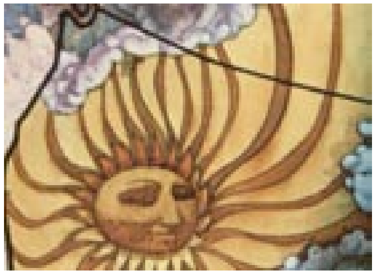
PASSIVE SOLAR ENERGY – The Starting Point

The sun's energy is an incredible bounty. The energy contained in solar rays makes its way through filtering atmosphere and is fundamental to human survival. It can also provide for our comfort.



The use of the sun's power is usually identified in 2 contexts -
PASSIVE SOLAR - that which uses natural processes without mechanical equipment or electricity and/or gas energy to operate, and
ACTIVE SOLAR - that which uses nature's resources with the inclusion of mechanical equipment driven by electricity and/or gas.

Passive and Active solar applications should be considered as the one-two punch of living with the sun. Both rely on the same strategies of heat flow, orientation, access to the sun, behavior of materials, and use of on-site resources, and vary only in the inclusion of mechanical equipment driven by external energy resources of gas and electricity,.

All passive solar applications start from a simple question -

WHAT CAN BE ACCOMPLISHED USING SITE SPECIFIC RESOURCES WITHOUT MECHANICAL EQUIPMENT AND EXTERNAL ENERGY ?

Even active system solar folks counsel starting with considerations of passive solar actions because it can:

1) directly meet needs so mechanical equipment is not necessary;
2) improve conditions in which equipment, both solar or standard, is required;
3) reduce the amount of equipment required;
4) reduce the amount of maintenance required due to less equipment used, &
5) minimize costs that accompany purchase, maintenance, and use of equipment.

What can be done by passive means – then what can be accomplished by active solar means, then how do the two combine in tandem to provide optimal effectiveness

PASSIVE SOLAR FIRST

The term Passive Solar has been identifed with heating and cooling of buildings. There is a broader context.- passive solar water heating, solar cooking, daylighting, and even passive solar devices which move louvers. Even the process of sunlight conversion to electricity can be considered a passive action since there ae no moving parts and no reliance on external energy sources.

NATURE'S CONTRIBUTION

Nature provides the tools to use - sunlight for a warming system breezes, water, earth, vegetation and materials for a cooling system We know the sun's position every day of the year and the amount of radiation it provides at any given location..

A south facing wall gets most energy from the sun than any other orientation. An angle directly perpendicular to the sun gets more energy per square foot than any other angle. The sun is less available in the winter (shorter days) than in the summer. Cool air settles and warm air rises, and this action occurs with fluids like water. Heat flows to cold, and materials have varying capability to absorb, hold, and give up heat.

We know how to capture sunlight for use, and how to mitigate unwanted heat. It is the application of this knowledge about natural processes and resources that makes passive, and active, solar so effective.

IN TUNE WITH NATURE

Passive solar use is dependent on natural elements and processes in providing comfort to people in a manner that is healthy and non-depleting of resources. Quite simply, a nature incorporating , comfort generating, security providing environment in which the building elements themselves are the "machinery" that provides security, health and comfort, and incorporates appropriate solar equipment to provide higher degrees of performance.

HISTORY

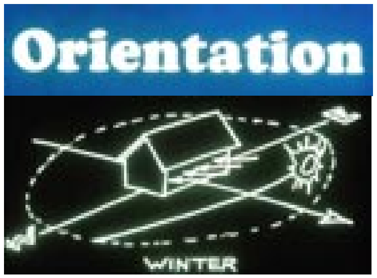
Arizona history is replete with examples of people living with the sun - both in use as a resource as well as dealing with its impacts. Arizona buildings, both private and public, used passive design straegies. Batch solar water heaters were prevalent in Arizona and included such notable historic buildings as the Ellis-Shackleford House in Phoenix and the Tempe Bakery .

ELLIS-SHACKLEFORD HOUSE

PASSIVE SOLAR ENERGY
PRELUDE TO SOLAR EQUIPMENT CONSIDERATION

There are a number of passive energy fundamentals which can be considered in reducing the amount of equipment and/or its' operation.

orientation-
It's the necessary thing



Like all direct solar applications, capturing the sun is as simple as providing a clear path to where it can do its work - be it heating water, cooking food, generating electricity, or warming a space. Orientation is a fundamental concept of solar use for passive and active systems -

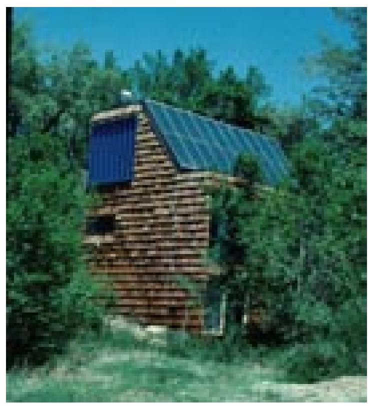
A properly oriented building is critical - one that presents a south face to the sun. Likewise, properly oriented solar equipment, (solar water heater, photovoltaic panel) will have optimum performance

Proper building orientation establishes the context for passive design elements and the foundation for the integration of solar equipment into the building form and shape without conflict, and optimal use of solar energy.

form -
It's the right thing

Solar buildings employ a form and that is responsive to the elements that impinge upon it, as well as the passive solar design elements that are within it Good building form is also beneficial when it comes to integration of solar equipment. Instead of racks, collector panels can be blended into the building architecture, and be as seamless as a skylight or clerestorey window.

For this reason roof design (slope and orientation) is important since this is a prime and sometimes ideal location for equipment placement.



location
It's the effective thing

Location of a building. and especially the placement of the spaces within it, is a critical passive element. Habitable spaces that benefit from passive solar heating are best located on the south side, and support spaces (closets, storage areas, etc.) are placed as environmental buffers, reducing heating and cooling loads. and amount of equipment needed.

Proper location and space planning also optimizes integrated solar equipment by minimizing piping runs and complex plumbing and wiring distribution. Efficient location of equipment coupled with effective equipment reducing passive applications result in significant cost savings.

materials
It's the smart thing

All solar heating and cooling systems are based on the ability to gather and store energy for a period of time. This is accomplished by using materials which absorb and hold heat until it is needed - for heating, or to be dispelled later as in cooling. Solar water heaters use water. Solar buildings use their own structure - floors, walls, even roofs.

Some material is better than others. Glass, wood, and insulation are not good. Dense material (adobe, stone, brick,etc.) are very good. This attribute is called **thermal mass.**

Thermal mass is used in passive heating – sunlight strikes the interior surfaces which absorb the heat, then release it back later as the space cools. Cooling uses the mass as a thermal sponge, absorbing undesirable daytime heat, then dissipating it in the evening with ventilation..

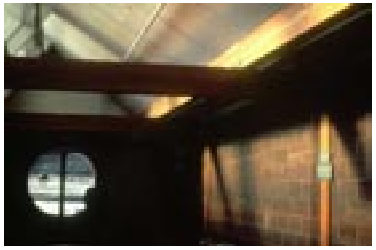
Passive solar buildings utilize the very fabric of the building as part of the heating and cooling system. Heating can be enhanced by integrating a solar hot water system to run heated water through a thermal mass wall, radiant floor or roof. Integrating a PV panel to move cool water through the system also enhances mitigating unwanted heat for cooling..

windows –
It's the clear thing

A major condition affecting building energy consumption is size and location of windows, the weakest point of the building envelope relative to heat transfer. The leakiest when it comes to energy, a square foot of glass will lose 12 times more energy than a wood wall with insulation.

As a rule, for heating, a majority of window area should be on the south side - **where the sun is!!**
East and west sides of dessert buildings should be minimized - these are the 2 worst exposures for early morning/late afternoon summer sun. Typical designer over-sizing of windows for the "feel of the great outdoors" is not an optimal situation good dessert solar design.

Clerestorey windows are a passive design tool to gain sunlight benefit to poorly lit or heated areas;.difusing direct solar impact, moderating glare, and with operable windows, for house ventilation cooling. North facing clerestorey windows, capitalizing on the eveness of light, can provide a south facing structural loca-tion for solar equipment integration..



thermal decompression–

It's the healthy thing

> Thermal Decompression – Transitioning through successive temperature zones until the zone adjacent to the building is closest to the interior temperature

A buildings' internal temperature will always be in conflict with the outdoor temperatures adjacent to it.. Heat always moves to cold - winter interior warmth moves to the exteror.. Summer heat moves to interior coolness.

In both situations, the greater the difference between inside and outside temperatures, the faster the movement of heat and the greater the amount of heat moved. More heat and cold means more equipment for mitigation. Additionally, sudden and abrupt changes in temperature is not good thing for the human health.

Mitigating extremes through Thermal Decompression is simply the layering of thermal zones, like rings of an onion, from buildingr to property line. The zones are of sequential density, in the form. of landscaping, vegetation, and built elements.

Summer heat is mitigated by the gradual density of the environment (light shading to heavy) to a point where temperatures adjacent to the building are cooler and much closer to the internal temperature,

Cold climate design is the reverse – rings of gradual warming (sun exposure, north side reflectors, heat absorbing, materials, etc) .ring the building.

Both conditions are enhanced with interior thermal zones at doorways (air locks), and the passive application of thermal decompression impact the amount cooling/heating/solar equipment needed.

PASSIVE APPLICATIONS

NATURAL LIGHTING

The sunlight received by a building will provide more than sufficient illumination. Natural lighting means no need for daytime artificial lighting, no energy used for those lights, and no utility cost..Natural light can be incorporated into most spaces, directly or indirectly, with light reflecting color choice, light shelves, and transparent and transluscent walls

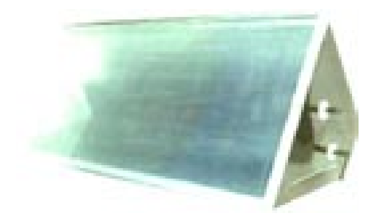
This has dual benefit - illumination, iand wintertime heating. Multi-faceted and multi-applicable, daylighting design is an effective passive solar approach which has a direct impact on the building's energy performance and energy consumption.

Add to this a solar electricity generation system (now smaller due to good design) and both daytime and nightime illumination requirements are met using the sun.

WATER HEATING

Batch or Integrated Collector Storage (ICS) System

Simply - ater in a tank or tubes within a container, exposed directly to the sun - the batch system combines solar collection, water heating, and storage into a single unitt. Direct heating makes this system compact, simple, and effective.



The "batch" approach has been used for some time and improvements in design have enhanced effectiveness.

Thermosiphon Systems

Hot water rises and cold water settles. A thermosiphon solar water heating system incorporates natural convection (without pumps) to move fluid heated by the collector to the storage tank. Hot water from the collector rises naturally to the top of the tank, cold water from the tank drops to the collector and the whole processs is a continuous circulation loop.

HEATING/COOLING

Passive solar applications for heating and cooling a building replace expensive heating and cooling using conventional electricity and gas.

Basics of passive applications are rooted in dealing with the sun (exposure to and capture of the sun's energy for warmth; protection from the sun for coolth); the materials used (for effective capture, storage, and use); and natural processes of physics for both.

Every passive system for solar heating requires exposure to the sunlight and trapping it - this is done by glazing - windows for a building and glass covers for solar panels. Every passive system is dependent upon materials which will absorb the sun's heat, store a good quantity of it and easily give it up. In a building, the effective solar material can be the structure itself, in the form of thermal mass (masonry, water, adobe,etc.).

Heat capture, storage and distribution follow a natural, predictable action.. Sunlight heats the surfaces it strikes. The amount of heat held depends on the material composition (straw is terrible, masonry is better. Generally there are 3 passive heating building concepts -

Direct Gain,
Indirect Gain and
Isolated Gain

These concepts have inherant within them cooling applications as well

DIRECT GAIN

HEATING - Simply stated, sunlight comes through windows warming people directly. The thermal mass of floors and walls, or even strategically placed containers of water, struck by the sunlight, absorb the heat. Later, as the space cools, the absorbed heat is reradiated, keeping people warm in the cooler evenings..

A Direct gain system is always working, letting in not only direct sunlight but also the diffuse light of cloudy days. Like any system, optimization is the goal - so building eaves and overhangs become a design element for seasonal heat control.. Unwanted summer sun is mitigated by the eaves, keeping sunlight off of the windows, while during winter conditions, with lower sun position, sunlight skirts under the building's brow to impact building interiors..

This approach, requires careful consideration of the site, solar energy availability, and seasonal conditions, to determine the appropriate amount of windows, thermal mass, and eave design. Too many windows in an Arizona desert setting will result in a human cooker; too few windows in the mountains will result in not enough capture

COOLING - Direct Gain Avoidance is the rule, BUT the thermal mass of the building can still be used in a cooling cycle. Mass walls, floors, and roofs bcan be used as "thermal sponges" drawing heat away from people, and dumping it in the evening by ventilation (or mechancially at off peak utility rate hours).

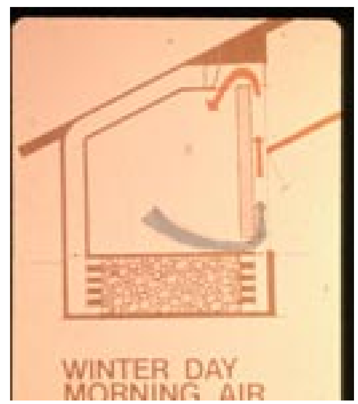
Interior control is done with moveable blinds or insulation, and cross ventiation strategic placement of wall vents (low intake at the cool side, high exhaust at the warm side). .

INDIRECT GAIN -

Indirect Gain is the "next step" from a Direct Gain system. Sunlight penetrates south facing windows (or glazing) , but instead of going into a living space, it strikes a thermal mass located directly behind the windows. The thermal mass acts as an absorber/radiator for heating and a thermal sponge absorber/disapator for cooling. There are three types of in-direct gain systems, each defined by where the thermal mass is located. The three strategies are

* Thermal Wall and Plenum
* Sunspace
* Thermal Roof

Thermal Wall and Plenum



South facing windows front a thermal mass wall, to create a vertical plenum. The dark color sun side of the wall absorbs, and stores heat while acting as a buffer to the interior spaces. This moderates temperature changes and provides for extended use of thermal gain well into the evening as a delayed action radiator.

At the same time the air between the windows and the mass heats up, and exits at upper wall vents and is replaced by incoming room air at lower wall vents in a convective loop action

There are a number of examples of this application - the Trombe wall which uses masonry, and water as in Steve Baer's application using water barrel walls..

Sunspaces

Sunspaces are a combination of Direct Gain and Thermal Wall systems, with a dedicated Direct Gain area (Sunspace) adjacent to the living spaces but separated by a thermal wall or mass element.

The Sunspace has south glazing and large daily fluctuations, while the adjacent living spaces are protected from these fluctuations by the separation mass. Vents or windows in the dividing wall allow warmed Sunspace air to circulate by natural convective actions during the day, and radiate the absorbed Sunspace heat to the living spaces in the evening. The additional area of the Sunspace is often used as an enclosed solar greenhouse for plants with operable windows and vents for temperature control.

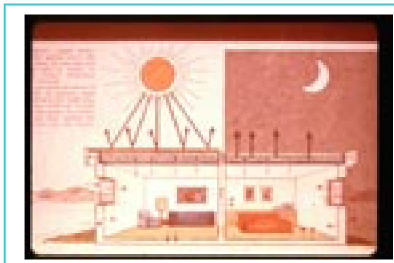
Thermal Roof

The Thermal Roof is simply thermal mass, in the form of water, on top of a building rather than at a wall. The system replaces a number of separate typical building elements. It is the roof, ceiling, heat/cool distribution system, as well as the heating and cooling system..

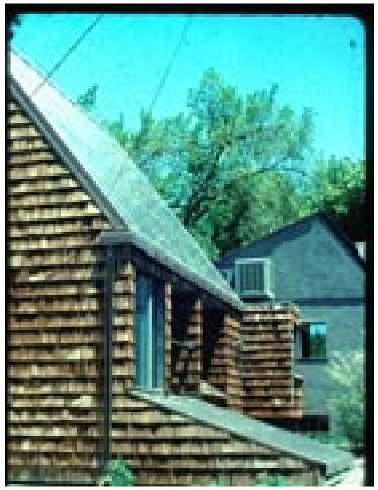
Water contained within clear UV inhibiting plastic beds, lie on a roof liner and heat transferring metal ceiling. Movable insulation, .the thermal "switch" for summer cooling or winter heating is above the ponds.

Winter condition – Insulation moves to expose the water beds to the sun The water beds absorb sunlight and transfer the heat to the spaces below. Panels close at night to extend the radiation process into the evening. The entire ceiling is a solar radiator, and heat is both gentle and even – no air blowing, no hot spots/cold spots..

Summer condition – Panels remain closed, and cool ponds are a thermal sponge, absorbing heat from the building.. Panels open at night, expose the beds to the night for heat dissipation by radiation and convection, and beds cool for another cycle.



ISOLATED GAIN



An indirect system - Solar collection for heat and storage is independent, using air heaters and rock bins, or water heaters and water storage tanks i a separate loop. Distribution to the building occurs in a separate, convective loop with interior air circulating through the bins or across the tanks to pick up heat and move it to the habitable spaces.

A hybrid of this system is moving solar heated water or air through a radiant floor system where the floor itself acts as the heat storage container. This variation can also use house supply or pool water to create a "cool" floor..

COOLING

Heating installations may be elements for cooling strategies. The thermal roof and some plenum wall systems can provide for both heating and cooling. Additional strategies include:

Cool Towers

Cool Towers are gravity driven evaporative coolers. Wet pads mounted high, cool warm air directly, which becomes more dense and falls to living spaces below. The falling cool air spills into the building, cooling both people and thermal mass surfaces, and pushes warmer out at strategicly placed vents. As the process continues, the cooler air settles at low points, creating cool zones and puddles - a cool enviroment in Az. desert conditions.

A "distribution" variation is the addition of a south facing thermal "chimney" - a solar air heater - to increase cool air distribution throughout the building. The Thermal chimney, located opposite and remote from the cool tower, drives interior evacuating air out of the building. This rapid venting has a drawing effect on the cool tower air which is pulled further than it would normally go, and is distributed more extensively through the building.

The solar chimney can also be designed to be a recirculating air heater, warming and distributing air from adjacent spaces during winter conditions.

Natural Cooling

There are three sources of undesirable heat -

*direct summer sun light through windows and impacting on walls and roofs;
*outside heat transmission through the building materials to the interiror; and
i*nternal heat produced by people and their equipment.

Direct solar heat gain at windows and walls can be easily controlled by preventing the sun's impact (except for good daylighting and operation of solar equipment) with vegetation, trellises, and external shading devices as wel as interior thermal insulating shutters.

Heat transmission conditions can be nullified by thermal decompression - setting up layers of vegetation and built structures like porches, water features, etc. to cool the temperatues adjacent to the building. Additionally, rough textures and light colors add to the cooling arsenal..

Heat from equipment can be mitigated by careful placement and venting, careful selection of energy efficient equipment, and by good timing - do the laundry in the evening.

SHADE
THERMAL DECOMPRESSION
EFFICIENT APPLIANCES
ACTIVITY TIMING

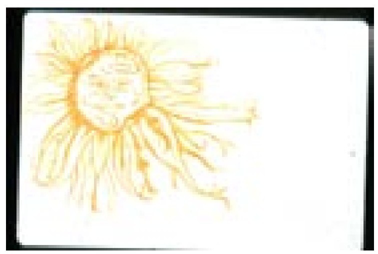
SOLAR COOKING

Use of the sun for food preparation is fun, energy saving, and saves money, both in the cooking operation, and in the cooling costs saved when the heat is taken out of the kitchen during the summer. A variety of cooking tools from box cookers to slat faced ovens are available - whether they be commercial products or hand built by the aspiring Solar Chef.

Arizona has long had a relationship in cooking with the sun, from the annual Solar Potluck in Tucson to the development of the Kerr/Cole box cooker used throughout the world.

Solar Energy has many faces and applications, and an effective Passive Solar strategy, whether in a building, a piece of equipment, or the ideal interelationship of both, incorporates natural processes and site elements to provide for comfort as well as mitigation of untoward conditions.

Passive solar applications are the first consideration in solar design and action in meeting needs, and reducing dependency and reliance on unecessary equipment. Passive design results in less dependency on equipment, less equipment, and less costs for equipment purchase, maintenance, and operation



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