The Oil Drum: Campfire

Discussions about Energy and Our Future

Passive Solar Design Overview – Part 1

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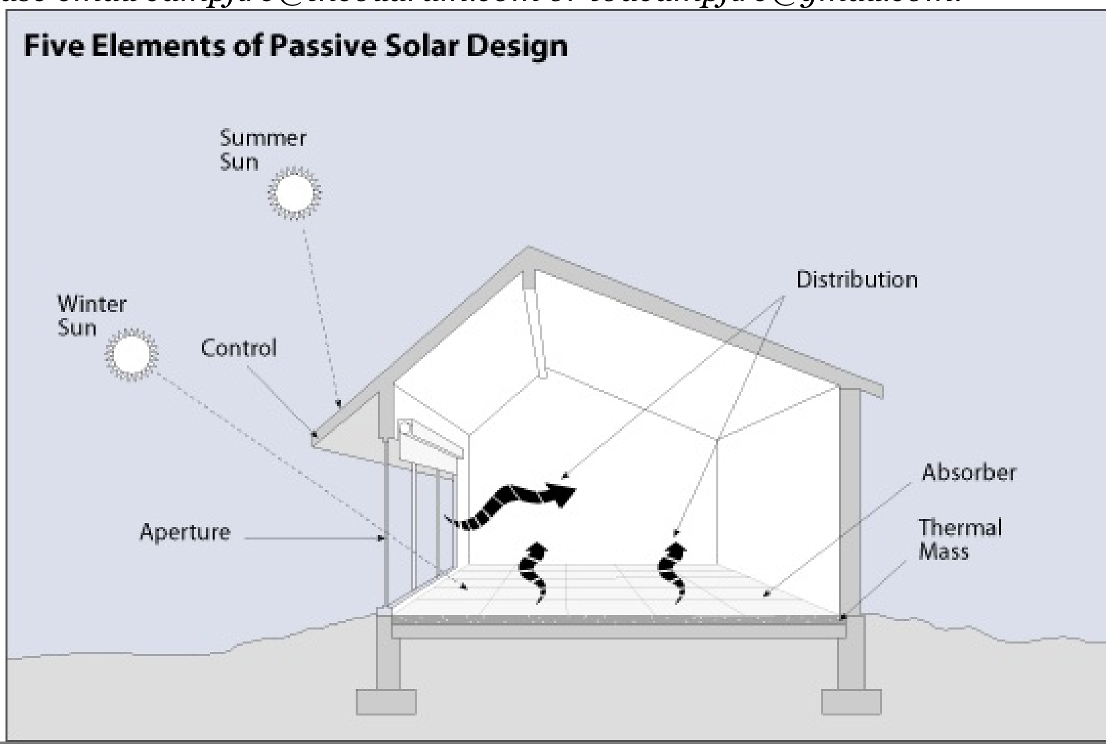
Below the fold is a TOD:Campfire post on Passive Solar, from longtime TOD reader Will Stewart. Will is a Systems Engineer in the Energy industry - he will have a follow up post in the near future. Please add your own experience and expertise with passive solar, including links and images in the comment section - the sun is as close as we get to a perpetual energy subsidy.....how we best access and take advantage of it is the subject of tonights post. *For submissions to this series, please email campfire@theoildrum.com or todcampfire@gmail.com.*



Passive Solar Design Overview – Part 1

Passive solar refers to the design and placement of a building to enable solar heating without the need for sensors, actuators, and pumps, in contrast to *active solar*, which utilizes pumps/blowers, sensors, and logic control units to manage collection, storage, and distribution of heat. The two techniques are not exclusive, however, and can work together effectively.

As solar radiation (insolation) is a diffuse energy source, and not at the beck and call of a thermostat, passive solar design techniques are at their best when combined with other related methods, such as energy efficiency (insulation, weatherization, building envelope minimization), daylighting, passive cooling, microclimate landscaping, and a conservation lifestyle (i.e., temperature settings, raising and lowering of insulated shades, etc). Most of these topics will be covered in other articles, though passive cooling will be addressed in this series, which is intended as an overview, as a complete engineering treatment on passive solar design would require several dozens of articles.

Even though solar insolation is diffuse, and generally weaker the further away from the equator, it can be the basis for the majority of a building's heat energy input even in high latitude places such as Canada, Norway, Germany, the Northern US (Maine, New Hampshire, Michigan, Wisconsin, Minnesota, North Dakota, Montana, Idaho, Washington state, etc), Scotland, the Netherlands, etc. Even the US Department of Defense has a passive solar design guide. Design approaches such as Passivhaus have achieved up to **90% reduction in energy use over traditional building methods**. In areas with reasonably consistent winter insolation, well insulated passive solar buildings with sufficient thermal mass storage can approach 100% of their space heating needs with passive solar. Enhancements can be added to existing buildings, through major or minor renovations, or through simple additions (Part 4 of the series).

History

The Greeks faced severe fuel shortages in fifth century BC, resorting to arranging their houses so that each could make maximum use of the sun's warming rays. A standard house plan emerged, with Socrates noting, "In houses that look toward the south, the sun penetrates the portico in winter." The great Greek playwright Aeschylus even proclaimed only primitives and barbarians "lacked knowledge of houses turned to face the winter sun". The Romans picked up on this technique, and improved it by adding windows of mica or glass to better hold in the heat. They passed laws to protect the solar access rights of owners of solar homes from shading by new buildings. In the Americas, the Pueblo and Anazazi took advantage of solar insolation in their adobe and cave dwellings, respectively.

In the 18th and early 19th centuries, solar greenhouses became popular for those of means to grow exotic tropical plantlife in temperate climes. In the 20th century, German architects such as Hannes Meyer, director of the influential Bauhaus architectural school, urged the use of passive solar design techniques that began to flourish in the 1930s, only to be pushed aside by the Nazis and WWII. Many German architects made their way to the US, and a small solar market developed. Built in 1948, Rosemont elementary school in Tuscon obtained over 80% of its heat via solar means, but in 1958, with cheap energy now available and an extensive addition planned, the school district chose to go with a gas-fired furnace. The 1970s saw more emphasis on renewable energy, and passive solar became a household word, though still only penetrating a very tiny percentage of builders' visions for the new homes market. More in-depth passive solar history details can be found at the California Solar Center.

The Basics

Location and Orientation

To assess whether passive solar is advantageous to a location, one must first find out the amount of winter sunlight that is available. The simplest way is to find solar insolation data for the site under consideration, ideally collected over a series of decades (noting that a changing climate can mean the data may need to be extrapolated). The data can come in tabular or map form, with the latter providing a quick indicator of the amount of winter insolation in one's area. Tabular data, however, is more precise, giving one the best information available about trends in their area. A note of caution: the data is usually an average of conditions, and does not necessarily take into consideration unusual weather years or how the **climate may change** in one's area of consideration.

Interpretation of Data:

Most of the maps and tabular data measure solar insolation as kWh/m2/day, which is roughly the number of kilowatt hours of energy striking a square meter of surface in a day. This is also referred to as a **Sun Hours** on some maps, and we will refer to it as such throughout this series. *Important note*: Since virtually all modern passive solar design focuses on vertical windows, data must be specified or converted to a vertical orientation. Some of the data currently available is for collectors tilted at an angle equal to the site's *latitude* (**L**) or a *horizontal surface* (**H**), which would need to be converted to a *vertical surface* (**V**). The table below contains a partial list of solar maps and data, though make sure any source you use focuses on winter data, as other maps/data are used for year around solar photovoltaic projections.

Region	**Maps**	**Data**
World	- Solarex (**L**) - FirstLook (Americas only currently)(**H**)	- WRDC (select *Global*)
Canada	- Solarex (**L**)	- WRDC (select *Global*)
Europe	- Satellite data map (**H**)	- WRDC (select *Global*)
US	- National Renewable Energy Labs (select *Vertical surface*) (**V**)	- Many US cities (**H**) - Detailed data (**H**) (manual) - Other sources
Australia	- Aus BOM June Map (**L**)	- Aus BOM site data (**L**)

The orientation of the building will determine how much solar insolation is captured during the desired period of the day. For example, a passive solar house facing the equator will receive an equal amount of solar heat before and after noon. The more a building is oriented away from true south (or north in the southern hemisphere) the less winter solar insolation it will be able to capture, and it becomes more susceptible to undesirable summer solar energy that is harder to shade with a properly sized overhang.

In addition to direct solar insolation beaming from the sun, there is also *diffuse* radiation from the sky, and *reflected* radiation from the ground.

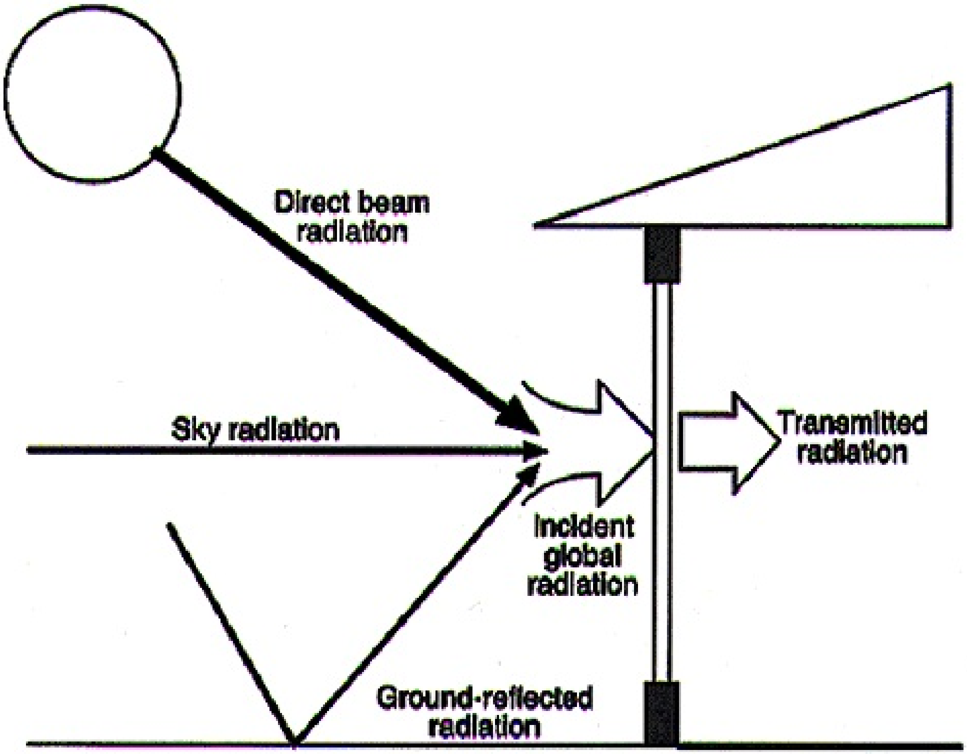


Figure 1 - Types of solar input

<u>Design Aspects:</u>

Passive solar building design revolves around 5 main aspects;

Aperature: The set of windows and overhangs that determine how much sun enters the building.
Absorber: The material that the sun's ray come into contact with.
Thermal Mass: The material that stores the sun's thermal energy for re-release after sundown.
Distribution: The means by which the thermal energy is released to the living/working spaces.
Control: The techniques used to control the collection and distribution of the sun's thermal energy.

These aspects can be configured by the designer/architect into roughly three main design themes (with endless variations);

1. Direct Gain: Sunlight shines into and warms the living space.
2. Indirect Gain: Sunlight warms thermal storage, which then warms the living space.
3. Isolated Gain: Sunlight warms another room (sunroom) and convection brings the warmed air into the living space.

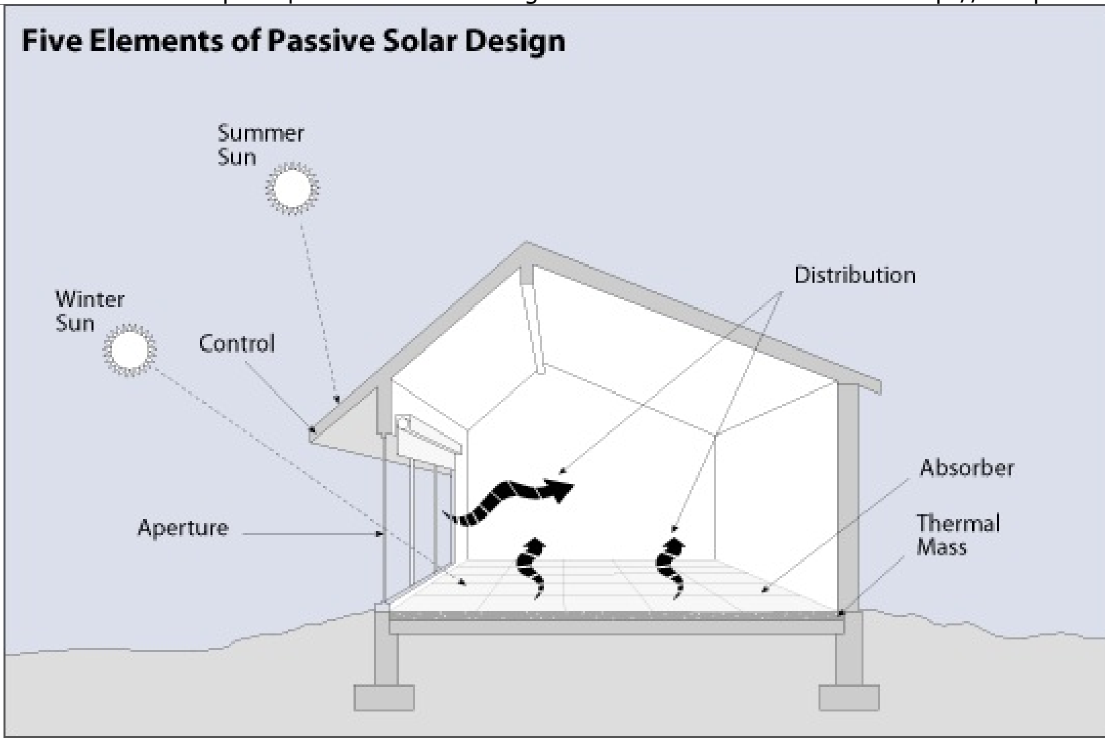


Figure 2 - Direct solar gain

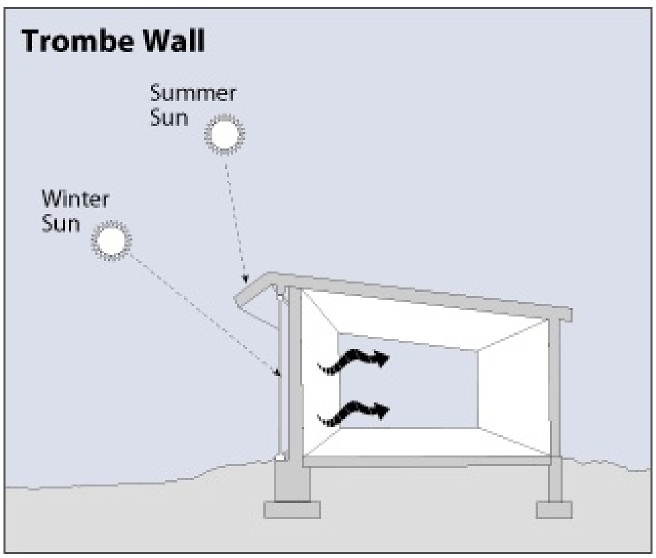


Figure 3 - Indirect solar gain

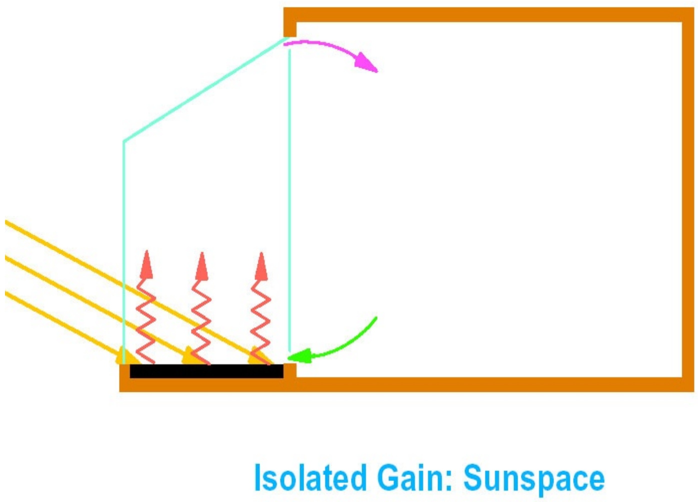


Figure 4 - Isolated Gain

In Part I of this series, we will cover the Aperature;

Aperture:

The first step in passive solar design is determining how to collect the sun's energy. In most climates that passive solar is employed, this means windows of one form or another. An important metric of a window is its Solar Heat Gain Coefficient (SHGC) that measures how much of the sun's energy passes through the window without reflection or absorbtion and re-radiation. The higher the SHGC, the more solar energy a window will allow through. A plain single pane window normally has a SGHC of 0.86 while a plain dual pane window is about 0.72.

In order to reduce heat loss in cool and cold climates, windows are normally at least dual pane, if not triple pane. The dead air space between window panes helps to increase the insulation factor, call the R-value (or its inverse, the U-value). One single pane of ordinary glass has an approximate R-Value of 0.85. A dual pane window with 3/8 inch of air space typically has an R-value of 2.1. The substitution of less viscous gases such as argon and krypton allow greater distances between panes before the gas begins to convect (tranferring heat at a much higher rate), increasing their insulating effect. Each pane added, however, blocks/absorbs/reflects more solar energy, which effectively reduces the window unit's SHGC. Additionally, low-E coatings that help to reduce the amount of infrared heat radiated out of a room through a window also reduces SHGC (amount dependent on the type of low-E coating). So a balance must be struck by the designer/architect between the amount of energy received during winter sunlight hours vs. the amount of energy lost 24 hours a day. There are windows available that have been designed for passive solar applications to provide sufficient SGHC while still providing adequate insulation (e.g., one such window has a SHGC = 0.56 and an R-value = 5).

There is ongoing research to bring aerogel windows to commercial production, as these windows provide extremely high R-values (approximately R-10 per inch) while having SHGCs of .52 or greater.

The orientation of the window is just as important; windows facing the equator receive the greatest amount of sunlight. And this orientation also greatly reduces unwanted solar collection during the warmer days of the year, as windows facing East and West are difficult to shade effectively with simple overhangs, requiring larger and/or view blocking awnings.

References:
California Solar Center: Passive Solar History
US DoE Passive Solar Home Design