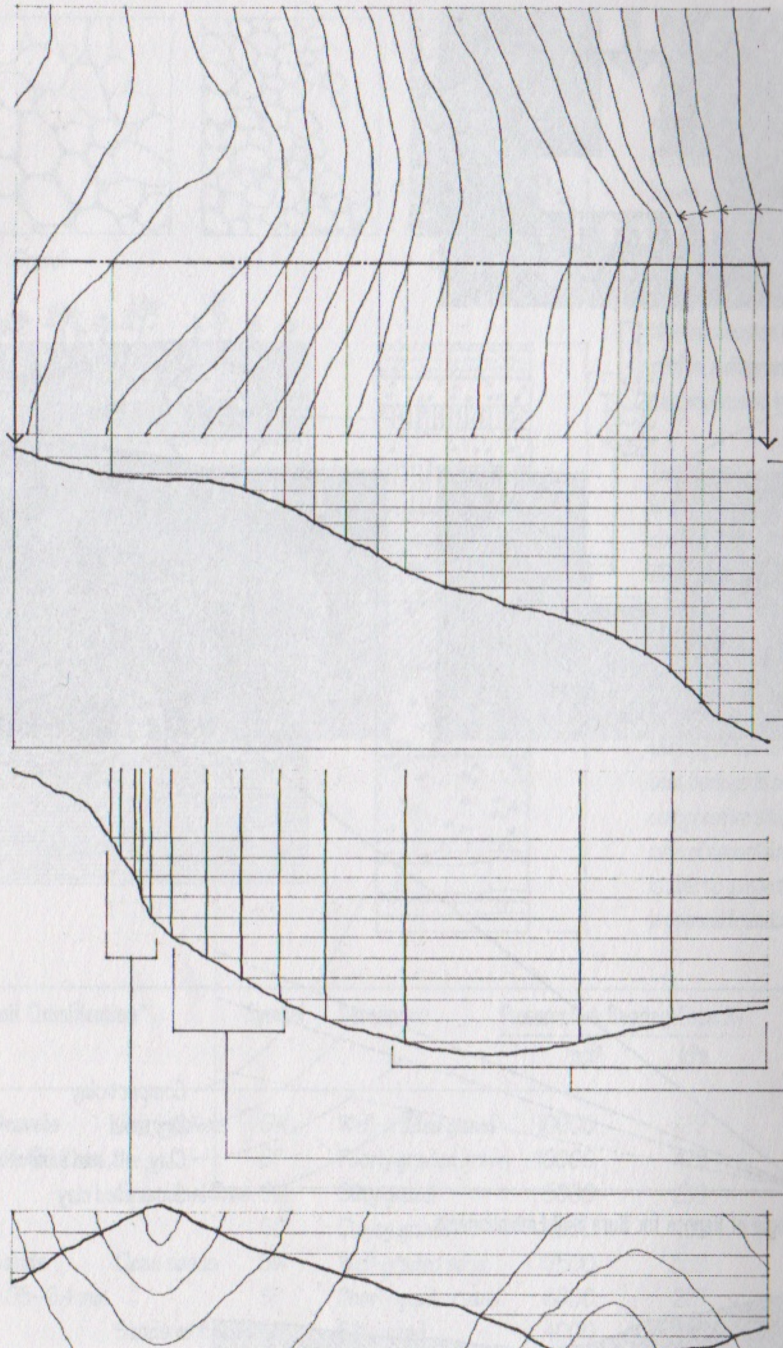


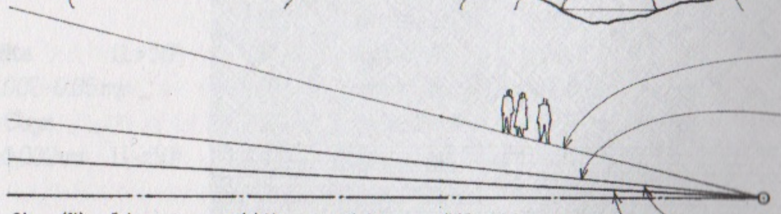
Topography refers to the configuration of surface features of a plot of land, which influences where and how to build and develop a site. To study the response of a building design to the topography of a site, we can use a series of site sections or a site plan with contour lines.

Contour lines are imaginary lines joining points of equal elevation above a datum or bench mark. The trajectory of each contour line indicates the shape of the land formation at that elevation. Note that contour lines are always continuous and never cross one another; they coincide in a plan view only when they cut across a vertical surface.

Contour interval refers to the difference in elevation represented by any two adjacent contour lines on a topographic map or site plan. The interval used is determined by the scale of a drawing, the size of the site, and the nature of the topography. The larger the area and the steeper the slopes, the greater the interval between contours. For large or steeply sloping sites, 20' or 40' (5 or 10 m) contour intervals may be used. For small sites having relatively gradual slopes, 1', 2', or 5' (0.5 or 1.0 m) contours may be necessary.

We can discern the topographical nature of a site by reading the horizontal spacing and shape of contour lines.

- Contours spaced far apart indicate a relatively flat or gently sloping surface.
- Equally spaced contours denote a constant slope.
- Closely spaced contours disclose a relatively steep rise in elevation.
- Contour lines represent a ridge when pointing toward lower elevations; they represent a valley when pointing toward higher elevations.



- Slope (%) = [elevation gain (v)/ horizontal distance (h)] x 100

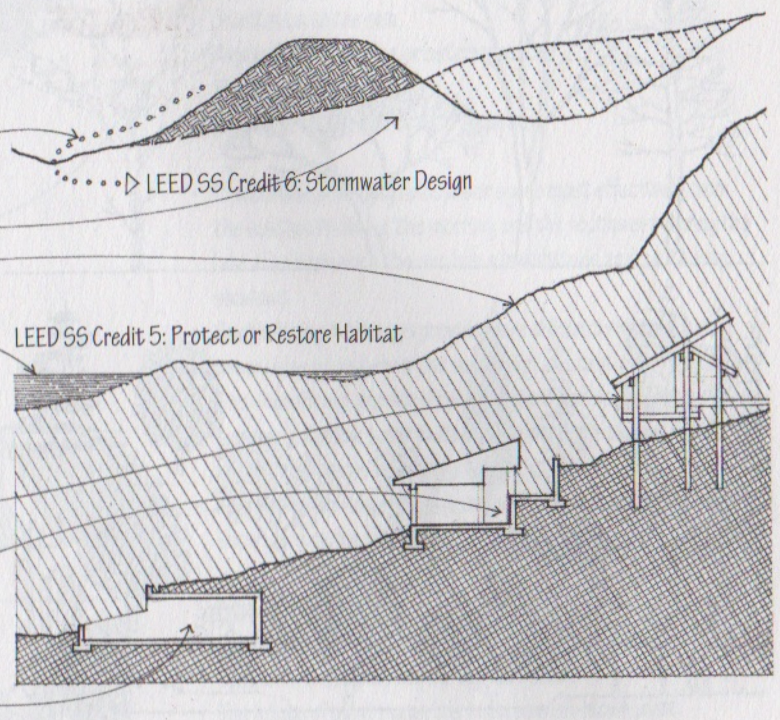
The ground slope between any two contour lines is a function of the total change in elevation and the horizontal distance between the two contours.

- Ground slopes over 25% are subject to erosion and are difficult to build on.
- Ground slopes over 10% are challenging to use for outdoor activities and are more expensive to build on.
- Ground slopes from 5% to 10% are suitable for informal outdoor activities and can be built on without too much difficulty.
- Ground slopes up to 5% are usable for most outdoor activities and relatively easy to build on.

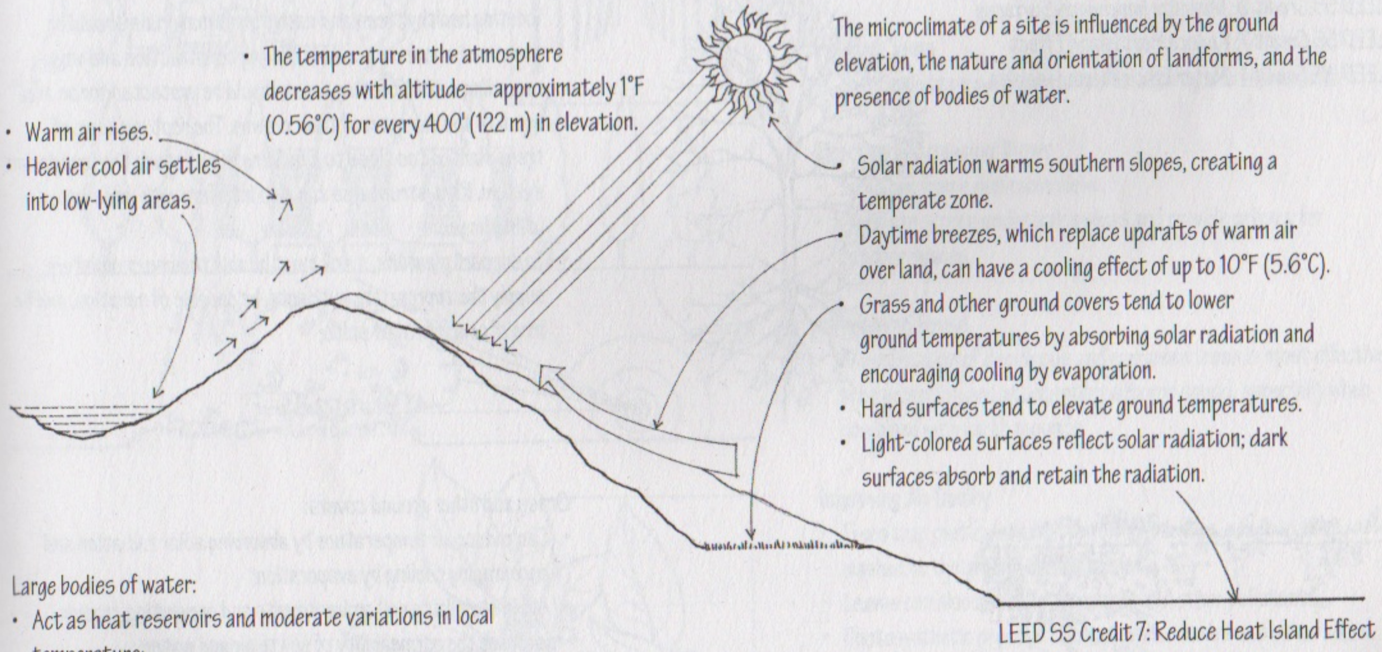
For aesthetic and economic, as well as ecological reasons, the general intent in developing a site should be to minimize the disturbance of existing landforms and features while taking advantage of natural ground slopes and the microclimate of the site.

- Site development and construction should minimize disrupting the natural drainage patterns of the site and adjacent properties.
- When modifying landforms, include provisions for the drainage of surface water and groundwater.
- Attempt to equalize the amount of cut and fill required for construction of a foundation and site development.
- Avoid building on steep slopes subject to erosion or slides.
- Wetlands and other wildlife habitats may require protection and limit the buildable area of a site.
- Pay particular attention to building restrictions on sites located in or near a flood plain.

- Elevating a structure on poles or piers minimizes disturbance of the natural terrain and existing vegetation.
- Terracing or stepping a structure along a slope requires excavation and the use of retaining walls or bench terracing.
- Cutting a structure into a slope or locating it partially underground moderates temperature extremes and minimizes exposure to wind, and heat loss in cold climates.



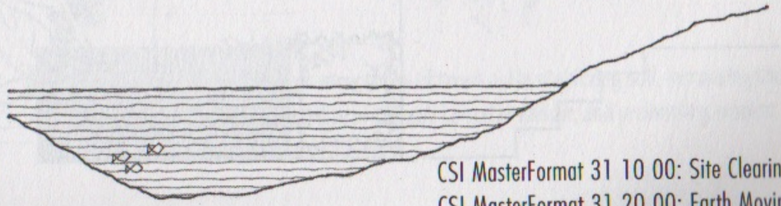
The microclimate of a site is influenced by the ground elevation, the nature and orientation of landforms, and the presence of bodies of water.



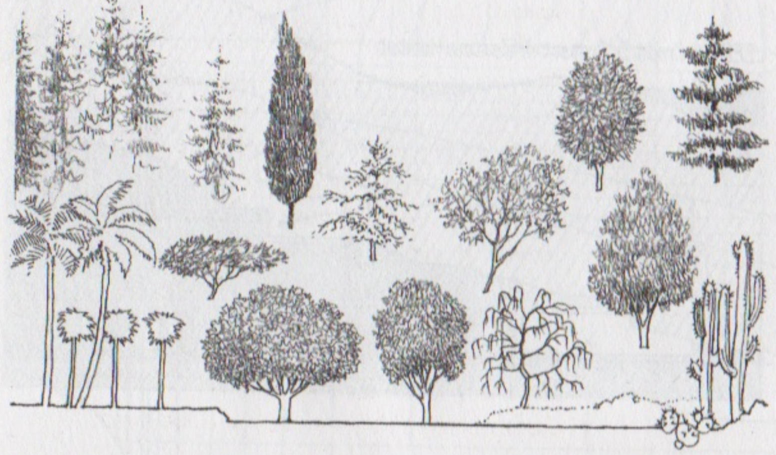
- The temperature in the atmosphere decreases with altitude—approximately 1°F (0.56°C) for every 400' (122 m) in elevation.
- Warm air rises.
- Heavier cool air settles into low-lying areas.
- Solar radiation warms southern slopes, creating a temperate zone.
- Daytime breezes, which replace updrafts of warm air over land, can have a cooling effect of up to 10°F (5.6°C).
- Grass and other ground covers tend to lower ground temperatures by absorbing solar radiation and encouraging cooling by evaporation.
- Hard surfaces tend to elevate ground temperatures.
- Light-colored surfaces reflect solar radiation; dark surfaces absorb and retain the radiation.

Large bodies of water:

- Act as heat reservoirs and moderate variations in local temperature;
- Are generally cooler than land during the day and warmer at night, generating offshore breezes;
- Are generally warmer than land in winter and cooler in summer.
- In hot-dry climates, even small bodies of water are desirable, both psychologically and physically, for their evaporative cooling effect.



CSI MasterFormat 31 10 00: Site Clearing
CSI MasterFormat 31 20 00: Earth Moving
CSI MasterFormat 32 70 00: Wetlands

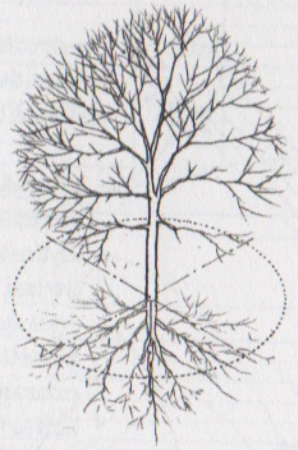


Plant materials provide aesthetic as well as functional benefits in conserving energy, framing or screening views, moderating noise, retarding erosion, and visually connecting a building to its site. Factors to consider in the selection and use of plant materials in landscaping include the:

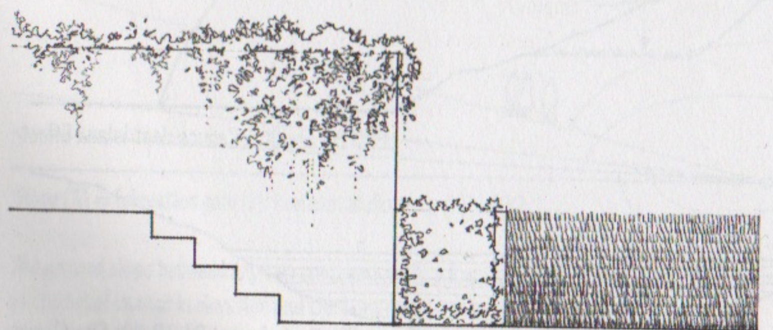
- Tree structure and shape
- Seasonal density, texture, and color of foliage
- Speed or rate of growth
- Mature height and spread of foliage
- Requirements for soil, water, sunlight, and temperature range
- Depth and extent of the root structure

- Trees and other plant life adapt their forms to the climate.

LEED SS Credit 6: Minimize Impervious Surfaces
LEED SS Credit 7: Reduce Heat Island Effect
LEED WE Credit 1: Water Efficient Landscaping



- Existing healthy trees and native plant materials should be preserved whenever possible. During construction and when regrading a site, existing trees should be protected for an area equal to the diameter of their crowns. The root systems of trees planted too close to a building may disturb the foundation system. Root structures can also interfere with underground utility lines.
- To support plant life, a soil must be able to absorb moisture, supply the appropriate nutrients, be capable of aeration, and be free of concentrated salts.



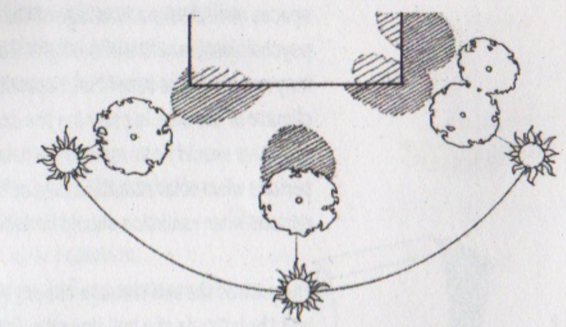
Grass and other ground covers:

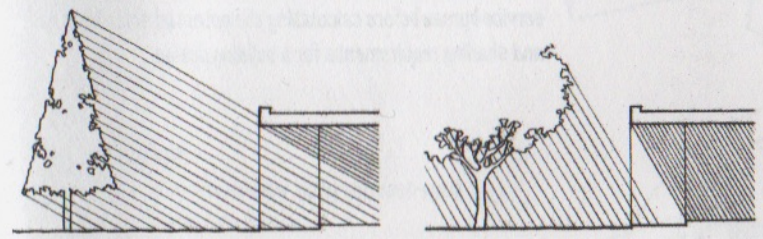
- Can reduce air temperature by absorbing solar radiation and encouraging cooling by evaporation;
- Aid in stabilizing soil embankments and preventing erosion;
- Increase the permeability of soil to air and water.

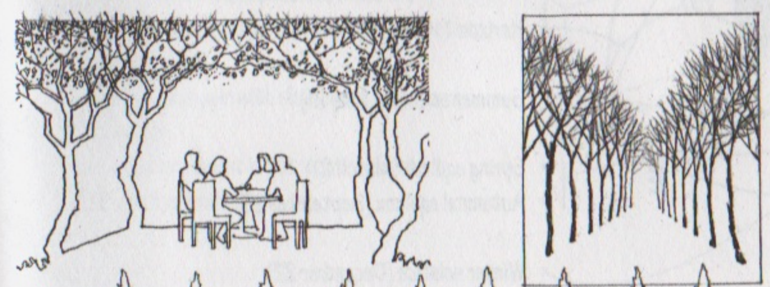
- Vines can reduce the heat transmission through a sunlit wall by providing shade and cooling the immediate environment by evaporation.

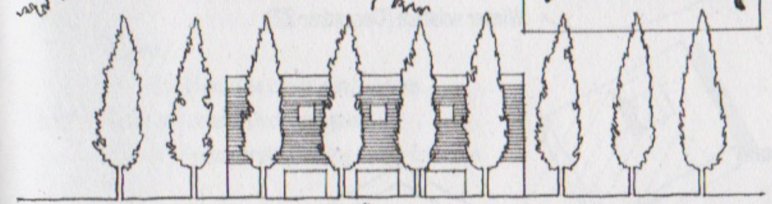
CSI MasterFormat 32 90 00 Planting

Trees affect the immediate environment of a building in the following ways:









Providing Shade

The amount of solar radiation obstructed or filtered by a tree depends on its:

- Orientation to the sun
- Proximity to a building or outdoor space
- Shape, spread, and height
- Density of foliage and branch structure

- Trees shade a building or outdoor space most effectively from the southeast during the morning and the southwest during the late afternoon when the sun has a low altitude and casts long shadows.
- South-facing overhangs provide more efficient shading during the midday period when the sun is high and casts short shadows.
- Deciduous trees provide shade and glare protection during the summer and allow solar radiation to penetrate through their branch structures during the winter.
- Evergreens provide shade throughout the year and help reduce snow glare during the winter.

Serving as Windbreak

- Evergreens can form effective windbreaks and reduce heat loss from a building during the winter.
- The foliage of plant materials reduces wind-blown dust.
- See also 1.24.

Defining Space

- Trees can shape outdoor spaces for activity and movement.

Directing or Screening Views

- Trees can frame desirable views.
- Trees can screen undesirable views and provide privacy for outdoor spaces.

Attenuating Sound

- A combination of deciduous and evergreen trees is most effective in intercepting and attenuating airborne sound, especially when combined with earth mounds.

Improving Air Quality

- Trees trap particulate matter on their leaves, which is then washed to the ground during rainfall.
- Leaves can also assimilate gaseous and other pollutants.
- Photosynthetic process can metabolize fumes and other odors.

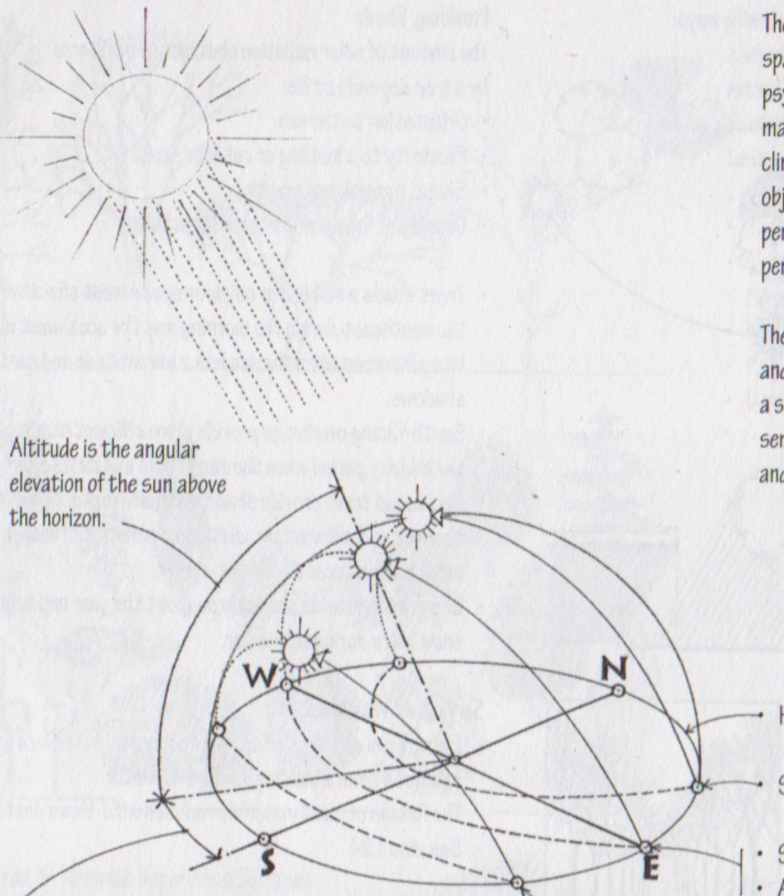
Stabilizing Soil

- The root structures of trees aid in stabilizing soil, increasing the permeability of the soil to water and air, and preventing erosion.

The location, form, and orientation of a building and its spaces should take advantage of the thermal, hygienic, and psychological benefits of sunlight. Solar radiation, however, may not always be beneficial, depending on the latitude and climate of the site. In planning the design of a building, the objective should be to maintain a balance between underheated periods when solar radiation is beneficial and overheated periods when radiation should be avoided.

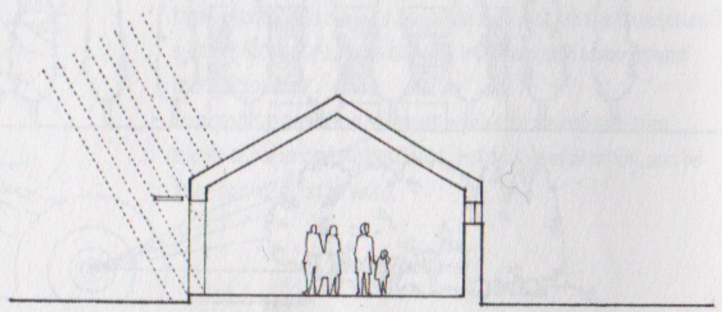
The path of the sun through the sky varies with the seasons and the latitude of a building site. The range of solar angles for a specific site should be obtained from a weather almanac or service bureau before calculating the potential solar heat gain and shading requirements for a building design.

- Altitude is the angular elevation of the sun above the horizon.



- Azimuth is the angle of horizontal deviation, measured clockwise, of a bearing from a standard south direction.

Solar Path Diagram



Representative Solar Angles

North Latitude	Representative City	Altitude at Noon		Azimuth at Sunrise & Sunset*	
		Dec. 22	Mar. 21/Sept. 22	Dec. 22	June 21
48°	Seattle	18°	42°	54°	124°
44°	Toronto	22°	46°	56°	122°
40°	Denver	26°	50°	58°	120°
36°	Tulsa	30°	54°	60°	118°
32°	Phoenix	34°	58°	62°	116°

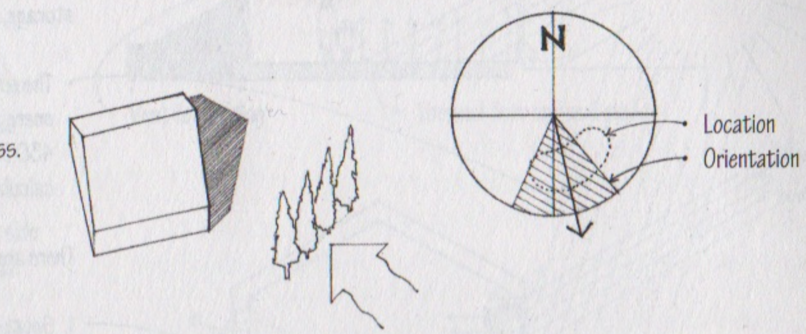
* Azimuth is east of south for sunrise, and west of south for sunset.

The following are recommended forms and orientations for isolated buildings in different climatic regions. The information presented should be considered along with other contextual and programmatic requirements.

Cool Regions

Minimizing the surface area of a building reduces exposure to low temperatures.

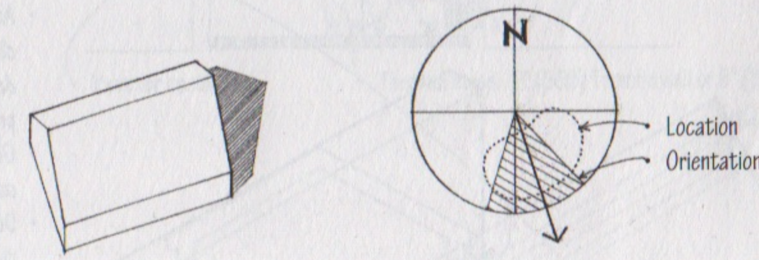
- Maximize absorption of solar radiation.
- Reduce radiant, conductive, and evaporative heat loss.
- Provide wind protection.



Temperate Regions

Elongating the form of a building along the east-west axis maximizes south-facing walls.

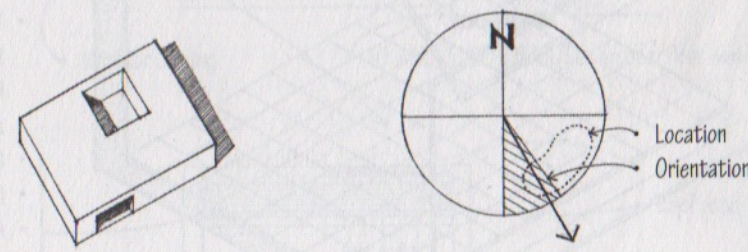
- Minimize east and west exposures, which are generally warmer in summer and cooler in winter than southern exposures.
- Balance solar heat gain with shade protection on a seasonal basis.
- Encourage air movement in hot weather; protect against wind in cold weather.



Hot-Arid Regions

Building forms should enclose courtyard spaces.

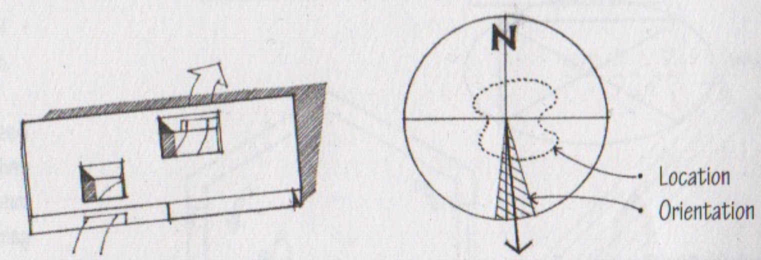
- Reduce solar and conductive heat gain.
- Promote cooling by evaporation using water features and plantings.
- Provide solar shading for windows and outdoor spaces.



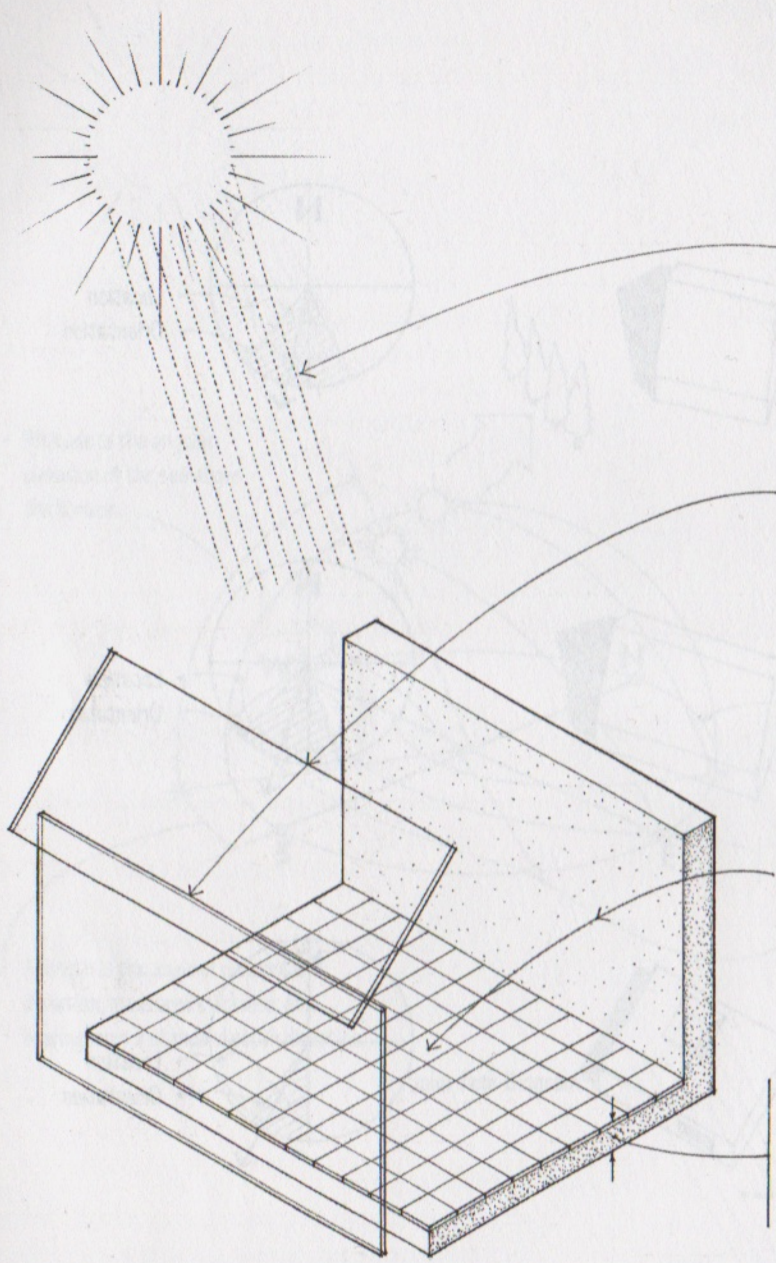
Hot-Humid Regions

Building form elongated along the east-west axis minimizes east and west exposures.

- Reduce solar heat gain.
- Utilize wind to promote cooling by evaporation.
- Provide solar shading for windows and outdoor spaces.



LEED EA Credit 1: Optimize Energy Performance



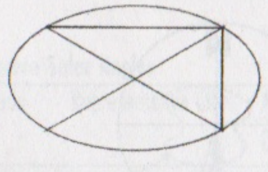
Passive solar heating refers to using solar energy to heat the interior spaces of a building without relying on mechanical devices that require additional energy. Passive solar systems rely instead on the natural heat transfer processes of conduction, convection, and radiation for the collection, storage, distribution, and control of solar energy.

- The solar constant is the average rate at which radiant energy from the sun is received by the earth, equal to 430 Btu per square foot per hour (1353 W/m²/hr), used in calculating the effects of solar radiation on buildings.

There are two essential elements in every passive solar system:

1. South-facing glass or transparent plastic for solar collection
   - Area of glazing should be 30% to 50% of floor area in cold climates and 15% to 25% of floor area in temperate climates, depending on average outdoor winter temperature and projected heat loss.
   - Glazing material should be resistant to the degradation caused by the ultraviolet rays of the sun.
   - Double-glazing and insulation are required to minimize nighttime heat loss.
2. A thermal mass for heat collection, storage, and distribution, oriented to receive maximum solar exposure
   - Thermal storage materials include concrete, brick, stone, tile, rammed earth, sand, and water or other liquid. Phase-change materials, such as eutetic salts and paraffins, are also feasible.
   - Concrete: 12" to 18" (305 to 455)
   - Brick: 10" to 14" (255 to 355)
   - Adobe: 8" to 12" (200 to 305)
   - Water: 6" (150) or more
   - Dark-colored surfaces absorb more solar radiation than light-colored surfaces.

- Vents, dampers, movable insulation panels, and shading devices can assist in balancing heat distribution.

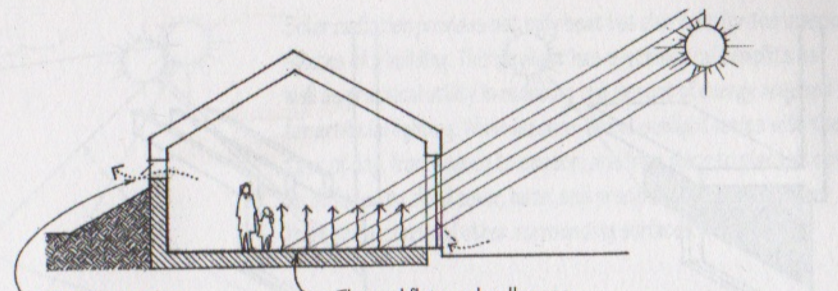


Based on the relationship between the sun, the interior space, and the heat collection system, there are three ways in which passive solar heating can be accomplished: direct gain, indirect gain, and isolated gain.

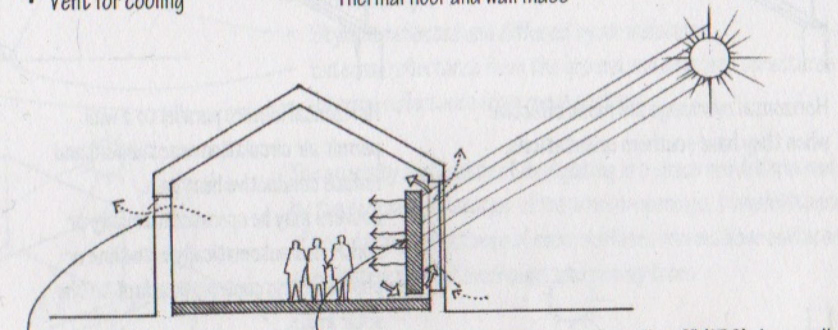
LEED EA Credit 2: On-Site Renewable Energy
LEED EA Credit 6 Green Power

CSI MasterFormat 23 56 00 Solar Energy Heating Equipment

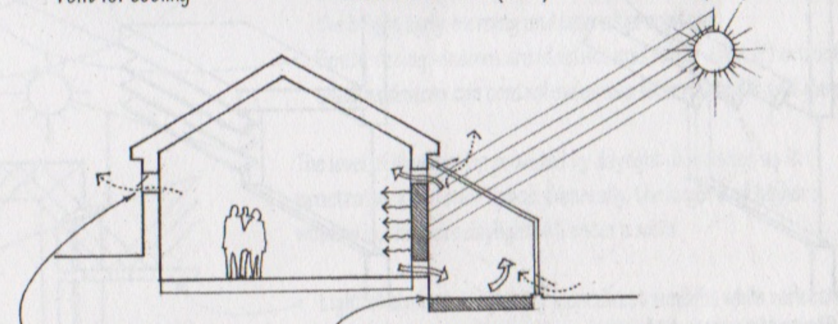
Direct Gain
Direct gain systems collect heat directly within an interior space. The surface area of the storage mass, which is incorporated into the space, should be 50% to 66% of the total surface area of the space. During the cooling season, operable windows and walls are used for natural or induced ventilation.



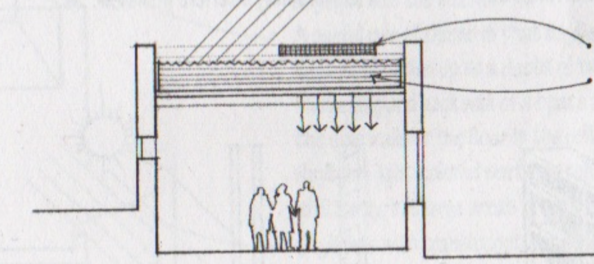
Indirect Gain
Indirect gain systems control heat gain at the exterior skin of a building. The solar radiation first strikes the thermal mass, either a concrete or masonry Trombe wall, or a drumwall of water-filled barrels or tubes, which is located between the sun and the living space. The absorbed solar energy moves through the wall by conduction and then to the space by radiation and convection.



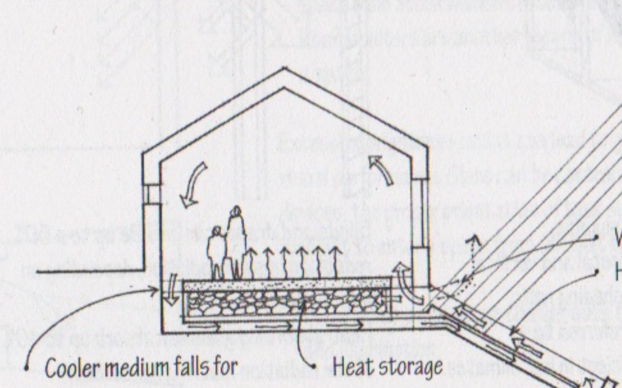
Sunspace
A sunroom or solarium is another medium for indirect heat gain. The sunspace, having a floor of high thermal mass, is separated from the main living space by a thermal storage wall from which heat is drawn as needed. For cooling, the sunspace can be vented to the exterior.



Roof Pond
Another form of indirect gain is a roof pond that serves as a liquid mass for absorbing and storing solar energy. An insulating panel is moved over the roof pond at night, allowing the stored heat to radiate downward into the space. In summer, the process is reversed to allow internal heat absorbed during the day to radiate to the sky at night.

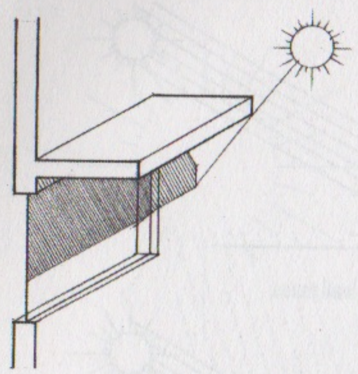


Isolated Gain
Isolated gain systems collect and store solar radiation away from the space to be heated. As air or water in a collector is warmed by the sun, it rises to the served space or is stored in the thermal mass until needed. Simultaneously, cooler air or water is pulled from the bottom of the thermal storage, creating a natural convection loop.

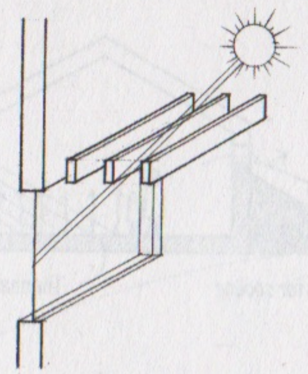


Shading devices shield windows and other glazed areas from direct sunlight in order to reduce glare and excessive solar heat gain in warm weather. Their effectiveness depends on their form and orientation relative to the solar altitude and azimuth for the time of day and season of the year. Exterior devices are more efficient than those located within interior spaces because they intercept solar rays before they can reach an exterior wall or window.

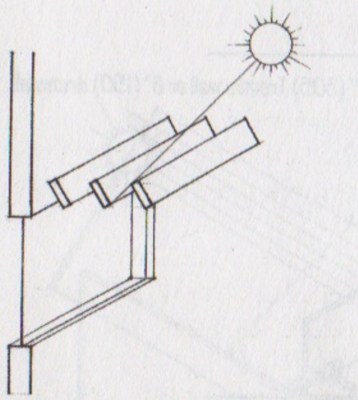
Illustrated are basic types of solar shading devices. Their form, orientation, materials, and construction may vary to suit specific situations. Their visual qualities of pattern, texture, and rhythm, and the shadows they cast, should be considered when designing the facades of a building.



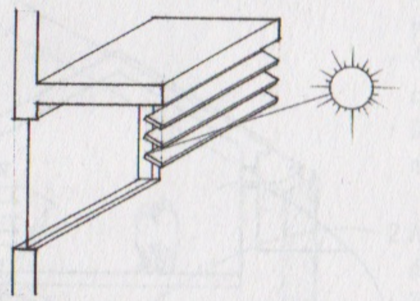
- Horizontal overhangs are most effective when they have southern orientations.



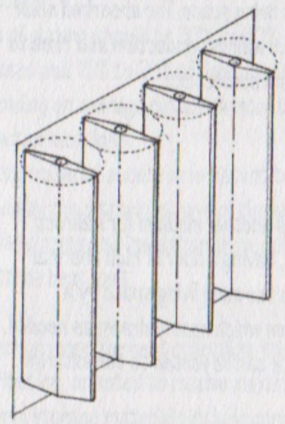
- Horizontal louvers parallel to a wall permit air circulation near the wall and reduce conductive heat gain.
- Louvers may be operated manually or controlled automatically with time or photoelectric controls to adapt to the solar angle.



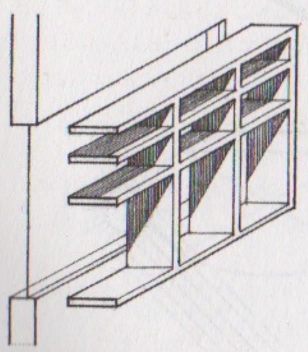
- Slanted louvers provide more protection than those parallel to a wall.
- Angle varies according to the range of solar angles.



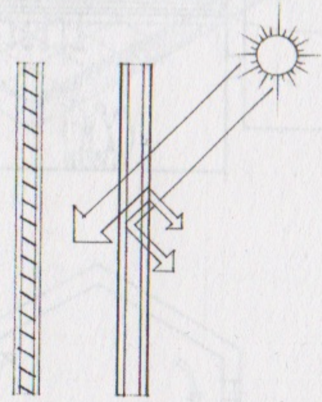
- Louvers hung from a solid overhang protect against low sun angles.
- Louvers may interfere with view.



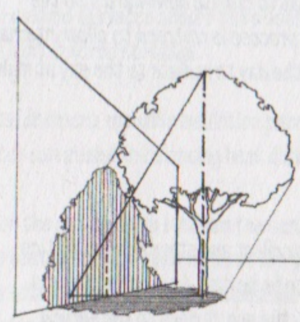
- Vertical louvers are most effective for eastern or western exposures.
- Louvers may be operated manually or controlled automatically with time or photoelectric controls to adapt to solar angle.
- Separation from wall reduces conductive heat gain.



- Eggcrates combine the shading characteristics of horizontal and vertical louvers and have a high shading ratio.
- Eggcrates, sometimes referred to as brise-soleil, are very efficient in hot climates.



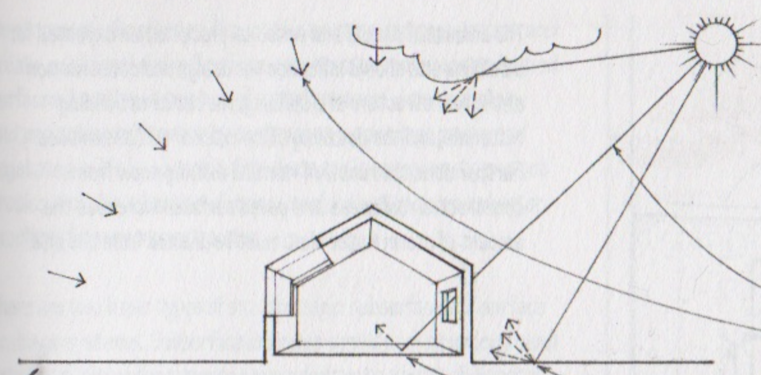
- Blinds and drapes can provide up to a 50% reduction in solar radiation, depending on their reflectivity.
- Heat-absorbing glass can absorb up to 40% of the radiation reaching its surface.



- Trees and adjacent structures may provide shade depending on their proximity, height, and orientation.

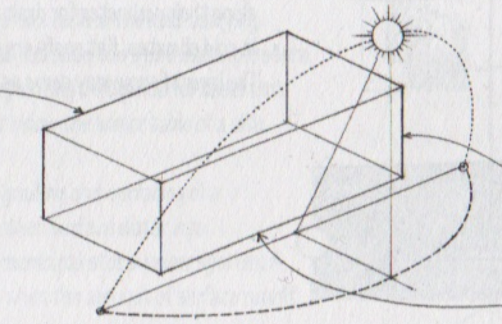
CSI MasterFormat 10 71 13 Exterior Sun Control Devices

Solar radiation provides not only heat but also light for the interior spaces of a building. This daylight has psychological benefits as well as practical utility in reducing the amount of energy required for artificial lighting. While intense, direct sunlight varies with the time of day, from season to season, and from place to place, it can be diffused by cloud cover, haze, and precipitation, and reflected from the ground and other surrounding surfaces.



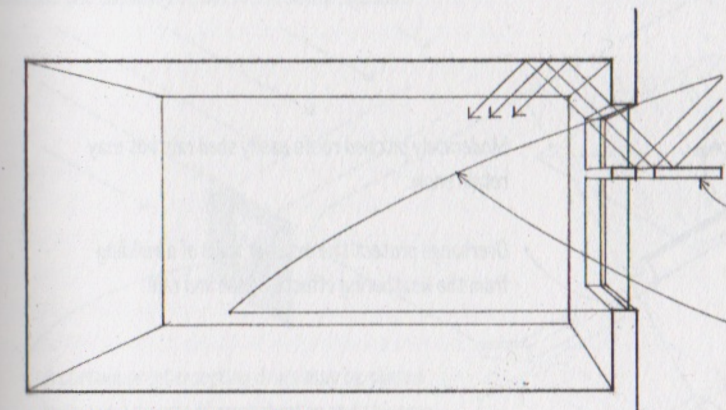
- Direct sunlight
- Skylight reflected and diffused by air molecules
- External reflectance from the ground and adjacent structures
- Internal reflectance from room surfaces

The quantity and quality of daylighting in a space are determined by the size and orientation of its window openings, transmittance of the glazing, reflectance of room surfaces and outdoor surfaces, and obstructions of overhangs and nearby trees.



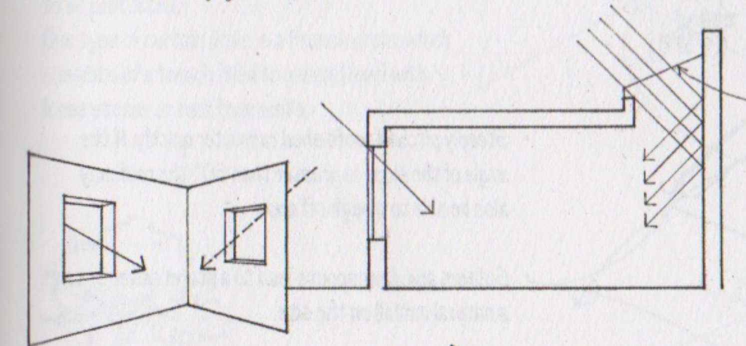
- North-facing windows let in soft, diffuse skylight.
- East- and west-facing windows require shading devices to avoid the bright early-morning and late-afternoon sun.
- South-facing windows are ideal sources for daylight if horizontal shading devices can control excessive solar radiation and glare.

The level of illumination provided by daylight diminishes as it penetrates an interior space. Generally, the larger and higher a window is, the more daylight will enter a room.



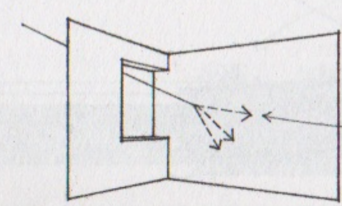
LEED EQ Credit 8: Daylight & Views

- Light shelves shade glazing from direct sunlight while reflecting daylight onto the ceiling of a room. A series of parallel, opaque white louvers can also provide solar shading and reflect diffused daylight into the interior.
- A useful rule of thumb is that daylighting can be effective for task illumination up to a depth of twice the height of a window.
- The ceiling and back wall of a space are more effective than the side walls or the floor in the reflection and distribution of daylight; light-colored surfaces reflect and distribute light more efficiently, but large areas of shiny surfaces can cause glare.

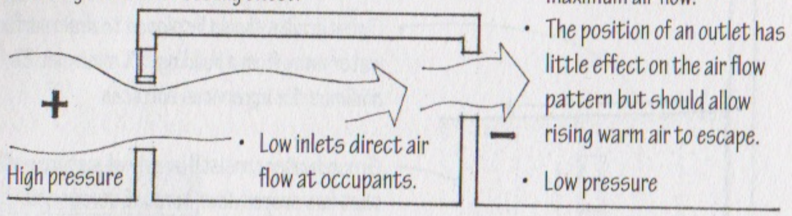


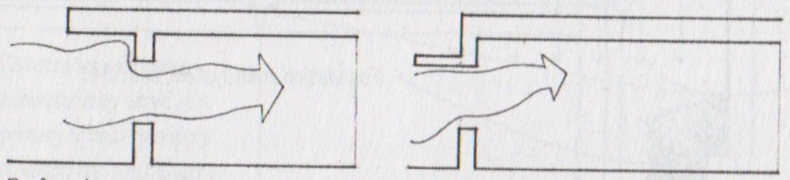
- Skylights with translucent glazing can effectively daylight a space from above without excessive heat gain.
- Roof monitors are another means of reflecting daylight into a space.
- For the most balanced daylighting, allow daylight to penetrate a space from at least two directions.

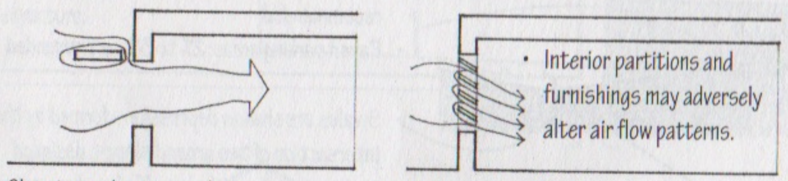
Excessive brightness ratios can lead to glare and impairment of visual performance. Glare can be controlled by the use of shading devices, the proper orientation of task surfaces, and allowing daylight to enter a space from at least two directions.

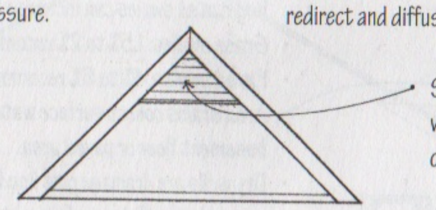


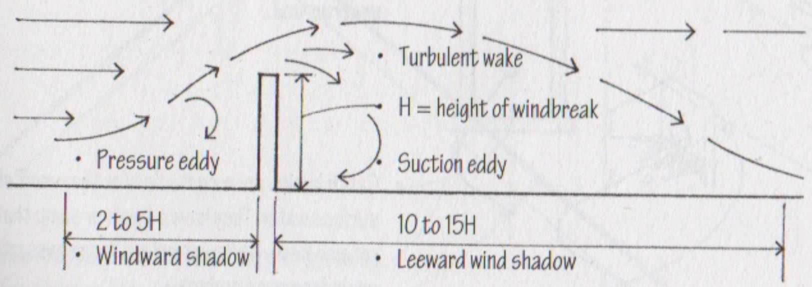
- Place windows adjacent to side walls for additional reflectance and illumination.

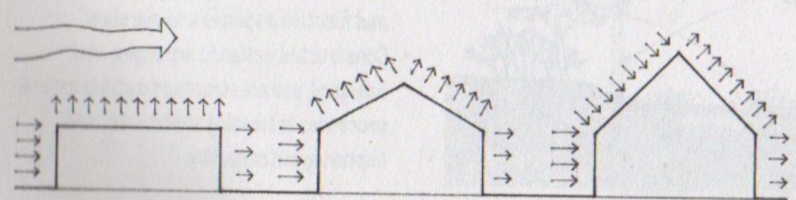












The direction and velocity of prevailing winds are important site considerations in all climatic regions. The seasonal and daily variations in wind should be carefully considered in evaluating its potential for ventilating interior spaces and outdoor courtyards in warm weather, causing heat loss in cold weather, and imposing lateral loads on a building structure.

Wind-induced ventilation of interior spaces aids in the air exchange necessary for health and odor removal. In hot weather, and especially in humid climates, ventilation is beneficial for convective or evaporative cooling. Natural ventilation also reduces the energy required by mechanical fans and equipment.
(LEED EQ Credit 2: Increased Ventilation)

The movement of air through a building is generated by differences in air pressure as well as temperature. The resulting patterns of air flow are affected more by building geometry and orientation than by air speed.

The ventilation of concealed roof and crawl spaces is required to remove moisture and control condensation. In hot weather, attic ventilation can also reduce overhead radiant heat gain.

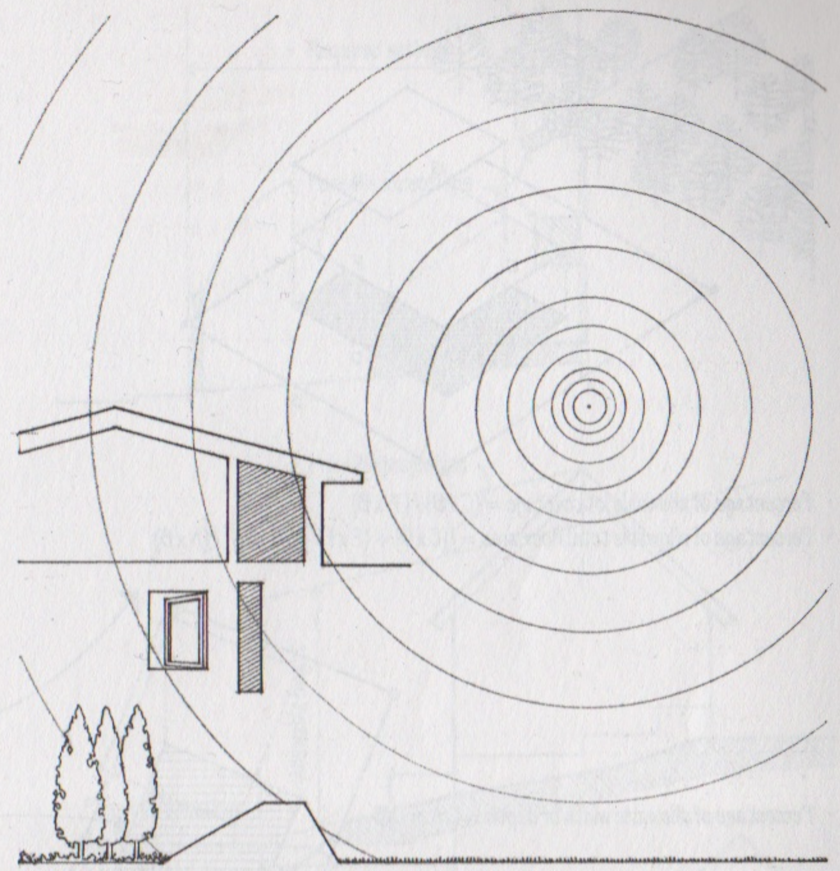
In cold climates, a building should be buffered against chilling winds to reduce infiltration into interior spaces and lower heat loss. A windbreak may be in the form of an earth berm, a garden wall, or a dense stand of trees. Windbreaks reduce wind velocity and produce an area of relative calm on their leeward side. The extent of this wind shadow depends on the height, depth, and density of the windbreak, its orientation to the wind, and the wind velocity.

- A partially penetrable windscreen creates less pressure differential, resulting in a large wind shadow on the leeward side of the screen.

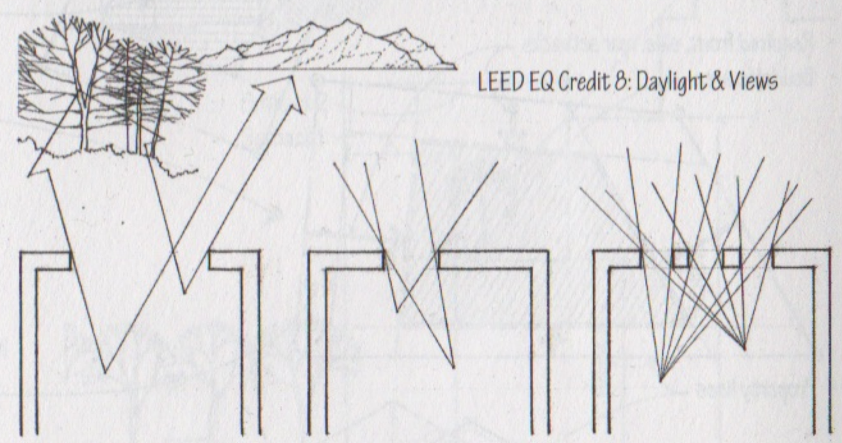
The structure, components, and cladding of a building must be anchored to resist wind-induced overturning, uplift, and sliding. Wind exerts positive pressure on the windward surfaces of a building and on windward roof surfaces having a slope greater than 30°. Wind exerts negative pressure or suction on the sides and leeward surfaces and normal to windward roof surfaces having a slope less than 30°. See 2.09 for more information on wind forces.

Sound requires a source and a path. Undesirable exterior sounds or noise may be caused by vehicular traffic, aircraft, and other machinery. The sound energy they generate travels through the air outward from the source in all directions in a continuously expanding wave. This sound energy, however, lessens in intensity as it disperses over a wide area. To reduce the impact of exterior noise, therefore, the first consideration should be distance—locating a building as far from the noise source as possible. When the location or dimensions of a site do not make this possible, then the interior spaces of a building may be screened from the noise source in the following ways.

- Use building zones where noise can be tolerated, for example, mechanical, service, and utility areas, as a buffer.
- Employ building materials and construction assemblies designed to reduce the transmission of airborne and structure-borne sound.
- Orient door and window openings away from the sources of undesirable noise.
- Place physical mass, such as earth berms, between the noise source and the building.
- Utilize dense plantings of trees and shrubs, which can be effective in diffusing or scattering sound.
- Plant grass or other ground cover, which is more absorptive than the hard, reflective surfaces of pavements.



An important aspect of site planning is orienting the interior spaces of a building to the amenities and features of a site. Given the appropriate orientation, window openings in these spaces should be positioned not only to satisfy the requirements for natural light and ventilation, but also to reveal and frame desirable views. Depending on the location of the site, these views may be close or distant in nature. Even when desirable views are nonexistent, a pleasant outlook can often be created within a building site through landscaping.



A window may be created within a wall in a number of ways, depending on the nature of the view and the way it is framed in the wall construction. It is important to note that the size and location of windows also affect the spatial quality and daylighting of a room, and the potential for heat loss or gain.

- South-facing windows can be effectively shaded while admitting daylight.
- North-facing windows are exposed to winter winds in cool climates.
- East- and west-facing windows are sources of overheating and are difficult to shade effectively.