

Week 5 (cont.) – PASSIVE SOLAR DESIGN

Recap

In the last lesson we covered:

5. **Room Layout** – locate the rooms that will be used most during the day on the south side for natural light. Keep all plumbing locations as close as possible to the water heater to reduce wasted water and energy.
6. **Insulation** – provide a continuous insulation layer, with appropriate thicknesses for the climate, around the entire conditioned space of the building to minimize heat loss in winter and heat gain in summer.
7. **Air-sealing** – there should also be a continuous air-barrier layer around the entire envelope in contact with the insulation layer to minimize heat loss in winter and heat gain in summer.

This week we will look at the last three of the our ten principles of Passive Solar Design, namely

8. **Ventilation**
9. **Thermal Mass** and
10. **Landscaping**

8 – Ventilation

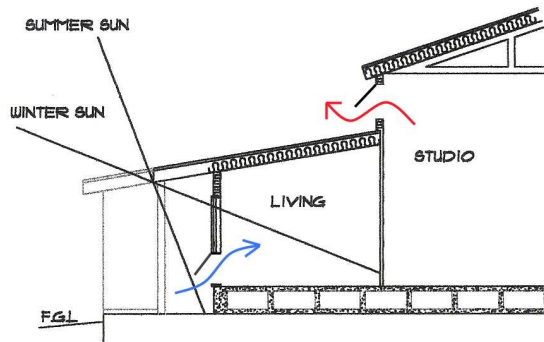
As we learned in the last class, in order to keep the heat in a Passive Solar building it is essential to provide BOTH a continuous insulation layer AND a continuous air-barrier around the entire conditioned space of the building. Together the insulation and air barrier make up the thermal boundary (or thermal envelope) of the building.

If this is done well the building will be very well insulated and air-sealed. This raises the issue of fresh air. Without a constant supply of fresh air the indoor air can become very polluted with carbon dioxide, chemicals from off-gassing or cleaning products, combustion gases and elevated levels of humidity. Too much humidity can lead to mold and rot problems which can further damage the indoor air quality and the components of the building. Most typical older buildings are so leaky that they let enough fresh air in through cracks and holes.

However, it is essential in an air-tight building to provide adequate fresh air for the occupants and the structure. This can be done in a number of ways.

1. **Open windows** to let in fresh air. This is a perfectly good way to cool a house in the summer time as long as there's a breeze blowing. However, in the winter time it totally negates the benefit of building a well insulated and air-sealed building. And even in the summer, if there's no wind blowing it can be difficult to get any air movement to cool things down.

2. Use the “**Stack Effect**”. Warm air rises so, by locating windows in the right places it is possible to create a breeze inside the building (even on a still day). This is done by opening windows up high in the structure to let the warm air out and other windows down low to let cool air in. As the warm air leaves the building up high it creates a slight negative pressure in the building which draws cooler air in near the base of the structure.



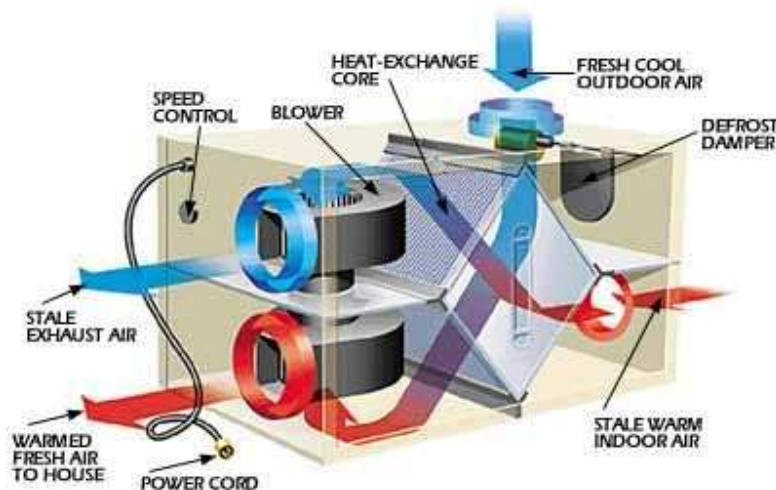
This is called the “stack effect” and can really help to cool a building on a still, hot day but also has the disadvantage of letting all the heat out of the building in winter. So in winter (or if you have really bad pollen or smoke or pollution in the

outside air in the summer) you have to keep the windows closed which means you have to rely on some form of mechanical ventilation such as...

3. **Exhaust fans** to blow stale air out of the building (this creates a negative pressure in the building and sucks fresh air in through any cracks in the thermal boundary). This is a very common strategy that can be an effective way to deal with excess humidity in buildings. Most homes have exhaust fans in bathrooms and range hoods in kitchen for exactly this reason. The problem with “Exhaust Only” ventilation is that the air that is getting sucked in through the cracks in the envelope is at outdoor air temperature which might be extremely cold or extremely hot depending on the time of year. So it’s no better than opening a window from the energy conservation perspective. Also, that air is getting sucked in through the building cavities that might contain fiberglass, or asbestos in many older buildings, or mold, or rodent droppings, or a host of other things which you probably don’t want in the air inside the building.
4. “**Supply Only Ventilation**”. This is not very common because it doesn’t work very well. In this case a fan (or fans) is used to blow air into the building which creates a positive pressure inside and forces air OUT through the same cracks as in 3 above. The obvious problem is that the air that is being blown into the house is at outdoor air temperature which might be really hot or really cold. Unless it is filtered it might also contain whatever contaminants are in the outside air. The less obvious problem is that in the winter time the positive pressure forces warm, moist air out through the building cavities. If it comes into contact with a cold enough surface on the way the moisture vapor in the air can condense and turn to

liquid moisture in hidden places in the structure. This can lead to mold and rot problems. So what's the solution?

5. **Balanced Ventilation.** In this case there is one fan (or fans) to blow air out of the building and another fan (or fans) to blow an equivalent amount of air into the building. This takes care of the problem of sucking air in or blowing air out through the building cavities because there is neither a negative or a positive pressure created between the building and the outdoors. However it does not solve the problem of the incoming air being at the same temperature as the outside air, for that you need...
6. **Heat Recovery Ventilation.** A Heat Recovery Ventilator (HRV) is a form of balanced ventilation that provides a constant supply of fresh air and a constant exhaust of stale air without losing much of the heat from inside the building. It uses the heat in the outgoing stale air to warm up the fresh air coming in. The diagram below shows a basic schematic of how an HRV works.



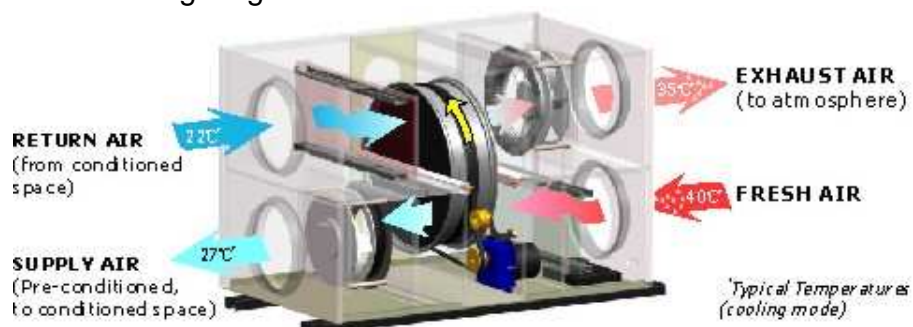
A typical unit features two fans—one to take out household air and the other to bring in fresh air. What makes an HRV unique is the heat-exchange core. The core transfers heat from the outgoing stream to the incoming stream in the same way that the radiator in your car transfers heat from the engine's coolant to the outside air. It's composed of a series of narrow alternating passages through which incoming and outgoing airstreams flow. As the streams move through, heat is transferred from the warm side of each passage to the cold, while the airstreams never mix.

HRVs can recover up to 85 percent of the heat in the outgoing airstream, making these ventilators a lot more energy efficient than opening a window. And, an HRV contains filters that keep particulates such as pollen or dust from entering the house.

HRV's work in both hot and cold climates to help keep the conditioned air inside the building fresh without letting the heat out (or in if it's hot). There is another type of air exchanger that is even more efficient and is especially useful in hot climates. It's called an...

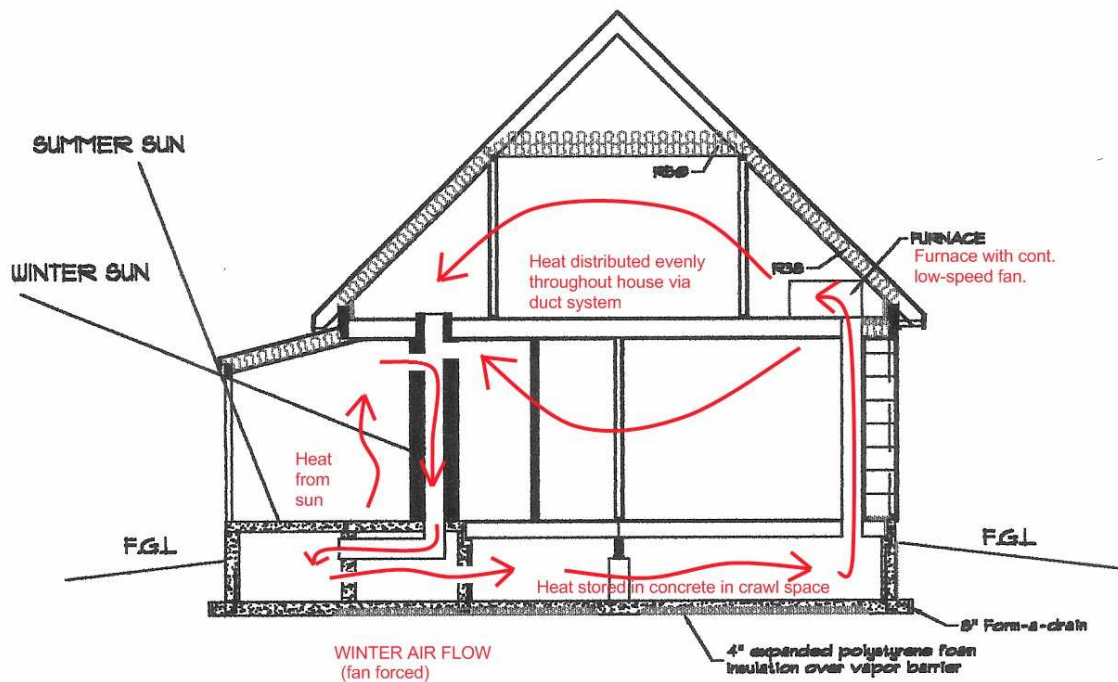
- 7. Energy Recovery Ventilator** – An Energy Recovery Ventilator (ERV) transfers heat and moisture from the exhaust airstream to the incoming air stream during the heating season, and transfer heat and water vapor from the incoming air stream to the exhaust air stream during the air conditioning season. They are called ERVs because there is a lot of energy held in water vapor and by recovering humidity as well as temperature ERVs capture more energy. They can achieve recovery efficiencies as high as 95% which is a great way to save energy.

The following diagram shows how an ERV works in the summer.



The heart of the Energy Recovery Ventilator is the desiccant coated energy recovery wheel, which slowly rotates between the two sections of the machine. In one section, the stale, conditioned air is passed through the wheel, and exhausted in the atmosphere. During this process, the wheel absorbs heat and water vapor from the conditioned air, which is used to cool or heat the incoming fresh air in the other section, during the second half of its rotation cycle.

Some form of air moving system can also be very useful in Passive Solar buildings in order to help to move the heat from the south side where the sun is shining to the rest of the building. Often buildings also contain point sources of heat such as gas fireplaces or electric heaters. These too can be used to heat the whole building if there is a way to distribute the heat throughout the conditioned space. HRV's and ERV's can be a very good way to do this. Another way is to use the fan and the ductwork in a forced-air heating system to distribute heat without necessarily adding any more heat. The diagram below demonstrates such a system.



In this example the furnace (in the upper right) has a setting that allows it to run the fan on low speed without adding any heat. So the heat from the sun can be distributed efficiently throughout the building, in this case via the crawl space which has a concrete floor to provide thermal mass.

9 – Thermal Mass

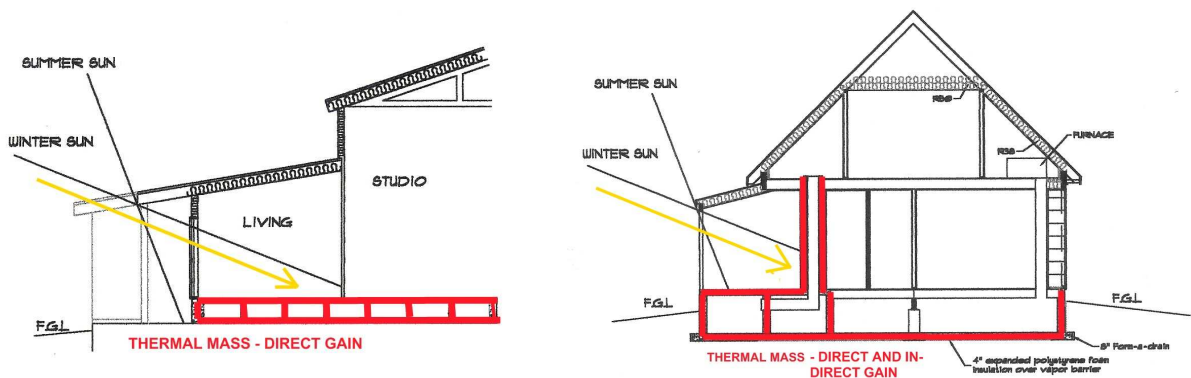
Thermal Mass consists of heavy materials such as brick, concrete, tile, stone, etc placed INSIDE the thermal boundary. Its purpose is to store heat and even out temperature fluctuations. The way it works is that, when the sun is shining and heating up the inside of the building, the thermal mass is busy soaking up that heat and storing it. Then, when the sun goes behind a cloud or sets for the day, the thermal mass begins to give off the heat that it has stored. If everything is perfectly balanced the mass will store enough heat during the day to keep the building comfortable for the whole night until the sun begins to shine again in the morning.

It is almost impossible to calculate exactly how much thermal mass is required and where it should be placed in the building. For one thing the weather outside is constantly changing. For another, there are also internal heat gains inside the building due to heat given off by appliances, and lights, and even people which are also constantly changing.

However, even if it is not perfectly balanced all the time, thermal mass does a good (and essential) job of evening out temperature fluctuations. Without mass to

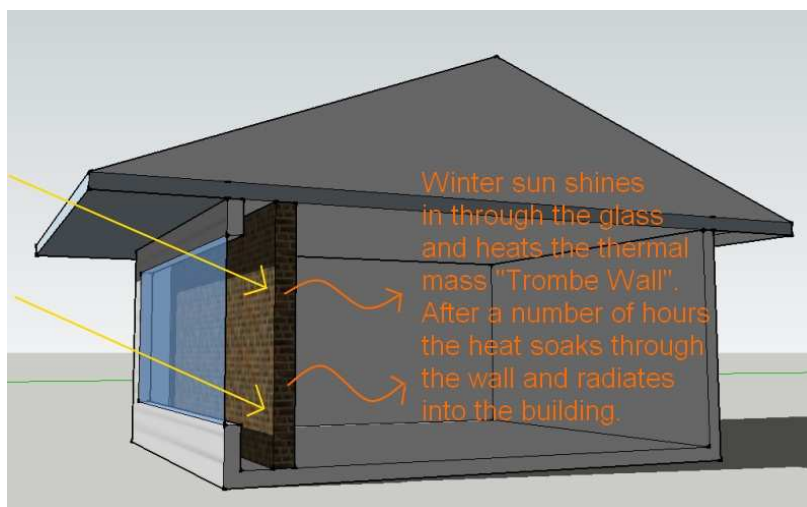
soak up some of the heat when the sun shines into a well-insulated Passive Solar building it will rapidly heat up. And without mass to store the heat it will cool down again much more quickly when the sun isn't shining. This can lead to constant and uncomfortable fluctuations in the indoor air temperature. With adequate thermal mass there will still be temperature fluctuations but they will be within a much smaller range.

Thermal mass can be in floors, walls, or both. It can be in direct sunlight or it can gain heat indirectly from the air that is warmed by the sun. The following diagrams show a couple of buildings with different arrangements of thermal mass.



In the example on the left, the thermal mass is in the floor and gains heat directly from the sun shining in through the south-facing windows in the winter. On the right, some of the thermal mass is gaining heat directly from the sun but much of it is down in the crawl space where it gains heat from the warm air that is passing through the crawl space as described in the Ventilation section above.

One way to make use of thermal mass is with a “Trombe Wall”.

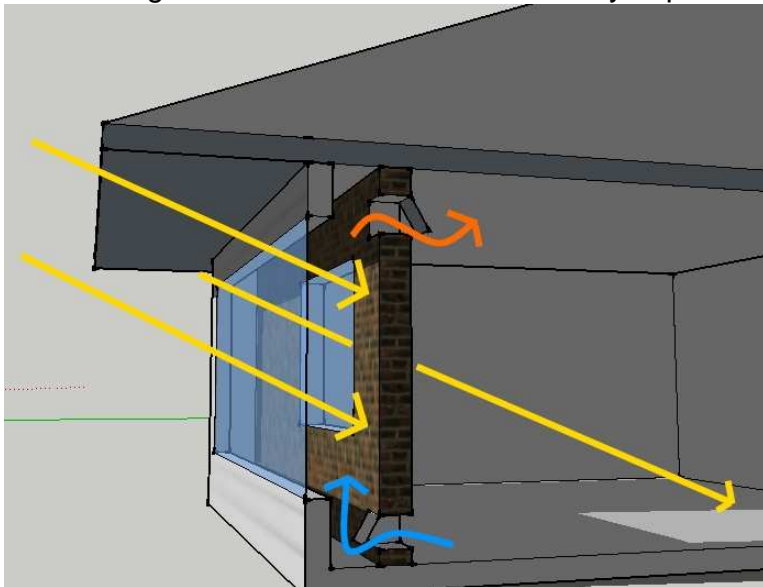


The **Trombe wall** was developed by the French engineer Félix Trombe in 1956. It consists of a thermal mass wall built behind south-facing glazing. During the day, sunlight shines through the insulated glazing and warms the surface of the

thermal mass. At night, heat escapes from the thermal mass, some to the outside

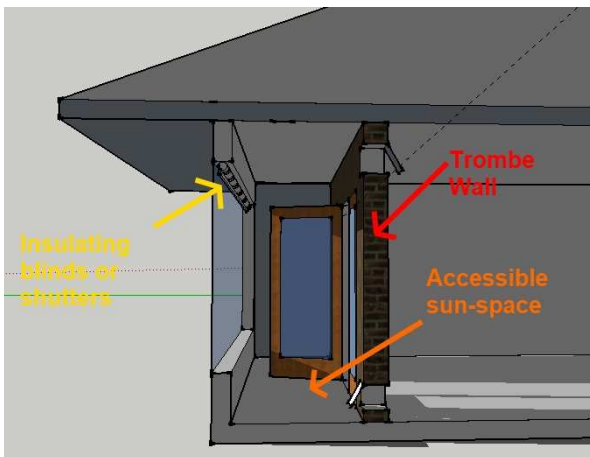
(back through the glass) and some to the inside. Because of the insulated glazing, the average temperature of the thermal mass can be significantly above the average outdoor temperature. If the glazing insulates well enough, and outdoor temperatures are not too low, the average temperature of the thermal mass will be significantly higher than room temperature, and heat will flow into the house interior. However no sun can get into the building with this arrangement.

Modern Trombe walls have vents added to the top and bottom of the air gap between the glazing and the thermal mass. Heated air flows via convection into the building interior. The vents have one-way flaps which prevent convection at night, thereby making



heat flow strongly directional. This kind of design is an isolated passive thermal collector. By moving the heat away from the collection surface, it greatly reduces thermal losses at night and improves overall heat gain. Generally, the vents to the interior are closed in summer months when heat gain is not wanted.

Another improvement in the modern Trombe wall is the inclusion of windows to the interior to allow sun and light into the building. However two main problems remain, one is that the space between the masonry wall and the outside layer of glass is small and can be hard to access for cleaning and maintenance. The second is that there is still potential for large amounts of heat loss back out through the exterior glass at night.



Both of these problems can be solved by moving the Trombe wall further inside, far enough to create a sunroom/greenhouse that can be occupied. This provides access both for cleaning and for opening and closing insulated blinds or shutters on the exterior windows at night to help keep the heat inside.

10 – Landscaping

Carefully thought-out landscaping and planting can help to maximize the performance of a Passive Solar Design and can help solve all sorts of problems with imperfect situations. Sometimes the existing landscape creates an ideal site as in the example below.



This infill site in Sheridan, WY is a perfect set-up for a passive solar home. The streets to the east and south create excellent solar access while the hill and mature trees to the north and west help to shelter the site and protect the home from the cold winter winds that prevail from that direction in that location.

More often, however, the site is not so perfect and we can use landscaping to overcome many deficiencies. If the slope of the ground isn't ideal it can be altered to some extent during excavations for the foundations of the building. Obviously there are limits to how far you can take this but the example below shows a site with great solar access and fabulous views to the south however the ground slopes slightly to the north east.



In order to maximize the benefits of this site the ground was dug out on the south side of the building that was built here to create a delightfully sunny and sheltered patio with beautiful rock retaining walls.



Planting trees in the right place can do a great deal for sheltering the site from cold winds in the winter and shading the building from hot sun in the summer. Deciduous trees in the right place can help to shade the building in the summer while letting in sun in the winter. Evergreen trees to the north and north-west can help to shelter the building from cold winter winds. Careful thought must be given to the location of trees and their full-grown size before they are planted. Don't forget that trees grow and that the cute little Spruce seedling in the south-east corner of your yard will someday grow into this...



Incorrect landscaping can render a Passive Solar design almost completely ineffective. The house shown at left will get absolutely no sun from the direction of these trees. Plus there are other potential problems with planting too close to a building. For one thing, trees need water and the last thing you want to be doing is pouring water into the ground close to the

foundations for your building. Tree roots can also destroy even the strongest concrete foundations over time and tree branches rubbing on roofs can literally wear holes in the roof, not to mention clogging the gutters with debris. Vines love

to sneak into cracks in a buildings exterior and, as they grow and get fatter, they can tear pieces right off the structure. Enough said...care needs to be taken when deciding where to place plants to aid with Passive Solar Design.

And don't forget that problems with plants and trees can be also be solved...



Summary

That completes the ten fundamental principles of Passive Solar Design. The key thing to keep in mind is that all ten of these concepts needs to be applied TOGETHER in a holistic approach in order for the design to function properly.

When this is done correctly Passive Solar Design works wonderfully to help heat a building in the winter and cool it in the summer. But, if you do everything right except you plant two (eventually) huge Spruce trees on the south side of your home it won't work. The house will be cold and gloomy in the winter time. Similarly if you do everything perfectly except you orient the building to the west because that happens to be where the best view is, you will bake in the summer time and you won't get enough south sun in the winter. Or (this is a common mistake) if you don't provide the right amount of eave overhang on the south side you will either cook in the summer (not enough overhang) or freeze in the winter (too much overhang). So apply common sense to ALL of the steps to ensure that the design works properly.

And apply good building science principles in order to control moisture and ensure that you create a healthy, durable, and comfortable building that will be a benefit for generations to come.