21MEO110T: Energy Systems for Sustainable Buildings

Unit II: Passive solar heating & cooling

(Passive Solar heating- Direct, Indirect & Isolated solar heat gain, Solar heat gain by Trombe mass walls, Water walls)

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- General principles of active and passive solar heating
- Key design elements of passive heating
- Direct solar heat gain by Trombe mass walls- Passive cooling and its key design elements, - Water walls
- Evaporative cooling- Convective air loops and solar chimney effects, Thermal Bridge and barrier
- Thermal insulation, load control, air infiltration- Odor removal and heat recovery in large buildings

Types of Solar Space heating

1. Direct gain
2. Indirect Gain
3. Isolated gain

1. Direct gain

1. Large glass area can be kept for direct heat gain
2. Design of building (color, building form) and orientation etc.
3. Control with over hangs and shading

2. Indirect Gain

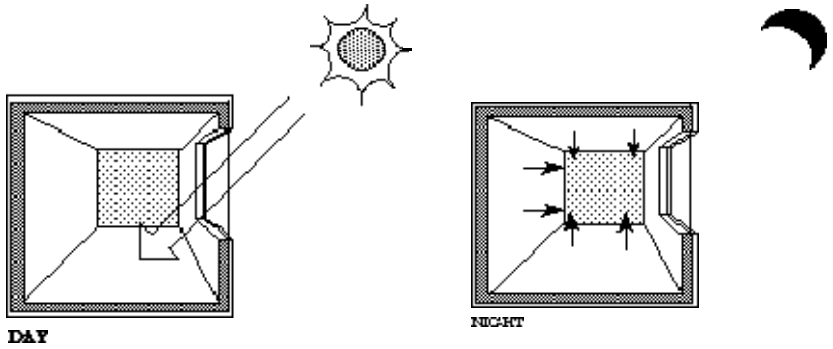
1. Thermal Mass (color, thickness, concrete material quantity etc.)
2. Heating & Cooling (Trombe wall), modified Trombe wall
3. Heating & Cooling (water wall, trans wall)
4. Cooling (Roof pond)

3. Isolated gain

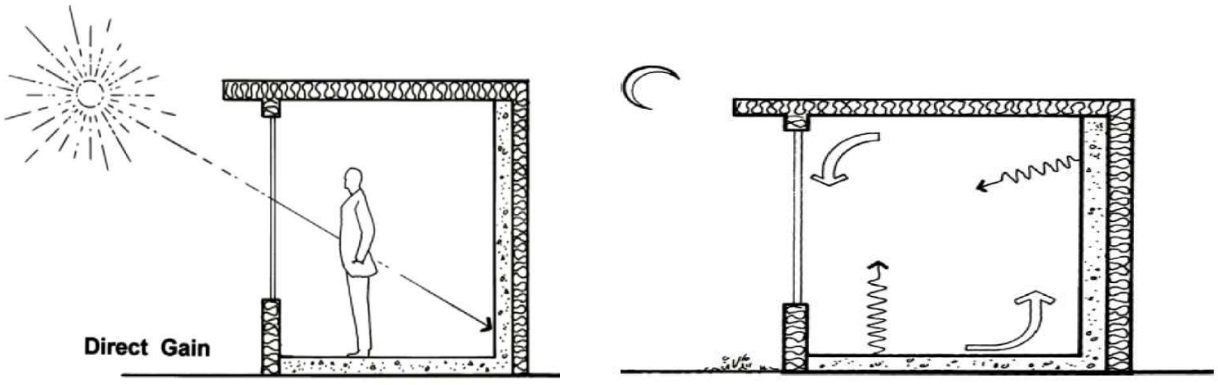
DIRECT GAIN

- The most common passive solar system is called direct gain. Direct gain refers to the sunlight that enters a building through windows and warming the interior space.

- A direct gain system includes south-facing windows. In cold weather, large thermal mass can be placed within the space will receive the most direct sunlight. Direct gain systems are probably the cost effective passive system.



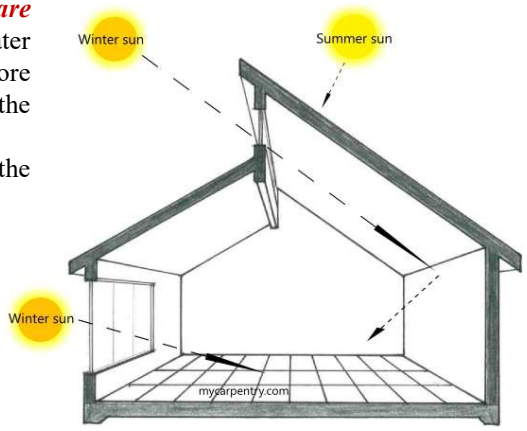
Direct gain



DIRECT GAIN

In this system, 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 directly and indirectly to the thermal mass materials in the building such as floors and walls. ***The direct gain system will utilize 60 – 75% of the sun's energy striking the windows.***

In a direct gain system, ***the thermal mass floors and walls are functional parts of the house***. It is also possible to use water containers inside the house to store heat. However, it is more difficult to integrate water storage containers in the design of the house.
The thermal mass will absorb the heat during the day. At night, the thermal mass radiates heat into the living space.



DIRECT GAIN

Direct gain system rules of thumb (case: Austin)

- A heat load analysis of the house should be conducted.
- Do not exceed 6 inches of thickness in thermal mass materials.
- Use a ***medium dark color for floors; use light colors for other lightweight walls; thermal mass walls can be any color***.
- Fill the cavities of any concrete block used as thermal storage with concrete or other high mass substance.
- Use thermal mass at less thickness throughout the living space rather than a concentrated area of thicker mass.
- The surface area of mass exposed to direct sunlight should be 9 times the area of the glazing.

Building Interior Space Planing

- Planning the room layout by considering how the rooms will be used in different seasons and at different times of the day, can save energy and increase comfort. In general, living areas and other high-activity rooms should be located on the south side to benefit from the solar heat.
- Clustering baths, kitchens and laundry rooms near the water heater will save the heat that would be lost from longer water lines. Another general principle is that an open floor plan will allow the collected solar heat to circulate freely through natural convection.

Main Considerations for passive solar

- **Surface Colour** The amount of heat storage depends on the amount of exposed thermal mass within the space and its colour. Light coloured surfaces will reflect light around within the space, distributing it over a greater number of surfaces. Dark coloured materials will absorb most of the incident energy as soon as it strikes.
- **Thermal Conductivity** Highly conducting materials will quickly transfer any heat build away from the surface deeper into the material resulting in less instantaneous re-radiation back into the space. In a poorly conductive material, however, the surface will heat up more and will quickly re-radiate most of the heat back into the space.
- **Thermal Capacity** For a given amount of incident sunlight, thermally lightweight materials will heat up more than the heavyweight materials.

Main Considerations

- **Design Requirements** The recommended mass surface-to-glass area ratio is 6:1. In general, comfort and performance increase with increase of thermal mass and there is no limit for the amount of thermal mass. Remember that covering the mass with materials such as carpet, cork, wallboard or other thermally resistive materials will effectively insulate the mass from the solar energy.

- **Protection From Losses** It is important to note that the same large areas of glazing that let heat in during the day can also readily let heat out at night. Thus, some form of night-time protection should be incorporated to minimise any conduction and convection losses through windows. Thick drawn curtains with a pelmet that forms a good seal at the top can be used as well as insulated internal/external roller shutters.

Site Planning for Solar Access

- The main objective of site planning for passive solar homes is to allow the south side as much unshaded exposure as possible during the winter season.
- A good design balances energy performance with other important factors such as,
  - the slope of the site,
  - the individual house plan,
  - the direction of prevailing breezes for summer cooling,
  - the views, the street lay out and so on.

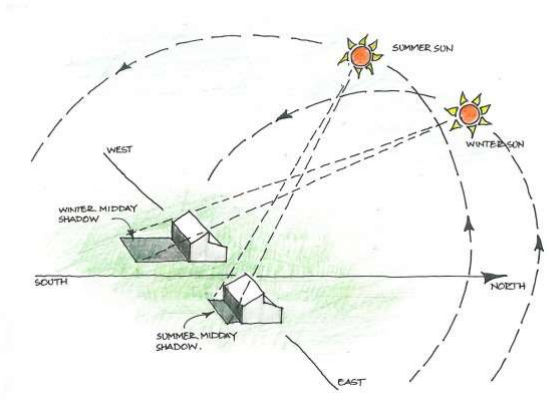
Landscaping

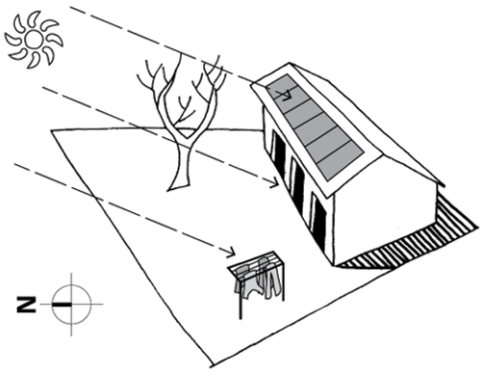
Trees and other landscaping features may be effectively used to shade east and west windows from summer solar gains.

Trees on the southside, however, can eliminate passive solar performance, unless they are very close to the house and the lower branches can be removed to allow the winter sun to penetrate under the tree canopy.

If a careful study of shading patterns is done before construction, it should be possible to accomodate the south-facing glazing while leaving in as many trees as possible.

Sun pathfinder





Gross errors in structure orientation, solar system sizing, collector placement, component specification, and scientific studies can result when designers/engineers fail to accurately assess shading patterns at proposed building/ecological sites.

Overhangs and Shading

Overhangs are one of the best (and least costly) shade design elements to include in your home. In the summer, when the sun is high in the sky, the overhangs should shade the room completely. In the winter, when the sun is low, the overhangs should allow the full sun to enter, warming the air, as well as the floor, wall and other features as shown in the Figure.

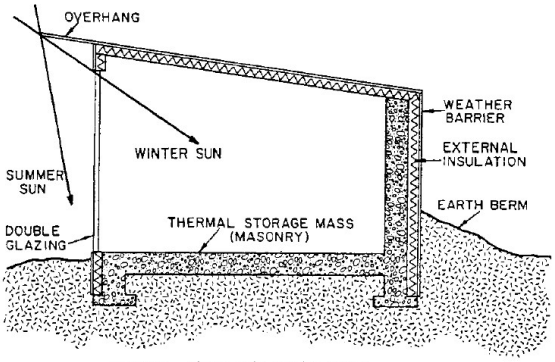


FIGURE 1. Direct gain heating system.

photo credit: National Renewable Energy Laboratory

Indirect Gain

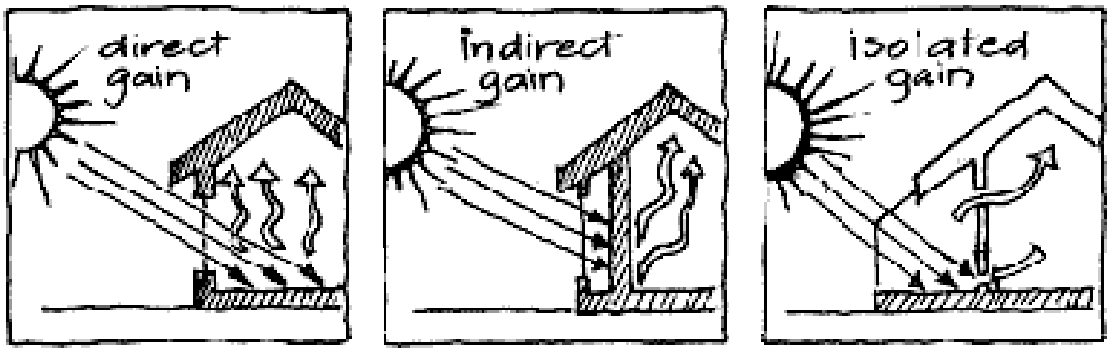
In an indirect gain system, thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes and transfers it to the living space by conduction. The indirect gain system will utilize 30 – 45% of the sun's energy striking the glass adjoining the thermal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

There are two types of indirect gain systems:

- Thermal storage wall systems (Trombe Walls)
- Roof pond systems

Indirect gain avoids the glare and damage to the material by ultraviolet radiation from the sun. It also reduces the magnitude of the temperature variation in the living space.

There are three approaches of passive systems - ***direct gain, indirect gain, and isolated gain***. The goal of all passive solar heating systems is to capture the sun's heat within the building's elements and release that when the building needs.

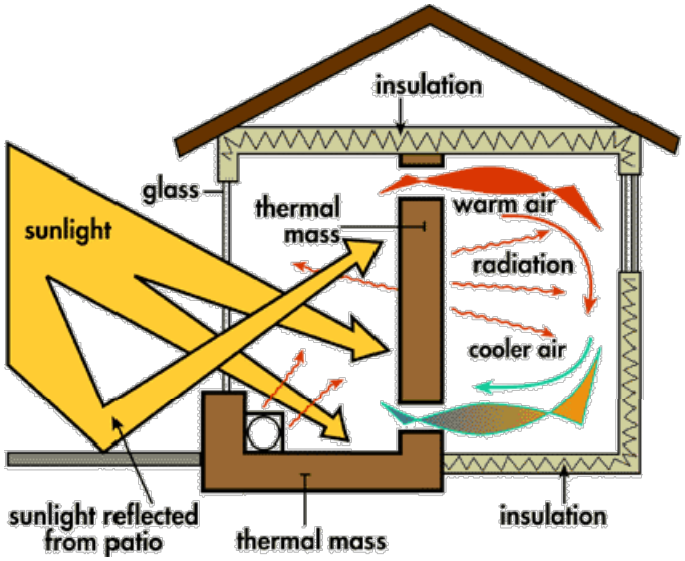


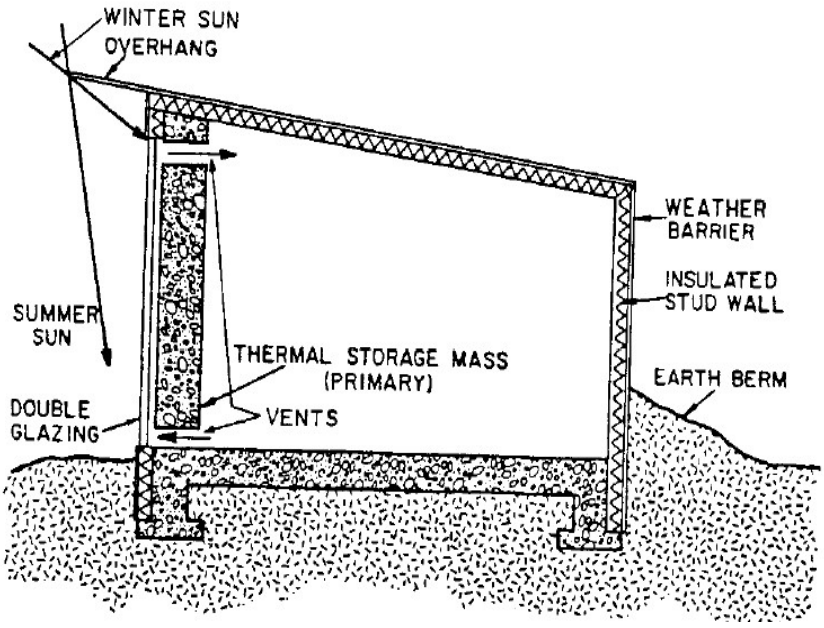
Direct Gain, Indirect Gain and Isolated Gain

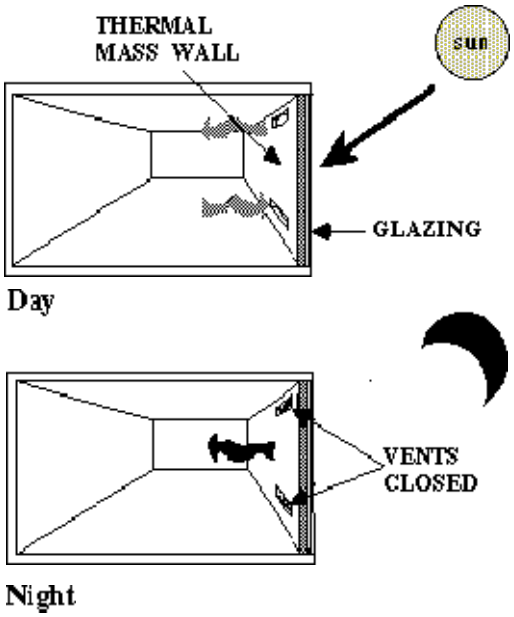
Thermal Mass

- If solar heat is needed when the sun is not shining, ***the excess heat must be stored***.
- Thermal mass or materials used to store the heat is an important part of most passive solar design. They are the materials with a high capacity for absorbing and storing heat (e.g., brick, concrete masonry, concrete slab, tile, water).

Thermal Mass



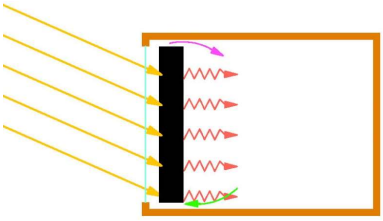




Trombe Wall

A Trombe wall is a south-facing masonry wall covered with glass spaced a few inches away. Sunlight passes through the glass which is absorbed and stored by the wall. The wall has vents provided at both upper and lower parts for air circulation. The glass and airspace keep the heat from radiating back to the outside. Heat is transferred by conduction as the masonry surface warms up, and is slowly delivered to the building some hours later.

Trombe walls can provide carefully controlled solar heat to a space without the use of windows and direct sunlight, thus avoiding potential problems from glare and overheating. The masonry wall is part of the building's structural system, effectively lowering costs. On the outside, the wall is painted black to increase its absorptive capacity. The inside, or discharge surface of the Trombe wall can be painted white to enhance lighting efficiency within the space. However, the outside large dark walls covered in glass must be carefully designed for both proper performance and aesthetics.

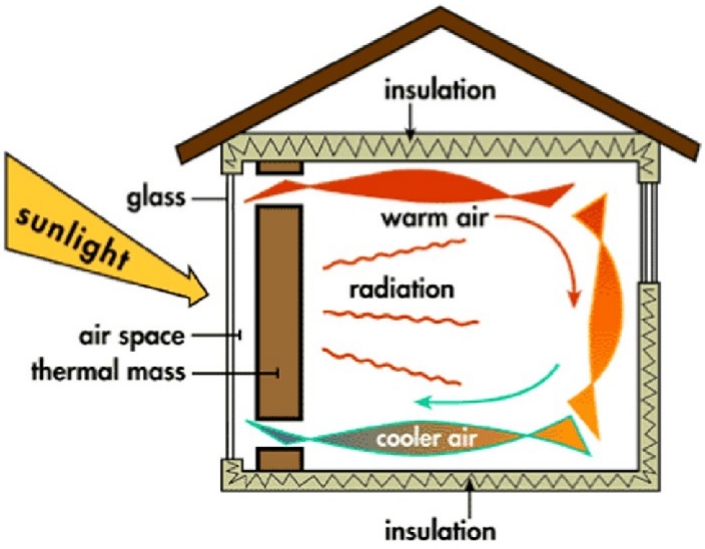


Indirect Gain: Mass Wall - Trombe Wall

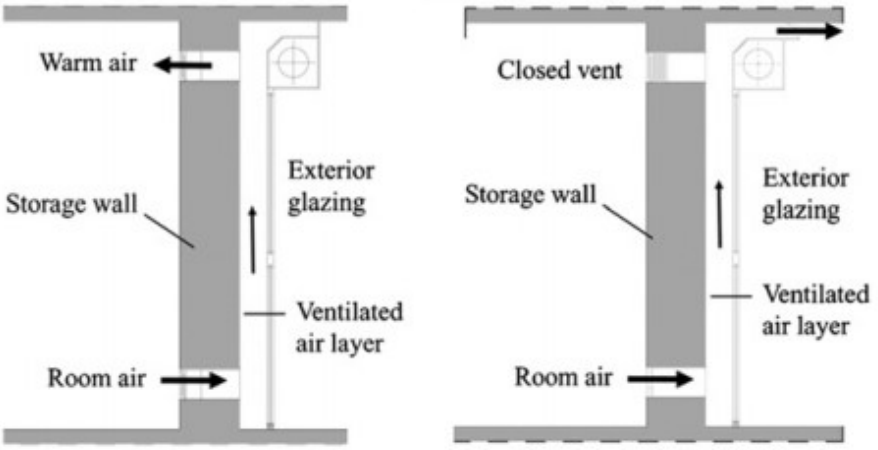
The idea was first explored by Edward S. Morse and patented by him in 1881. In the 1960s it was fully developed as an architectural element by French engineer Félix Trombe and architect Jacques Michel.

Trombe Wall

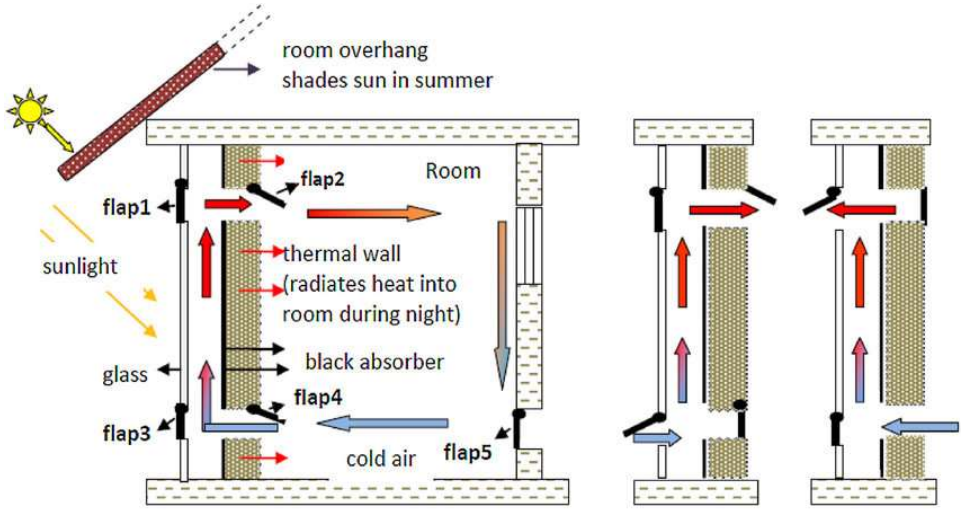
Solar radiation is absorbed by the blackened surface and stored as sensible heat in the wall. Air, in the space between the glazing and the wall gets heated up and enters the living spaces through upper vents. Cool room air takes its place through the lower vents, thus establishing a natural circulation pattern. The distribution of heat into the living space can be almost immediate or delayed depending on air circulation. Furthermore, the delay can be varied depending on the thickness of the wall, and the time lag properties of the wall materials. If the vents are provided with dampers, the air flow can be controlled. Use of movable insulation in the form of a curtain, between the wall and glazing provides another mode of control.



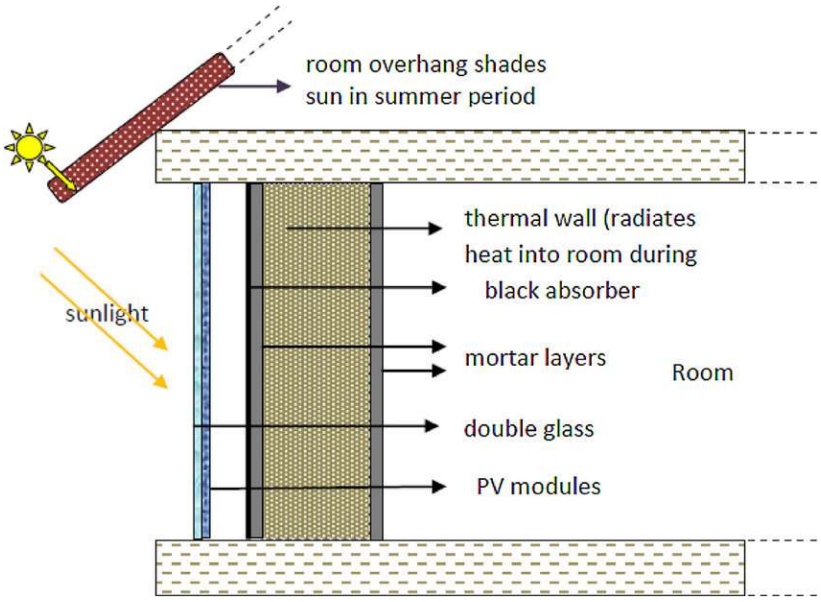
Trombe Wall- Winter and Summer operation



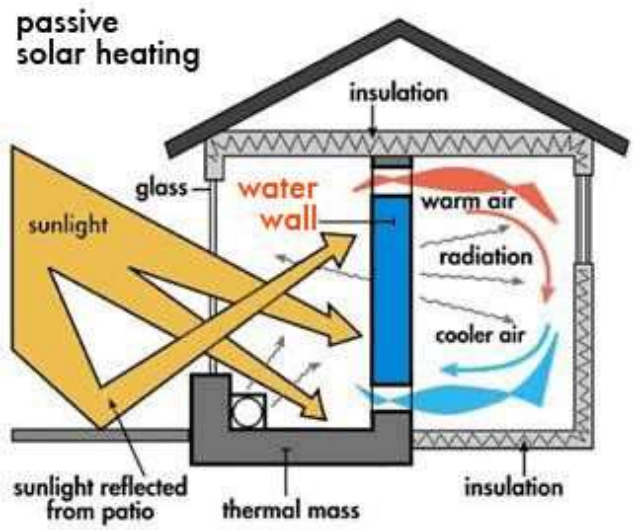
Modified Trombe Wall



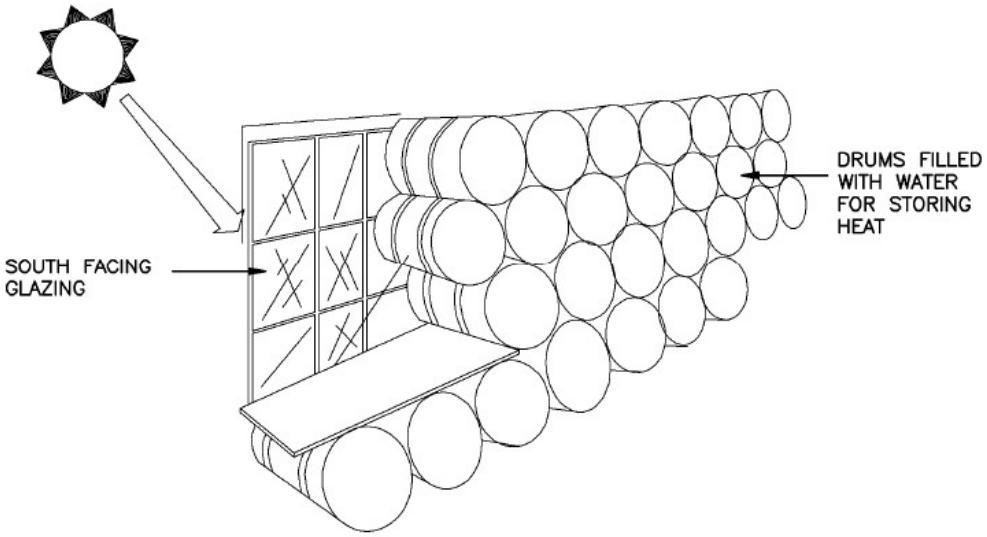
Modified Trombe Wall



Water wall



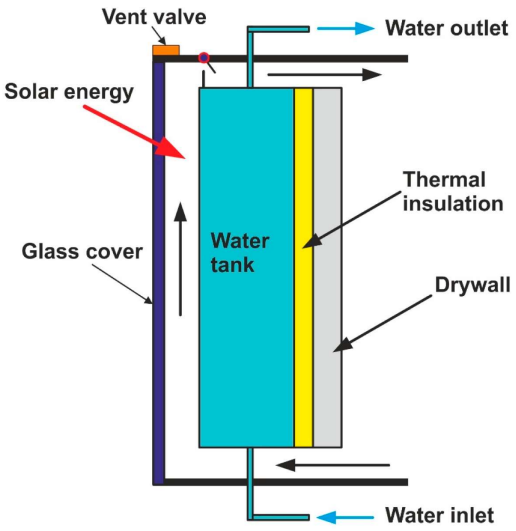
Water Wall



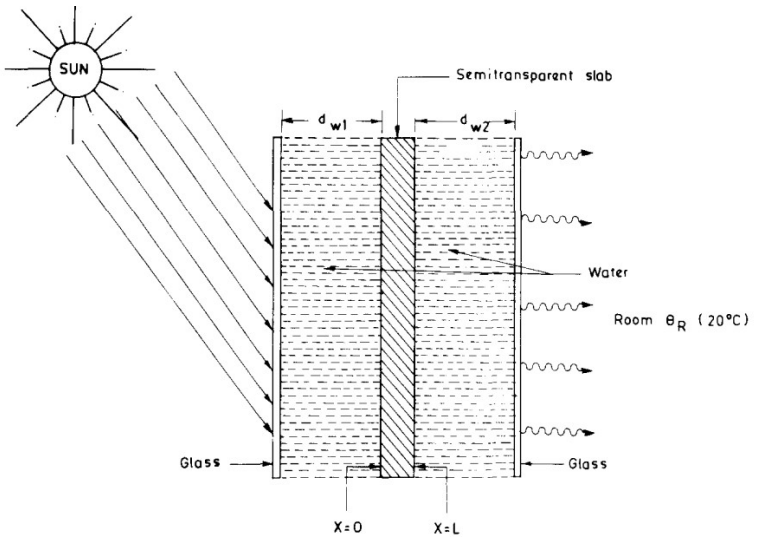
Water wall

Solar water walls have also been made out of other materials but these ones are made out of a clear fibreglass. They can be filled with dyed water to increase efficiency or for aesthetics. The example here has a blue dye inserted.

Water wall



Trans wall

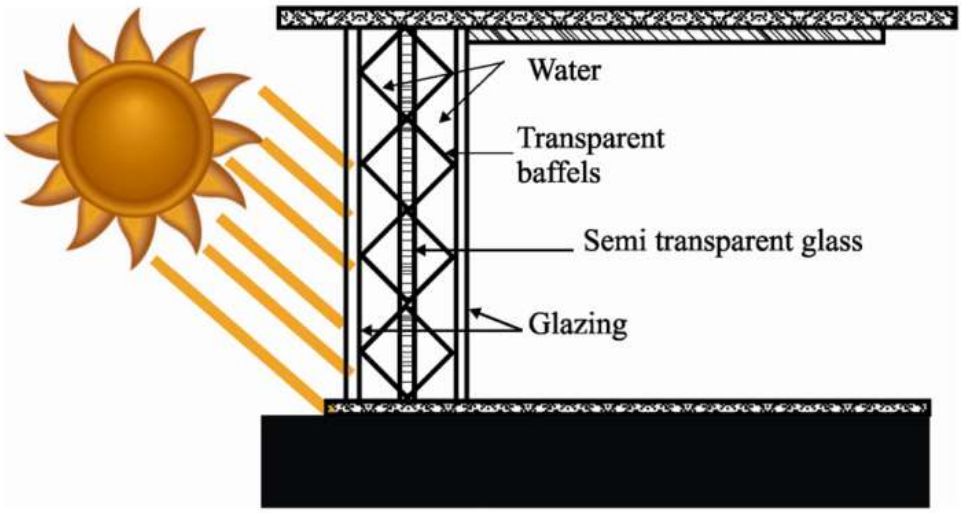


Part of the solar energy is absorbed within the transwall and the remaining part is transmitted to the living space.

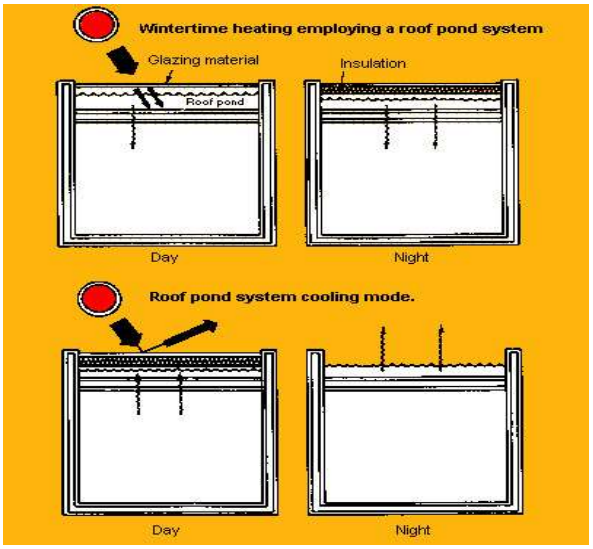
The advantages of a transwall are,

- First, in contrast to a conventional thermal storage wall, most of the solar energy is absorbed at the centre and not at the front facing the window.
- Secondly, the room is heated directly and illuminated by the transmitted fraction of the solar energy as in a direct gain system. This fraction, however, can be made small enough to avoid overheating, glare and photo degradation of interior furnishings.

Trans wall



Roof pond



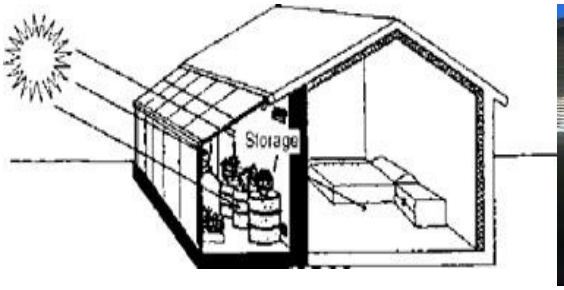
A roof pond uses water stored above the roof to maintain the internal temperatures in hot desert environments. This system is best for cooling in low humidity climates but can be modified to work in high humidity climates.

Indirect gain system thumb rules

- ✓The exterior of the mass wall (toward the sun) should be a dark color.
- ✓Use a minimum space of 10 cm between the thermal mass wall and the glass.
- ✓Vents used in a thermal mass wall must be closed at night.
- ✓If movable night insulation will be used in the thermal wall system, reduce the thermal mass wall area by 15%.
- ✓Thermal wall thickness should be approximately 60-85 cm for brick, 75-110 cm for concrete, 50-75 cm for adobe or other earth material and at least 35 cm for water.

Isolated Gains

Isolated gain or sunspace passive heating collects the sunlight in an area that can be closed off from the rest of the building. The doors or windows between the sunspace and the building are opened during the day to circulate collected heat and then closed at night to avoid the heat loss.



The Advantages of Passive Solar Design

- High energy performance: lower energy bills all year round.
- Investment: independent from future rises in fuel costs, continues to save money long after initial cost recovery.
- Value: high owner satisfaction, high resale value
- Attractive living environment: large windows and views, sunny interiors, open floor plans
- Low Maintenance: durable, reduced operation and repair
- Unwavering comfort: quiet (no operating noise), warmer in winter, cooler in summer (even during a power failure)
- Environmental friendly: clean, renewable energy doesn't contribute to global warming, acid rain or air pollution.

Thank you