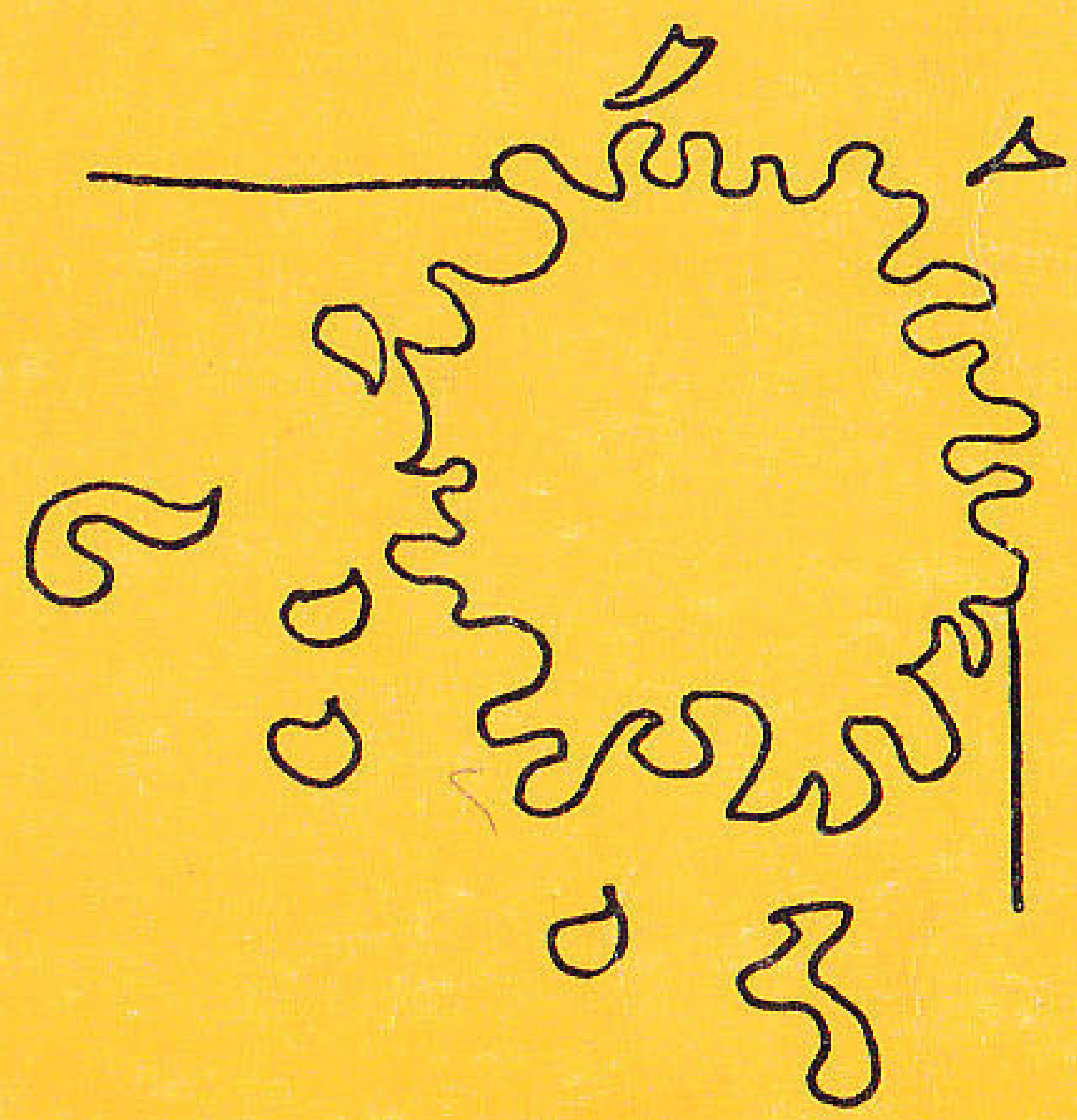

SOLAR ARCHITECTURE

DESIGN CONCEPTS & PRINCIPLES

Compiled by
C.L. Gupta, V. Geeta and Punit Dhandhania
Solar Agni International, PONDICHERRY
FOR
GUJARAT ENERGY DEVELOPMENT AGENCY
VADODARA, GUJARAT, INDIA
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TABLE OF CONTENTS

1.0 INTRODUCTION

The last few years have dramatically changed the way most people think about energy. In fact, ten years ago most of us probably didn't think much about it all. It was abundant and cheap and we used lots of it. Then came a series of "energy crises" that changed our awareness and understanding of energy issues. We had to face the implications of being dependent on limited supplies of non-renewable fuels—fuels that would never be cheap again.

That fact is driven home every time a fuel bill arrives. The prices we pay for fuel have generally been increasing at a faster rate than inflation. Most homeowners, by now are aware of the need to take some measures to lessen the impact of impending fuel shortages and rising utility costs.

Which measures to take and how much hope to place in renewable energy sources, such as solar energy, are generally not so well understood. Part of the confusion arises from conflicting popular attitudes about solar energy. Some think of it as "free energy," while others refer to it as "impractical". Actually, it is neither. The sun is a promising energy source, especially since it is abundant, non-polluting and universally available. However, there are real costs involved in capturing and using solar energy. There are also a variety of ways to harness the sun. Some are economical, some are not.

This series of fact sheets has been prepared to give the designers a basic knowledge of solar energy, the types of systems being used in homes, and the costs and energy savings of such systems. The first, few pages (2-10), provide an introduction to the fundamental concepts governing energy transfer and solar energy. The others describe specific systems.

2.0 ALTERNATIVE ENERGY SOURCES

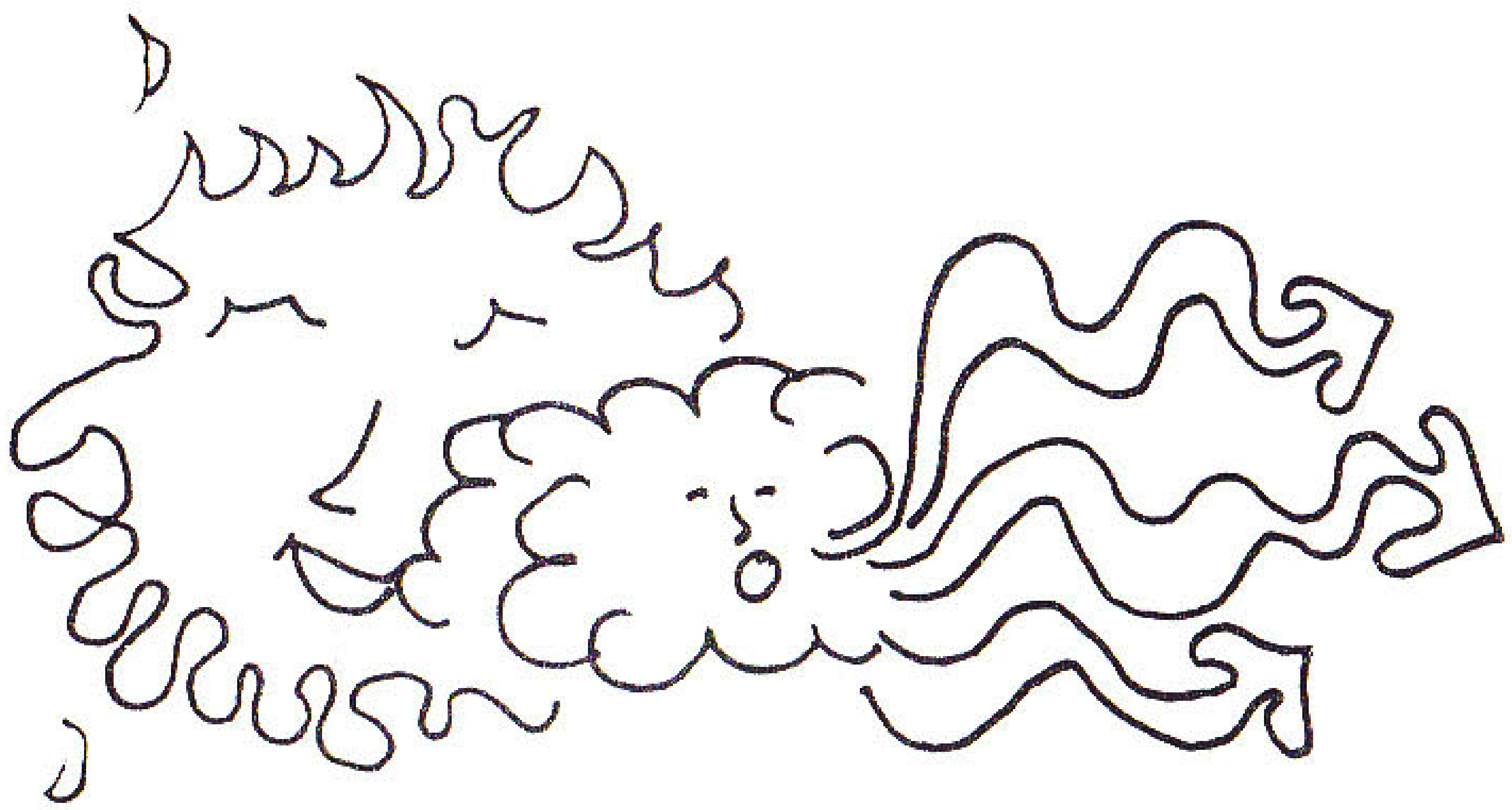
It is only after your home is as energy-efficient as possible that you should consider installing a RENEWABLE ENERGY SYSTEM. In other words, you will get a better return on your energy cost by investing it first in conservation and then on a renewable system. However, it is still a big step to take. It can be expensive and may require professional assistance, so you should learn what to expect from renewable energy systems in given climate and what options are available before you before you proceed.

In the broadest sense, all fuel systems in use today are based on solar energy. Fossil fuels store solar energy over millions of years. Natural gas, coal and petroleum are stored solar reserves that cannot be renewed in our planet's lifetime. Wood fuels store solar energy for hundreds of years, and can be a renewable energy resource if used with careful reforestation.

Solar energy stored in plants and crop residues can be released into biomass energy generation systems, and renewed in periods as short as months or years. Systems which make direct use of solar radiation are using energy that is renewed daily, hourly, or instantaneously. The term RENEWABLE ENERGY SYSTEMS generally refers to the use of these latter energy alternatives.

Renewable energy systems take many forms. Wind energy conversion systems use air flow patterns generated by solar radiation. This energy is usually used to perform mechanical work or is converted into electricity. Photovoltaic solar systems—arrays of tiny silicon discs—can generate electricity directly from the sun.

Systems which use the sun's rays directly for heat are usually referred to as either ACTIVE or PASSIVE solar systems. These systems can be used both to heat or cool a home, to heat domestic hot water. The sun's energy is well-suited to these relatively low temperature tasks.



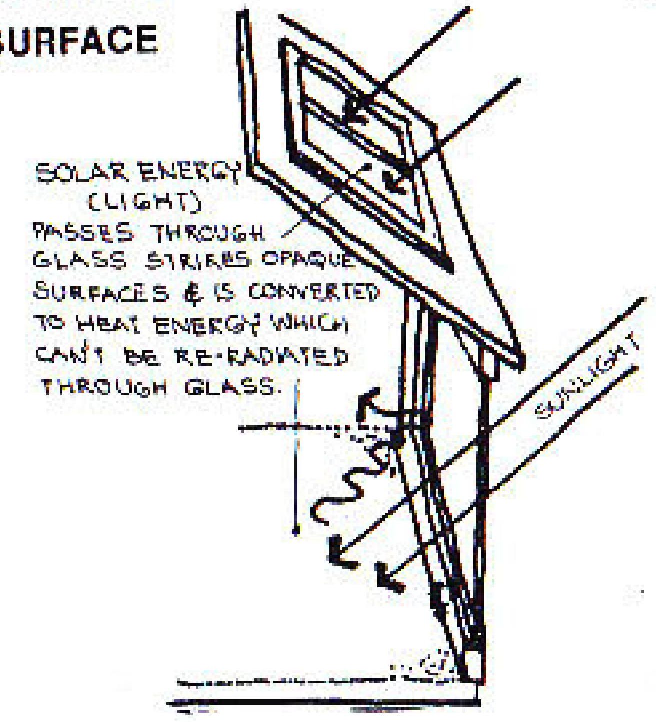
3.0 CHARACTERISTICS OF A SOLAR SYSTEM

All residential solar energy systems — whether active or passive are characterized by three basic components or processes. They must have a method for the collection of solar radiation, a way to distribute captured energy to wherever it is needed, and some way to provide energy storage both to prevent too much energy from flowing when not needed and allow energy to be extracted and used when the sun is not available.

In addition to these basic components, most solar systems also require an energy retention component to diminish energy flow in the wrong direction (as in window insulation for night-time use) and an energy overload regulation component (such as summer-time shading) to prevent unwanted energy flow into the building.

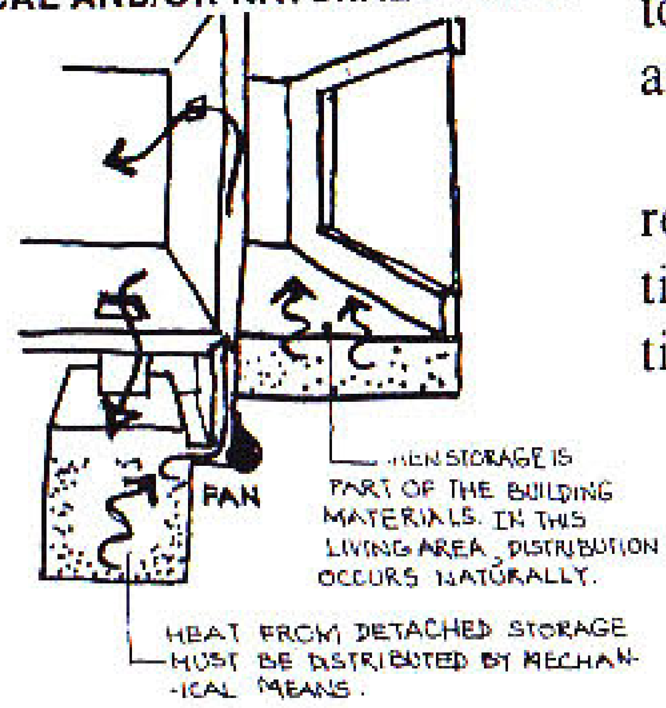
1. COLLECTION

SOLAR ENERGY COLLECTED BEHIND A GLAZED SURFACE



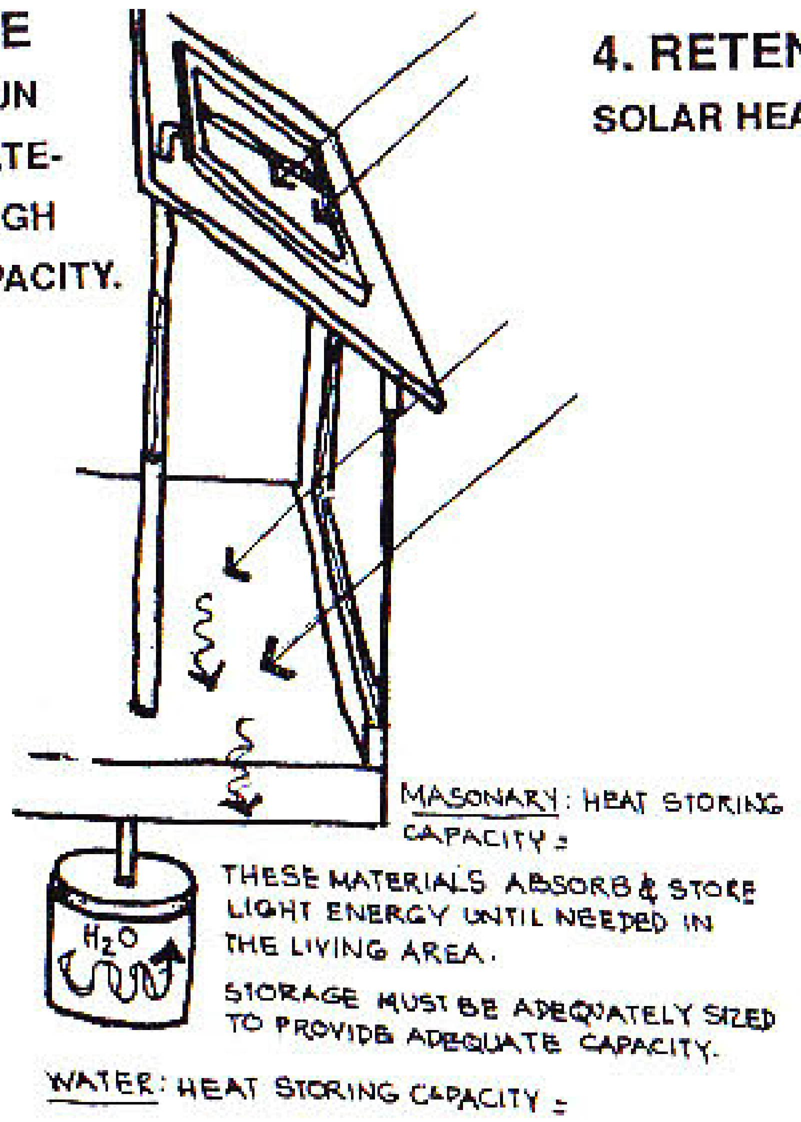
2. DISTRIBUTION

HEAT DISTRIBUTED TO LIVING SPACE BY MECHANICAL AND/OR NATURAL MEANS.



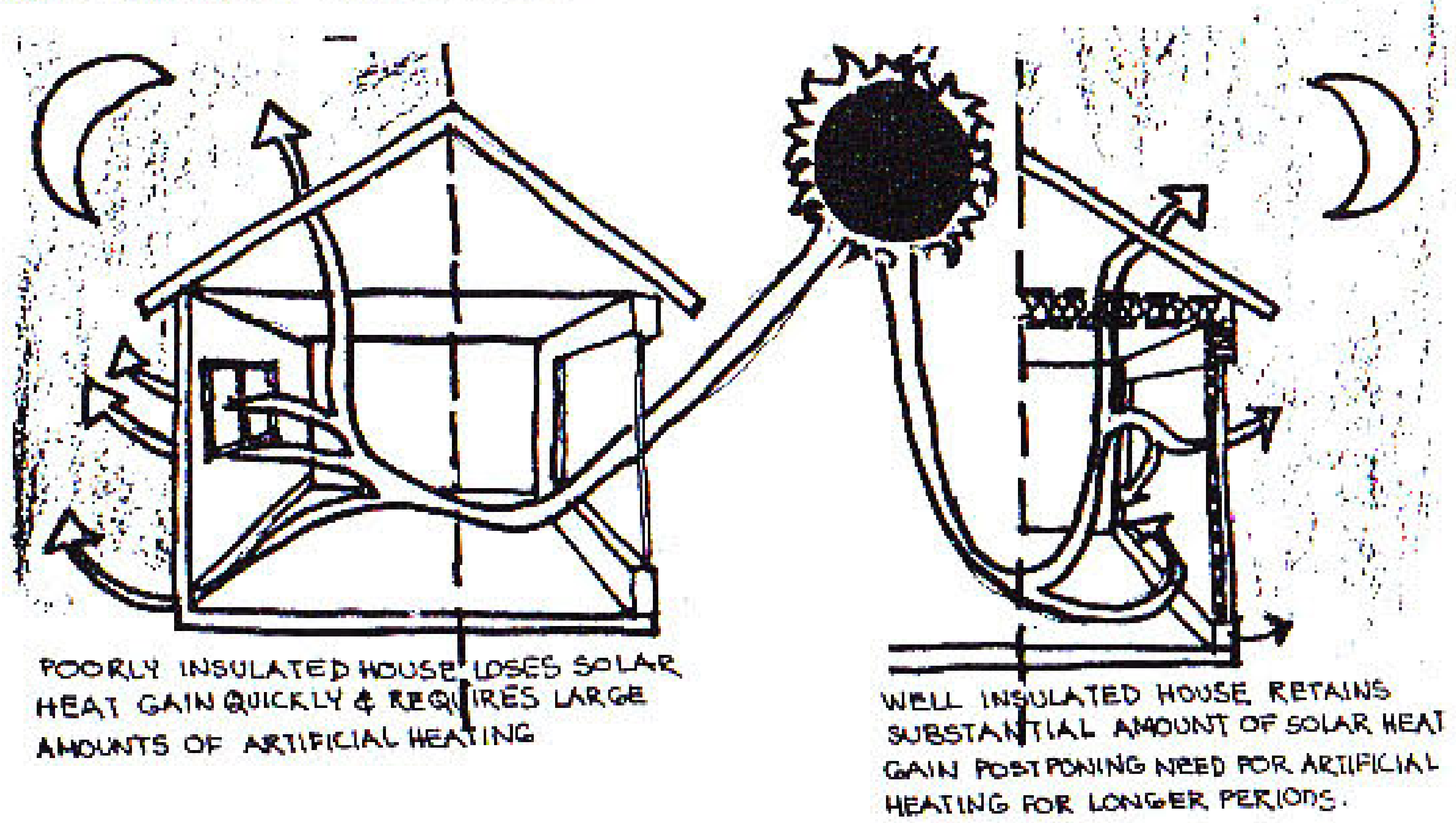
3. STORAGE

HEAT FROM SUN STORED IN MATERIALS WITH HIGH THERMAL CAPACITY.



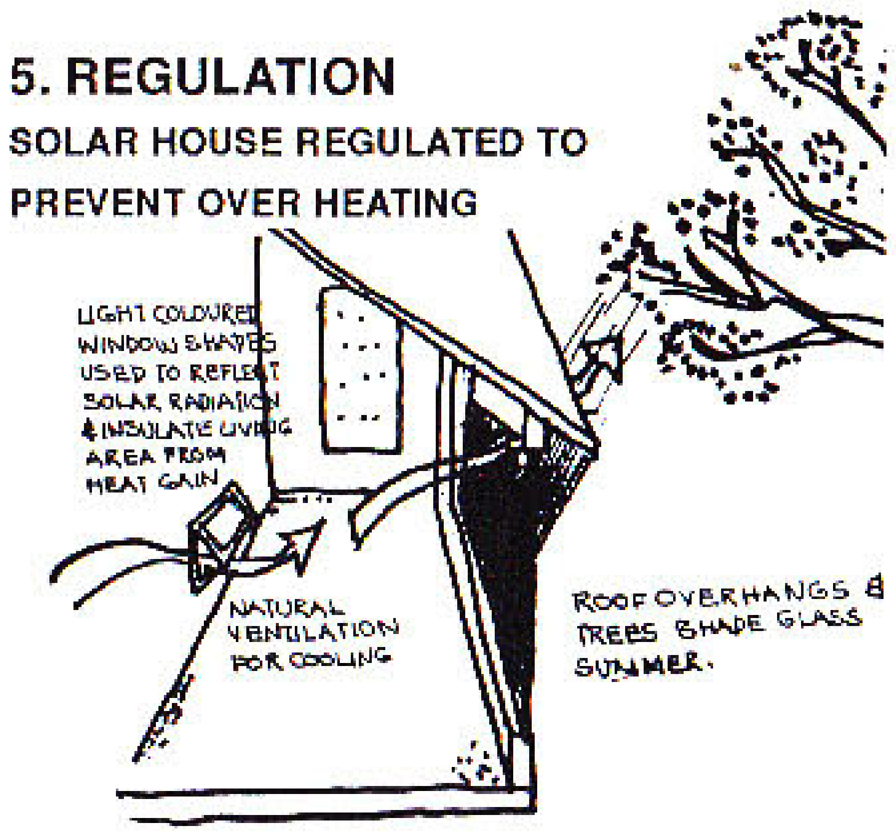
4. RETENTION

SOLAR HEAT GAIN RETAINED THROUGH SERIES OF CONSERVATION MEASURES



5. REGULATION

SOLAR HOUSE REGULATED TO PREVENT OVER HEATING



PASSIVE SOLAR SYSTEMS have no solar panels. Instead, parts of the building itself collect, store, and distribute solar energy. Passive solar buildings or additions are designed and built with materials that enable the structure to perform these functions. Southfacing windows, doorways, greenhouses, or skylights serve as solar collectors, while floors or walls contain the thermal storage mass necessary to store excess heat until it is needed. A variety of energy-conserving techniques are incorporated into the building to help keep heat in. There are few, if any, mechanical devices in the passive system. Instead, these systems rely on the natural processes of heat transfer—radiation, convection and conduction—to distribute collected heat. There are several different types of passive systems: DIRECT GAIN, INDIRECT GAIN, and ISOLATED GAIN (or SUNSPACE).

ACTIVE SOLAR SYSTEMS use solar panels for heat collection and electrically-driven pumps or fans to transport the heat to the living area or to storage. Electronic devices regulate the collection, storage, and distribution of heat within the system. Hybrid systems combine features of both passive and active systems. The successful performance of any solar system depends upon good design, the proper balance among the various components of the system and quality construction and installation.

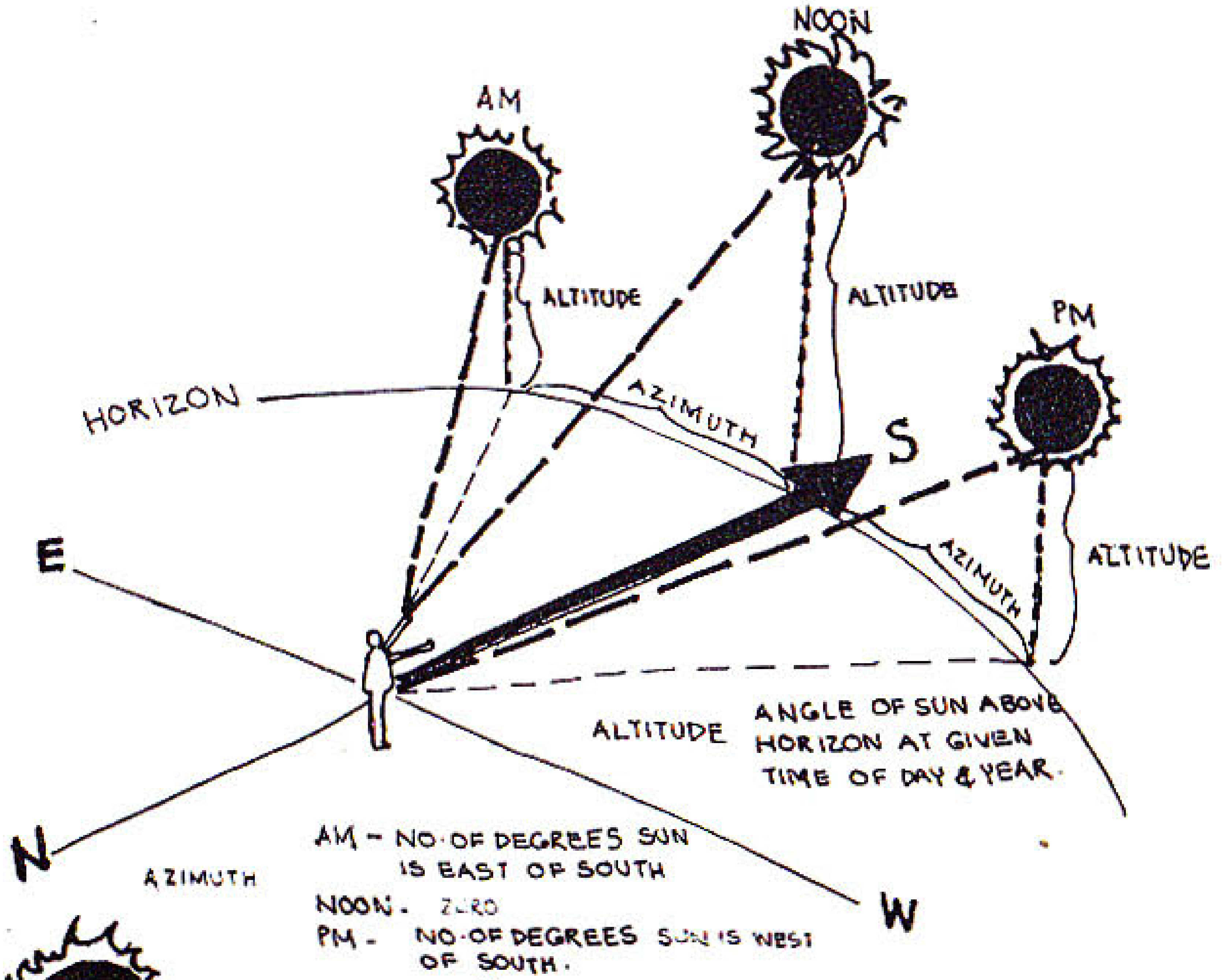
4 SOLAR FUNDAMENTALS

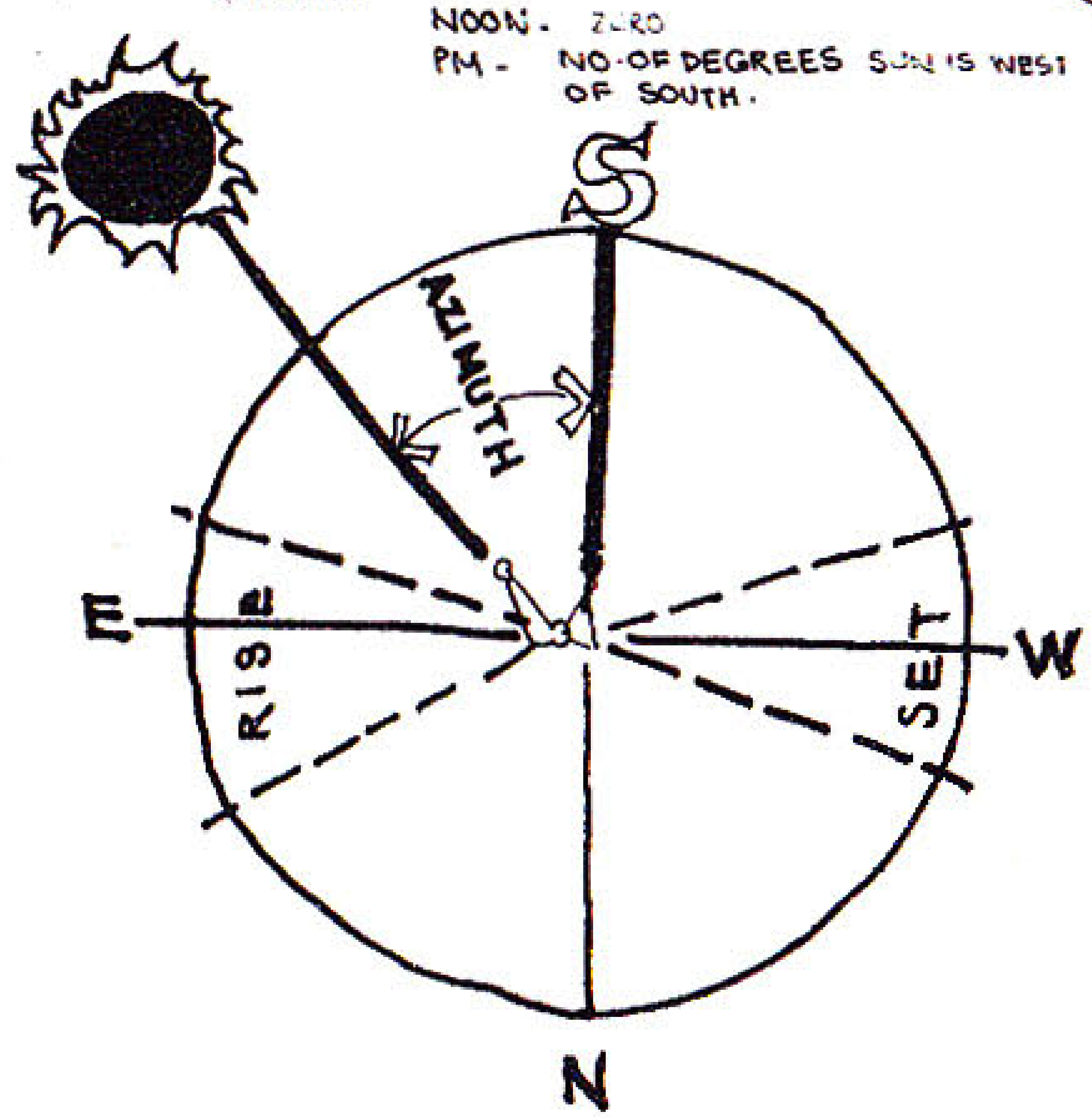
4.1. SOLAR ALTITUDE AND AZIMUTH

The sun's position in the sky changes from morning to night and from season to season. It is important to understand and chart these position changes so that we know how to locate a collecting surface to take best advantage of available solar energy. SOLAR ALTITUDE is the height of the sun in the sky and is measured by its angle above the horizons SOLAR AZIMUTH is a measure of the sun's position in relation to true South—or its bearing angle.

Both the altitude and the azimuth of the sun change with the progression of the seasons. The only times the sun rises exactly in the East and sets in the West are on September 21 and March 21. In the summer it rises and sets closer to Northeast and Northwest, and in winter closer to Southeast and Southwest.

The altitude changes as well. In the winter at Baroda latitude, the sun only makes an angle of approximately 45 ° with the horizon at midday, while it reaches an altitude of approximately 90 ° at noon on June 21st. From this it is possible to create a SOLAR WINDOW for each latitude which defines the sun's position in the sky during the months and times of day when solar collection is most desirable. (Figure next page)



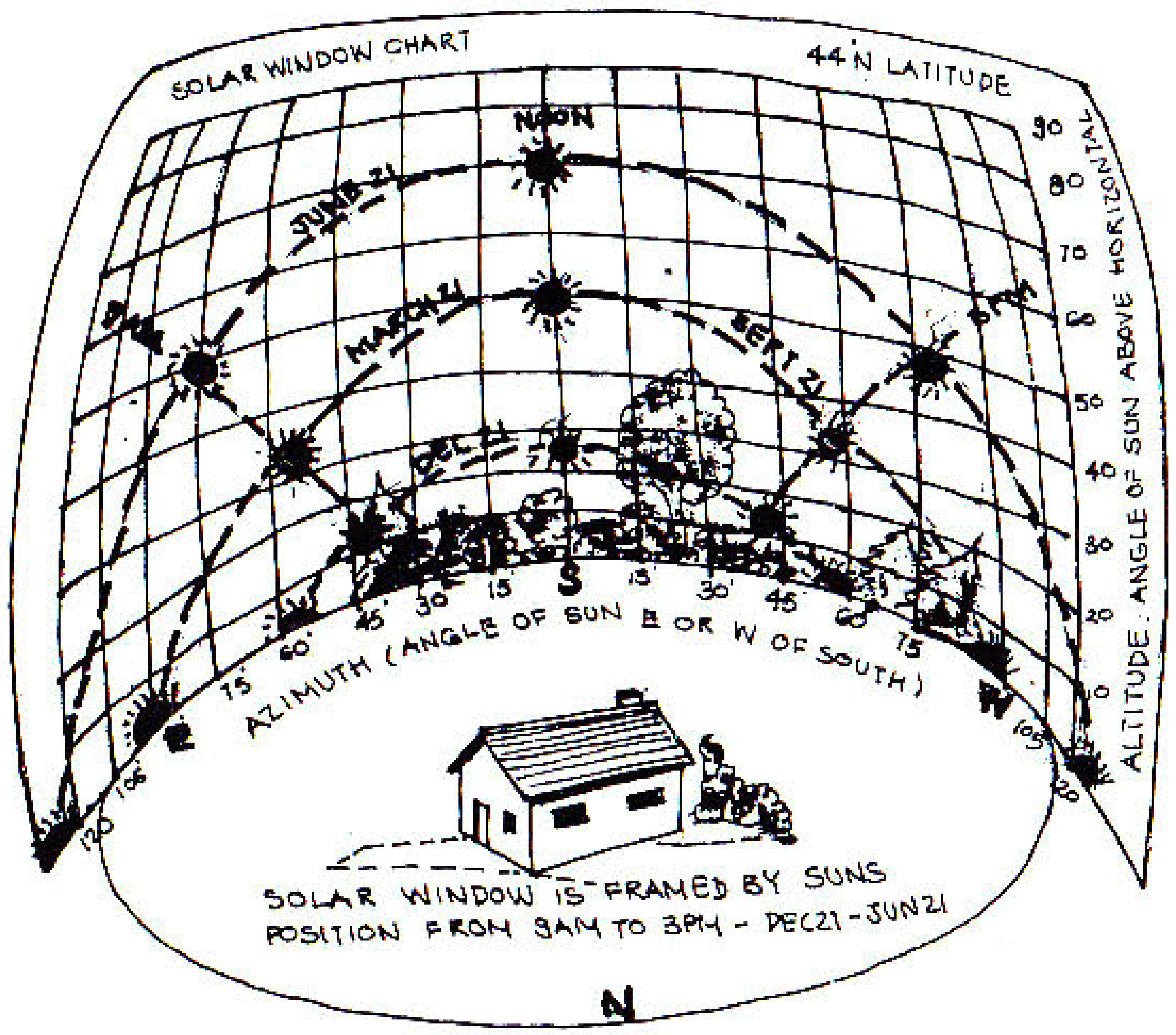


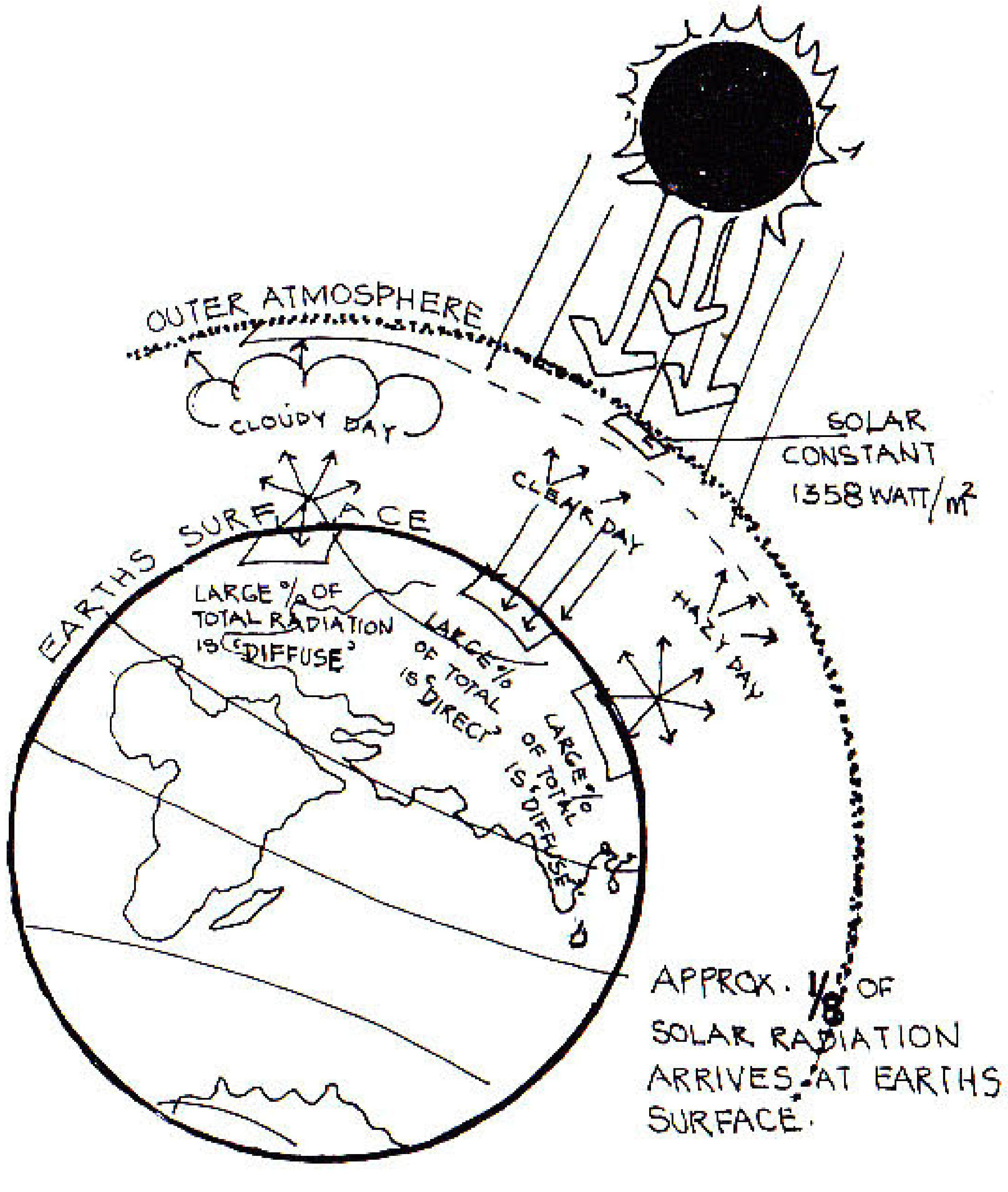
4.2. SOLAR CONSTANT

The amount of solar radiation reaching the outside of the earth atmosphere 1358 watt/m2 — nearly a constant value. Once this radiation strikes and enters the earth's atmosphere, however, it incurs losses due to absorption and scattering. The amount of reduction in solar radiation depends upon atmospheric conditions such as clouds, dust particles, and moisture content.

4.3 SOLAR AVAILABILITY

The amount of solar radiation on the earth's surface on a clear day at a given latitude and time of the year must be adjusted based on the angle of the collecting surface. The maximum amount of radiation is collected when this surface is perpendicular to the incoming rays. For this reason, active solar collectors are tilted to (Latitude + 15) so that the sun's rays will strike at an angle of approximately 90 ° during the winter months when the heating demand is highest. Domestic hot water collectors are positioned at a lower angle to give good year-round collection. Since it is not sunny 100% of the time, these amounts are corrected according to the amount of sunshine available during a given month in a particular area. (See Data sheets in client's brief).



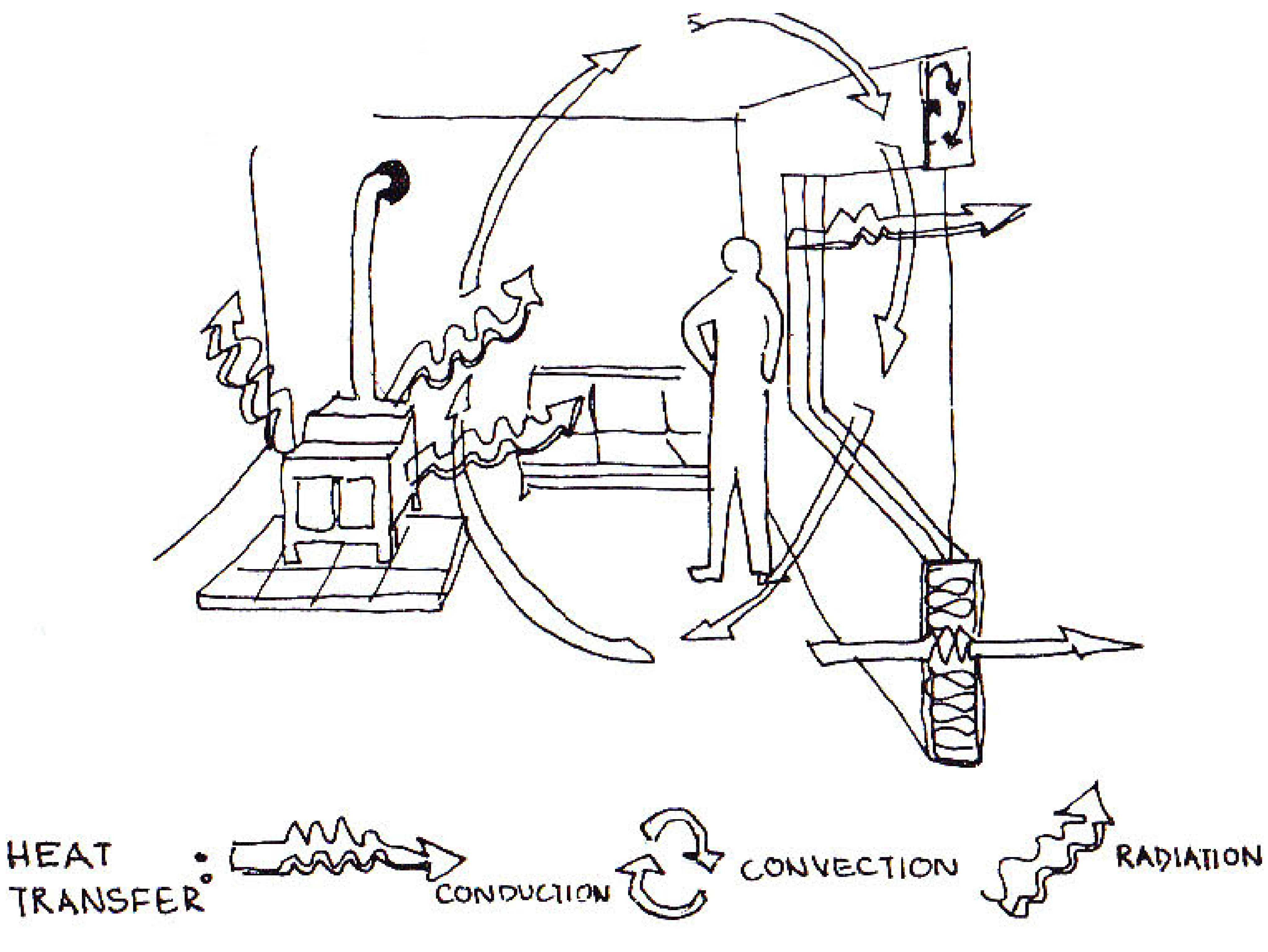


5. FUNDAMENTALS OF HEAT ENERGY

5.1 THERMAL ENERGY FLOW

There are two fundamental concepts in understanding thermal energy (heat) flow: direction of flow, and rate of flow. The direction of heat flow is always from warm to cool. Thus in winter heat flows from inside to the colder outdoors, whereas in summer the flow reverses and travels from the hot outdoors towards the cooler interior. If it cools off sufficiently at night, warm house air will again flow outwards, seeking equillibrium.

The speed or rate of this flow is proportional to the difference in temperature. The greater the temperature difference, the faster the rate of flow. Heat transfer is accomplished in three basic ways: conduction, convection and radiation.

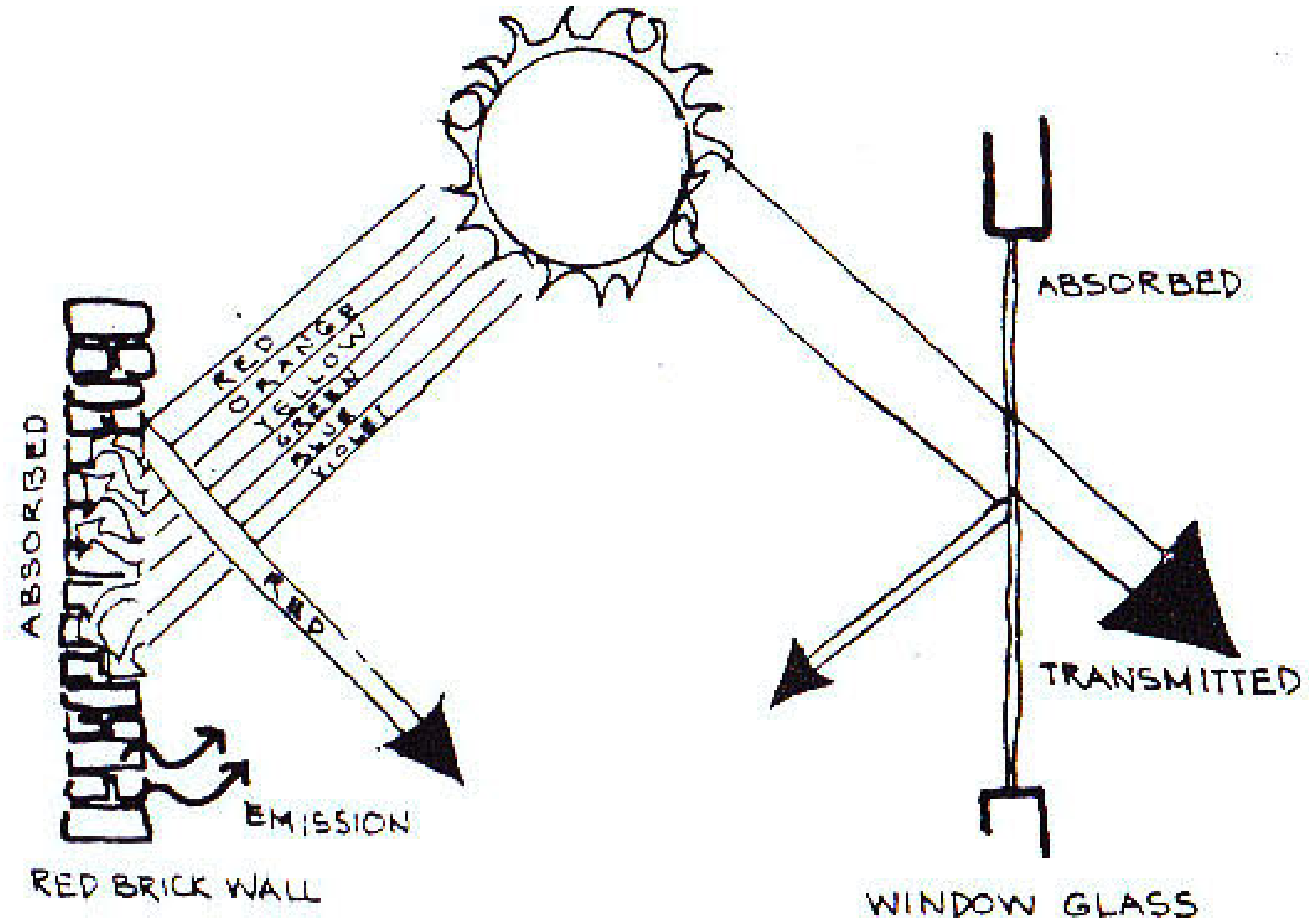


CONDUCTION is the transfer of heat from one molecule to the next within a material or between materials touching each other. Materials vary in heat-conducting ability. Metal conducts heat rapidly while insulation (with its many air pockets) retards heat conduction. A material's resistance to heat flow (or a measure of its conductivity) is referred to as its R-value. The higher the R-value, the better its resistance to conductive heat flow. Since the difference in temperature from one side of a material to the other is also a factor, the rate of heat loss can be calculated by dividing the temperature difference (T) by the value of the material(s). (When there is more then one material, as in a wall, the R-value for each material can be added together to get a total R.)

$$\text{HEAT LOSS Watt/m}^2 = \frac{\Delta T}{R - \text{value (s)}}$$

CONVECTION is the transfer of heat by movement of molecules in a fluid. The molecules in a fluid near a heat source begin to move more rapidly creating more space between molecules. This makes the fluid less dense and it rises and is replaced by cooler, more dense fluid, setting up convective flow/heat transfer. The opposite occurs when air (a fluid) near a cold surface like a window is cooled. It becomes denser, sinks and is replaced by warmer, less dense air. The pattern continues as long as there are temperature differences. Infiltration through cracks is also a type of convective heat transfer. Convective air currents also develop in a wall cavity (unless it is full of insulation) which speeds up heat flow through the wall.

RADIATION: Materials constantly radiate thermal energy in all directions due to the vibrational motion of their molecules. Warm objects radiate thermal energy to cooler objects. The warmer the body, the more heat it radiates. A person standing near a cold wall radiates heat to it, and therefore feels cool, while a person near a stove receives radiative heat from it and feels warmer.



REFLECTION, ABSORPTION, TRANSMISSION, EMISSION.

5.2 REFLECTION, ABSORPTION AND TRANSMISSION

When thermal energy strikes a material, some of it is reflected, some absorbed, and some transmitted. Different materials have different reflection, absorption, and transmission characteristics.

An object reflects a certain amount of the light energy that strikes it. The wavelengths of reflected light give the object its perceived color. The rest of the energy striking it is either absorbed or transmitted. A white object reflects most of the radiation striking it—thus white clothing keeps us cooler. It appears white because white is a combination of all wavelengths in the visible spectrum. A black object, on the other hand, absorbs most of the energy striking it: the absence of reflected light makes it appear black. For this reason black surfaces make the best solar collectors. Energy that isn't reflected is transmitted or absorbed. Transparent and translucent objects (such as glass) transmit most of the radiation that strikes them, while opaque objects will absorb most of the energy striking them. Once solar energy is absorbed by a material, it is converted to thermal energy (heat) & emitted through raising temperature of the material.

5.3 THERMAL CAPACITY

Any material stores heat as its temperature rises. Its heat-storing ability is referred to as THERMAL CAPACITY. Some materials can store more heat per degree rise in temperature than others. This is a function of a material's specific heat (a constant for each material) times its density, and is given as the number of KCal/kg °C. Water and masonary both have relatively good heat capacities and are generally chosen for solar storage because they are abundant and economical: water having 5 times storage capacity as compared to most masonry materials.

Materials also store or release a large amount of heat energy when they change phase, i.e., from solid to liquid or liquid to gas. This is called LATENT HEAT. You have experienced the large amount of heat energy stored in steam if you have ever put your hand in it. The burn sensation was the release of heat energy as the steam condensed. Conversely, the process of EVAPORATION requires heat input and therefore leaves one feeling cooler. Storing heat in a material during its phase change is desirable for solar storage because large amounts of heat can be stored in a small volume. Eutectic salts are used this way because they melt and solidify in the 80°—90° C temperature range used for home heating. Inspite of their promise, however, high cost and short lifespan are still drawbacks with eutectic salts.

5.4 HUMAN COMFORT

We often think only in terms of temperature when we define environmental comfort. However, there are a number of other factors that influence our comfort level. They are relative humidity, air flow, and mean radiant temperature (the average temperature being radiated from objects in the living area). If the humidity in our homes is low (evaporation from our bodies is more rapid), air is moving (infiltration or drafts), or the objects around us are cold (walls, floors, windows, etc.) then it will take a higher temperature to make us feel warm. We could feel just as warm at a lower temperature if the humidity was higher, air movement was decreased, or the mean radiant temperature increased. Weatherstripping and insulation accomplish these things while they curb heat loss. Passive solar homes with a warm thermal storage mass in the living area are comfortable at lower room air temperatures because the mean radiant temperature is relatively high. For India, a tropical summer index (TSI) of 25°C (CBRI Dig.127) (TSI: Dry bulb temperature in still air at 50 %R.H. in a uniformly radiant enclosure) is comfortable.

5.5 BUILDING ENERGY CONTENT

ENERGY IS USED IN BUILDING CONSTRUCTION, MAINTENANCE AND OPERATION IN THREE PRINCIPLE WAYS.

1. In the manufacturing process of material employed.
2. In the construction technique employed for fabricating &assembling building elements.
3. For operating the building services including lights, appliances, water supply and waste treatment, environmental control and indoor air circulation.

The designer should endeavour to explicity choose all these systems for maximizing energy conservation and efficiency.

An explicit statement outlining the quantum of energy saved per unit additional expenses incurred, if any can normally be computed as an index of effectiveness of the design. Energy contents of building materials commonly employed are given in the following Table:

5.6 MICROCLIMATE

The local microclimate in the campus, which forms the environmental envelope of the building, can be enhanced favourably by proper landscaping, use of water bodies and earth masses and location of energy plantation trees to act as wind breaks and noise and dust barriers. These have to be taken into account along with the building and utilities etc., for an integrated design.

TABLE: MATERIAL ENERGY CONTENT

MATERIAL	MJ/KG (THERMAL BASIS)
STEEL	22
FINISHED STEEL	54
TIN PLATE	55
ALUMINIUM	191
ROLLED/EXTENDED ALUMINIUM	239
ALUMINIUM CASTINGS	287
RECYCLED ALUMINIUM	10–20
COPPER	53
COPPER ROLLED	79
ZINC	55
PVC	81-102
POLYSTYRENE	140
LOW DENSITY POLYETHYLENE	75-109
HIGH DENSITY POLYETHYLENE	103
POLYPROPYLENE	113
NATURAL RUBBER	6
SYNTHETIC RUBBER	140
GLASS	25-50
GLASS FIBRE	43
BRICK	4
CONCRETE	4
CEMENT	8-18
CERAMICS	11-250
PAPER AND BOARD	25-38

REF: 'A Manually —Repositioned Concentrating Photovoltaic Water Pump.' A thesis submitted by R.W. BENTLEY at the University Of Reading (1987)

6. PASSIVE SYSTEMS

Passive techniques may seem overly simple to many people. Insulated shutters, heat-storing brick or concrete floors and walls, air vents for use of natural convection and thermopane windows are not high-technology discoveries, but they work.

Whether the prospective solar user decides to go with either a passive or active system, the first step, almost a cardinal rule, is to insulate. "Adequate insulation is still one of the most cost effective ways to save energy in a new or used dwelling-and it is a vital element for any house that incorporates a solar system.

Passive systems are generally integrated into the architectural scheme of the structure. Properly designed, these systems can be the most cost-effective, natural way to provide for a structure's heating and cooling needs and to reduce energy consumption. The various generic approaches to passive energy design may be categorized into five basic groups.

6.1 DIRECT GAIN

Direct Gain approach is one in which one simply has an expanse of glass (usually double glass) facing south. The building should have considerable thermal mass, either a poured concrete floor or a massive masonry construction with insulation on the outside. The characteristic sun angles result in a favourable situation, since the south face is exposed to a maximum amount of solar energy in the cold winter months when the sun angles are low.

6.2. THERMAL STORAGE WALL

Thermal Storage Wall is one in which the thermal storage is in a wall which absorbs the solar energy after it comes through the glazing and which stores the heat energy. The wall is usually painted black to enhance absorbtion qualities and it may consist of either water in containers or a heavy masonry (Trombe) wall.

6.3 SOLAR GREENHOUSE

Solar Greenhouse is one which combines the features of direct gain and thermal storage wall techniques. For this type of system, one builds a greenhouse onto the south side of a building with some kind of thermal storage wall between the greenhouse and the house. The temperature in the greenhouse does not require very good control (as long as the plants do not freeze), and solar energy normally provides all of the heat required for the greenhouse, and provides a substantial amount of energy for heating the house.

6.4 ROOF POND

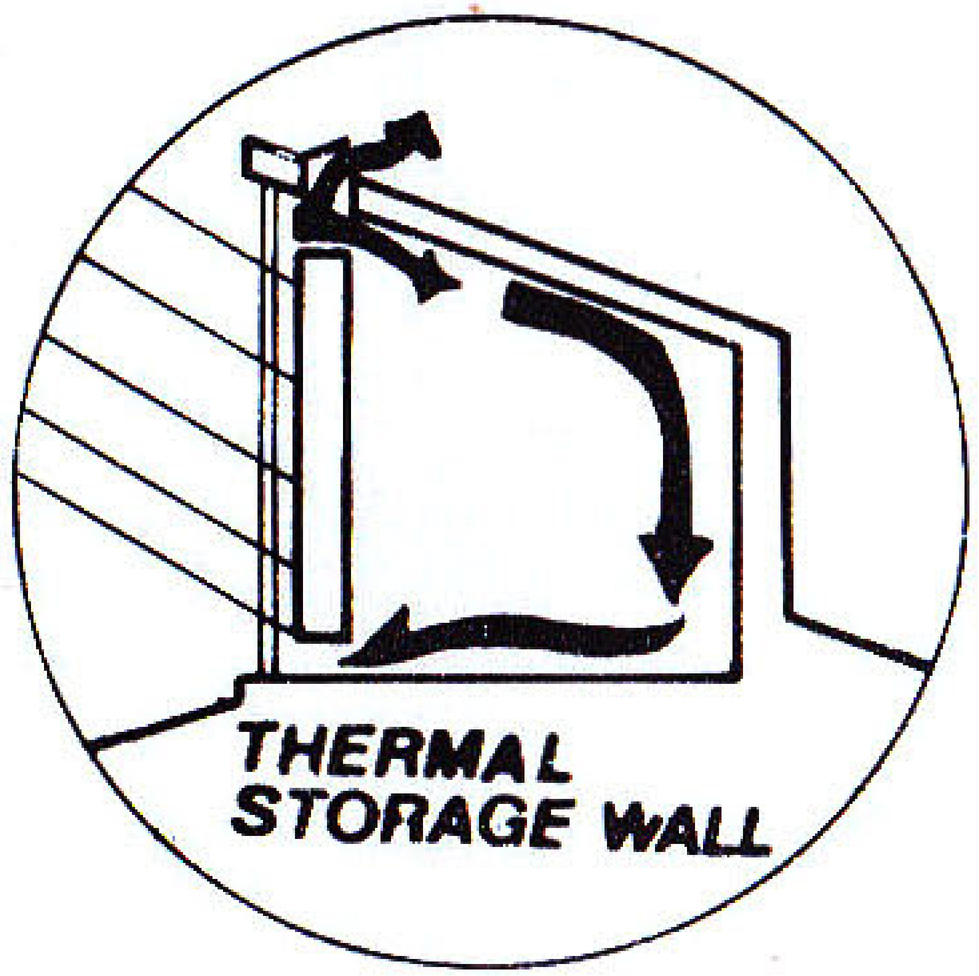
Roof Pond has the thermal storage in the ceiling of the building. In this case, movable insulation is needed because sun angles cause large solar inputs in the summer and small inputs in the winter. The system provides good natural cooling since the movable insulation allows one to take advantage of nightime radiation from the roof pond to the sky.

6.5 NATURAL CONVECTIVE LOOP

This utilizes the simple fact that heat rises. By placing Collection below the heat storage or the living space, a building can heat space without the need for circulating fans or pumps.

The cost differential between passive and conventional systems is hard to determine because passive elements are an integral part of the building's architecture. However, many believe that passive design will prove to be the most cost effective solution and should not cost more than 20-30% of total building cost (excluding services) additionally.

HEATING OF SPACES



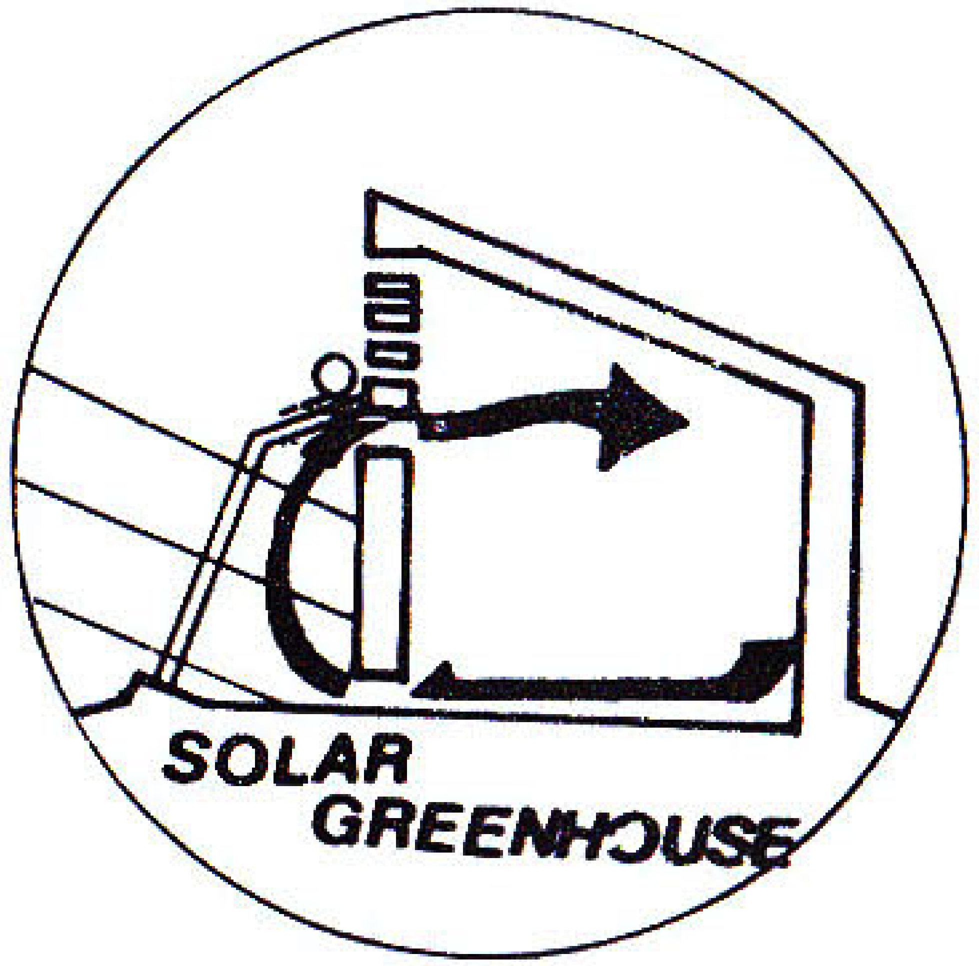
1. DIRECT GAIN: passive design incorporates an expanse of glass facing south. Solar energy heats the living space directly. Energy is stored in the thermal mass of the floors and walls, to reradiate later at night. Both excessive heat gain in the day and night time radiation loss are controlled by the use of movable insulation.

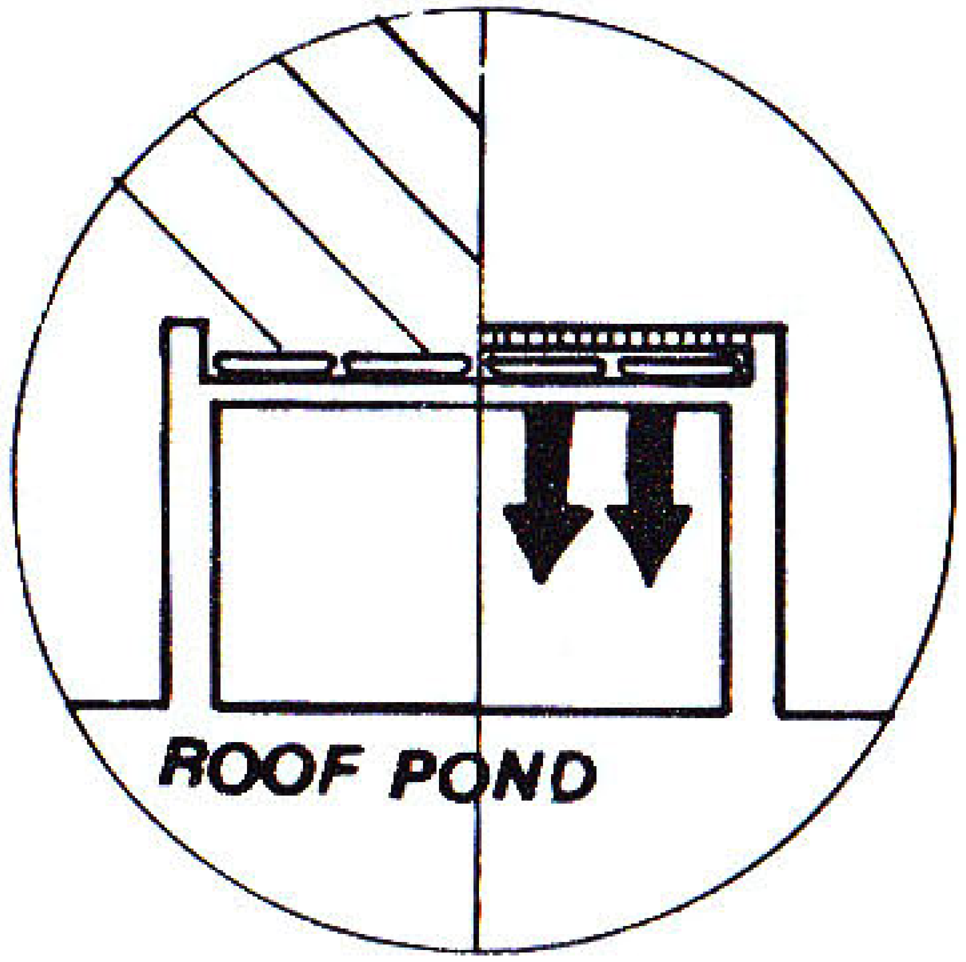
2. A THERMAL STORAGE WALL faces south and it absorbs and stores solar energy. The double glazing of the Trombe wall shown here prevents radiation loss while also creating a chimney effect, which can transport heat, in the living space. In summer, it can be vented outside and thus be used to draw cool northside air into the living space.

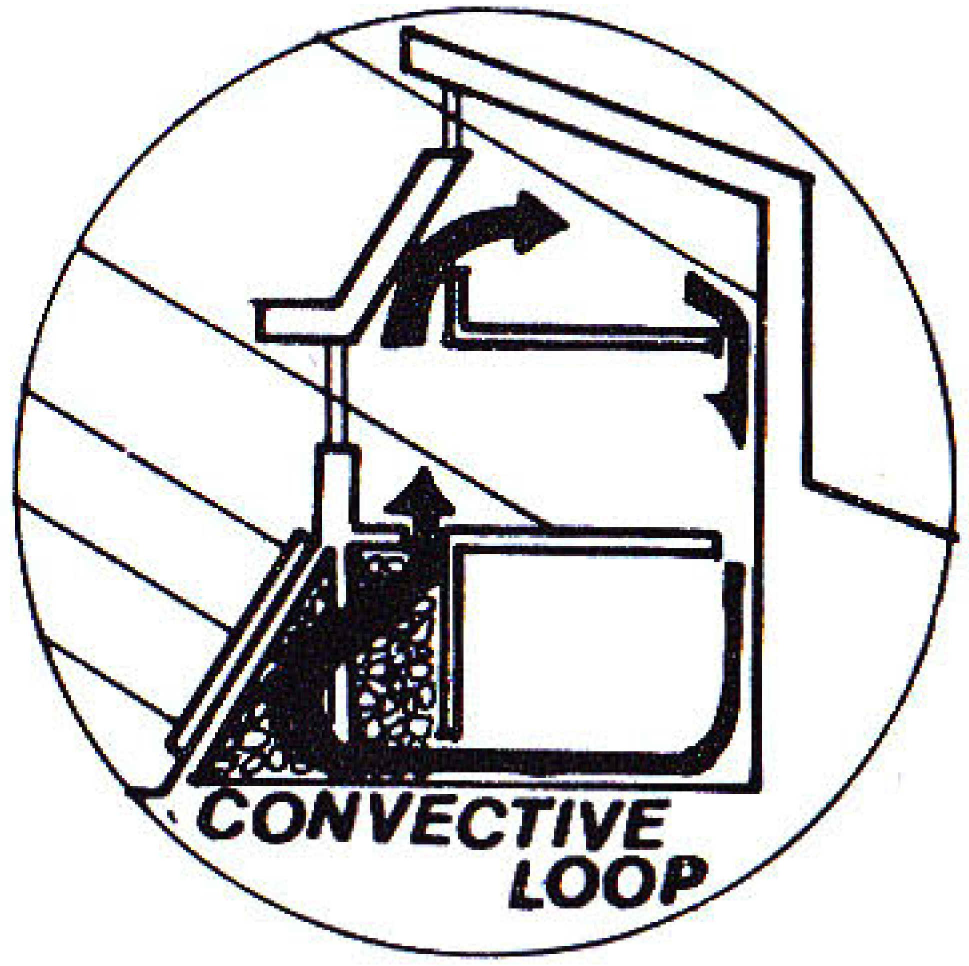
3. The south facing SOLAR GREENHOUSE combines Direct Gain and Thermal Storage Wall techniques. Movable insulation may be used to prevent excesses of heat gain or loss. Besides providing substantial heating for the living space, a Solar Greenhouse also provides humidity, oxygen, food and plants.

4. ROOF POND uses pillows of water for thermal storage. Movable insulation controls the gain and loss of this heat in the winter mode shown here. Insulation is opened for daytime heat gain, at night the insulation directs the heat down into the living space.In summer the insulation is opened at night to cool the roof pond and prepare for daytime cooling needs.

5. CONVECTIVE LOOP design shown here has its solar collector below most of the living space and adjacent to the rock thermal storage mass. Because hot air rises and cold air falls, this type of building with proper movable and fixed insulation needs no electric fans for distribution of heat.







7.0 CHOOSING THE SYSTEM

Each system has specific design limitations and use. That system must be chosen, which satisfies most of the design criteria in relation to its thermal needs and availability of space. The following is a general assessment of the characteristics displayed by the respective system;

7.1 DIRECT GAIN SYSTEM

Building form

The building is usually oriented along the east-west axis, with spaces needing heat located along the south wall.

Glazing

The major glass area must be oriented towards the south and it is essential that windows be carefully designed to eliminate the problem of glare often associated with direct gain systems.

Materials

The system generally implies a heavy building in the interior wall and floors constructed of masonry materials.

Thermal control

Direct gain systems are characterized by daily indoor fluctuations. To prevent over-heating, shading devices are used to reduce solar gain, or excess heat is vented out by opening windows/vents.

System efficiency

When properly designed, a direct gain system is roughly 30 to 75% efficient in winter.

Retrofitting

Retrofitting an existing building with a direct gain system is somewhat difficult, since the building by itself is the system.

Conclusion

This system demands a skillful and total integration of all architectural elements within each space-windows, walls, floor, roof and interior surface finishes. A direct gain system can usually be built for the same cost as a conventional masonry building.

7.2 INDIRECT GAIN SYSTEM (Thermal Storage Wall)

Building form

The depth of a space is limited to approximately 5 to 6 metres, since this is considered the maximum distance for effective radiant heating from a solar wall.

Glazing

The south-facing glass functions as a collecting surface only and admits no natural light into the space.

Materials

Either water or masonry can be used for a thermal mass wall. Double glazing in front of the wall is necessary unless insulating shutters are applied over the glazing at night.

Thermal control

Indoor temperature fluctuations are controlled by wall thickness. The heat output of a masonry wall can be regulated by the addition of thermocirculation vents with openable dampers or by movable insulating panels or drapes placed over the inside face of the wall.

System efficiency

The overall efficiency of the system is approximately 30 to 45% For the same area of wall and heat storage capacity, a water wall will be slightly more efficient than a masonry wall.

Retrofitting

This system can be added without much difficulty to the south wall of a building.

Conclusion

The system allows for a wide choice of construction materials (exclusive of the thermal wall) and interior finishes, and offers a high degree of control over the indoor thermal environment.

7.3 ATTACHED GREENHOUSE SYSTEM

Building form

The greenhouse must extend along the south face of the building adjoining the spaces to be heated.

Glazing

To heat one square metre of building floor area (excluding the greenhouse) approximately 1– 1/2 times as much greenhouse glass area is needed.

Materials

The major construction material in the green-house is double glass or transparent plastic and the common wall between (thermal mass-masonry or water) greenhouse and building.

Thermal control

Temperature control in adjoining spaces is the same as for a thermal wall storage system.

System efficiency

The overall efficiency of the system is approximately 60 to 75% during the winter months. The percentage of heat supplied to adjoining spaces is roughly 10 to 30% of the energy incident on the collector face.

Retrofitting

Retrofitting can be carried out easily by adding a south wall to an existing building.

Conclusion

The unique feature of the system is that it produces fresh food and has the potential to heat itself and spaces adjoining it.

7.4 ROOF POND SYSTEM

Building form

Since the roof itself is a collector, this system is most suitable for heating or cooling one-storey buildings, or the upper floor of a two-or more storey structure. The roof area containing the ponds can be flat, stepped upto the north or pitched.

Glazing

For summer cooling, the pond must be exposed to as much of the night skydome as possible.

Materials

Roof ponds are generally 15-30 cm in depth. A structural metal deck, which also acts as a finished ceiling and radiating surface is the most commonly used support for the ponds themselves.

Thermal control

Roof pond heating and cooling is characterized by stable indoor temperatures and high levels of comfort due to large area of radiative surface.

System efficiency

Roof ponds which are double-glazed (usually with an inflated plastic air cell) range in efficiency from 30 to 45%. It should be noted that the effectiveness of the seal made by the movable insulation will have an impact on the efficiency of the system.

Retrofitting

The requirements of a large area of radiating surface plus structural and modular considerations make it difficult to apply to existing structures.

Conclusions

Solar roof ponds are an inexpensive and effective method of providing both heating at lower latitudes and cooling in dry climates with clear night skies.

8.0 THUMB RULES

8.1 WALL THICKNESS

The best thickness of a Trombe wall is from 30 cm to 45 cm. The masonry should have high density-at least 1600 kg/m3

8.2 GLASS AREA

Half a meter square of south facing double glazing should be used for each W/°C of additional thermal load (i.e. exclusive of the glazing). This will give 70% to 80% solar heating at latitudes around 35° for a building kept within the range of 18°C to 24°C.

8.3 THERMAL STORAGE

A thermal storage capacity of at least 150 kg of water, or 5 times in weight of masonry or rock should be used for each square metre of south facing glass, This storage should be located in the direct sun. If it is not located in the sun, four times more storage is needed.

8.4 SEASONAL ADJUSTMENTS

Shading of a south glazing should be used to reduce summer and autumn over heating. An effective geometry is a roof overhang which will just shade the top of the glazing at a noon sun elevation of 45° and will fully shade the glazing at a noon sun elevation of 80°. If it is not possible to do this for the entire glazing, it is absolutely imperative for the windows in the wall behind the glazing, For heat wave periods, openable vents can be provided in the double glazing which discharge the hot air outside. The area is to be a minimum of five percent of the glazing spread over the entire length.

8.5 DAILY ADJUSTMENTS

Thermocirculation vents can be used to increase daytime heating but will not increase night time minimums. Vents should have lightweight passive back draft dampers or other means of preventing reverse flow at night. The area of vents depends upon the area of the glazing as well as the room height and plan ratio. Upper and lower vents should each be one percent of the glazing area and uniformly distributed over the EW. length of the south facing wall.

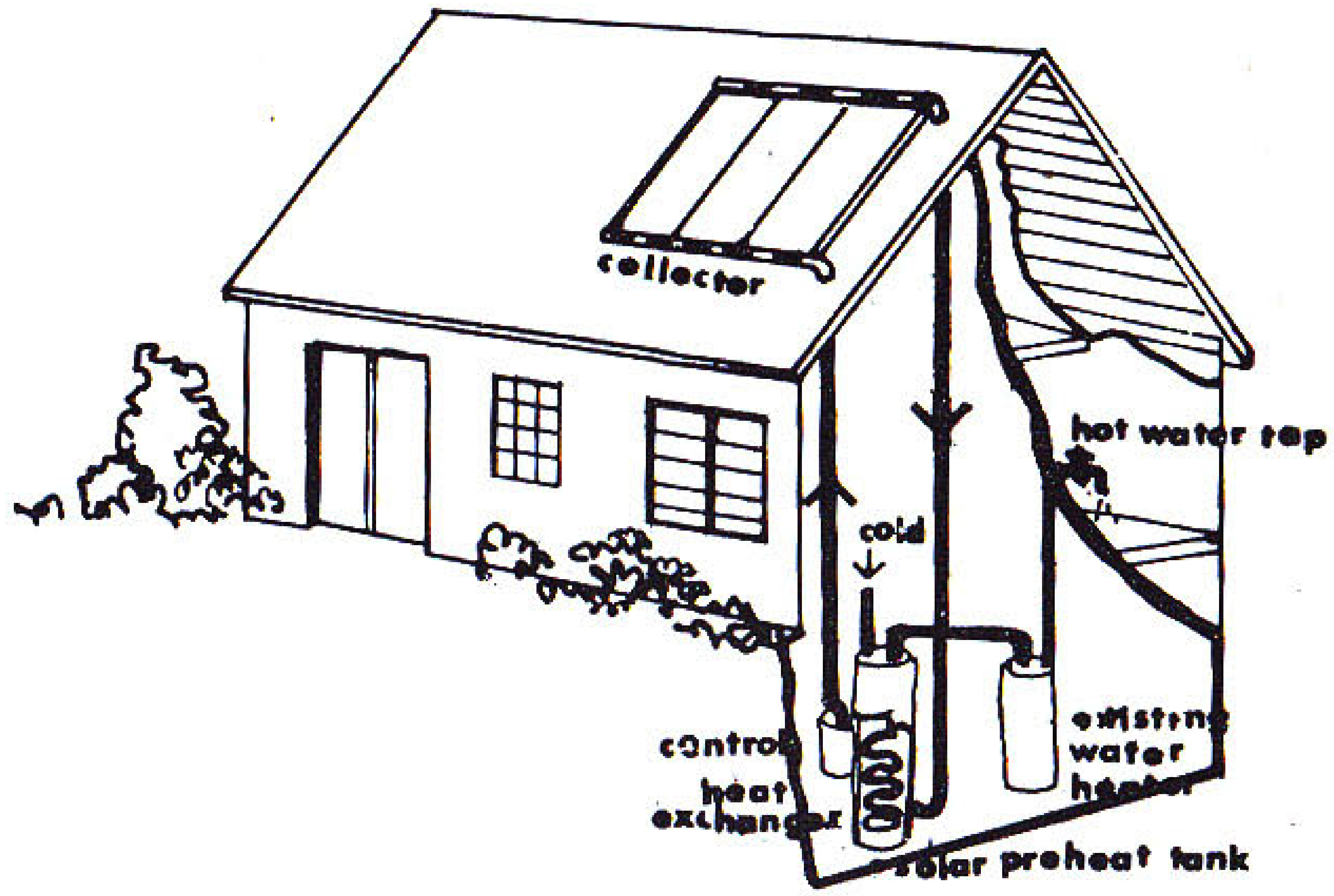
9.0 SOLAR DOMESTIC HOT WATER

A solar hot water heating system can be a stand alone or a supplemented solar system. It can also connect to the existing system if any, for providing an additional source of energy-the sun, Its main feature is an array of collectors that absorbs solar radiation and converts it to usable heat.

Domestic hot water (DHW) heating, if affordable, is the largest item in the family household energy budget. A solar hot water system can reduce this bill by 50-80%. Many homes have the potential for a solar DHW installation since the space requirements for collectors and storage are much smaller.

Two collector panels ($4m^2$) usually provide sufficient hot water for a family of four. Most roofs are at least partially free of shading, have adequate space, and can support the additional weight. Collectors are generally mounted on roof racks which can be positioned to avoid obstructions and face south even if the house is not properly oriented. The storage component of the solar DHW system can be in the present hot water tank (one tank system) or in a separate pre-heat tank connected to the existing hot water tank (two tank system)

Solar DHW systems are labeled either PASSIVE or ACTIVE depending on whether natural flows or mechanical equipment (pumps or fans) circulate fluid through the collectors. They are further defined as DIRECT (open-loop) if tap water circulates through the collector, or INDIRECT (closed-loop)-if some other



SOLAR DOMESTIC HOT WATER

fluid-treated water, air, glycol, or special oil-circulates in the collectors and transfers heat to the household water supply but never mixes with it. Heat is transfered to water in the storage tanks and the fluid passes through a coil called a heat exchanger. A double-walled heat exchange is desirable when the fluid in the system is not suitable for drinking.

Types of solar DHW systems

The simplest and least expensive solar DHW system is a THERMOSIPHON. In this passive, open-loop system, the storage tank must be located 30 to 50 cms above the collectors. This enables water in the system to circulate by natural means-rising as it is heated-through the collectors to the storage tank.

The system, however, has no freeze protection and is only suited to warm climates such as Baroda.

In a DRAIN DOWN system, a pump circulates water through the collectors. This allows the storage tank location to be below or some distance away from the collectors. This is an open-loop system, so it must be designed to withstand city water line pressures and it should not be installed where the water is hard or acidic in order to avoid mineral deposits or corrosion problems.

In a DRAINBACK system, a pump circulates tap water (with copper piping) or water with a corrosion, inhibitor (with galvanized pipe) through a closed collector loop and heat exchanger. The system is protected from freezing by a "Drainback" provision. Pipes in the system must have a positive downward slope from the collector to the storage tank. When the collector drops below a certain pre-set temperature, the controller automatically stops the pump, and water in the loop drains by gravity from the collectors and exposed piping into a small storage tank. The closed loop keeps the inlet water pressure from preventing gravity drainback when the pump turns off. This system is a good choice when the pipe runs can be installed with the proper slope as water is the most efficient and least costly transfer fluid.

AIR systems use a fan to force air through the collectors and an air-to-liquid heat exchanger in the storage unit. They pose no freezing or boiling problems, but do require more space for ducts and more collectors, since air carries less heat than liquids and the air-to-liquid heat exchanger also contributes to reduced efficiency. For this reason, an air system for DHW is most often installed in combination with a solar space heating system rather than as a separate unit.

LIQUID closed-loop systems circulate a freeze-Inhibited solution through the collectors. A differential thermostat controls the circulating pump so fluid flows only when the collector temperature is higher than the storage tank temperature. Liquid system require yearly checks of the fluid for proper freeze protection and PH levels as high summer temperatures can change the chemical balance of the anti-freeze solution. These systems offer the most lay-out flexibility for installation in existing homes.

Collection

The typical DHW "flat plate" collectors is an insulated, weather tight box containing a dark plate to absorb heat under a single transparent cover. The collectors are usually 2 Metre x 1 Metre An average family requires 1 M^2 of collector per person to obtain a reasonable amount of hot water from the sun. Collectors are tested and given an efficiency based on their average heat output. Consumers should check this rating when comparing products. In addition to performance information, engineering data should indicate that the collector is capable of withstanding cycling, stagnation temperatures, exposure to ultraviolet light, and freezing temperatures over 20-30 year lifespan. A quality installation includes neat and thoroughly insulated pipes and attention to aesthetics.

Siting and orientation

The collectors should be positioned to receive the maximum amount of sunlight. Roof mounted collectors are common because of reduced shading problems, Ideally, collectors should be oriented TRUE SOUTH, however, variations of upto 15 east or west will have a negligible effect on performance. The optimum tilt angle is equal to the latitude for year round use and 15 degrees more than latitude for winter use.

Storage

Solar heated water is typically stored in a well-insulated 'Pre–heat' tank that is connected to the existing water heater, or else in a single tank that has an electric back up heating element in it. The one-tank system takes less space and generally costs less, but cannot be used with oil or gas back-up and cannot deliver as much continuous hot water as the two-tank system. The tank is usually sized to hold at least one day's supply of hot water.

Distribution

S olar pre-heated water may be above or below the desired tap water temperature depending on weather conditions. When too low the conventional water heater will kick in, and when too high a tempering valve will automatically add cold water to prevent scalding. It is unlikely that a solar DHW system will supply all the family's hot water needs, but with wise and timely use it can provide a major portion of it (80 to 90 percent in Baroda).

Costs & benefits

The cost for active solar domestic hot water systems is normally given as a total system cost or as the cost per square metre of collector. This usually includes the cost of the other system components, namely, storage tanks, pumps, controls, piping, insulation, duct work, and installation. Balance of system cost are nearly equal to that of collectors cost which are in Rs.2000/ M^2 bracket. Inspite of a higher initial cost for solar DHW systems than for solar space heating systems per square metre of collector, the yearly savings and payback are more favourable because the domestic hot water system is operational year-round and is extremely efficient during the summer months. Ministry of Energy subsidies (administered by GEDA in Gujarat) bring the payback period to less than four years. After installation, a solar DHW system should require very little maintenance. A closed loop liquid system does require an annual fluid check to assure proper freeze protection and PH. A fluid change is recommended once every three years. This cost is included in an annual operation and maintenance allowance of 0.5%.

10.0 SOLAR PASSIVE COOLING

Solar cooling methods have been introduced in both the Trombe Wall and the Roof Pond solar passive heating systems. However, to outline in more detail some tested methods of cooling by the sun, five types of passive cooling are briefly defined;

Nocturnal radiation

Briefly described in the roof pond solar passive building type, night sky radiation involves the cooling of a massive body of water or masonry, by exposure to a cool night sky. Although this depends on a large day-night temperature change, a clear night sky will act as a large heat sink to draw away the daytime heat, which has accumulated in the mass, until temperatures are equal to or cooler than the low night temperatures. During the day, this mass then acts as a "Cold storage" to draw heat away from the living space, providing natural cooling.

Evaporative cooling

When either moisture or bodies of water are present in an overheated but somewhat dry climate, the sensible heat of air will be converted into latent heat in evaporating the water. Although the resulting formation of water vapor will increase the humidity of the air, it will also decrease the dry bulb temperature. The increase of humidity coupled with the decrease of sensible temperature combines to make the environment more comfortable. The spraying of the roof deck with water, or mechanical fans combined with water filters (evaporative coolers) are all examples of this natural cooling method.

Dessicant cooling

On the other hand, the drying of very humid air can also provide natural cooling. Since high humidities prevent man, from naturally cooling by sweating (the sweat will instead sit on the skin and not evaporate to cool the body), man's tolerance of higher temperatures is reduced. The dehumidiciation of air in the 23°–27°C range, intolerable at high relative humidities, will provide natural comfort at these temperatures. The use of dessicant salts, once easily available in the southeast, for ventilation or mechanical dehumidifiers all represent methods of Dessicant Cooling.

Underground building

Underground construction also provides excellent cooling potential. The temperature of the ground remains almost stable throughout the year and depending on latitude, at approximately annual mean temperature of air. In climates with severe summer temperatures or severe winter temperatures or both, underground construction provides considerably improved 'outside' design temperatures, to remove much of the demand from the heating system, and all the demand from the cooling system. Two words of caution in underground; first, humidity and moisture conditions which result from below grade construction may greatly influence living comfort in the already humid regions; and secondly, underground buildings cannot take maximum advantage of comfortable outside temperatures, but instead have constant exposure to the cooler ground temperatures.

Induced ventilation

The fifth solar passive cooling system makes use of sunshine to induce air movement to augment natural ventilation for building comfort. By using the sun to heat air in one restricted area, with a location some what lower than adjacent non-solar heated areas, a temperature difference is set up, causing natural air movements, in which hot air will rise. The pocket of hot air created inside, at temperatures greater than ambient, will vent to the outside, drawing replacement air from the living spaces. The living spaces in turn should draw replacement air from the coolest outdoor air source, usually near planted north areas. Thus, a "thermal chimney" can by use of solar energy, cause continuous air circulation through a building to provide solar passive cooling.

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