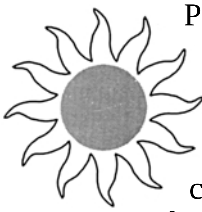
Passive Solar Design for a Northern Climate

Keep the Sun in Mind



Passive solar design is a group of building design strategies that can be utilized to reduce the need for mechanical heating, cooling and lighting. When combined with basic energy conservation and energy efficiency practices, these strategies can actually increase the comfort of buildings and can make dramatic reductions in energy costs. These strategies include passive solar heating, daylighting, natural ventilation, radiative and ground-coupled heating and cooling, and peak-load shifting with thermal mass.

Four Key Components

Design of passive solar buildings focuses on four key components:

- Building envelope - should be thermally tight as well as having low air leakage (Reference: Minnesota Power's "Triple E" Energy Efficient Home Construction Standards)
- Windows (glazing) - critical factors include location, size, glazing material, overhang size dependent on the building's heating, cooling and lighting needs
- Thermal mass - elements of the building structure that serve as heat storage components
- Building siting and orientation - good southern exposure

Building Envelope

A key component in the design of a passive solar building is the careful construction of a thermally efficient building envelope. Meticulous attention to the following key features will result in a home with lower energy bills, a healthier indoor environment, increased comfort, and greater building durability.

Key Features of a cold climate energy-efficient home include:

- A well-designed, dry and warm foundation system
- Full coverage, continuous interior vapor/air barrier
- Carefully installed, high R-value insulation
- Full coverage exterior weather barrier
- Energy-efficient and condensation-resistant windows and doors
- Whole house mechanical ventilation system
- Safe and efficient heating and cooling systems
- Efficient and safe appliances and lighting

Refer to Minnesota Power's "New Construction Guide to Triple E Homes" for specific standards and incentives.

Windows - Let the Light In (and Sometimes the Heat)

Glazing is critical to the success of a passive solar design. Major window openings should be on the south, southeast and southwest sides of the building according to the internal requirements of each space. Glazing on the south side should allow for solar radiation to enter the space but retain the thermal energy within the space. Window manufacturers are now producing many products that help in the control of heat as well as light through glazed surfaces. When selecting south-facing windows for optimum solar gain, select windows with a high R-value and a high **Shading Coefficient (SC)**. The shading coefficient is the ability of a glazing system to transmit solar heat. The higher the SC, the more solar heat that is transmitted through the glass. On the east, west and north sides of the building, the window openings should be kept to a minimum and should have a high R-value to resist heat loss from the interior of the building. In order to get natural light and radiant energy in the northern part of a building's space, **clerestories** and **skylights** can be added to the design. Clerestories have the advantage of being vertical and projecting up from the roof plane and they can have overhangs for summer shading built into the roof structure. They can be opened to provide for natural ventilation and cooling in the summer months.

Thermal Mass Stores Heat and Moderates Temperature Swings

Another key component of a passive solar design is the thermal mass. During the winter months, direct solar radiation can be stored as heat in interior building components which is then released into the building's space in the evening or during periods of cloudiness. During the summer months, the thermal mass can moderate the need for mechanical cooling by being a heat sink during the day, releasing its heat to the outside by natural ventilation. Both water and masonry materials are used as thermal storage. Water has the advantage of holding more heat per unit volume but masonry has the advantage of being an integral part of the building's structure as a floor or a wall. The outside surface of the thermal mass should be of dark color and be in direct contact with the solar radiation.

Building Siting and Orientation

To take advantage of the heat and light provided by the sun, a building should have its orientation, with a large portion of its windows, towards the south. This means that it should have an elongated shape (not square), with its longest dimension on an east-west axis. Since heat gain is desirable in the winter but not in the summer, the south-facing windows should have overhangs that

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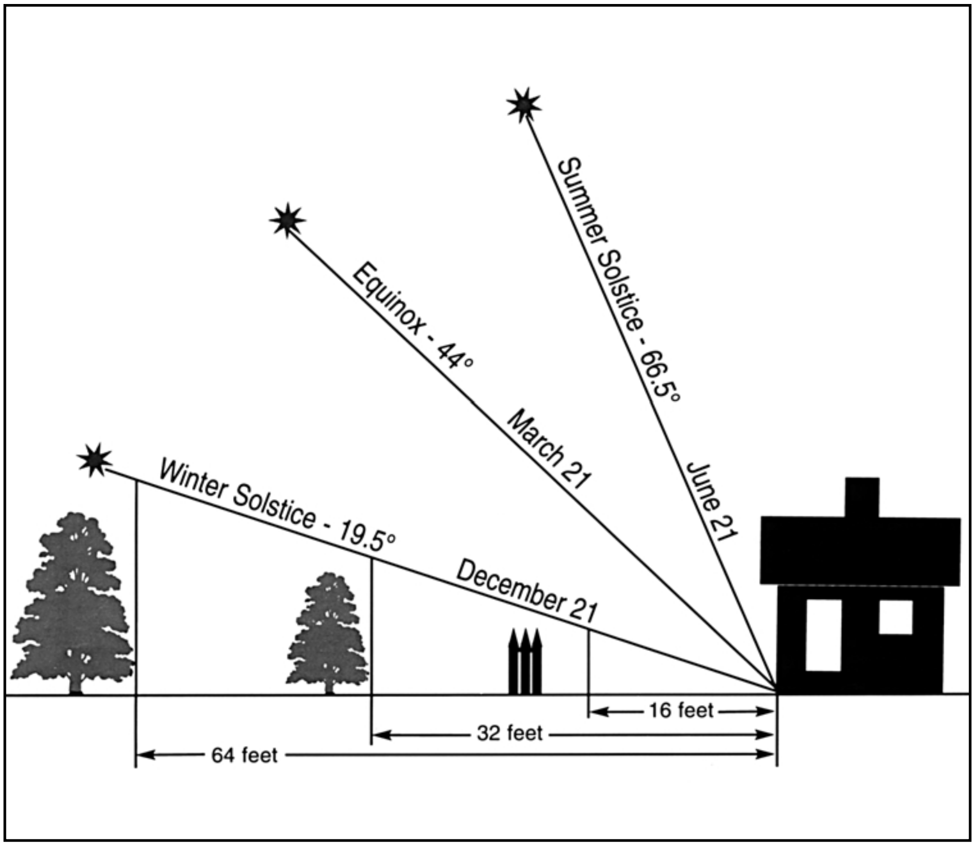
allow for entry of the low angle solar radiation in the winter but block the higher angle sun in the summer (see Solar Geometry). A general recommendation is a two-foot overhang for each eight feet of wall. Buildings that are more than a story high can incorporate "eyebrow" overhangs for each level. Trees, plants and other objects that would block the solar radiation on the south side of the building need to be minimized. On the other hand, it is good to provide landscaping on the other sides to provide shelter from the prevailing winds and shade to block the early morning and late afternoon summer sunlight. The building's shape should allow the north side to slope towards the ground to minimize shading on that side. Building into south-facing slopes or earth-berming north walls will also serve this function.



Solar Geometry

The major consideration in designing a passive solar building is the building's relationship to the position of the sun during different seasons. In northern latitudes, the sun is higher in the southern sky in the summer months and lower in the sky in the winter months. The angle formed between the horizon and the sun is called the **solar altitude**. This angle is the greatest at the summer solstice (mid-June) and the least at the winter solstice (mid-December). The following table gives some typical solar altitudes at solar noon for various Northland locations:

Acceptable Distances from Objects to House

Acceptable distances from objects to house:

Zone A: 0 to 16 feet - No building allowed

Zone B: 16 to 32 feet - Fences only

Zone C: 32 to 64 feet - One-story buildings and trees that are 12 feet or less at maturity

Zone D: 64 feet or more - Two-story buildings or trees that are 24 feet or less at maturity

		Solar Altitude		
Latitude	**Location**	**Summer Solstice**	**Spring/Fall Equinox**	**Winter Solstice**
46°N	Little Falls, MN	67.5°	44°	20.5°
47°N	Two Harbors, MN	66.5°	43°	19.5°
48°N	Lake Vermilion, MN	65.5°	42°	18.5°

Putting it All Together

- A successful passive solar building must be located in an area that can take full advantage of the solar radiation between 9:00 a.m. and 3:00 p.m. (sun time).
- Its shape should be elongated on an east-west axis to expose more area to the south and to minimize the heating and cooling requirements.
- Shape the building so that the north side slopes toward the ground or, if possible, berm earth against the north face of the building.
- Design spaces so that high use areas (living, kitchen/dining, bedrooms, etc.) are on the south side while low use (storage, hallways, stairs, etc.) are on the north side of the building.
- Main entrances to the building should be through protected spaces, with a double entry or airlock to lessen the amount of warmed (or cooled) air from leaving each time a door is opened.

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- Major glass area should be toward the south (30° east or west of south is okay).
- Three passive systems seem appropriate for this climate.
  - *Direct gain systems* use thermal mass in floors or north walls that come in contact with the solar radiation in the winter months.
  - *Thermal storage walls* are interior water or masonry walls on the south side of the building with glazing functioning as a solar collector only, admitting no natural light into the space. Windows can be incorporated in this wall to provide light, heat or a view.
  - *Attached greenhouse* is a third option in which the greenhouse's major component is glazing and the common wall between the living space and the greenhouse is a thermal mass.
- Proper sizing and placement of both the glazing and thermal mass is very important to prevent overheating in the winter or inadequate cooling in the summer.
- Shading devices need to be incorporated in the structure to keep out solar radiation during summer months.
- Additional considerations include **movable insulation** to prevent heat loss at night through the glazing and **reflectors** to increase solar radiation during the day.

Resources

- **The Passive Solar Energy Book**, by Edward Mazria, Rodale Press, 1979.
- **Passive Solar Strategies: Guidelines for Builders**, Passive Solar lndustries Council, 1996.
- **Passive Solar Energy: The Home Owner's Guide to Natural Heating and Cooling**, by Bruce Anderson and Malcolm Wells, Brick House, 1993.
- **Energy - 10 Design Assistance Software**, Passive Solar lndustries Council, 1996.
- **SUN-EARTH: Sustainable Design**, by Richard Crowther, American Solar Energy Society, 1994.
- **The Solar Home Book**, by Bruce Anderson, Cheshire Books, 1976.

Passive Solar Glossary

Clerestory - a window that is placed vertically in a wall above one's line of vision to provide natural light into a building.

Direct gain - solar radiant energy that is converted to heat energy as a result of sunlight entering directly through a window. It is absorbed and stored in floors or walls.

Glazing - transparent or translucent window glass, having three principal performance characteristics that affect energy use: **U-value**, which determines conductive heat loss and gains, **visible-light transmission**, which determines relative amount of light that will enter the space, and **shading coefficient**, which determines relative amount of solar gain, relating to cooling loads.

Sunspace - a south-facing room that takes advantage of direct gain, collecting and absorbing heat that is used in the sunspace and adjacent areas.

Thermal mass - walls, floors and other objects that absorb heat during the day and release it during the night as temperatures drop in the winter. In the summer, it cools down at night and absorbs heat during the day.

Thermal storage wall - a south-facing wall glazed on the outside. Sunshine penetrates the glazing and heats the wall and, over time, that heat is conducted to the building's interiors.

Acknowledgment

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