MISSOURI DEPARTMENT OF ECONOMIC DEVELOPMENT
DIVISION OF ENERGY

Great Homes Checklist - Passive Solar Design

Division of Energy fact sheet 9/2013

A good passive solar house requires more than just a good design and quality construction. It requires that the plan and the site be considered together during the design phase to assure that they work together to optimize solar performance. The best-designed solar house plan will not work unless it is placed properly on a building site which allows solar access. Similarly, a site with clear solar access provides little advantage to the building placed upon it unless the building is designed and oriented to take advantage of the site's solar potential.

Passive solar concepts are not difficult to apply, but require consideration from the preliminary stages of design to be most effective. This checklist is presented as a planning tool, with references to other, more complete resources. The ***Great Homes Checklist—Energy-Efficient Design and Construction*** fact sheet, which provides complimentary information, is also available from the Missouri Department of Economic Development's Division of Energy.

Benefits:

Good passive solar homes are not difficult to design or expensive to build. However, they do require the use of basic, common-sense methods of working with the environment rather than against it. When you build a solar home correctly, you can count on it being:

1. **Comfortable** - Solar homes are warm in the winter and cool in the summer.
2. **Economical** - Homeowners receive an excellent return from their investment. Heating and cooling bills for a 3,000 square feet home can be less than $300 per year. Incremental first cost is usually minimal and easily recouped when resold.
3. **Durable** - Solar homes are usually built from long-lasting, low-maintenance materials.
4. **Attractive** - Solar homes are full of light and are well connected to the outdoors.
5. **Environmentally Responsible** - Solar homes make efficient use of our energy resources.

Site Selection and Building Layout Checklist:

☩ *Determine true south and true level from the center and bottom of the solar aperture.*

1. At the midpoint between sunrise and sunset, the sun casts a shadow from a vertical wall corner that is true north. A simple level will determine the zero degree solar elevation angle.
2. A 9.5-inch stick at the end of a yardstick forms a 15-degree angle to your eye when the other end of the stick is held at your forehead. This can be used to plot the approximate southern skyline on a sunchart (Figure 1) using elevation and azimuth angles from the direction of true south and true level as observed from the center and bottom of the solar aperture.

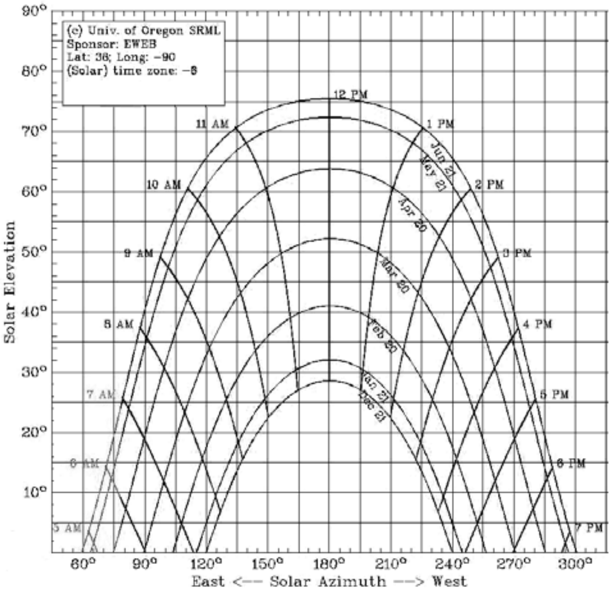

Figure 1. A sunchart for 38 degrees north latitude.
University of Oregon SRML Sunchart Program
http://solardat.uoregon.edu/SunChartProgram.html

⁜ Check for the availability of sunlight during winter months using a sunchart.

1. The midday sun is low in the southern sky during winter months and high in the southern sky during summer months (Figures 2 and 3). Plot the southern horizon, trees, and buildings on a sunchart (Figure 1) to determine sunlight availability.
2. Most of the south windows should receive sunlight from 10 a.m. to 2 p.m.

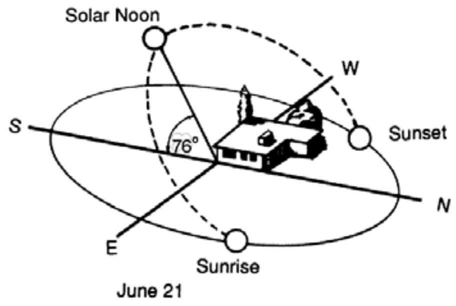

Figure 2. Angle of summer sun is 76 degrees from horizontal at solar noon for 38 degree north latitude.

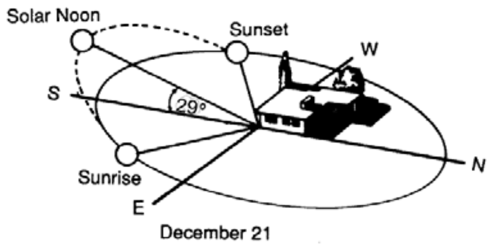

Figure 3. Angle of winter sun is 29 degrees from horizontal at solar noon for 38 degree north latitude.

⁜ The longest wall of the home should face within 15 degrees, plus or minus, of true south to receive the most winter solar heat gain and reduce summer cooling costs.

1. At 30 degrees east or west of south, winter heat gain is reduced by 15 percent from the optimum.
2. Minimizing east and west facing walls and windows reduces excessive summer heat gain.
3. Do not rely on compass readings to determine true south. See previous discussion.

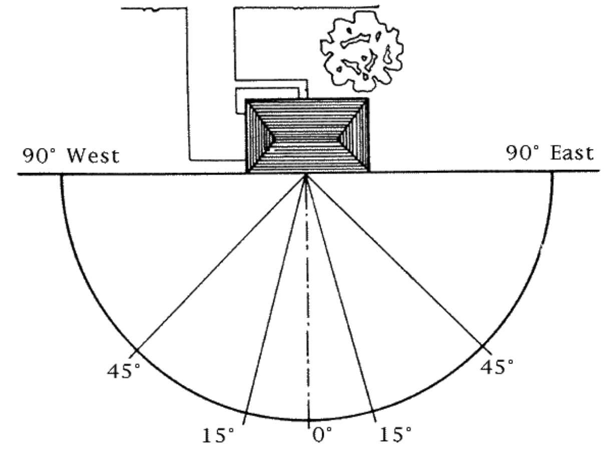

Figure 4. Orientation: A house can be angled as much as 15 degrees east or west of true south and still be energy efficient.

Design Strategies and Building Material Checklist:

⁜ Size south facing windows and thermal mass appropriately.

1. ***Sun-tempered homes*** with no added internal solar thermal mass should have south facing windows with a glass area of no more than 7 percent of the heated floor area.
2. ***Direct-gain systems*** can have up to 12 percent of the floor area in south-facing windows. However, every square foot of south-facing glass over the 7 percent sun-tempering allowance must be accompanied by thermal mass (4-inch thick masonry) at the following rates: An additional square foot of direct-gain glazing may be added for every 5.5 square foot of uncovered sunlit floor mass. (The maximum "sunlit" floor mass may be estimated as about 1.5 times the south window area.) An additional square foot of direct gain glazing may be added for every 40 square foot of thermal mass in the floor of the room, but not in the sun. An additional square foot of direct-gain glazing may be added for each 8.3 square foot of thermal mass placed in the wall or ceiling of the room in line of sight with the sunlit surfaces.
3. ***Sunspaces*** should include only vertical glass. Sloped glazing can cause serious overheating. Every square foot of south facing glass must be accompanied by 3 square feet of 4-inch thick (or greater) masonry**.**
4. ***Thermal storage or Trombe walls*** should be 8- to 12-inch thick masonry. The outside of the masonry wall should be coated with a selective surface and the inside surface should be free of coverings. The outside of the glass should be covered or shaded in summer months.
5. ***A south facing walkout basement*** provides a unique opportunity for a large amount of mass and a large area of south facing windows. Design the solar system of each story separately by assuming no heat is transferred from one story to another. Check the resulting composite design.
6. ***Integrate any or all of the above*** into a single home. Use *BuilderGuide* software or worksheets and the *Guidelines* manual to calculate solar savings fraction,

maximum winter temperature swing, and annual auxiliary heating and cooling energy requirements. If you need assistance, please call the Energy Center.

Window type and window placement are critical.

1. Minimize or eliminate east and west windows. They do not provide any net solar heating in winter and add to the summer cooling load by allowing direct sunlight penetration.
2. Since north light is mostly indirect, it is very desirable. Use north windows for daylighting, but try to keep the total area below 4 percent of the total floor area. North windows have little solar gain and a lot of heat loss.
3. Size south windows according to thermal mass, as stated above.
4. Low-E glass (especially on non-south windows) and double-glazing should be used for all windows. Typical U-values are less than .38 BTU/(hr-sqft-degF).
5. To maximize solar heat gain into a passive solar home or sunspace the solar heat gain coefficient (SHGC) should be as large as possible. Spaces without adequate thermal mass or with east or west exposures should have a SHGC of 0.55 or less.

Consider night window insulation.

1. Generally R-9 night insulation over double pane windows provides an approximate 20 to 30 percent increase in annual solar savings fraction over systems using double pane windows without night insulation.
2. Generally movable insulation is used only on very cold nights or during very cloudy weather.

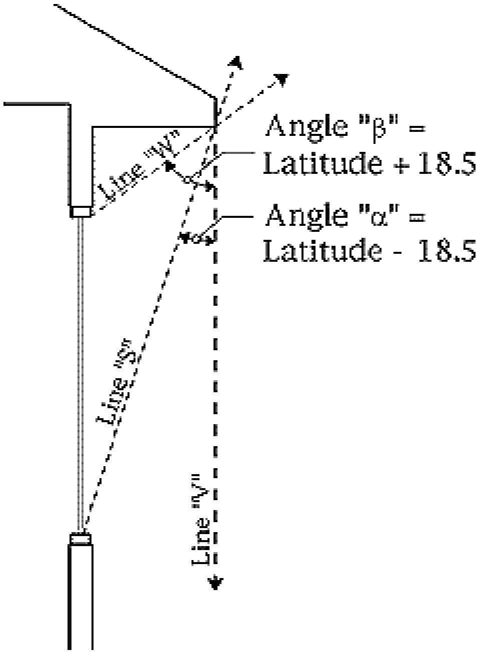

Figure 5. Sizing Overhangs: The following link is an excellent design tool that provides an hourly animation of the overhang shadow over the window for any day of the year. http://www.susdesign.com/overhang/index.html

Size south overhangs properly.

1. To prevent summer gains, the angle “ά" between a line "S" from the edge of the overhang to the bottom of the window and a vertical line "V" should be approximately equal to the latitude minus 18.5 degrees. (See Figure 5 for design information.)
2. To prevent winter shading, the angle “β" between a line "W" from the edge of the overhang to the top of the window and a vertical line should be approximately equal to the latitude plus 18.5 degrees.
3. An overhang designed with these formulas will provide shade most of the summer and full sun in the coldest part of the winter.
4. East and west overhangs are usually ineffective as the sun always drops below them in the summer months. North, east, and west overhangs serve mainly as a rain drip.

Distribute the mass throughout the room.

In direct gain systems, performance is fairly insensitive to the locations of mass in the room. It is relatively the same in west or north walls. It is important to put some mass in the direct sun, but rarely is it possible to expose all the required thermal mass because of furniture and floor coverings. Comfort is improved if the mass is distributed evenly in the room because the increased surface area reduces localized hot or cold spots. Light colored, lightweight materials "bounce" the sunlight to more massive materials. Also, vertical mass surfaces not in direct sunlight can reduce temperature swings by absorbing excess heat in the air.

Masonry walls can be any color in direct gain systems.

Actually, it is best to use colors in the middle range of the absorptivity scale to diffuse the solar energy over all the storage mass in the room. (The absorptivity range of concrete masonry falls in this range without paints or special treatment being necessary.) These colors need to be somewhat darker than lighter weight material colors; however, if the storage mass is too dark, surfaces exposed to the direct rays of the sun will soon reach high temperatures. This can lead to overheating of the air; while other surfaces in the room may receive very little of the day's solar energy. Trombe walls should always be very dark to increase solar absorption.

Do not cover the storage mass with furniture.

Rugs and wall tapestries can also reduce the effect of storage mass to some degree. It is wise to plan in advance to match the system to room use.

Lightweight materials should be lighter in color.

Lighter colors absorb less energy (sunlight) and are more reflective. When light energy is absorbed, it is transferred into heat energy. If the material does not have sufficient storage mass, the material may heat up too quickly and release the excess heat to the room air causing overheating.

Match the solar heating system to the room use.

Consider occupancy patterns when choosing a system. What are the heating, lighting and privacy needs after sunset? A Trombe wall might be a logical choice for a room requiring privacy. A living room, on the other hand, which needs daytime and early evening heat and has a higher lighting requirement, might benefit from a direct gain system or a sunspace.

Consider a sunspace in front of a living room.

1. An entry foyer to a living room is a great place to locate a sunspace. It serves as an entry buffer, a source of heat in the winter months and a solarium during cooler periods of the year. They are usually closed off during winter nights.
2. Locate sunspaces on the south side. If you have overhead glass, you should use low-transmittance glass to prevent summer overheating.
3. You need about three times as much sunspace thermal mass area as sunspace glazing. This will allow the temperature in the sunspace to swing about 30ºF above the house temperature, thus transferring heat to the house during the day.
4. Operable doors and windows are the preferred method to allow heat transfer via natural convection.
5. The total opening between the sunspace and the house should be 15 percent of the sunspace glazing.
6. A mass wall at least 8 inches thick between the sunspace and the home works well. It will provide heat for several hours into the night (after the sunspace is closed off) due to the heat slowly propagating through the mass.
7. A sunspace must be vented during the summer season. Operable windows, doors and vents should take advantage of prevailing winds to provide cross-ventilation. Use high and low vents totaling up to 15 percent of the floor area. A small thermostat-controlled fan and louver may be necessary
8. A well designed sunspace will require only a small heater on very cold nights to protect plants. Many people move all plants out of the sunspace during winter months.

Consider clerestories for heating north rooms.

1. Clerestories are vertical windows installed in the roof. These are very effective for heating and lighting north rooms and should be considered as part of the direct solar gain.
2. Clerestories are superior to skylights because they do not serve as direct gain in the summer months.
3. Operable clerestories can serve to vent hot ceiling air in the summer while drawing in cool outside air into the living area.

Buffer the north side of the building.

Place rooms with low heating, lighting, and use requirements, such as utility rooms, storage rooms and garages, on the north side of the building to reduce the effect of winter heat loads. This can reduce the normally higher heat loss through northern walls while not interfering with solar access. Rooms that generate their own internal heat, such as the kitchen, should also be placed on the north side. Landscaping elements, such as evergreen trees on the north and west sides of the house, can buffer against the cold winter winds and strong afternoon summer sun.

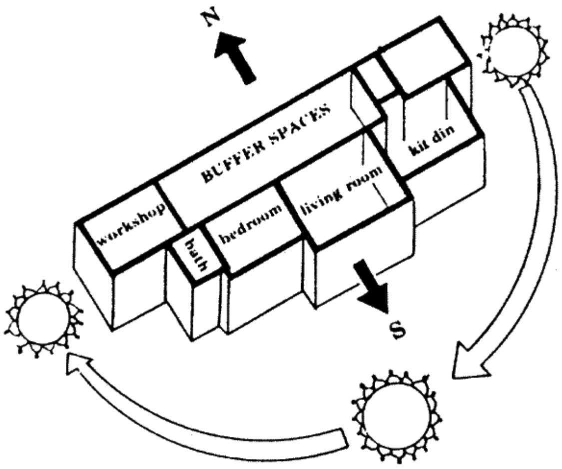

Figure 6. Buffer Spaces: Place rooms where they are compatible with the suns path. Buffer spaces should be placed to the north.

Shading with Landscaping

1. Trees and shrubs can cut air conditioning use in the summer by 20 to 40 percent.
2. Leave the south side of the house open to the sun in winter months from 9 a.m. to 3 p.m. This usually means a wedge-shaped area extending 45° from each southern corner. Avoid planting trees in this area. Overhangs will block any unwanted summer sun.
3. Shading the east and west sides of the house can provide the greatest cooling energy savings. Give priority to the west, because heat from the late afternoon sun adds a great deal of heat gain to the house after it has built up heat during the day.
4. Try to reduce the amount of pavement close to the house by using ground covers.

Adequate insulation is a good investment and is necessary for good solar performance and comfort.

1. Please refer to the Energy Center fact sheet: “Recommendations for Energy Efficient Design for Low-Rise-Residential Construction”.
2. R-16 walls, R-38 ceilings, and R-10 perimeter insulation are considered adequate minimums.

Ducts and Air Flow Strategies

1. Ducts work well in transferring heat with central air systems where there is a large difference from supply temperature to room temperature. This large difference does not exist in solar heated systems, making ducts ineffective in transferring solar heat.

2. In a well designed home, natural convection loops through doorways generally provide adequate distribution of heat. Try to design spaces so they are one door away from the solar heat source.

☩ *Air leakage*

1. Blower door tests are highly recommended as a way to measure air infiltration. These tests should be done after the vapor barrier is installed, but before sheetrock is installed, so that leaks can be detected early.
2. Leakage should be in the range of .25 to .50 air changes per hour at average annual wind velocity.
3. Leakage should not exceed .20 to .30 cubic feet per minute per square foot of conditioned floor space at 50 pascals blower door pressure.
4. A home that is built too tight will require mechanical ventilation.

Other Sources of Information:

Computer Simulation Software and Low Energy Design Handbooks

The Sustainable Buildings Industry Council (SBIC) offers workshops around the country for builders and architects on the energy and cost savings that can be achieved through more than a dozen sustainable design strategies using a pre-design energy simulation program called Energy-10. Hourly energy simulations help you quantify the benefits of daylighting, passive solar heating, natural ventilation, well-insulated envelopes, better windows, modern lighting systems, efficient mechanical equipment, and more.

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Reading List

Buildings for a Sustainable America, Burke Miller, Boulder, CO: American Solar Energy Society, 1997.

Climate Design, Donald Watson and Kenneth Labs, New York, NY: McGraw-Hill Book Co., 1983.

The Climatic Dwelling: An Introduction to Climate-Responsive Residential Architecture, Eoin O. Cofaigh, John A. Olley, J. Owen Lewis, London, UK: James & James (Science Publishers) Ltd., 1997.

The New Solar Home Book, Bruce Anderson and Michael Riordan, Andover, MA: Brickhouse Publishing Co., Inc., 1987.

Passive Solar Energy, Bruce Anderson and Malcolm Wells, Andover, MA: Brickhouse Publishing Co., Inc., 1994.

The Passive Solar Design and Construction Handbook, edited by Michael J. Crosbie, New York, NY: John Wiley and Sons Ltd, 1997.

The Passive Solar House: Using Solar Design to Heat and Cool Your Home, James Kachadorian, White River Junction, VT: Chelsea Green Publishing Co., 1997.

Web Sites

U.S.Department of Energy, Energy Efficiency and Renewable Energy
Passive Solar Design for the Home
www.eere.energy.gov/consumerinfo/factsheets/passive_solar.html

The North Carolina Solar Center
www.ncsc.ncsu.edu/
www.ncsc.ncsu.edu/information_resources/factsheets/shnc2.pdf

South Carolina Energy Office web site:
www.state.sc.us/energy/
www.state.sc.us/energy/Residential/solar.htm

Kentucky Division of Energy:
www.energy.ky.gov/publications/kdoepublications/energyefficienthomeplans.htm

Enertia Building Systems
www.enertia.com/index.htm

Sun Plans Inc.
www.sunplans.com/html/home_page.php3

Sunlight Homes
www.sunlighthomes.com/

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Additional information from: "Passive Solar Design Strategies: Guidelines for Home Builders", and “Guidelines for Building Passive Solar Homes in Los Alamos, New Mexico”; www.nmsea.org/Curriculum/Courses/Passive_Solar_Design/Guidelines/Guidelines.htm

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