the important points is presented here; details may be found in the individual sections on siting, shading, glazing selection....

Provide effective summer shading for all south, west and east glazing.

Use trees and shrubs to shade the house from summer heat gains.

Start with a good energy saving design. Insulate the house well to reduce heating and cooling loads. Use caulking, weatherstripping and sealing to reduce unwanted air infiltration.

Site the house so that its longer side faces within 20° of south.

Relocate windows from the north, west and east sides of the house to the south side. Maintain enough windows on all four walls to provide good natural ventilation.

Unless thermal mass is incorporated into the house, do not use a south-facing collection glazing area exceeding 10% of the floor area. (200 ft.² of south glass in a 2000 ft.² house). Don't exceed 5% in the milder regions of the Southeast.*

CONVENTIONAL

ENERGY CONSERVING

SUN TEMPERED

* A very important exception is the use of large window areas in very mild climates - southern Florida for example. In such cases, windows can be very beneficial, if they are well shaded by porches, vegetation, overhangs, shutters or other devices.

SIZING FIXED OVERHANGS

This section provides a method of sizing fixed overhangs to provide summer shading from direct solar radiation. Overhangs sized by this method will provide effective shading for the five most severe hours on August 1. It may be assumed that complete protection from direct radiation is provided; only the diffuse component contributes to heat gain. In air-conditioning load calculations, this is the equivalent of making the assumption that the glazing faces north. This method is applicable only to overhangs which are considerably wider than the windows they shade. For example, a three-foot-wide overhang centered over a three-foot-wide window would allow morning and afternoon sun to strike the window.

PROCEDURE

The effective length of the shadow provided by an overhang may be found by the following steps.

- I. Locate the latitude of the site on the vertical scale by using the map or by reading directly on the scale.
- II. Select the appropriate curve for the direction which the window faces.
- III. From the latitude scale, read horizontally to the right to the direction curve and then down to the shadow length scale. The value on the shadow length scale is the length of effective shadow provided by each foot of overhang. Multiply this number by the length of the overhang (in feet) to obtain the total effective shadow length (in feet).

OVERHANG CHART

To use the chart, locate your location on the map and determine your approximate latitude. Follow this latitude straight across the graph to the intersection of the heavy curved line. Projecting this intersection straight down, then read the scale to determine the feet of vertical wall in shade for every one foot of overhang.

Example ..

Example: Atlanta, Georgia is very near the 34 degree latitude line. Coming straight across the graph to the heavy curved lines, it may be seen that for each foot of overhang on the south side, about 3.8 feet of vertical wall will be in shade in summer. Similarly for walls facing southeast or southwest, about 1.4 feet of vertical shade corresponds to a one foot overhang. Note that east and west walls have a constant 0.8 feet of shade per foot of overhang regardless of latitude. For a south facing window, in summer with the bottom of the glass located 5 feet from the overhang, the desired shading could therefore be provided by a 1.3 foot overhang ($5.0 \text{ feet} \div 3.8 \text{ feet of shade per foot} = 1.3 \text{ feet}$).

To maximize potential for heat gain in winter, using a 1.3 foot overhang, we would locate the top of the window's glass out of the area of shade in winter, or 0.8 feet below the overhang.

Similarly, for an existing two foot overhang, the amount of shading on a south wall in summer would be 7.6 feet ($2 \text{ feet} \times 3.8 \text{ feet of shade per foot overhang} = 7.6 \text{ feet}$).

REFERENCE: National Association of Homebuilders Insulation Manual, 1979, P. 54.

MATERIALS AND RESOURCES

*COLLECTION

- Glazing Materials
- Window Frames
- Collector Sizes
- Collector Costs
- Manufacturers

*STORAGE

- Materials
- Liquid Containers
- Phase-Change Materials
- Manufacturers

*DISTRIBUTION

- Fans and Blowers
- Ducts and Dampers
- Manufacturers

*MODIFIERS

- New Products
- Conventional Products
- Greenhouses
- Manufacturers

*CONSTRUCTION

- Insulation
- Sealers
- Caulking
- Vapor Barriers
- Manufacturers

*DEFINITIONS

*LATITUDES

*BIBLIOGRAPHY

APPENDIX

7

MATERIALS & RESOURCES

COLLECTION

Any material exposed to the sun will collect solar energy. Glazing products have the unique property of trapping long-wave radiation creating the greenhouse effect so useful for collecting solar energy. Windows, skylights and greenhouses are all collectors.

There are several factors to consider in selecting a collector. First might be its transmittance. Transmittance is the percentage of solar energy that will pass through a material. Clean window glass, for example, will transmit 85% of the energy striking it.

Another factor is weatherability. Will the product chosen stand up to sun, rain, cold, pollution, thermal expansion, etc., as long as the retrofit is intended to last?

The heat lost back out the collector is another concern. Collectors in general are very poor insulators and prone to air leaks around the edges. If night insulation is not used, it may be necessary to go to the additional expense of double glazing or installing storm windows. Also, bear in mind that some types and brands of window units seal much tighter than others because of the way in which they operate.

Finally, cost is always a central concern. It makes little sense to spend three times the money for a glazing that will save only a few extra cents in heating each year. Conversely, a collector that is cheap to install today may not seem like such a bargain if it has to be replaced in just a few years. This section compares various collection products - their sizes, characteristics and costs - as a guide for the consumer. Manufacturers listed at the end of this section and local suppliers should be consulted for more detailed information and current prices.

MATERIALS & RESOURCES — COLLECTION

COMPARISON: GLAZING MATERIALS

Each design that involves glazing will dictate different performance criteria for the glazing material depending on how and where it is used. These criteria along with other factors such as cost and aesthetics will affect the glazing selection process. A compact comparison of available rigid glazing types is presented below to aid in the material selection. It includes the solar transmittance, the pros and cons, a few representative brand names and their relative cost based on single glazing equal to 1.

<u>TYPE</u>	<u>COMMENTS</u>	<u>BRAND NAME</u>	<u>TRANS-MITTANCE</u>	<u>COST</u>
GLASS	<p>Pros: Excellent selective transmission, life-time and weatherability, low thermal expansion, resistant to ultraviolet degradation, air pollution and heat.</p> <p>Cons: Expensive, heavy, difficult to install and breaks easily.</p>	<p>2 Categories</p> <p>-Window Glass</p> <p>-Special Glass:</p> <p>Double strength</p> <p>Tempered</p> <p>Double Glazing</p> <p>Triple Glazing</p>	<p>85%</p> <p>85</p> <p>85</p> <p>71</p> <p>60</p>	<p>1</p> <p>1.3-3.0</p> <p>4</p> <p>5.3-12.0</p> <p>9.3-13.3</p>
ACRYLICS	<p>Pros: High transmissivity, strength and weatherability. Lightweight.</p> <p>Cons: Expensive (less than glass) easily scratched.</p>	<p>Single Wall:</p> <p>- PLEXIGLAS</p> <p>- LUCITE</p> <p>- ACRYLITE</p> <p>Twin Wall:</p> <p>- ACRYLITE SDP</p> <p>- COR-X-ACRYLIC</p> <p>- 220 TWIN WALL</p> <p>- POLYLUX</p>	<p>~92</p> <p>85-92</p>	<p>1.3-2.6</p> <p>2.2-4.0</p>
POLY-CARBONATES	<p>Pros: High impact resistance, similar to acrylics with reduced transmission.</p> <p>Cons: Expensive, easily scratched, non-rigid, prolonged exposure to sun causes embrittlement and color change.</p>	<p>MERLON</p> <p>LEXAN</p> <p>TUFFAK TWINWALL</p>	<p>86</p> <p>82-89</p>	<p>3-4.3.0</p> <p>1.6-2.3</p>
FIBERGLASS	<p>Pros: Low cost, lightweight, good solar transmission, high strength and durability (with coatings).</p> <p>Cons: Medium life span, not transparent, U-V coatings reduce transmittance, will yellow and "blossom" without coatings.</p>	<p>LASCOLITE</p> <p>FILON</p> <p>SUNLITE</p> <p>Flat: Standard</p> <p>- U-V Resistant</p> <p>- Coated</p> <p>- Corrugated</p>	<p>79-80</p> <p>85-90</p>	<p>.3-.6</p> <p>.5-.7</p> <p>.7-1.1</p> <p>.3-.8</p>

* Cost is based on single glazing equal to 1

MATERIALS & RESOURCES — COLLECTION

COMPARISON: GLAZING MATERIALS

Some situations such as greenhouses or temporary storm windows require an inexpensive, flexible glazing material. Plastic films can be a solution. Their short life span can be increased by using the film as the second glazing in a double glazed system where it can be protected from the weather and other physical damage. Below is a comparison of available plastics and films to aid in the material selection. It includes the solar transmittance, pros and cons, a few representative brand names and their relative cost based on polyethylene.

<u>TYPE</u>	<u>COMMENTS</u>	<u>BRAND NAME</u>	<u>TRANS-MITTANCE</u>	<u>COST</u>
POLY-ETHYLENE	<p>Pros: Extremely low cost, light, flexible, easy to install, good for inner glazing.</p> <p>Cons: Short life (less than a year), not wind or heat resistant. U-V resistant is better.</p>	<p>Standard</p> <p>U-V Resistant</p> <p>MONSANTO 602</p>	85%	<p>1</p> <p>3-5</p>
POLYESTERS	<p>Pros: Low cost, high surface hardness.</p> <p>Cons: Medium life span, up to 5 years if U-V coated.</p>	MYLAR	85	4.5-17.5
POLYVINYL-FLUORIDES	<p>Pros: Excellent weatherability, durability, strength and solar transmittance. Good U-V and weather-resistance.</p> <p>Cons: Expensive, available only in thin films (4 mil).</p>	TEDLAR	90-94	40
FLUORO-CARBONS	<p>Pros: Exceptional resistance to heat, weather and chemicals. High solar transmittance.</p> <p>Cons: Expensive, available only in thin films (1 mil).</p>	TEFLON FEP	98	29.5

* Cost is based on standard polyethylene equal to 1

MATERIALS & RESOURCES — COLLECTION

COMPARISON: WINDOW FRAMES

The frame of a window can affect its performance by as much as 25%. The frame comparisons below assume that the window has been installed and sealed correctly and is in proper working order. Note that the infiltration rate for a casement or awning window whose joints seal by compression is higher than that of a fixed window with no operable joints, but lower than that of a single or double hung window which has a sliding type seal. Also, the good insulating qualities of wood make it the optimum frame for cutting heat loss. When using a metal frame window, be certain that it has a thermal break to reduce heat losses through the frame.

METAL

(Aluminum or Steel)

PROS: Strength, stability (will not shrink or swell) durability, precision consistency.

CONS: Can corrode or rust. Needs paint or coating. Poor thermal insulator without thermal break.

WOOD

(Pine, Fir, Spruce or Cedar)

PROS: Good thermal insulation qualities if vinyl coated, minimal maintenance and distortion, etc., economical.

CONS: Will swell, shrink and wear. Can be minimized with vinyl coating. Must be painted or sealed if not vinyl coated.

INFILTRATION COMPARISON

Window Type

Fixed
Casement
Awning
Single hung
Double hung
Sliding glass
Hoppers
Jalousie

Infiltration

Low
↓
High

HEAT LOSS COMPARISON

FRAME AND GLAZING TYPE

Double glazed wood sash with storm window
Double glazed metal sash with thermal break & Storm
Single glazed wood sash with wood storm
Single glazed metal sash with wood storm
Single glazed metal sash with metal storm
Double glazed with storm (without thermal break)
Double glazed wood sash
Double glazed metal sash with thermal break
Double glazed metal sash
Single glazed wood sash
Single glazed metal sash

Heat Loss

.423 Btu/ft²°F hr.
.470
.476
.518
.560
.564
.585
.650
.780
1.074
1.130

MATERIALS & RESOURCES — COLLECTION

COLLECTOR SIZES

Prefabricated collection systems come in a wide variety of sizes. Custom systems can be made in almost any size. The purpose of the next two pages is to give a range of available sizes. Since there can be over 50 different sizes of one type window, it is best to check with different manufacturers for exact sizes and costs.

PICTURE

SLIDING

DOUBLE HUNG

AWNING

CASEMENT

MATERIALS & RESOURCES — COLLECTION

COLLECTOR SIZES

SKYLIGHT

SKY WINDOW

WINDOW WALL

SLIDING DOOR

GREENHOUSE

MATERIALS & RESOURCES — COLLECTION

COLLECTOR COST

There are many other methods of using glazing for passive gains other than windows. Some of these are listed below with their approximate cost as of July 1980. It must be understood that these prices will vary widely from region to region and job to job.

SKYLIGHTS

Area	Single Cover	Double Cover
0-10 sq. ft. Installed	\$11	\$17
10-20	9	13
20-30	11	16
30-65	8	12

SKY WINDOWS

\$10-\$15 per sq. ft. installed (note that overhead glazing should be tempered, safety glass or plastic).

STORM WINDOWS

\$3 to \$5 per sq. ft. installed
\$1.50 to \$3.50 materials

GREENHOUSE

Lean-to \$7.50 to \$18 per sq. ft. (with larger areas at lower end)

WINDOW WALL

Approximately \$13.00 sq. ft. (depends on size, height, mullion spacing, etc.)

SLIDING DOORS

Single glazed - \$4/sq. ft. installed (Cheapest doors are aluminum frame. Wood frame and better quality, tighter doors are more expensive.)
Double glazed - \$6/sq. ft. installed
Single doors - (34" x 76") Can be found for as low as \$9 (.50/sq. ft.)
Double glazed doors - (34" x 76") Can be found for as low as \$35 (1.80/sq. ft.)

MATERIALS & RESOURCES — COLLECTION

MANUFACTURERS

The following list of manufacturers and sources is included to help the homeowner in locating and obtaining more information on a specific product. It is not intended to be a listing of all available manufacturers, but rather an aid in locating specialized passive products for more information. It is also recommended that the homeowner check the yellow pages for local suppliers and manufacturers.

ITEM

SOURCE

WINDOWS, SLIDING GLASS DOORS, STORM WINDOWS

*See yellow pages under windows, jalousies, storm windows, doors, hardware, building materials, mill work, etc.

SKYLIGHTS

*See yellow pages under skylights.

GREENHOUSES

- *Aztec Solar Company
Post Office Box 272
Maitland, Fla. 32751
(305) 628-5004
- *Bio-Energy Systems, Inc.
Box 489
Mountaindale Road
Spring Glen, N. Y. 12483
(914) 434-7858
- *Bromack
6554 East - 41st Street
Tulsa, Oklahoma 74145
(918) 664-5300
- *Colorado Sunworks
Post Office Box 455
Boulder, Colorado 80306
(303) 443-9199
- *Creighton Solar Concepts
662 Whitehead Road
Lawrenceville, N. J. 08648
(609) 587-6527
- *Dalen Products, Inc.
201 Sherlake Drive
Knoxville, Tennessee 37922
(615) 584-3663
- *Earth Metabolic Design
Box 2016 - Yale Station
New Haven, Ct. 06520
(203) 776-4921
- *Egge Research
Route 6 - Box 394-B
Kingston, N. Y. 12401
(914) 336-5597

ITEM

SOURCE

GREENHOUSES (CONTINUED)

- *The Energy Factory
5622 East Westover
Suite 105
Fresno, Ca. 93727
(209) 292-6622
- *Housewarming Development
Corporation
Box 8 - 1928-6th Street
Boulder, Co. 80306
(303) 443-7970
- *Kalwall Corporation
Post Office Box 237
Manchester, N. H. 03105
(603) 627-3861
- *Lord & Burnham
Irvington-On-Hudson
New York, N. Y. 10533
(914) 591-8800
- *Multi-Research Corp.
Highway 35
Keyport, N. J. 07735
(201) 264-8000
- *Rolscreen Company (Pella)
Pella, Iowa 50219
(515) 628-1000
- *Skytherm Processes and
Engineering
2424 Wilshire Blvd.
Los Angeles, Ca. 90057
(213) 389-2300
- *Solar Dynamics of Arizona
1100 N. Lake Havasu Drive
Lake Havasu City, Az. 86403
(602) 855-7555
- *Solargenics, Inc.
9713 Lurline Avenue
Chatsworth, Ca. 91311
(213) 998-0806
- *Solar Masters Unlimited
606 North - 1st Street
Atwood, Kansas 67110
(913) 626-9593

MATERIALS & RESOURCES — COLLECTION

MANUFACTURERS

ITEM

GREENHOUSES (CONTINUED)

SOURCE

- *The Solar Room Company
Box 1377
Taos, New Mexico 87571
(505) 758-9344
- *Solar Technology Corp.
2160 Clay Street
Denver, Colorado 80211
(303) 455-3309
- *Solar Technology, Inc.
119 North Center Street
Statesville, N. C. 28677
(704) 873-7959
- *Solartherm, Inc.
110 Sprint Street
Silver Spring, Md. 20910
(301) 882-4000
- *Texas Greenhouse Company
2717 St. Louis Avenue
Ft. Worth, Texas 76110
(817) 926-5447
- *U.S. Solar Pillow Corp.
2458 Highway 6 & 50
Grand Junction, Co. 81501
(303) 242-2743

SPECIAL GLAZING

- *TEFLON, MYLAR, LUCITE
Dupont
1007 Market Street
Wilmington, Delaware 19898
(302) 774-1000
- *FILON
Filon Div., Vistron Corp.
12333 Van Ness Avenue
Hawthorne, Ca. 90250
(213) 757-5141
- *ACRYLITE SDP
CYRO Industries
Wayne, New Jersey 07470
(201) 839-4800
- *LEXAN
General Electric Company
1000 Western Avenue
Peabody, Mass. 01960
(617) 532-1977

ITEM

SPECIAL GLAZING (CONTINUED)

FILMS

SOURCE

- *TUFFAK-TWINWALL
Rohm & Haas
Independence Mall West
Philadelphia, Pa. 19106
(215) 592-3000
- *Dun-Ray
Dunmore Corporation
Newtown Industrial Commons
Pennsylvania Trail
Newtown, Pa. 18940
(215) 968-0442
- *Kool-Vue
Solar Screen
53-11 105th Street
Corona, N. Y. 11368
(212) 592-8222
- *Llumar
Martin Processing, Inc.
Post Office Box 5068
Martinsville, Va. 24112
(703) 629-1711
- *NunSun SumSun
Standard Packaging Corp.
National Metallizing Div.
Cranbury, N. J. 08512
(609) 655-4004
- *Plastic-View Film
Plastic-View Transparent
Shades
Post Office Box 25
Van Nuys, Ca. 91408
(213) 786-2801
- *P-19 Film
3M Company
3M Center
Saint Paul, Mn. 55101
(612) 733-1110
- *Reflecto-Shield
Vanleer U.S.A.
64 Industrial Parkway
Woburn, Ma. 01801
(617) 935-7850
- *Sanguard
Metallized Products
224 Terminal Drive South
St. Petersburg, Fla. 33712
(813) 822-0212

MATERIALS & RESOURCES

STORAGE

Once collected, heat needs to be stored for later use. Any material will absorb and hold heat for a time, but only certain materials will do it efficiently and cheaply enough to be practical. Basically, there are three mediums used for thermal storage--water, solids such as concrete, masonry and rocks, and phase-change materials.

Water is easily the cheapest material and stores large amounts of heat in a relatively small area. Leakproof storage, however, can be difficult to construct and sometimes expensive, although very inexpensive options are available.

Rocks, concrete and masonry can also be relatively inexpensive. They are very heavy, however, and space consuming. It takes almost five times more brick or rock than water by weight to store one Btu of heat. This can possibly create some structural problems, but the masonry or concrete storage can also serve as a floor slab or wall.

Phase-change materials store a great deal of heat in a small area and are very costly. These chemical combinations are formulated to change state at about 80°F. and absorb heat as they melt, or release it as they solidify. Compared to other types of storage, they can hold tremendous amounts of heat, but their cost may make them prohibitive unless space is at a premium.

In addition to characteristics of the more common storage materials and water containers, this section lists their relative costs based on the cost-per-Btu of storage or on dollars-per-gallon of water stored. The two cost guides may also be cross-referenced using the comparison of materials on p. (130). More detailed and updated information is available from the local suppliers or the manufacturers listed at the end of this section.

MATERIALS & RESOURCES — STORAGE

COMPARISON: MATERIALS

There are many different types of storage materials. Some of the factors affecting a material's applicability to a specific design are size, weight and/or cost. Also, any special construction or containers that may be required should be considered. The following table gives data to help in this selection process. The cost data is the relative cost-per-unit of storage based on brick equal to 1. For example, a concrete block storage system will cost 1.63 times more than a brick storage system that will store the same amount of energy.

	<u>TYPE</u>	<u>UNIT SIZE</u>	<u>WEIGHT PER UNIT</u>	<u>COST</u>
Face Brick	2½" x 4" x 8"	5.7 lbs.	1
	Brick Paver	½" x 4" x 8"	1.14	10.8
Quarry Tile	6" x 6" x ½"	1.28	13.9
	Concrete Slab (s.f.)	4" thick	38.6	1.35
		6" thick	58.0	1.35
Lightweight Concrete Block	8" x 8" x 16"	24.0	1.63
	Lightweight Concrete Block with filled core	8" x 8" x 16"	50.0	.88
Heavyweight Concrete Block	8" x 8" x 16"	42.0	.69
	Heavyweight Concrete Block with sand filled core	8" x 8" x 16"	68.0	.49
Sand	1 Cubic Foot	94.6	.22 *
	2"-3" Rock (30% voids)	1 Cubic Foot	115.5	.18 *
Water	1 Cubic Foot	62.3	.003*

*Cost is for material only, storage container not included.

MATERIALS & RESOURCES — STORAGE

COMPARISON: MATERIALS

A comparison of five basic storage materials by weight, by volume and by cost is included on this page. In the cost comparison, brick is equal to 1. Because of this, the relative cost of any storage material from the preceding page can be directly compared to the water and phase-change salts. Also, since the liquid storage container comparison on the following page is based on water storage in a 55-gallon drum, their relative cost can be multiplied by the .21 for water in a 55-gallon drum to compare the different liquid storage system costs to the other available systems.

EQUIVALENT HEAT CAPACITY BY WEIGHT:

BY VOLUME:

BY COST:

MATERIALS & RESOURCES — STORAGE

COMPARISON: LIQUID CONTAINERS

There are many types of containers for liquid storage systems. The following chart lists some of these containers, their size, capacity and relative cost based on a 55-gallon drum equal to 1. The galvanized steel can be custom-made in almost any size up to 20' long, but was sized the same as the Kalwall tubes for a direct comparison. Other containers such as bottles, cans and milk jugs can be collected for free. The container should be air-tight and corrosion resistant to provide a long maintenance-free life.

<u>TYPE</u>	<u>SIZE</u>	<u>CAPACITY</u>	<u>COST</u>
<u>FIBERGLASS</u>	12" dia. x 4'	23.5 gals.	12
(KALWALL)	12" dia. x 8'	47	7.8
	18" dia. x 5'	66.2	7.0
Includes end caps	18" dia. x 10'	87.3	6.4
	60" dia. x 5'	734.5	1.9

<u>GALVANIZED STEEL</u>	12" dia. x 4'	23.5	10.4
	12" dia. x 8'	47	7.2
Includes end caps	18" dia. x 5'	66.2	5.9
	18" dia. x 10'	87.3	6.5
	60" dia. x 5'	734.5	1.6

<u>CUSTOM TANKS</u>			
Fiberglass and Steel	Any Size	Any Quantity	2.5 to 12.7

<u>STACKED TANKS</u>			
Fiberglass (One Design)	95 x 16½ x 24½	94	14.5
Steel (One Design)	94 x 12½ x 24	107.2	8.4

DRUMS

55 Gallon	1'9" dia. x 3'	55	1
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WATER BEDS

Twin	3' x 6' x 11"	127	2.4
King	6' x 6' x 10"	235	1.3

BOTTLES, CANS, JARS, MILK JUGS

Varies	.2 to 1 gal.	*
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* These items can often be collected for free.

MATERIALS & RESOURCES — STORAGE

COMPARISON: PHASE-CHANGE MATERIALS

Phase-change materials are typically chemical compounds that melt and change from a solid to a liquid at around 80°F. As they melt, they absorb a great deal of energy, but remain at 80°F until they are completely melted. They can then continue to absorb energy with about the same efficiency as rock (see the graph below). As they cool-down and begin to solidify, they release the stored energy as heat. These materials store large amounts of energy in a small volume but at a relatively high cost.

HEAT STORAGE CAPACITY:

AVAILABLE MATERIALS:

CEILING TILES

TYPE	BRAND NAME	MATERIAL	SIZE	WEIGHT	COST
Polymer Resinous Concrete Tile	SOL-AR-TILE	Glaubers Salt	2' x 2'	44 lbs.	\$40.00
3 Ply Aluminum Foil Laminate Pouch	HEAT PAC	Sodium Sulfate	16½ x 24 x ¾"	10	12.60

RODS

TYPE	BRAND NAME	MATERIAL	SIZE	WEIGHT	COST
Black Polyethylene Pipe	THERMALROD-27	Calcium Chloride Hexahydrate	6' x 3½ diameter	35	10.82
Black Polyethylene Pipe	THERMOL-81	Calcium Chloride Hexahydrate with additives	3½" diameter 6' length	35	12.17

DRUMS

TYPE	BRAND NAME	MATERIAL	SIZE	WEIGHT	COST
Steel Cylinder	TEXXOR HEAT CELL	Calcium Chloride Hexahydrate (Bisol II)	4.26" diameter 7" length	4.56	14.43

* Cost are storage cost in dollars per 1000 BTU's stored and are based on manufacturers prices as of 7/80.

MATERIALS & RESOURCES — STORAGE

MANUFACTURERS

The following list of manufacturers and sources is included to help the homeowner in locating and obtaining more information on a specific product. It is not intended to be a listing of all available manufacturers, but rather an aid in locating specialized passive products for more information. It is also recommended that the homeowner check the yellow pages for local suppliers and manufacturers.

ITEM	SOURCE	ITEM	SOURCE
BRICK, TILE, BLOCK, ETC.	*Yellow pages under new and used building material suppliers, rock quarries, salvage yards, etc.		*Professional Fiberglass Products Post Office Box 1179 Ada Industrial Park Ada, Oklahoma 74820
KALWALL TUBES	*Kalwall Corporation Box 237 1111 Candia Road Manchester, N.H. 03105 (603) 627-3861		*Also see yellow pages for custom fabrication
STEEL CULVERT	*Yellow pages under culvert, drainage	STACKED TANKS	*One Design Mountain Falls Road Winchester, Va. 22601 (703) 877-2172
STEEL TANKS	*Independent Living, Inc. 2300 Peachford Road Suite 2200 Doraville, Georgia (404) 449-5900 *Solar Energy Products, Inc. 1208 N.W. - 8th Avenue Gainesville, Fla. 32601 (904) 377-6527 *Solar Energy Systems of Georgia, Inc. 5825 Glenridge Dr., N.E. Building #10 Atlanta, Georgia 30323 *State Industries, Inc. Cumberland Street Ashland City, Tn. 37015 (800) 251-8170 *Also see yellow pages for custom fabrication	DRUMS	*See yellow pages under barrels and drums
		WATER BEDS	*See yellow pages under water beds
		CANS, JARS, BOTTLES, ETC.	*Look at local bars, restaurants, around the house, canning and bottling companies, etc.
		PHASE-CHANGE MATERIALS	*SOL-AR-TILE Architectural Research Corporation 40 Water Street New York, N.Y. 10004 (212) 943-3170 *HEAT PAC Collodial Materials, Inc. Post Office Box 696 Andover, Ma. 01810 (617) 475-3276 *THERMALROD-27 Energy Materials, Inc. 2622 South Zuni Englewood, Co. 80110 (303) 934-2444 *THERMOL-81 PSI Energy Systems, Inc. 1533 Fenpark Drive St. Louis, Mo. 63026 (314) 343-7666
FIBERGLASS TANKS	*Acorn Structures, Inc. Post Office Box 250 Concord, Ma. 01742 (617) 369-4111 *Owens-Corning Fiberglass Corporation Fiberglass Tower Toledo, Ohio 43659 (419) 248-8063		

MATERIALS & RESOURCES — STORAGE

MANUFACTURERS

ITEM

SOURCE

PHASE-
CHANGE
MATERIALS
(CONTINUED)

*TEXXOR HEAT CELL
Texxor Corporation
9910 North - 48th Street
Omaha, Nevada 68152
(402) 453-7558

BRICK
STORAGE BINS

*Hyro-Flex Corporation
2101 N.W. Brickyard Rd.
Topeka, Kansas 66618
(913) 233-7484

*Solar Shelter Engineering,
Incorporated
35 South Maple Street
Kutztown, Pa. 19530
(215) 683-6769

ROCK
STORAGE BINS

*Energy Alternatives, Inc.
2212 South Main Street
Moscow, Indiana 83843
(208) 882-0200

*National Energy Corp.
21716 Kendrick Avenue
Lakeville, Mn. 55044
(612) 469-3401

*Solaron Corporation
720 South Colorado Blvd.
Denver, Colorado 80222
(303) 759-0101

MATERIALS & RESOURCES

DISTRIBUTION

In many passive retrofit designs, some sort of distribution device is necessary to get the heat from the thermal storage to where it is needed. These devices include fans, blowers, ducts, and dampers. If your passive system must have a fan or blower, be sure that the amount of energy it consumes will not negate or exceed the amount of heating energy that your system is supposed to be saving, or your investment will be lost.

Adequate levels of ventilation are very important to human comfort even during the heating season. Fans and blowers keep air from stagnating and smelling stale in the winter when your home is sealed from fresh outside air. They also can reduce the mechanical cooling load of your home in the summer by creating air movement which takes heat off of your body by convection. A good ceiling fan for example, will allow the thermostat setting to be reduced by several degrees without affecting the comfort of the people inside.

Buying and installing a ceiling or other type of fan is relatively simple, but designing a duct and blower system and integrating it with an existing system requires

professional advice. There are enough types, sizes, and brands of distribution devices to fill an entire catalog, so in this section we describe only the more common types of ducts, duct insulation, grilles, dampers, fans, and blowers and their general price ranges. The manufacturers and sources listed at the end of this section as well as local suppliers should be consulted before selecting any distribution system.

MATERIALS & RESOURCES — DISTRIBUTION

COMPARISON: FANS & BLOWERS

The following table lists some of the available types of fans along with their range of sizes, capacities, energy usage and cost. Note that an energy use of 100 watts cost 1/2 cent per hour of continuous use at an electric rate of 5 cents per kwh. The costs for the fans only are taken from July, 1980 data. Installation is not included and can be costly for house ventilators, blowers and attic fans.

<u>TYPE</u>	<u>SIZE</u>	<u>CAP. (CFM)</u>	<u>ENERGY USE *</u>	<u>COST **</u>
Ceiling	36" to 52"	1000-7000	55-155	\$50-250
House Ventilator	14" to 36"	1250-3000	130-300	115-450
Blower		250-2660	120-455	35-335
Attic	6" to 36"	375-1000		110-455
Freestanding	20"	1500-2000	100-165	20-45
Oscillating	12" to 16"	1000-2100		20-60
In Duct Booster	5" to 8"	55-250	12-35	19-33

* Energy use in watts per hour.
 ** Prices as of 7/80.

MATERIALS & RESOURCES — DISTRIBUTION

COMPARISON: DUCTS & DAMPERS

When building an addition or modifying an existing room for passive solar collection, various ducts, dampers and grilles are required. Sometimes, a duct can be made by sealing off the bottom of two joists with plywood or thermax etc. to form a between joist duct. The available sizes and material costs of other ducts and dampers are included in the list below.

TYPE

SIZE

COST*

DUCTS

Fibre	2" to 6" dia.	\$0.54 - 2.35/l.f.
Aluminum	4" to 16" dia.	1.48 - 7.12/l.f.
Steel	4" to 16" dia.	1.18 - 7.20/l.f.
Flexible (insulated)	6" to 8" dia.	2.00 - 2.85/l.f.
Between Joist	9½" by 14½" (typ.)	**

DUCT INSULATION

Blanket	.13/s.f.	\$1.00/s.f.
Board	1.30/s.f. (Material Only)	3.50/s.f. (Installed)

DAMPERS

Register Wall	4" x 8"-12" x 20"	\$16 - 43
Baseboard	8" x 10"-12" x 13"	19 - 27
Floor	4" x 6"-10" x 16"	9 - 21
Backdraft (on wall)	Varies	=.08/s.f. (Materials Only)
In Duct (motorized)		50 - 200

GRILLES

Adjustable	4" x 8"-12" x 20"	\$7.50 - 18
Nonadjustable	6" x 6"-16" x 16"	5.00 - 10.50

* Prices as of 7/80.

** Cost vary depending on location of joist in house and material used. (Can be plywood, duct board, thermax, etc.)

MATERIALS & RESOURCES — DISTRIBUTION

MANUFACTURERS

The following list of manufacturers and sources is included to help the homeowner in locating and obtaining more information on a specific product. It is not intended to be a listing of all available manufacturers, but rather an aid in locating specialized passive products for more information. It is also recommended that the homeowner check the yellow pages for local suppliers and manufacturers.

<u>ITEM</u>	<u>SOURCE</u>	<u>ITEM</u>	<u>SOURCE</u>
FANS & BLOWERS	*Airtrol Corporation 203 West Hawick Street Rockton, Illinois 61072 (815) 624-8051		*Also see yellow pages under fans and small electric appliances
	*American Coolair Corp. Post Office Box 2300 Jacksonville, Fla. 32203 (904) 389-3646		*Also see local hardware and building material suppliers
	*Hudson Products Corp. Post Office Box 36100 Houston, Texas (713) 785-4000	BACKDRAFT DAMPERS	*Hot Stuff 406 Walnut Street La Jara, Colorado 81140 (303) 274-4069
	*Hunter (div. of Robbins & Myers, Inc.) 2500 Frisco Avenue Post Office Box 14775 Memphis, Tennessee 38114 (901) 743-1360		*Can also be homemade
	*I.L.G. 2850 Pulaski Road Chicago, Illinois 60641 (312) 725-8016	DAMPERS, DUCTS & GRILLES	*See yellow pages under heating equipment, local hardware and building material suppliers
	*Kalwall Corporation Box 237 1111 Candia Road Manchester, N.H. 03105 (603) 627-3861		
	*Lay Blower Company, Div. of Phillips Industries 2027 Home Avenue Dayton, Ohio 45407		
	*Weather Energy Systems, Inc. 39 Barlows Landing Road Pocasset, Mass. 02559 (617) 563-9337		
	*W. W. Grainger, Inc. 5500 West Howard Street Skokie, Illinois 60077 (312) 982-9000		

MATERIALS & RESOURCES

MODIFIERS

Modifiers control the amount of heat that flows through the Wall, the Window, or the Space by either shading or insulating it. A modifier can be anything from a simple drapery liner to the very sophisticated "Bead Wall" system. Overhangs, reflectors, and Venetian blinds are also types of Modifiers.

Care should be taken in selecting a Modifier so that it will perform the job of controlling heat in the most efficient manner possible. For example, a single device which will both insulate in the winter and shade in the summer will often be less expensive than buying two separate devices for insulating and shading.

Shading devices perform best on the exterior of a window because they intercept the sun's heat before it enters the room. Insulation also has advantages being on the outside of a window where it will not cause condensation on the glazing which can occur with interior window insulation. Exterior devices, however, must be built to withstand the effects of weather. They also can be very difficult to design so they operate from the inside, and aesthetically, some exterior devices may not fit in with the existing design of your home.

This section is divided into three parts which give a brief description of many common modifying products. First, are the new products on the market; second, are conventional building products used to control the sun; and lastly, are modifying products for greenhouses and sunspaces. The manufacturers listed at the end of this section can provide more detailed information as well as current prices on all of the products shown.

MATERIALS & RESOURCES — MODIFIER

TYPES: NEW PRODUCTS

There are many new products available for insulating and/or shading a window or glazing area. They can be divided into five basic categories: 1) pull down type, 2) crank down (interior and exterior), 3) horizontal sliding, 4) shutter, and 5) drapery. These products as well as a few specialty devices are described in this section along with specific cost data as of July, 1980. For more information and current costs on these specific products, see the manufacturers listing at the end of this section.

	<u>TYPE</u>	<u>BRAND NAME</u>	<u>DESCRIPTION</u>	<u>COST \$/S.F.</u>
PULL DOWN	ATC WINDOW QUILT	A five layer insulating shade (R-4.3) on tracks. Two layers insulation, one layer reflective film, two layers finished fabric with quilt pattern finish.	\$4.50
		SUN QUILT THERMAL GATE	Three layer motorized shade (R-7) with a quilt pattern finish. Runs in tracks.	5.00 - 8.00
		INSEALSHAD	Three independent shades 1) reflective, 2) heat absorbing, 3) clear in one unit. They are used in various combinations depending on time of year and weather conditions.	8.50
IS HIGH "R" SHADE	Five layer pull down shade (R-8) maximum width - 64", length - 96". Expands to include four layers of air space as it is lowered.	6.00
TTC SELF INFLATING CURTAIN WALL	Four layered reflective fabric shade (R-10) on tracks with electric drive. Expands to include air spaces as it is rolled down, compresses when rolled up.	4.00 - 8.00
NRG SHADE	Single layer pull down shade with magnetic bottom clip and an R-value of 2.1.	3.00
		PLASTIC VIEW SHADE	Two or three layered roll up shade comes in a variety of sizes up to 144" x 138".	2.50 - 6.00
SOL-R-VEIL	An interior or exterior shade made of fiberglass yarn and used as a sunscreen. Exterior must be custom-made.	5.00 - 7.00
		WIND-N-SUN SHIELD	Heat radiant, heat reflective roller shade. Reflect summer heat out, turned around reflects furnace heat in. Comes in three standard sizes and can be custom-made.	1.00 - 1.40

MATERIALS & RESOURCES — MODIFIER

TYPES: NEW PRODUCTS (CONTINUED)

	<u>TYPE</u>	<u>BRAND NAME</u>	<u>DESCRIPTION</u>	<u>COST \$/S.F.</u>
CRANK DOWN (INTERIOR)	BALI BLINDS	Interior horizontal venetian blinds with 1" aluminum slats. Can be used on a slope, available in 66 colors.	4.70 - 6.00
		BRATTLEBORO DESIGN GROUP SHADE	Slatted crank down shade for sliding glass patio doors. Installs on the inside.	5.00 - 10.00
		SOLEX	Interior wood crank down blinds can be manually or electrically operated (additional \$250/100 s.f.).	12.00
		THERMO-SHADE	Interior pull down shade (R-5) comprised of sealed hollow segments on a track. Can be motorized (\$60).	6.00
CRANK DOWN (EXTERIOR)	PEASE ROLLING SHUTTER	Exterior slatted blind of PVC plastic. Can be strap, crank or electrically operated from interior.	8.00 - 18.00
		ROLLADEN SHUTTER	Exterior blinds of vinyl (R-2.2) and aluminum with thermax core (R-1.9). Can be motorized. Provides security as well as energy savings.	Vinyl - 9.00 - 10.00 Aluminum - 13.00 - 14.00
		SERRANDE SHUTTER	Exterior blinds comprised of PVC slats operated from interior.	11.00 - 15.00
HORI- ZONTAL SLIDING	PANEL DRAPE	Horizontal sliding insulation stores in wall pockets. Difficult to retrofit.	8.00 - 16.00
		SUN FLAKE	Sliding panels of 1½" thermax sandwiched between two layers of steel. Either slides into a wall "pocket" or slides by the glazing (by-pass). The wall "pocket" is difficult to retrofit.	13.00

MATERIALS & RESOURCES — MODIFIER

TYPES: NEW PRODUCTS

(CONTINUED)

	<u>TYPE</u>	<u>BRAND NAME</u>	<u>DESCRIPTION</u>	<u>COST \$/S.F.</u>
SHUTTER	INSUL SHUTTER	Rigid panel shutter of thermax with plywood skins. (R-9.1). Comes in three styles and material finishes.	8.00 - 13.50
		THERMAFOLD SHUTTER	Exterior bi-fold hinged shutters (R-9.9) for sliding doors. They are operable from the interior.	8.50
DRAPERY	WIND-N-SUN SHIELD	Heat radiant, heat reflective drapery liner 36" x 95". Hangs independently behind existing drapes. Can be cut to fit.	.85
		WINDOW BLANKET	Three layer blanket with polyester filling (R-2.0) 45" x 84" or custom sized.	2.25
SPECIAL-TIES	SKYLID (ZOME WORKS)	Insulating temperature sensitive automatic louvers (R-4) with a manual override. Available in eight standard sizes plus custom.	12.00 - 25.00
		BEAD WALL (ZOME WORKS)	Double glazed window filled with foam beads at night (R-8) and mechanically drained during the day (R-1.5). Two standard sizes, 34 x 76 and 46 x 76.	25.00 - 33.00
		Home Made Devices	Insulated shutters made of thermax covered with plywood, masonite, cloth, etc. R-value varies with thickness. Mounting can be pop-in, hinged, clips, magnetic and Velcro fasteners, etc.	3.00 - 4.00

MATERIALS & RESOURCES — MODIFIER

TYPES: CONVENTIONAL PRODUCTS

The products in this table are the conventional products used for insulating and shading a window or glazing area. A description and cost data for each type are included. The cost data is per square foot as of July, 1980. For more information see local suppliers and manufacturers.

TYPE **VENETIAN BLINDS**

DESCRIPTION

COST \$/S.F.

- Standard metal \$5.00 - 6.00
- 1" slats 3.40 - 4.00
- Wood 1 3/8" slats 16.00 - 20.00
- 2" slats 10.00 - 12.50

PULL DOWN SHADES

- Vinyl covered woven fiberglass .75 - 1.50
- Homemade quilt pull down shade 3.00 - 3.50

CANVAS ROLL DOWN

- Canvas on a roller hardware included 1.25 - 1.50

WOVEN SHADES

- Thin wood slats woven together 4.25 - 6.00
- Bamboo matchstick blinds .40 - .60
- Vinyl matchstick blinds .20 - .30

SHUTTERS

- Wood (Exterior) 2.75 - 3.00
- Wood (Interior) 3.00 - 3.50
- Homemade with insulation 3.00 - 3.50

DRAPES

- With insulating fabric 4.50 - 5.50

AWNINGS

- Canvas on operable galvanized frame 5.50 - 8.00*

* Area is calculated as length times overhang

MATERIALS & RESOURCES — MODIFIER

TYPES: FOR GREENHOUSES

A greenhouse must be shaded in the summer to reduce heat gains and insulated in the winter to minimize heat losses. This can be done in many ways, some of these ways along with their cost data are described on this page. They each have their advantages and disadvantages, therefore, careful consideration should be given before choosing a system. The greenhouse manufacturers listed in the COLLECTION section would be a good source of information and current prices.

TYPE RIGID PANELS

DESCRIPTION

Interior & Exterior applications, can be press fit, magnetic, clipped, hinged or sliding.

- Homemade panels of plywood and insulation with hardware

COST \$/S.F.

\$3.00 - 5.00

FABRICS

Interior: Can be draped, stretched or on rollers.

- Polypropylene cloth .15 - .35
- Canvas on rollers 1.25 - 1.50
- Vinyl .45 - .65
- Quilt type on rollers 3.00 - 3.50

Exterior:

- Canvas on rollers 1.25 - 1.50

BLINDS & ROLL UPS

Interior:

- Venetian blinds (1") 3.40 - 4.00

Exterior: rollers

- Aluminum slats 5.50 - 6.50
- Plastics slats 3.00 - 3.50
- Bamboo slats .40 - .60
- Vinyl slats .20 - .30
- Wood slats 1.25 - 1.50

FILMS

Interior & Exterior films*

.45 - 1.50

*The humidity in a greenhouse will adversely affect the water based films.

*The humidity in a greenhouse will adversely affect the water based films.

MATERIALS & RESOURCES — MODIFIER

MANUFACTURERS

The following list of manufacturers and sources is included to help the homeowner in locating and obtaining more information on a specific product. It is not intended to be a listing of all available manufacturers, but rather an aid in locating specialized passive products for more information. It is also recommended that the homeowner check the yellow pages for local suppliers and manufacturers.

ITEM

PULL DOWN

SOURCE

*ATC WINDOW QUILT
Appropriate Technology Corp.
P. O. Box 975
Brattleboro, Vt. 05301
(802) 257-4501

*SUN QUILT THERMAL GATE
Sun Quilt Corporation
P. O. Box 374
Newport, N.H. 03773
(603) 863-2243

*INSEALSHAD
Arc-Tic-Seal Systems, Inc.
P. O. Box 428
Butler, Wisconsin 53007
(414) 276-0711

*IS HIGH "R" SHADE
The Insulating Shade Co., Inc.
P. O. Box 282
Branford, Connecticut 06405
(203) 481-2337

*TTC SELF INFLATING CURTAIN
WALL
The Thermal Technology Corp.
P. O. Box 130
Snowmass, Colorado 81654
(303) 963-3185

*NRG SHADE
Sun Control Products, Inc.
431 Fourth Avenue, S. E.
Rochester, Mn. 55901
(507) 282-2778

*PLASTIC VIEW SHADE
Plastic-View Transparent
Shade, Inc.
P. O. Box 25
Van Nuys, Ca. 91408
(213) 786-2801

*SOL-R-VEIL
Sol-R-Veil, Inc.
60 West Eighteenth Street
New York, N. Y. 10011
(212) 924-7200

ITEM

CRANK DOWN (INTERIOR)

SOURCE

*WIND-N-SUN SHIELD
Wind-N-Sun Shield, Inc.
P. O. Box 1434 E. Y.
Melbourne, Fla. 32935
(305) 777-3558

*BALI BLINDS
Marathon Casey-McFall
Loyal Sock Avenue
Montoursville, Pa. 17754
(717) 368-2621

*BRATTLEBORO DESIGN GROUP
SHADE
Brattleboro Design Group
P. O. Box 235
Brattleboro, Vt. 05301
(802) 257-7644

*SOLEX
Division ELR, Inc.
244 San Lorenzo Avenue
Coral Gables, Fla. 33134
(305) 443-1053

*THERMO-SHADE
Solar Energy Components, Inc.
212 Welsh Pool Road
Lionville, Pa. 19353
(215) 644-9017

CRANK DOWN (EXTERIOR)

*PEASE ROLLING SHUTTER
The Pease Company
P. O. Box 510
New Castle, Ind. 47362
(317) 529-1700

*ROLLADEN SHUTTER
American German Ind., Inc.
14601 North Scottsdale Road
Scottsdale, Arizona 85260
(602) 991-2345

*SERRANDE SHUTTER
Serrande of Italy
P. O. Box 1034
West Sacramento, Ca. 95691
(916) 371-6960

MATERIALS & RESOURCES — MODIFIER

MANUFACTURERS

ITEM	SOURCE	ITEM	SOURCE
HORIZONTAL SLIDING	<p>*PANEL DRAPE Shelter, Inc. P. O. Box 108 Oakland, Md. 21550 (301) 334-4445</p> <p>*SUN FLAKE Sunflake 625 Goddard Avenue P. O. Box 676 Ignacio, Co. 81137 (303) 563-4597</p>	BLINDS, SHADES AND SHUTTERS	<p>*See local hardware stores, building material suppliers and department stores.</p> <p>*Also see yellow pages under specific item name.</p>
SHUTTERS	<p>*INSUL SHUTTER Insul Shutter, Inc. P. O. Box 338 Silt, Colorado 81652 (303) 876-2743</p> <p>*THERMAFOLD SHUTTER Shutters, Inc. 110 East Fifth Street Hastings, Mn. 55033 (612) 437-2566</p>	CANVAS ITEMS	<p>*See yellow pages under canvas manufacturers and awning dealers.</p>
DRAPERY	<p>*WIND-N-SUN SHIELD Wind-n-Sun Shield, Inc. P. O. Box 1434 E. Y. Melbourne, Florida 32935 (305) 777-3558</p> <p>*WINDOW BLANKET Window Blanket Company, Inc. Route 1, Box 83 Lenoir City, In. 37771 (615) 986-2115</p>	HOMEMADE ITEMS	<p>*See local hardware stores and building material suppliers.</p> <p>*Also see yellow pages under name of specific components.</p>
SPECIALTIES	<p>*SKYLID (ZOME WORKS) Zomeworks Corporation P. O. Box 712 Albuquerque, N. M. 87103 (505) 242-5354</p> <p>*BEADWALL (ZOME WORKS) Zomeworks Corporation P. O. Box 712 Albuquerque, N. M. 87103 (505) 242-5354</p>	GREENHOUSE SHADING	<p>*See collection section for list of greenhouse manufacturers and their accessories (shading rollers, slats and films).</p> <p>*Also see local hardware stores, building material suppliers, department stores and yellow pages for adaptable items.</p>
		HARDWARE	<p>*NIGHT WALL CLIPS and other hardware Zome Works Corporation P. O. Box 712 Albuquerque, N. M. 87102 (505) 242-5354</p> <p>*Magnetic Tape Brookstone 127 Vose Farm Road Peterborough, N.H. 03458</p> <p>*Also see local hardware stores and department stores, as well as yellow pages</p>

MATERIALS & RESOURCES

CONSTRUCTION

Twenty-seven percent of the average home's heat loss is due to infiltration. This is why, before any significant energy savings can be realized through the solar retrofit, it is essential to properly seal your home. Common materials for this purpose include caulking, sill sealer, and weatherstripping. While it is impossible to install a sill sealer on an existing home, doors, windows, vents, and outlets on exterior walls as well as the sill plate can be caulked and/or weatherstripped to stop heat from escaping. Sill sealer is an essential component of all new construction such as greenhouses and sunspaces.

Insulation and vapor barriers are also important to energy conservation. Insulation is available as loose fill, rigid board, batts and blankets, and spray-foam. Loose fill insulation is particularly well suited for attic spaces, while spray-foam insulation can be blown into uninsulated wall cavities and around outlets on exterior walls. A vapor barrier on the inside surface is important to prevent moisture build-up in the wall. This moisture condensation will greatly reduce the effectiveness of the insulation and eventually cause it and the wall to rot.

This section provides a list of the properties and costs of these common building products. Consult manufacturers and local suppliers for more information on these products and their proper installation as well as their current prices.

MATERIALS & RESOURCES — CONSTRUCTION

TYPES: INSULATION

Over one-half of the heat losses in the typical house are conduction losses through the walls, the roof and the floor. Insulation will help minimize these losses, but there is a point at which additional insulation will cost more than it can potentially save. The available types of insulation are shown below along with their thermal resistance (R-value per inch) and relative cost based on glass fiber batts equal to 1.

TYPE :

RIGID BOARDS are gaining in popularity and are usually made from fiberglass, urethane, or extruded polystyrene in 4'x 8' sizes.

BATTS/BLANKETS are most commonly made from fiberglass, 15" to 23" wide and may be purchased with or without a vapor barrier.

LOOSE FILL may use fiberglass, rock wool, cellulose, or vermiculite.

FOAMS of urea-formaldehyde have an extremely high R-value, but have come under increasing pressure for tighter quality controls due to odors and shrinkage.

LOOSE FILL

RIGID BOARD

BATTS/BLANKETS

FOAMS

BRAND NAME

"Thermax", "High-R"
or "Climate Guard"

Styrofoam

Beadboard, "Supersheath"
"Super-R Plus"

Cellulose

Glass Fiber

Rock Wool

Perlite and Vermiculite

Fiberboard Sheathing

Rock Wool

Glass Fiber

TYPE

Rigid

Rigid

Rigid

Loose Fill

Batts

Batts

Loose Fill

Rigid

Loose Fill

Loose Fill

R-VALUE/ INCH

8.0

5.41

4.25

3.7

3.2

3.2

2.6

2.6

2.5

2.2

COST

3.6

4.9

4-6.5

.88

1

1.22

2.1-2.4

5.88

1.22

1

*NOTE: Cost are relative, where glass fiber batts equal 1, based on cost per s.f. per R-value.

MATERIALS & RESOURCES — CONSTRUCTION

TYPES: SEALERS

Sealing a residence is the first step in energy conservation. Infiltration can account for over one quarter of the heat losses in a typical residence. Twenty-five percent of these heat losses due to infiltration are under the sill plate and 17% are through the doors and windows. The items listed below can drastically reduce these losses.

TYPE

WET FOAM

DESCRIPTION

Polyurethane based wet foams in an aerosol can. One can equals 15-25 cartridges of caulking. Interior use only. Good for any interior caulking application. Names: "Great Stuff", "MonoFoam", "Polycel One" and "Instafoam".

COST

\$6.00 - 8.00
per can

SILL SEALERS

A fiberglass material 1" thick and 4" wide that is rolled down on top of the foundation and compressed by the sill plate. It is used in place of caulking or wet foams. If not available, a fiberglass pipe wrap (3" x 25' typical) can also be used.

\$.05/l.f.

WEATHERSTRIP

Strips that can be screwed, glued, nailed, clipped, etc., to form a sealed barrier in cracks in doors and windows to decrease infiltration rates.

-vinyl	\$.40/l.f.
-neoprene	.50
-sponge type	.07 - .15
-spring metal	.35 - .60

THRESHOLD

A plate which goes under the door to seal the bottom edge. A good replacement is usually two pieces of metal with an inter lock system, one piece goes on the floor and the other goes on the bottom of the door.

\$2.50 - 5.00
per l.f.

MATERIALS & RESOURCES — CONSTRUCTION

TYPES: CAULKING

Over one-quarter of the energy losses in a residence occurs through infiltration. The major leakage points are the sill plate, wall outlets, ducts, windows, doors, fireplaces, range vents and sliding glass doors. Caulking these areas is the quickest, cheapest and most efficient method of conserving energy. This should be the first step in reducing energy usage. The available caulking compounds are described in the table below.

<u>TYPE</u>	<u>DESCRIPTION</u>	<u>COST \$/TUBE</u>
OIL BASE	Cheapest and most common. Ages poorly, dries and hardens, bleeds through water thinned latex paint.	1.25
LATEX	Made for use with water thinned latex paint. Dries fast, shrinks less, lasts longer and costs more than oil base. Latex and acrylic are the same.	1.50 - 3.00
BUTYL RUBBERS	Extremely flexible, last longer and cost more than oil base. Takes 7-10 days to cure, difficult to work smoothly.	
POLYVINYL ACETATE	Durable and mildew resistant, flexible. Special solvents required for clean-up.	1.75 - 2.00
SILICONE	Tough, flexible expensive, cannot be painted. Not good over impregnated wood or oil based caulking and paint.	4.50 - 6.00
POLYSULFIDES & POLYURETHANES	Durable, elastic, expensive, requires a primer, deteriorates in U-V light.	3.00
LEAD BASE	Toxic, illegal in some states, not recommended.	

MATERIALS & RESOURCES — CONSTRUCTION

TYPES: VAPOR BARRIERS

Vapor barriers just inside the interior wall finish can prevent moisture in the house from reaching the insulation and condensing there. If the insulation were to get wet, it would greatly reduce its effectiveness. There is also the possibility that the exterior paint would blister and the structural framing would rot from the moisture. Any addition should have a vapor barrier on the warm side of the exterior wall to eliminate these problems. The different types of vapor barriers are shown below along with their cost per 100 square feet.

NO VAPOR BARRIER

VAPOR BARRIER

<u>TYPE</u>	<u>DESCRIPTION</u>	<u>COST*</u>
ASPHALT	Most common type, also called kraft paper. Comes mounted on Fiberglass batt type insulation. Not for use with foil faced rigid foam wall sheathing.	1
METALLIC FOILS	Available as foil backed gypsum board or can be applied and used with blown-in insulation that has no vapor barrier. Not for use with foil faced wall sheathing.	1.5
PLASTIC FILMS	A 4 mil thickness can be used with all types of insulation except "Thermax" and "High R", these require a 6 mil layer. Often used in crawl spaces.	4 mil - 1.6 6 mil - 2.3

*cost are relative, where asphalt (kraft paper) is equal to 1 based on cost per square foot.

MATERIALS & RESOURCES — CONSTRUCTION

MANUFACTURERS

The following list of manufacturers and sources is included to help the homeowner in locating and obtaining more information on a specific product. It is not intended to be a listing of all available manufacturers, but rather an aid in locating specialized passive products for more information. It is also recommended that the homeowner check the yellow pages for local suppliers and manufacturers.

<u>ITEM</u>	<u>SOURCE</u>
CAULKING	<ul style="list-style-type: none">*See local hardware stores, building material suppliers and department stores*Also see yellow pages under caulking materials
WET FOAMS	<ul style="list-style-type: none">*GREAT STUFF Kalwall Corporation P. O. Box 237 1111 Candia Road Manchester, N. H. 03105 (603) 627-3861*INSTA-FOAM Insta-Foam Products, Inc. 1500 Cedarwood Joliet, Il. 60435 (815) 741-6800
SILL SEALERS, WEATHER- STRIPPING AND THRESHOLDS	<ul style="list-style-type: none">*See local hardware stores, building material suppliers and department stores.*Also see yellow pages under specific product name
INSULATION	<ul style="list-style-type: none">*See local hardware stores, building material suppliers and department stores*Also see yellow pages under insulation contractors and materials
VAPOR BARRIERS	<ul style="list-style-type: none">*See local hardware stores, building material suppliers and department stores

DEFINITIONS

ABSOLUTE HUMIDITY - A measure of the water vapor content of air, expressed as the mass of water vapor per mass of dry air, pounds of water per pound of dry air or grains per pound of dry air.

ABSORPTANCE - A measure of the ability of a material sample to absorb radiant energy. In general, dark color surfaces have a higher absorptance than light colored surfaces.

ACTIVE SYSTEM - A solar heating or cooling system which transfers energy by using pumps, fans or blowers to circulate a liquid or air. An outside source of power is required to drive the circulators. Active systems are made up of individual pieces of hardware (solar collectors, pumps, heat exchangers, controls, tanks...) which are installed on or in a building.

AIR COLLECTOR - A solar collector using air rather than a liquid as the circulated heat transfer fluid.

ALTITUDE, SOLAR - The angular elevation of the sun above the horizon. The solar altitude angle is low during winter and high during summer.

AMBIENT TEMPERATURE - The temperature of the surroundings; in most cases, the outdoor dry-bulb air temperature.

AZIMUTH ANGLE, SOLAR - The angular position of the sun in a horizontal plane measured from true south. Each day, at solar noon, the sun is due south (Azimuth Angle = 0°).

BTU - British Thermal Unit. The amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

BUILDING LOAD COEFFICIENT (BLC) - The rate at which a building loses heat, expressed as BTUs per heating degree day per square foot of floor area, $\frac{\text{BTU}}{\text{DD ft}^2}$. The BLC allows direct comparison of several buildings without consideration of climate.

COMFORT ZONE - The combined range of ambient air temperature, relative humidity, air movement and mean radiant temperature in which a majority of people find comfort.

DIFFUSE INSOLATION - The portion of the total solar energy reaching the earth's surface after being reflected or scattered by the atmosphere. On hazy or overcast days, there is a high fraction of diffuse insolation.

DIRECT RADIATION - The portion of the total solar energy reaching the Earth's surface as beam radiation without being reflected or bent by the atmosphere. Direct radiation causes distinct shadows.

DRY BULB TEMPERATURE - The commonly quoted air temperature measured with a dry thermometer (see also wet bulb temperature).

EFFICIENCY - A measure of how well a cycle or device converts input energy to useful work.

$$\text{Efficiency} = \frac{\text{Useful output}}{\text{input}}$$

DEFINITIONS

EVAPORATIVE COOLER - A device which cools and humidifies air by evaporating water into the air. Evaporative coolers are most practical in areas which have low ambient humidity, such as the southwest.

GREENHOUSE EFFECT - The one-way "energy trap" effect by which passive systems and most flat plate collectors operate. Shortwave radiant energy from the sun passes through the glazing and heats the interior of the building or solar collector. However, the glazing reflects most of the long wave or infrared heat emitted by the interior. It's a trap!

HEAT SINK - A heat reservoir large enough that significant quantities of heat may be added to or taken from it without appreciably changing its temperature, for example, a large lake.

HUMIDIFY - To increase the moisture (water) content of air. Removes heat from the air and raises the wet bulb temperature.

HUMIDITY - A measure of the moisture content of air (see also absolute humidity and relative humidity).

INFILTRATION - The exchange of air between a building and the environment. This change of air may be needed as a source of fresh air in a conditioned space or may be an unwanted cause of energy loss. Infiltration often represents more than a third of the heating or cooling load on a well insulated building. Infiltration may be measured in air changes per hour (ACH) or cubic feet per minute (CFM).

INSOLATION - An abbreviation for incident solar radiation - A measure of the total solar radiation which strikes a surface in a given time period. Includes both direct (beam) and diffuse (scattered) solar radiation. Common units are BTUs per square foot per hour.

INSULATION - A material which is used to retard the flow of heat. Good insulators have low K values (thermal conductivity) and high R values (thermal resistance).

LANGLEY - A measure of Solar Radiation. One Langley is equal to 3.687 BTU/Ft²

LATENT HEAT - Heat used to change the phase or state, i.e. solid, liquid or gas, of a material without changing its temperature. About 144 BTU of heat is required to melt one pound of ice at 32°F into one pound of water at 32°F.

NATURAL CIRCULATION - Circulation of a gas or liquid due to density differences resulting from temperature variations. Hot air rises - cold air sinks. (See thermosyphon).

NATURAL CONVECTION - Transfer of heat by natural circulation.

NOCTURNAL RADIATION - Loss of energy by radiation to the night sky when the radiating surface is warmer than the effective sky temperature. May be used as a method of cooling in clear, dry climates, less effective in areas with high humidity or pollution levels.

DEFINITIONS

ORIENTATION - The position of a building relative to the influences of the natural environment, mainly the sun and wind. In general a passive building should be oriented so that its long side faces south.

REFLECTANCE - A measure of the ability of a material sample to reflect radiant energy. Reflectance increases when the energy strikes a flat surface at an angle.

ROCK STORAGE BED - A chamber filled with rocks for storing heat. Air is circulated through the rocks to store heat or remove it for use.

SENSIBLE HEAT - Heat which is available as a result of a temperature change, not as a result of a phase change.

SENSIBLE HEAT STORAGE - Storage of heat by raising or lowering the temperature of a storage medium, possibly a tank of water, rock bed or concrete floor.

SOLSTICE - The time of year when the sun is highest in the sky (summer solstice, near June 21) or lowest in the sky (winter solstice, near December 21).

SPECIFIC HEAT - A measure of the heat storage capacity of a material with a change in temperature. The heat energy required to raise a mass of substance one degree in temperature (BTU/lb°F or cal/gm°C). Water has a specific heat of 1.0 BTU/lb°F and rocks 0.2 BTU/lb°F.

THERMAL INERTIA OR THERMAL FLYWHEEL EFFECT - Resistance to rapid changes in temperature due to the presence of large amounts of thermal storage mass. Thermal inertia is usually desirable in a passive system.

THERMAL LAG - The time delay in the transmission of heat from a hot area to a cool area; for example, through a concrete block wall heated by the summer sun. Thermal lag is longer through walls with low conductivity and high mass (concrete) than through less massive walls (wood frame).

TRANSMITTANCE - A measure of the ability of a material sample to transmit radiant energy. Varies between zero and one. A double-strength glass pane has a transmittance of about .86 to solar energy.

$$\text{Transmittance} = \frac{\text{Transmitted Energy}}{\text{Total Incident Energy}}$$

TROMBE WALL - A passive heating concept consisting of a vertical masonry wall with glazing in front. Solar radiation is absorbed by the wall, converted to heat and transferred to the building by conduction and radiation. Vents may be used to circulate warm air from the space between the glass and wall to the building.

WET BULB TEMPERATURE - The temperature obtained if a wet wick is wrapped around a thermometer and the thermometer moved rapidly in air. Used in connection with dry bulb temperature to determine the humidity. The wet bulb temperature is the lowest temperature an evaporative cooler can attain.

SUN ANGLES

SUMMER AND WINTER SOLSTICE

SUMMER AND WINTER SOLSTICE
ANGLES FOR VARIOUS LATITUDES
IN THE SSEC REGION

NORTH LATITUDE	ALTITUDE ¹						AZIMUTH ²					
	Summer (June 22)			Winter (Dec. 22)			Summer (June 22)			Winter (Dec. 22)		
	9AM	Noon	3PM	9AM	Noon	3PM	9AM	Noon	3PM	9AM	Noon	3PM
26°	49	87	49	24	45	24	96	0	96	45	0	45
30°	49	83	49	21	36	21	92	0	92	44	0	44
34°	49	79	49	18	32	18	87	0	87	43	0	43
38°	49	75	49	15	28	15	82	0	82	42	0	42
40°	49	74	49	14	27	14	80	0	80	42	0	42

NOTE: Values given in this table are approximations for each latitude. Refer to the latitude map for the latitudes of major cities in the SSEC region. More accurate values can be found for a particular city by interpolation.

¹Altitude given in degrees from horizontal for Solar Times listed.

²Azimuth given in degrees from south for Solar Times listed.

SSEC REGION LATITUDE MAP

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complexity design calculations; in-
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THE PASSIVE SOLAR ENERGY BOOK

Passive Solar Systems - Principles
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Passive Solar Design Handbook-Vol. 1
Balcomb, Passive Solar Design Con-
cepts, D.O.E./CS-0127/1, \$13.25

Passive Solar Design and Analysis:

Passive Solar Design Handbook-Vol. 2
Passive Solar Design Analysis,
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Technical Information Service, U.S.
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Royal Road, Springfield, Virginia
22161. The most complete treatment
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American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
345 East - 47th Street
New York, New York 10017

Residential Insulation Guide:

INSULATION MANUAL - Home and Apartments

Prepared by:
National Association of Home Builders
Research Foundation, Inc.
627 Southlawn Lane
P. O. Box 1627
Rockville, Maryland 20850
(301) 762-4200
Cost: \$10.00

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National Climatic Center
Federal Building
(704) 258-2850
Asheville, North Carolina 28801

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No. 81 (Requested by State)
Price: 25¢ (Checks and money orders
should be made payable to Commerce,
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Active Solar Fundamentals and Basic Design:

Sunset Homeowner's Guide to Solar Heating,
Lane Publishing Company
Menlo Park, California 04025
Cost: \$2.95

Residential Cooling and Heating Load Calculations:

Load Calculations for Winter and Summer Residential Air-Conditioning,
Air Conditioning Contractors of America (ACCA)
1228 - 17th Street, N. W.
Washington, D. C. 20036
(202) 296-7610
Cost: \$5.50 (Members)
\$11.00 (Non-members)

Energy Efficient Site Planning:

Solar Site Planning - A Guide to Residential Landscaping for Energy Efficiency, by Dave Marlatt, Jon Rubel and Richard Seedorf.
Available from:

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

Solar Retrofit of Existing Buildings:

Passive Retrofit Handbook, Solar Applications For Residences by Thompson, Hancock, Witte, Architects and Planners
Available From:
Southern Solar Energy Center
61 Perimeter Park
Atlanta, Georgia 30341
(404)458-8765