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General Principles of Passive Solar Heating and Passive Cooling in Buildings

Dr. Mukesh Kumar Lalji[1], Dr. Ashish Dongre[2], Surjeet Singh Rajpoot[3]

[1]Principal-Part Time Diploma Course, Vice-Principal, S. V. Polytechnic College, Department of Technical Education, Employment and Skill Development, M. P. Govt., Bhopal, Madhya Pradesh, India
[2]Government Women's Polytechnic College, Indore, Madhya Pradesh, India
[3]Assistant Professor, SCOPE College of Engineering, Bhopal, Madhya Pradesh, India

ABSTRACT

Uninvolved heating and cooling in homes is only a question of figuring out where the sun openness is, and attempting to catch and keep as a lot of that hotness as possible in the colder time of year while keeping it out in the late spring. This might appear to be a difficult task, yet the occasional situation of the sun advantageously serves this end. In the colder time of year the sun is low and will venture far into your home, in summer it is high overhead and simple to keep out the principal thing to comprehend is that there are two sorts of sun based assortment in home plan - dynamic and aloof. A functioning sunlight based home has a costly cluster of boards; either photovoltaic for power age or warm sun oriented for heat assortment. Both are convoluted frameworks that will probably incorporate some moving parts that will ultimately. Uninvolved sun oriented plan then again is just presence of mind. Simply sort out where the sun is, and point your windows at it. A ton of free hotness, and on the off chance that you plan your concealing appropriately with shades and window design, you can assist with keeping it normally cool in the mid-year. On the off chance that you add superior execution triple coated Passive House affirmed windows, then, at that point, they will be advanced to acquire and hold the sun's hotness.

KEYWORDS: *Solar, Passive Heating, Cooling, Zonings, Comfort, Buildings, Direct Gain, Solar Aperture, Nature, Climate, Materials, Sun Space, Dehumidification, Mass Effect, Effect, Ventilation, Air HAV, Courtyards, Ponds*

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INTRODUCTION

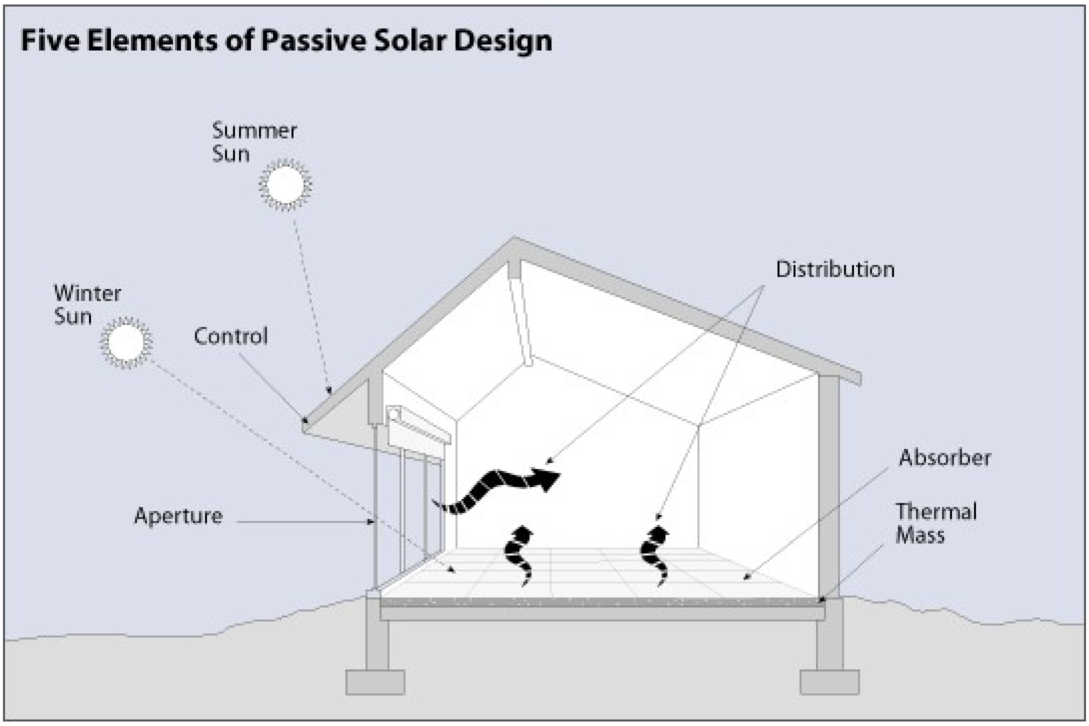
Passive solar design refers to the use of the sun's energy for the heating and cooling of living spaces by exposure to the sun. When sunlight strikes a building, the building materials can reflect, transmit, or absorb the solar radiation. In addition, the heat produced by the sun causes air movement that can be predictable in designed spaces. These basic responses to solar heat lead to design elements, material choices and placements that can provide heating and cooling effects in a home.

Unlike active solar heating systems, passive systems are simple and do not involve substantial use of mechanical and electrical devices, such as pumps, fans, or electrical controls to move the solar energy.

Passive Solar Design Basics

A complete passive solar design has five elements:

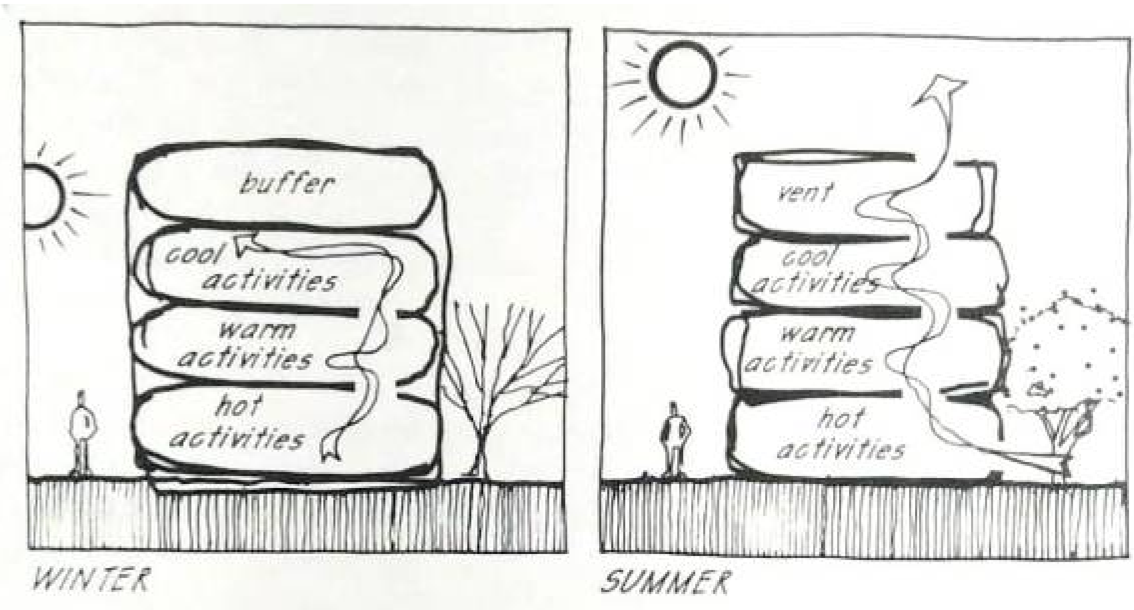
- **Aperture/Collector:** The large glass area through which sunlight enters the building. The aperture(s) should face within 30 degrees of true south and should not be shaded by other buildings or trees from 9a.m. to 3p.m. daily during the heating season.



- **Absorber:** The hard, darkened surface of the storage element. The surface, which could be a masonry wall, floor, or water container, sits in the direct path of sunlight. Sunlight hitting the surface is absorbed as heat.
- **Thermal mass:** Materials that retain or store the heat produced by sunlight. While the absorber is an exposed surface, the thermal mass is the material below and behind this surface.
- **Distribution:** Method by which solar heat circulates from the collection and storage points to different areas of the house. A strictly passive design will use the three natural heat transfer modes- conduction, convection and radiation- exclusively. In some applications, fans, ducts and blowers may be used to distribute the heat through the house.
- **Control:** Roof overhangs can be used to shade the aperture area during summer months. Other elements that control under and/or overheating include electronic sensing devices, such as a differential thermostat that signals a fan to turn on; operable vents and dampers that allow or restrict heat flow; low-emissivity blinds; and awnings.

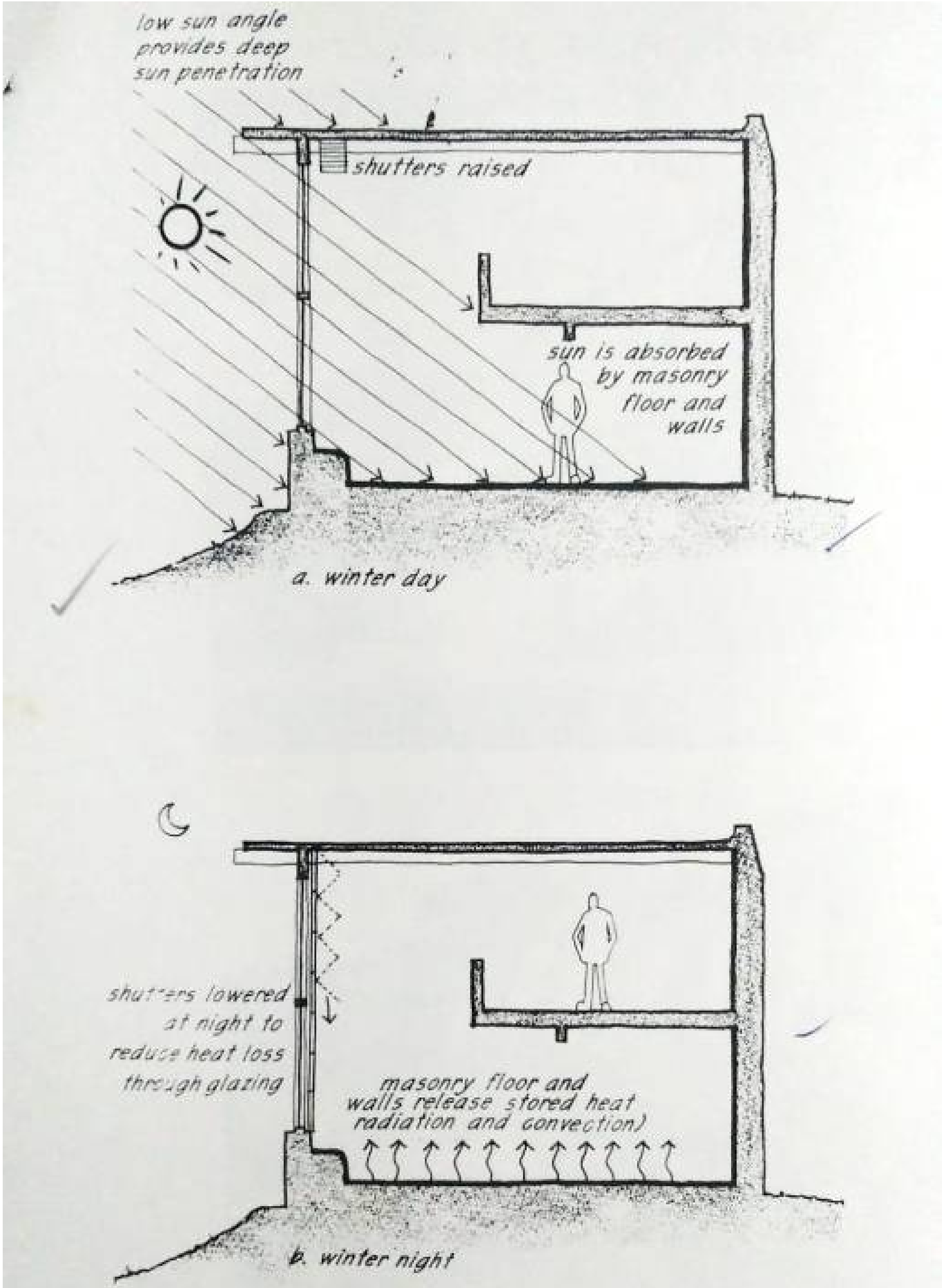
Passive Solar Heating

The goal of passive solar heating systems is to capture the sun's heat within the building's elements and to release that heat during periods when the sun is absent, while also maintaining a comfortable room temperature. The two primary elements of passive solar heating are south facing glass and thermal mass to absorb, store, and distribute heat. There are several different approaches to implementing those elements.



Direct Gain

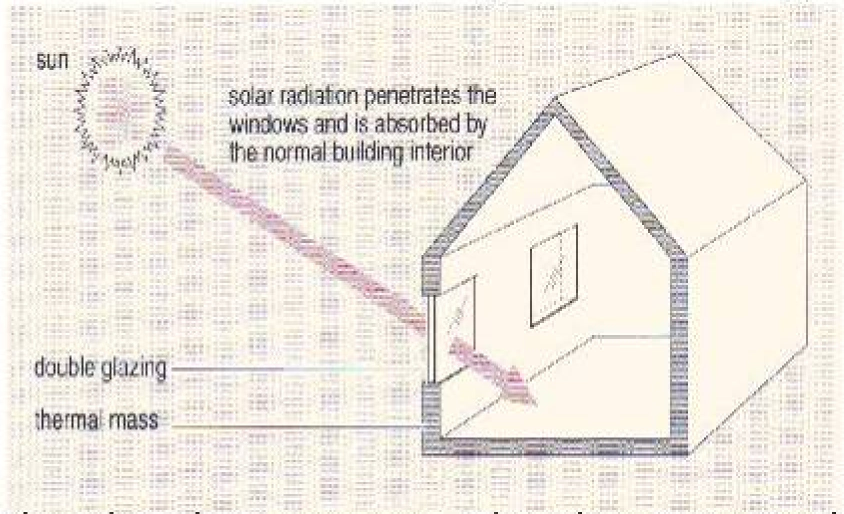
The actual living space is a solar collector, heat absorber and distribution system. South facing glass admits solar energy into the house where it strikes masonry floors and walls, which absorb and store the solar heat, which is radiated back out into the room at night. These thermal mass materials are typically dark in colour in order to absorb as much heat as possible. The thermal mass also tempers the intensity of the heat during the day by absorbing energy. Water containers inside the living space can be used to store heat. However, unlike masonry water requires carefully designed structural support, and thus it is more difficult to integrate into the design of the house. The direct gain system utilizes 60-75% of the sun's energy striking the windows. For a direct gain system to work well, thermal mass must be insulated from the outside temperature to prevent collected solar heat from dissipating. Heat loss is especially likely when the thermal mass is in direct contact with the ground or with outside air that is at a lower temperature than the desired temperature of the mass.



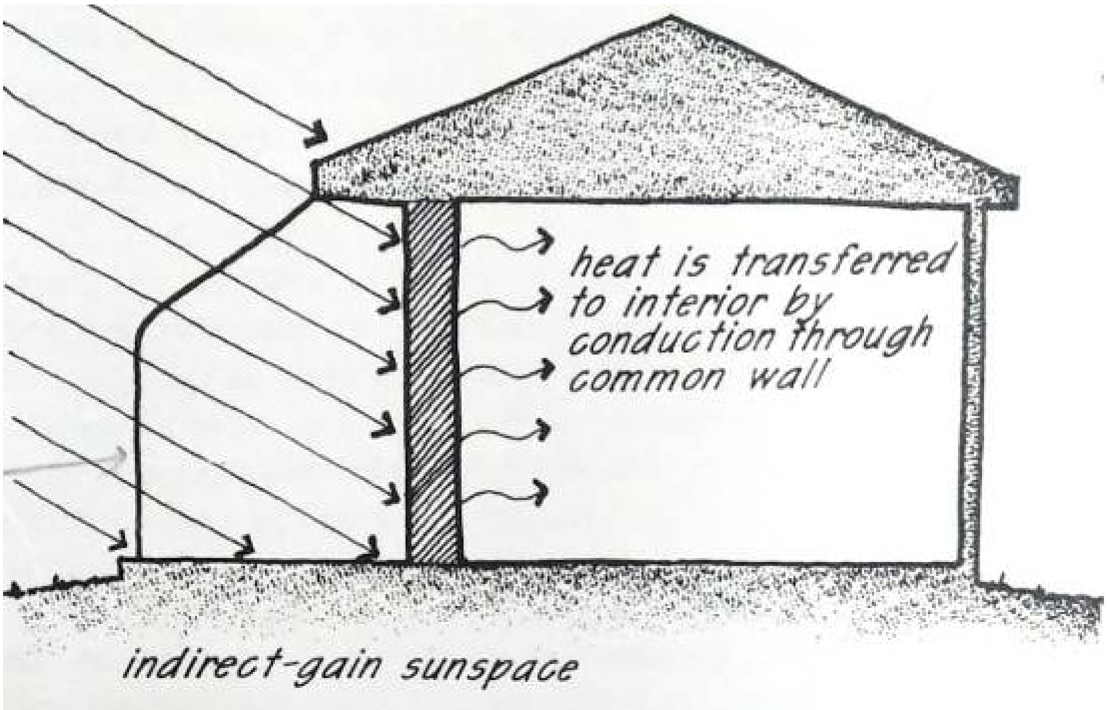
Indirect Gain

Thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. The indirect gain system will utilize 30-45% of the sun's energy striking the glass adjoining the thermal mass.

Direct Gain Space Heating



Why is thermal mass important? (Thermal time constant of building?) Why did medieval lords live in stone castles? Are these best for dry or wet climates?

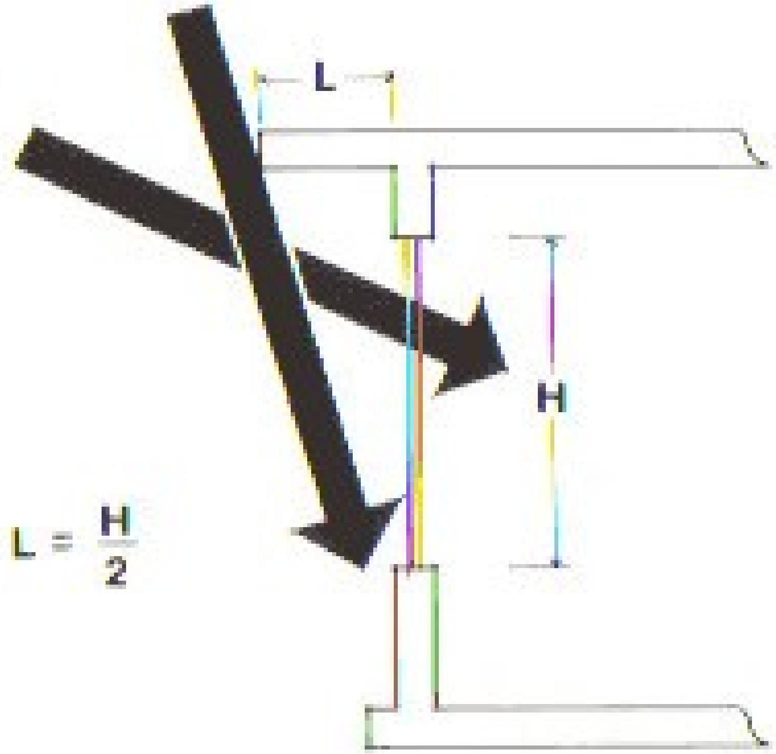


Passive Solar Cooling

Passive solar cooling systems work by reducing unwanted heat gain during the day, producing non-mechanical ventilation, exchanging warm interior air for cooler exterior air when possible, and storing the coolness of the night to moderate warm daytime temperatures. At their simpliest, passive solar cooling systems include overhangs or shades on south facing windows, shade trees, thermal mass and cross ventilation.

Shading

To reduce unwanted heat gain in the summer, all windows should be shaded by an overhang or other devices such as awnings, shutters and trellises. If an awning on a south facing window protrudes to half of a window's height, the sun's rays will be blocked during the summer, yet will still penetrate into the house during the winter. The sun is low on the horizon during sunrise and sunset, so overhangs on east and west facing windows are not as effective. Try to minimize the number of east and west facing windows if cooling is a major concern. Vegetation can be used to shade such windows. Landscaping in general can be used to reduce unwanted heat gain during the summer.



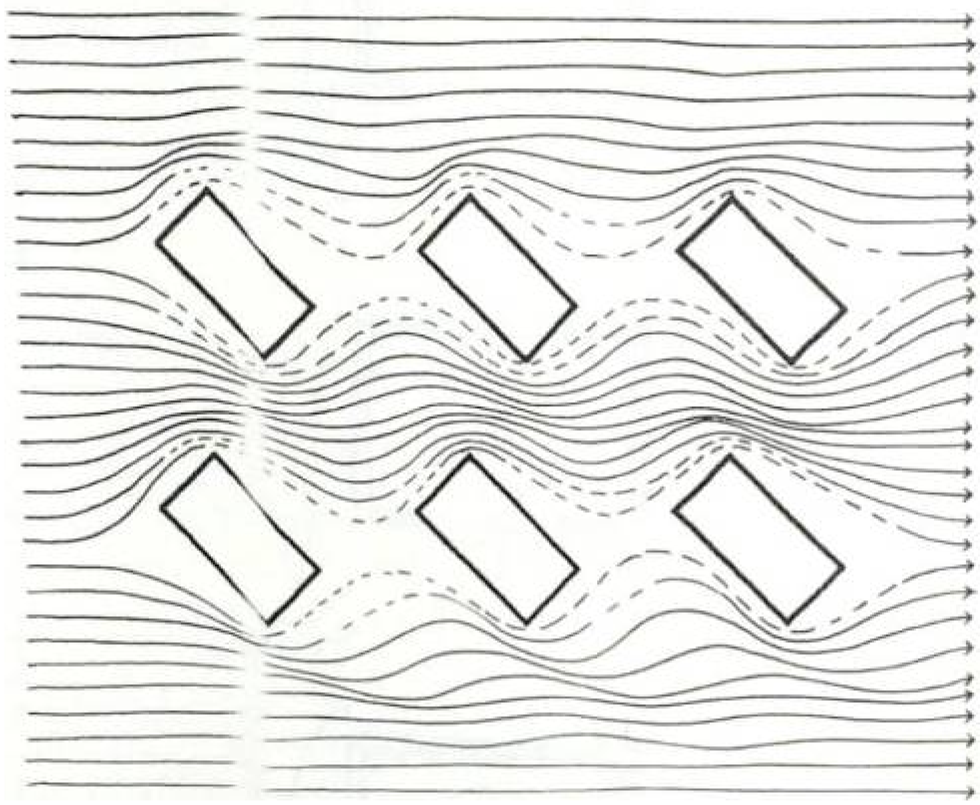
Overhang design for shading. The steeper arrow shows the angle of the sun's rays during the summer, while the shallower arrow indicates the angle during the winter.

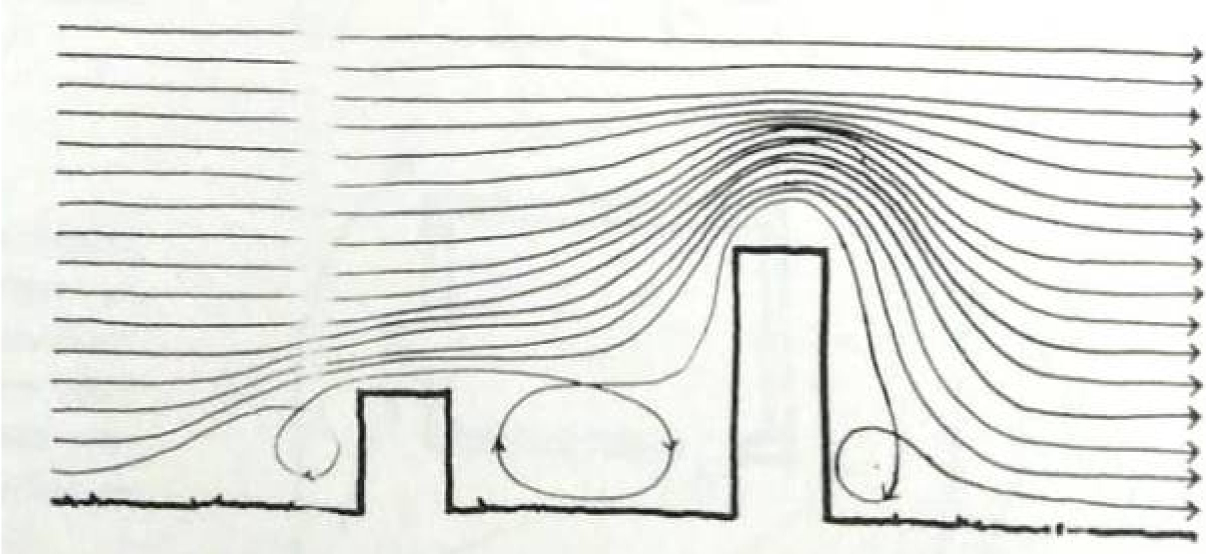
Thermal Mass

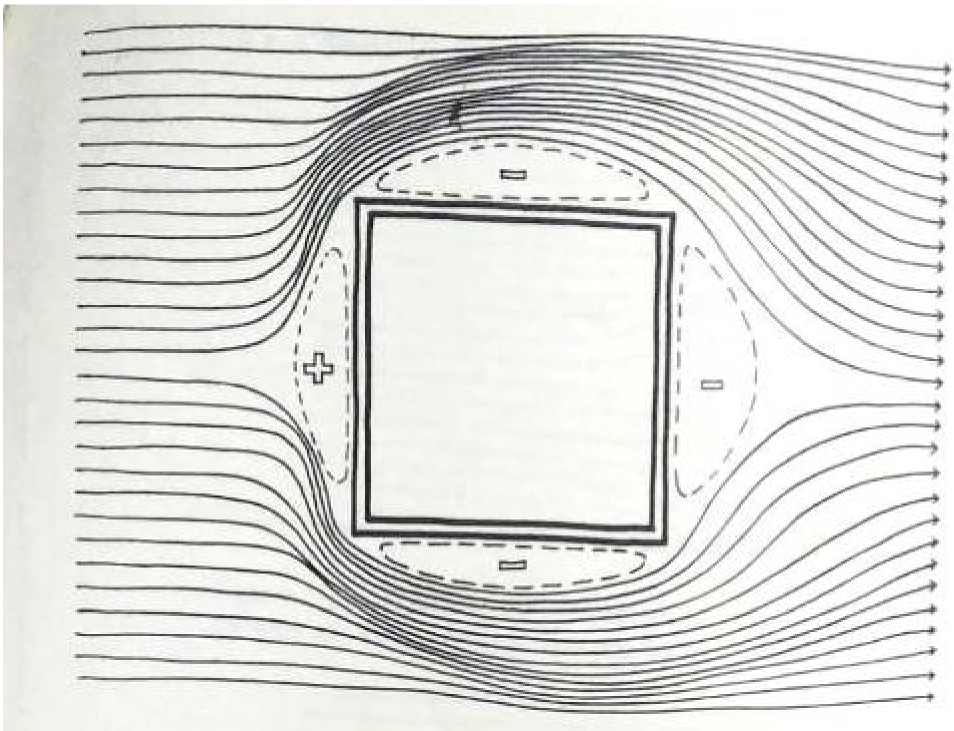
Thermal mass is used in a passive cooling design to absorb heat and moderate internal temperature increases on hot days. During the night, thermal mass can be cooled using ventilation, allowing it to be ready the next day to absorb heat again. It is possible to use the same thermal mass for cooling during the hot season and heating during the cold season.

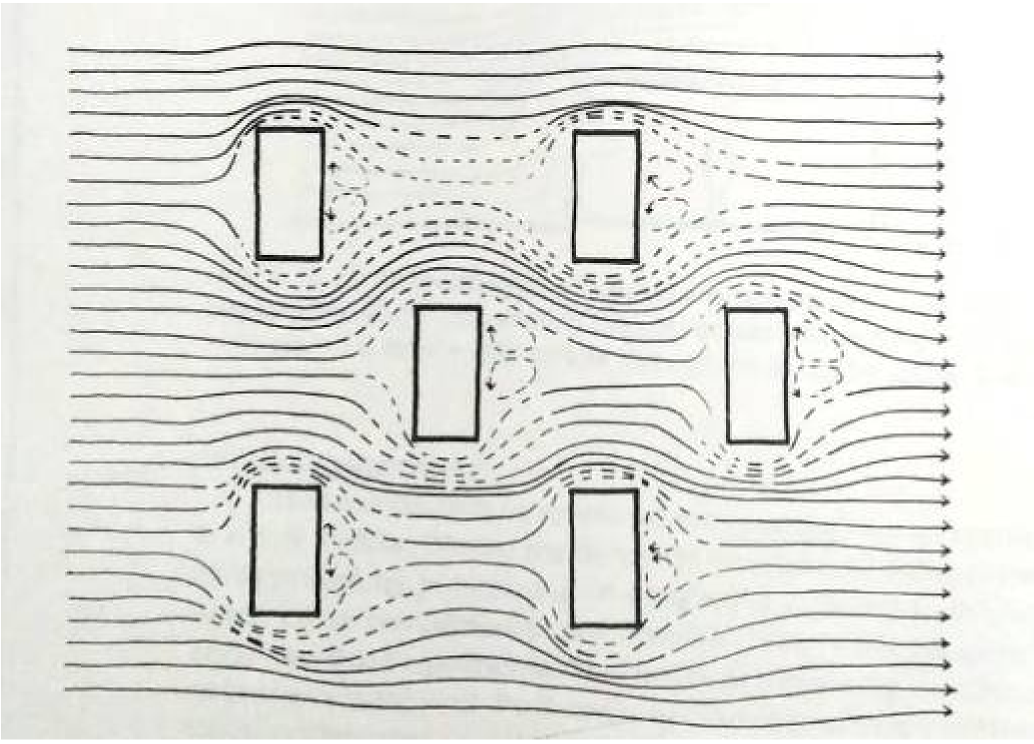
Ventilation

Natural ventilation maintains an indoor temperature that is close to the outdoor temperature, so it's only an effective cooling technique when the indoor temperature is equal to or higher than the outdoor one. The climate determines the best natural ventilation strategy.

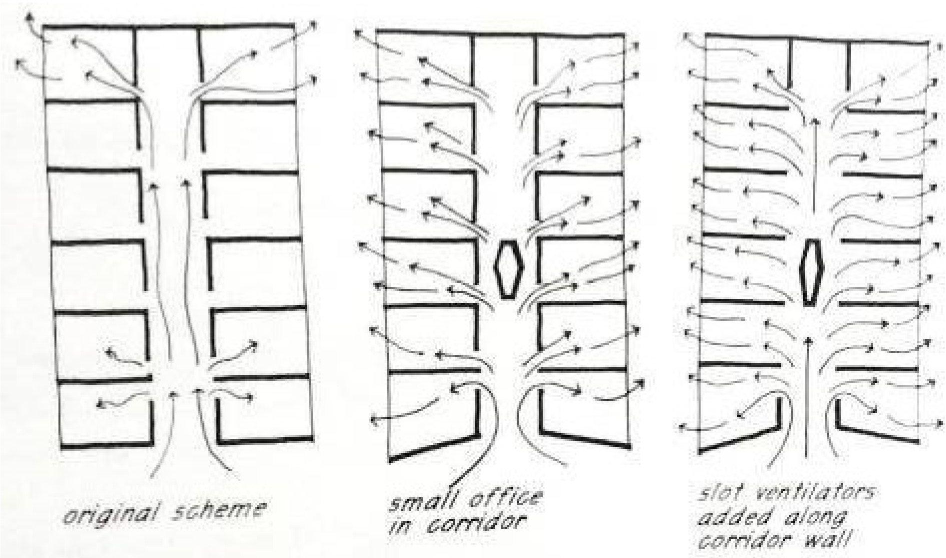








In areas where there are daytime breezes and a desire for ventilation during the day, open windows on the side of the building facing the breeze and the opposite one to create cross ventilation. When designing, place windows in the walls facing the prevailing breeze and opposite walls. Wing walls can also be used to create ventilation through windows in walls perpendicular to prevailing breezes. A solid vertical panel is placed perpendicular to the wall, between two windows. It accelarates natural wind speed due to pressure differences created by the wing wall.



In a climate like New England where night time temperatures are generally lower than daytime ones, focus on bringing in cool night time air and then closing the house to hot outside air during the day. Mechanical ventilation is one way of bringing in cool air at night, but convective cooling is another option.

Convective-Cooling

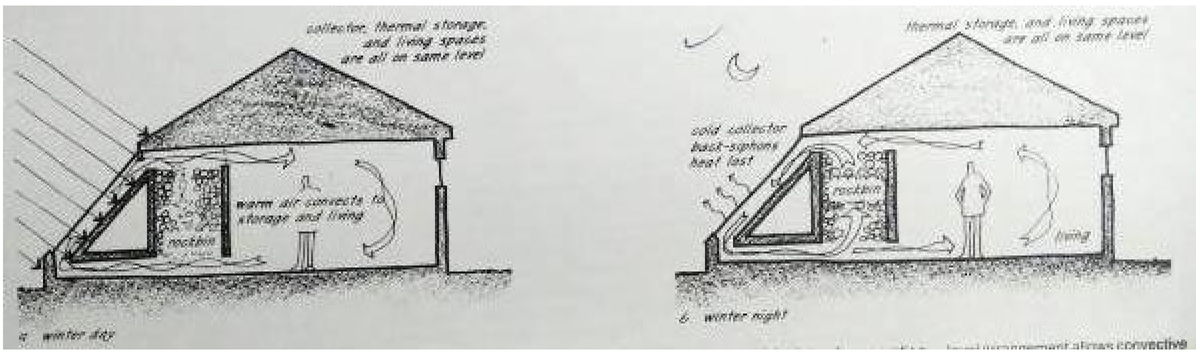
The oldest and simplest form of convective cooling is designed to bring in cool night air from the outside and push out hot interior air. If there are prevailing nigh time breezes, then high vent or open on the leeward side (the side away from the wind) will let the hot air near the ceiling escape. Low vents on the opposite side (the side towards the wind) will let cool night air sweep in to replace the hot air.

At sites where there aren't prevailing breezes, it's still possible to use convective cooling by creating thermal chimneys. Thermal chimneys are designed around the fact that warm air rises; they create a warm or hot zone of air (often through solar gain) and have a high exterior exhaust outlet. The hot air exits the building at the high vent, and cooler air is drawn in through a low vent.

There are many different approaches to creating the thermal chimney effect. One is an attached south facing sunroom that is vented at the top. Air is drawn from the living space through connecting lower vents to be exhausted through the sunroom upper vents (the upper vents from the sunroom to the living space and any operable windows must be closed and the thermal mass wall of the sunroom must be shaded).

Site Selection

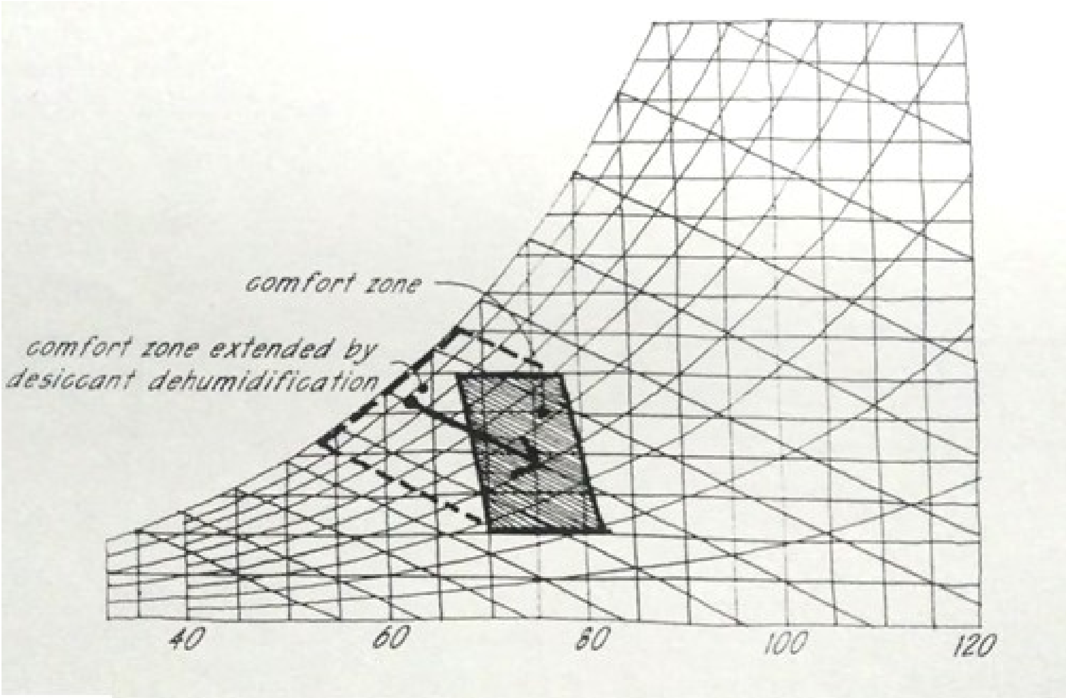
If you're planning a new passive solar home, a portion of the south side of your house must have an unobstructed "view" of the sun. Consider possible future uses of the land to the south of your site—small trees become tall trees, and a future multi-story building can block your home's access to the sun. In some areas, zoning or other land use regulations protect landowners' solar access. If solar access isn't protected in your region, look for a lot that is deep from north to south and place the house on the north end of the lot.



Dehumidification:

The process in which the moisture or water vapor or the humidity is removed from the air keeping its dry bulb (DB) temperature constant is called as the dehumidification process. This process is represented by a straight vertical line on the psychrometric chart starting from the initial value of relative humidity, extending downwards and ending at the final value of the relative humidity. Like the pure humidification process, in actual practice the pure dehumidification process is not possible, since the dehumidification is always accompanied by cooling or heating of the air. Dehumidification process along with cooling or heating is used in number of air conditioning applications. Let us see how these processes are obtained and how they are represented on the psychrometric chart.

This article describes psychrometric processes like dehumidification, cooling and dehumidification, and heating and dehumidification. The article describes how these processes are achieved and how they are represented on the psychrometric chart.



Psychrometric chart showing desiccant dehumidification as a constant

Cooling and Dehumidification Process-

The process in which the air is cooled sensibly and at the same time the moisture is removed from it is called as cooling and dehumidification process. Cooling and dehumidification process is obtained when the air at the given dry bulb and dew point (DP) temperature is cooled below the dew point temperature.

The cooling and dehumidification process is most widely used air conditioning application. It is used in all types of window, split, packaged and central air conditioning systems for producing the comfort conditions inside the space to be cooled. In the window and split air conditioners the evaporator coil or cooling coil is maintained at temperature lower than the dew point temperature of the room air or the atmospheric air by the cool refrigerant passing through it. When the room air passes over this coil its DB temperature reduces and at the same time moisture is also removed since the air is cooled below its DP temperature. The dew formed on the cooling coil is removed out by small tubing. In the central air conditioning systems the cooling coil is cooled by the refrigerant or the chilled water. When the room air passes over this coil, it gets cooled and dehumidified.

APPLICATION

Passive solar heating strategies should only be used when appropriate. Passive solar heating works better in smaller buildings where the envelope design controls the energy demand. This means a space that is not already heated by busy people, lights, computers and other internal heat gain. Strategies, such as trombe walls, exist to mitigate unwanted glare and excessive heat gain, but care must be taken when introducing solar heat into workspaces. Passive solar heating is often used on circulation spaces such as lobbies and atria, hallways, break rooms, and other types of spaces with low internal heat gain that afford occupants the flexibility to move out of the sun.

The primary types of buildings that can benefit the most from the application of passive solar heating principles are:

- Barracks and other low-rise housing in temperate and cold climates (locations that experience above 2,000° days annually)
- Small Post Exchange (PX) facilities (less than 10,000 ft^2)
- Warehouses
- Maintenance facilities.

Economics

Modest levels of passive solar heating, also called sun-tempering, can reduce building auxiliary heating requirements from 5% to 25% at little or no incremental first cost and should be implemented for all small buildings in temperate and cold climates. More aggressive passive solar heated buildings can reduce heating energy use by 25% to 75% compared to a typical structure while remaining cost-effective on a life-cycle basis. This approach should be considered for many small buildings in temperate and cold climates.

With the help of experienced passive solar designer architects and builders, passive solar design costs little more than conventional building design and saves money over the long term. However, in areas where experienced solar architects and builders are not available, construction costs can run higher than for conventional buildings, and mistakes can be made in the choice of building materials, especially window glass. For example, passive solar homes are often built using glass that rejects solar energy. Unfortunately, this is a costly mistake. The right glass choice depends on the climate and on which side of the building (east, west, north, or south) the glass is installed.

During the summer or in consistently warm climates, daylighting could actually increase energy use in a building by adding to its air-conditioning load.

Design Considerations

The following are general recommendations that should be followed in the application of passive solar heating technology.

- Pay careful attention when constructing a durable, energy-conserving building envelope.
- Address orientation issues during site planning. To the maximum extent possible, reduce glass on the east and west sides and protect openings from prevailing winter winds.
- Establish an air-tight seal around windows, doors, and electrical outlets on exterior walls. Employ entry vestibules and keep any ductwork within the insulated envelope of the building to ensure thermal integrity. Consider requiring blower-door tests of model homes to demonstrate air-tightness and minimize duct losses.
- Specify windows and glazing that have low thermal transmittance values (U values) while admitting adequate levels of incoming solar radiation (higher solar heat gain coefficient [SHGC]). The amount of glazing will depend on building type and climate.
- Ensure that the south glass in a passive solar building does not contribute to increased summer cooling. In many areas, shading in summer is just as critical as admitting solar gain in winter. From the overhang figure below, use summer (B) and winter (A) sun angles to calculate optimum overhang design.

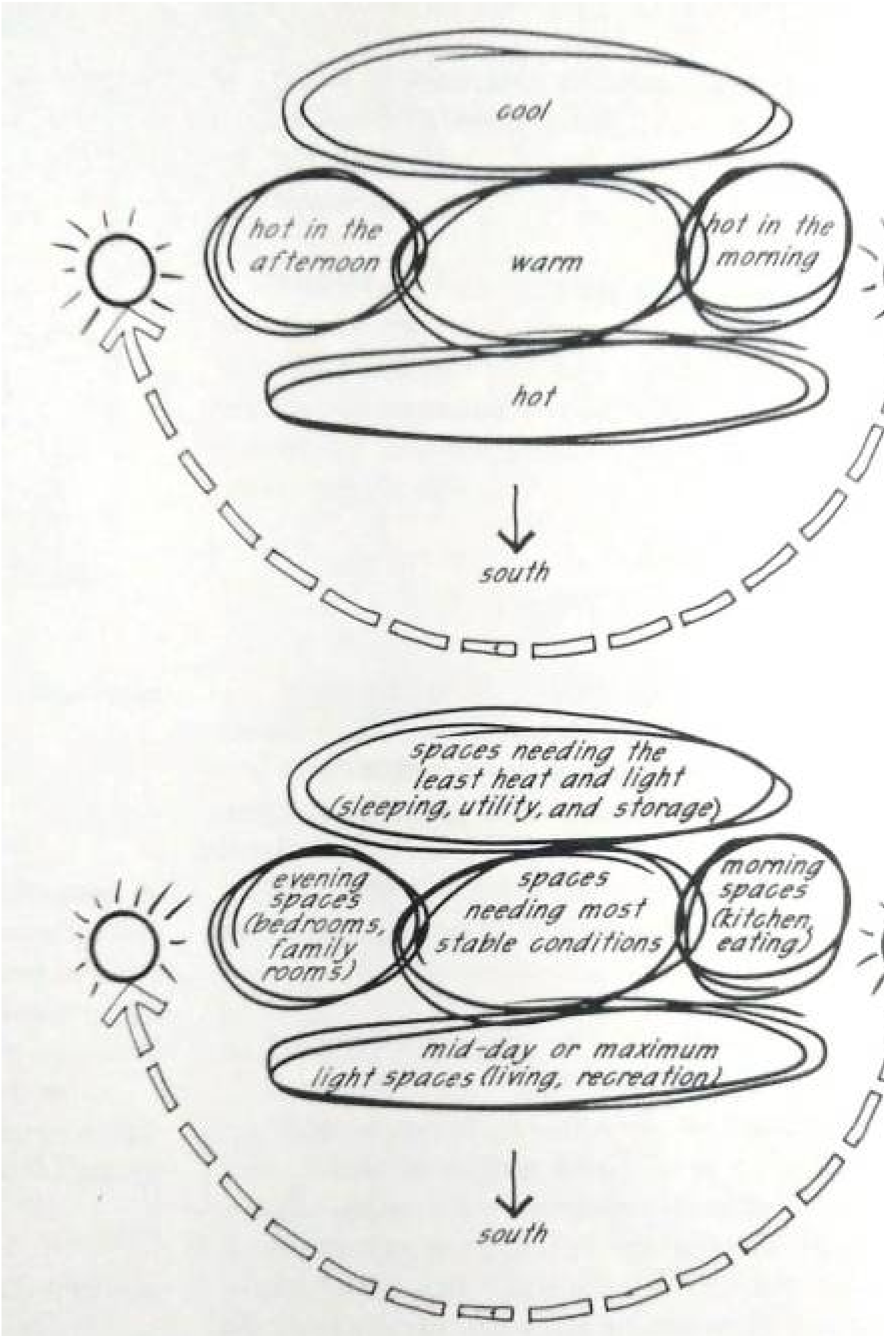
Passive Solar Technologies

Passive heating and cooling systems are used to avoid using air conditioning or a heater. Many of the most advanced techniques for home temperature control use passive methods to accomplish energy efficiency. There are a variety of different technologies that selectively harness or shield against the Sun's energy to heat or cool a building without using a heater or air conditioner. These technologies include operable windows, solar chimneys, solar walls, and trombe walls.[2]

These technologies regulate internal space temperatures by capturing or venting heat from solar radiation. Shading technology can also be used strategically to reduce heating. By creating places where shade can be increased or decreased, the amount of solar radiation entering a space is reduced, therefore keeping the room cool without the use of an air conditioner.

These technologies can be used for a newly built structure and can also be incorporated into existing structures. Local climate is always the biggest factor when designing and implementing passive solar heating and cooling systems.

Here's an article with a more in depth discussion of architecture in passive solar heating and cooling.



Refining the Design

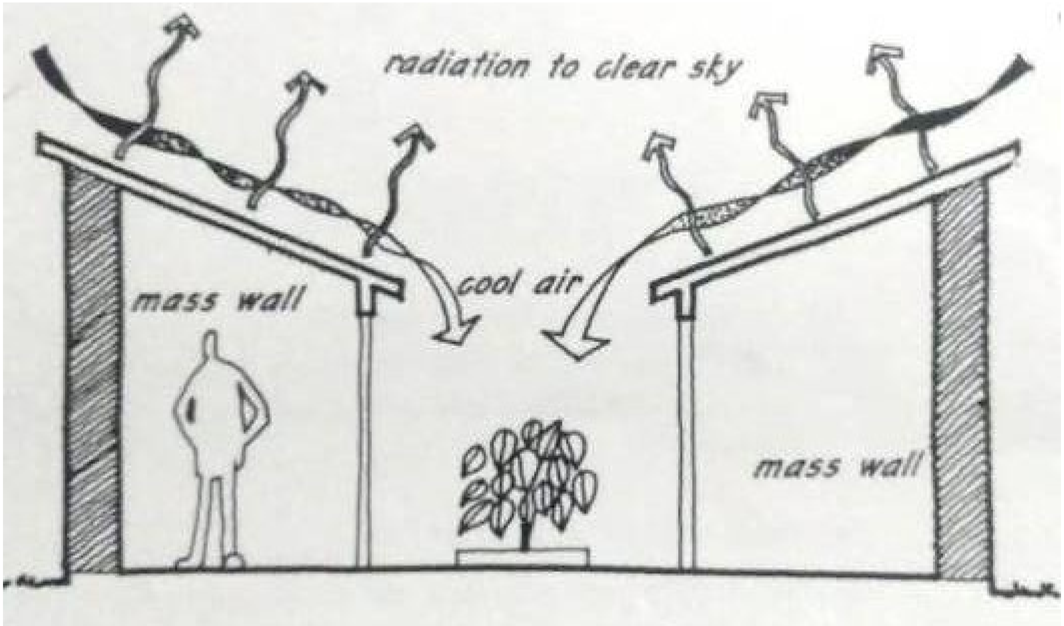
Although conceptually simple, a successful passive solar home requires that a number of details and variables come into balance. An experienced designer can use a computer model to simulate the details of a passive solar home in different configurations until the design fits the site as well as the owner's budget, aesthetic preferences, and performance requirements.

Some of the elements the designer will consider include:
- Insulation and air sealing
- Window location, glazing type, and window shading
- Thermal mass location and type.
- Auxiliary heating and cooling systems.

The designer will apply these elements using passive solar design techniques that include direct gain, indirect gain, and isolated gain.

Courtyard-

The courtyard houses are found in most of the climates and world regions, though it is most commonly associated with the Mediterranean and Middle Eastern regions. It is the dominant vernacular prototype of many of the world's hot arid climates. Many different societies in very different locations have used this traditional housing form. The vernacular courtyard house form has been viewed as an architectural response to a set of physical and cultural factors intrinsic to a particular physical and socio-economic environment. The courtyard house creates a complex regulating system that creates a microclimate, which historically worked, and still works, in a "passive way": heat transfer processes are all natural, without mechanical devices powered by non-renewable energy. The courtyard house in the Arab or Islamic world may be considered as prototype diffused in many variations through all Arab countries.



CONCLUSION-

For passive heating, direct addition is more helpful for daylight hours warming and rest of the ideas are utilized for private structures. Solarium will be valuable for both the applications. Utilization of twofold coated framework prompts decrease of hotness gain and decrease of misfortunes contrasted with single-coated framework. Uncovered dividers ought to be twofold coated to trap greatest sunlight based radiation inside the room with least worth. For uninvolved cooling, the blend of evaporative cooling and wind tower ends up being exceptionally compelling and can decrease the temperature. Evaporative cooling is the most affordable idea for cooling of a structure. For latent warming/cooling, mix of Trombe divider, cool rooftop, and warm protection can accomplish investment funds in winters and summers, separately. Framework gives better outcome as far as proficiency, warm climate, space warming, day lighting, and power use. Photovoltaic frameworks are among the most encouraging elective energy source. Building-incorporated photovoltaic frameworks can give investment funds in power costs, diminish contamination, and furthermore add to the design allure of the structure.

REFERENCES-

[1] Agrawal, P. C. 2020. A review of passive systems for natural heating and cooling of buildings. Solar Wind Technol. 6: 557– 567.

[2] Jie, J., Y. Hua, P. Gang, J. Bin, and H. Wei. 2019. Study of PV- Trombe wall assisted with DC fan. Build. Environ. 42: 3529– 3539.

[3] Chandel, S. S., and R. K. Aggarwal. 2018. Performance evaluation of a passive solar building in Western Himalayas. Renewable Energy 33: 2166– 73.

[4] Depecker, P., C. Menezo, J. Virgone, and S. Lepers. 2017. Design of buildings shape and energetic consumption. Build. Environ. 36: 627– 635.

[5] Stevanović, S. 2016. Optimization of passive solar design strategies: a review. Renew. Sustain. Energy Rev. 25: 177– 196.

[6] Aldawoud, A. 2015. The influence of the atrium geometry on the building energy performance. Energy Build. 57: 1– 5.

[7] Capeluto, I. G. 2014. Energy performance of the self- shading building envelope. Energy Build. 35: 327– 336.

[8] Tuhus-Dubrow, D., and M. Krarti. 2013. Genetic- algorithm based approach to optimize building envelope design for residential buildings. Build. Environ. 45: 1574– 1581

[9] Mingfang, T. 2012. Solar control for buildings. Build. Environ. 37: 659– 664.

[10] Inanici, M. N., and F. N. Demirbilek. 2011. Thermal performance optimization of building aspect ratio and south window size in five cities having different climatic characteristics of Turkey. Build. Environ. 35: 41– 52.

[11] Balcomb, J. D., J. C. Hedstrom, and R. D. McFarland. 2010. Simulation analysis of passive solar -heated buildings- Preliminary results. Sol. Energy 19: 277– 282.

[12] Liu, Y. W., and W. Feng. 2011. Integrating passive cooling and solar techniques into the existing building in South China. Adv. Mater. Res. 368–373: 3717– 3720.

[13] Tiwari, G. N., and S. Kumar. 2013. Thermal evaluation of solarium-cum-passive solar house. Energy Convers. Manage. 32: 303– 310.

[14] Tiwari, G. N. 2012. Solar energy-fundamentals, design, modelling and applications. Narosa Publishing House Pvt. Ltd, Delhi.

[15] Tiwari, G. N., and Y. P. Yadav. 2009. Analytical model of a solarium for cold climate- A new approach. Energy Convers. Manage. 28: 15– 20.

[16] Tiwari, G. N., Y. P. Yadav, and S. A. Lawrence. 2008. Performance of a solarium: an analytical study. Build. Environ. 23: 145– 151.