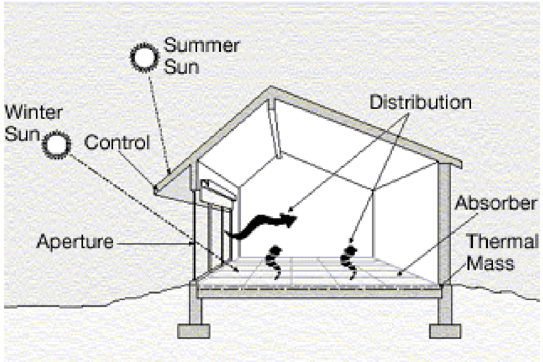
Passive solar building design

In **passive solar building design**, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. This is called passive solar design or climatic design because, unlike active solar heating systems, it doesn't involve the use of mechanical and electrical devices.[1]



Elements of passive solar design, shown in a direct gain application

The key to designing a passive solar building is to best take advantage of the local climate. Elements to be considered include window placement and glazing type, thermal insulation, thermal mass, and shading. Passive solar design techniques can be applied most easily to new buildings, but existing buildings can be adapted or "retrofitted".

Passive energy gain

Passive solar technologies use sunlight without active mechanical systems (as contrasted to active solar). Such technologies convert sunlight into usable heat (water, air, thermal mass), cause air-movement for ventilating, or future use, with little use of other energy sources. A common example is a solarium on the equator-side of a building. Passive cooling is the use of the same design principles to reduce summer cooling requirements.

Some passive systems use a small amount of conventional energy to control dampers, shutters, night insulation, and other devices that enhance solar energy collection, storage, and use, and reduce undesirable heat transfer.

Passive solar technologies include direct and indirect solar gain for space heating, solar water heating systems based on the thermosiphon or geyser pump [2], use of thermal mass and phase-change materials for slowing indoor air temperature swings, solar cookers, the solar chimney for enhancing natural ventilation, and earth sheltering.

More widely, passive solar technologies include the solar furnace and solar forge, but these typically require some external energy for aligning their concentrating mirrors or receivers, and historically have not proven to be practical or cost effective for widespread use. 'Low-grade' energy needs, such as space and water heating, have proven, over time, to be better applications for passive use of solar energy.

As a science

The scientific basis for **Passive Solar Building Design**[3] has been developed from a combination of climatology, thermodynamics (particularly heat transfer: conduction (heat), convection, and electromagnetic radiation), fluid mechanics / natural convection (passive movement of air and water without the use of electricity, fans or pumps), and human thermal comfort based on heat index, psychrometrics and enthalpy control for buildings to be inhabited by humans or animals, sunrooms, solariums, and greenhouses for raising plants.

Specific attention is divided into: the site, location and solar orientation of the building, local sun path, the prevailing level of insolation (latitude / sunshine / clouds / precipitation (meteorology)), design and construction quality / materials, placement / size / type of windows and walls, and incorporation of solar-energy-storing thermal mass with heat capacity.

While these considerations may be directed toward any building, achieving an ideal optimized cost / performance solution requires careful, holistic, system integration engineering of these scientific principles. Modern refinements through computer modeling (such as the comprehensive U.S. Department of Energy "Energy Plus"[4] energy simulation software), and application of decades of lessons learned (since the 1970s energy crisis) can achieve significant energy savings and reduction of environmental damage, without sacrificing functionality or aesthetics.[5] In fact, passive-solar design features such as a greenhouse / sunroom / solarium can greatly enhance the livability, daylight, views, and value of a home, at a low cost per unit of space.

Much has been learned about passive solar building design since the 1970s energy crisis. Many unscientific, intuition-based expensive construction experiments have attempted and failed to achieve zero energy - the total elimination of heating-and-cooling energy bills.

Passive solar building construction may not be difficult or expensive (using off-the-shelf existing materials and technology), but the scientific passive solar building design is a non-trivial engineering effort that requires significant study of previous counter-intuitive lessons learned, and time to enter, evaluate, and iteratively refine the computer simulation input and output.

One of the most useful post-construction evaluation tools has been the use of thermography using digital thermal imaging cameras for a formal quantitative scientific energy audit. Thermal imaging can be used to document areas of poor thermal performance such as the negative thermal impact of roof-angled glass or a skylight on a cold winter night or hot summer day.

The scientific lessons learned over the last three decades have been captured in sophisticated comprehensive energy simulation computer software systems (like U.S. DOE Energy Plus, *et al.*).

Scientific passive solar building design with quantitative cost benefit product optimization is not easy for a novice. The level of complexity has resulted in ongoing bad-architecture, and many intuition-based, unscientific construction experiments that disappoint their designers and waste a significant portion of their construction budget on inappropriate ideas.

The economic motivation for scientific design and engineering is significant. If it had been applied comprehensively to new building construction beginning in 1980 (based on 1970's lessons learned), America could be saving over $250,000,000 per year on expensive energy and related pollution today.

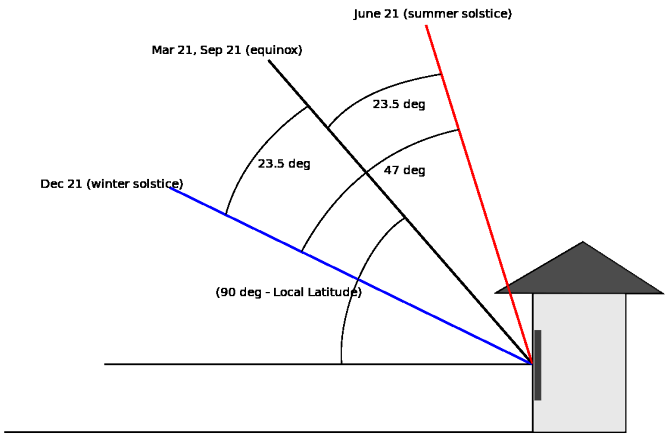
Since 1979, Passive Solar Building Design has been a critical element of achieving zero energy by educational institution experiments, and governments around the world, including the U.S. Department of Energy, and the energy research scientists that they have supported for decades. The cost effective proof of concept was established decades ago, but cultural assimilation into architecture, construction trades, and building-owner decision making has been very slow and difficult to change.

The new terms "Architectural Science" and "Architectural Technology" are being added to some schools of Architecture, with a future goal of teaching the above scientific and energy-engineering principles.

The solar path in passive design

The ability to achieve these goals simultaneously is fundamentally dependent on the seasonal variations in the sun's path throughout the day.

This occurs as a result of the inclination of the Earth's axis of rotation in relation to its orbit. The sun path is unique for any given latitude.



Solar altitude over a year; latitude based on New York, New York

In Northern Hemisphere non-tropical latitudes farther than 23.5 degrees from the equator:

- The sun will reach its highest point toward the South in the Northern Hemisphere and the North in the Southern Hemisphere (in the direction of the equator)
- As winter solstice approaches, the angle at which the sun rises and sets progressively moves further toward the South and the daylight hours will become shorter
- The opposite is noted in summer where the sun will rise and set further toward the North and the daylight hours will lengthen[6]

The converse is observed in the Southern Hemisphere, but the sun rises to the east and sets toward the west regardless of which hemisphere you are in.

In equatorial regions at less than 23.5 degrees, the position of the sun at solar noon will oscillate from north to south and back again during the year.[7]

In regions closer than 23.5 degrees from either north-or-south pole, during summer the sun will trace a complete circle in the sky without setting whilst it will never appear above the horizon six months later, during the height of winter.[8]

The 47-degree difference in the altitude of the sun at solar noon between winter and summer forms the basis of passive solar design. This information is combined with local climatic data (degree day) heating and cooling requirements to determine at what time of the year solar gain will be beneficial for thermal comfort, and when it should be blocked with shading. By strategic placement of items such as glazing and shading devices, the percent of solar gain entering a building can be controlled throughout the year.

One passive solar sun path design problem is that although the sun is in the same relative position six weeks before, and six weeks after, the solstice, due to "thermal lag" from the thermal mass of the Earth, the temperature and solar gain requirements are quite different before and after the summer or winter solstice. Movable shutters, shades, shade screens, or window quilts can accommodate day-to-day and hour-to-hour solar gain and insulation requirements.

Careful arrangement of rooms completes the passive solar design. A common recommendation for residential dwellings is to place living areas facing solar noon and sleeping quarters on the opposite side.[9] A heliodon is a traditional movable light device used by architects and designers to help model sun path effects. In modern times, 3D computer graphics can visually simulate this data, and calculate performance predictions.[5]

Passive solar thermodynamic principles

Personal thermal comfort is a function of personal health factors (medical, psychological, sociological and situational),ambient air temperature, mean radiant temperature, air movement (wind chill, turbulence) and relative humidity (affecting human evaporative cooling). Heat transfer in buildings occurs through convection, conduction, and thermal radiation through roof, walls, floor and windows.[10]

Convective heat transfer

Convective heat transfer can be beneficial or detrimental. Uncontrolled air infiltration from poor weatherization / weatherstripping / draft-proofing can contribute up to 40% of heat loss during winter;[11] however, strategic placement of operable windows or vents can enhance convection, cross-ventilation, and summer cooling when the outside air is of a comfortable temperature and relative humidity.[12] Filtered energy recovery ventilation systems may be useful to eliminate undesirable humidity, dust, pollen, and microorganisms in unfiltered ventilation air.

Natural convection causing rising warm air and falling cooler air can result in an uneven stratification of heat. This may cause uncomfortable variations in temperature in the upper and lower conditioned space, serve as a method of venting hot air, or be designed in as a natural-convection air-flow loop for passive solar heat distribution and temperature equalization. Natural human cooling by perspiration and evaporation may be facilitated through natural or forced convective air movement by fans, but ceiling fans can disturb the stratified insulating air layers at the top of a room, and accelerate heat transfer from a hot attic, or through nearby windows. In addition, high relative humidity inhibits evaporative cooling by humans.

Radiative heat transfer

The main source of heat transfer is radiant energy, and the primary source is the sun. Solar radiation occurs predominantly through the roof and windows (but also through walls). Thermal radiation moves from a warmer surface to a cooler one. Roofs receive the majority of the solar radiation delivered to a house. A cool roof, or green roof in addition to a radiant barrier can help prevent your attic from becoming hotter than the peak summer outdoor air temperature[13] (see albedo, absorptivity, emissivity, and reflectivity).

Windows are a ready and predictable site for thermal radiation.[14] Energy from radiation can move into a window in the day time, and out of the same window at night. Radiation uses photons to transmit electromagnetic waves through a vacuum, or translucent medium. Solar heat gain can be significant even on cold clear days. Solar heat gain through windows can be reduced by insulated glazing, shading, and orientation. Windows are particularly difficult to insulate compared to roof and walls. Convective heat transfer through and around window coverings also degrade its insulation properties.[14] When shading windows, external shading is more effective at reducing heat gain than internal window coverings.[14]

Western and eastern sun can provide warmth and lighting, but are vulnerable to overheating in summer if not shaded. In contrast, the low midday sun readily admits light and warmth during the winter, but can be easily shaded with appropriate length overhangs or angled louvres during summer. The amount of radiant heat received is related to the location latitude, altitude, cloud cover, and seasonal / hourly angle of incidence (see Sun path and Lambert's cosine law).

Another passive solar design principle is that thermal energy can be stored in certain building materials and released again when heat gain eases to stabilize diurnal (day/night) temperature variations. The complex interaction of thermodynamic principles can be counterintuitive for first-time designers. Precise computer modeling can help avoid costly construction experiments.

Site specific considerations during design

- Latitude, sun path, and insolation (sunshine)
- Seasonal variations in solar gain e.g. cooling or heating degree days, solar insolation, humidity
- Diurnal variations in temperature
- Micro-climate details related to breezes, humidity, vegetation and land contour
- Obstructions / Over-shadowing - to solar gain or local cross-winds

Design elements for residential buildings in temperate climates

- Placement of room-types, internal doors & walls, & equipment in the house.
- Orienting the building to face the equator (or a few degrees to the East to capture the morning sun)[9]
- Extending the building dimension along the east/west axis
- Adequately sizing windows to face the midday sun in the winter, and be shaded in the summer.
- Minimising windows on other sides, especially western windows[14]
- Erecting correctly sized, latitude-specific roof overhangs,[15] or shading elements (shrubbery, trees, trellises, fences, shutters, etc.)[16]
- Using the appropriate amount and type of insulation including radiant barriers and bulk insulation to minimise seasonal excessive heat gain or loss
- Using thermal mass to store excess solar energy during the winter day (which is then re-radiated during the night)[17]

The precise amount of equator-facing glass and thermal mass should be based on careful consideration of latitude, altitude, climatic conditions, and heating/cooling degree day requirements.

Factors that can degrade thermal performance:

- Deviation from ideal orientation and north/south/east/west aspect ratio
- Excessive glass area ('over-glazing') resulting in overheating (also resulting in glare and fading of soft furnishings) and heat loss when ambient air temperatures fall
- Installing glazing where solar gain during the day and thermal losses during the night cannot be controlled easily e.g. West-facing, angled glazing, skylights[18]
- Thermal losses through non-insulated or unprotected glazing
- Lack of adequate shading during seasonal periods of high solar gain (especially on the West wall)
- Incorrect application of thermal mass to modulate daily temperature variations
- Open staircases leading to unequal distribution of warm air between upper and lower floors as warm air rises
- High building surface area to volume - Too many corners
- Inadequate weatherization leading to high air infiltration
- Lack of, or incorrectly installed, radiant barriers during the hot season. (See also cool roof and green roof)
- Insulation materials that are not matched to the main mode of heat transfer (e.g. undesirable convective/conductive/radiant heat transfer)

Efficiency and economics of passive solar heating

Technically, PSH is highly efficient. Direct-gain systems can utilize (i.e. convert into "useful" heat) 65-70% of the energy of solar radiation that strikes the aperture or collector. To put this in perspective relative to another energy conversion process, the photosynthetic efficiency theoretical limit is around 11%.

Passive solar fraction (PSF) is the percentage of the required heat load met by PSH and hence represents potential reduction in heating costs. RETScreen International has reported a PSF of 20-50%. Within the field of sustainability, energy conservation even of the order of 15% is considered substantial.

Other sources report the following PSFs:

- 5-25% for modest systems
- 40% for "highly optimized" systems
- Up to 75% for "very intense" systems

In favorable climates such as the southwest United States, highly optimized systems can exceed 75% PSF.[19]

Key passive solar building design concepts

There are six primary passive solar energy configurations:[20]

- direct solar gain
- indirect solar gain
- isolated solar gain
- heat storage
- insulation and glazing
- passive cooling

Direct solar gain

Direct gain attempts to control the amount of direct solar radiation reaching the living space. This direct solar gain is a critical part of passive solar house designation as it imparts to a direct gain.

The cost effectiveness of these configurations are currently being investigated in great detail and are demonstrating promising results.[21]

Indirect solar gain

Indirect gain attempts to control solar radiation reaching an area adjacent but not part of the living space. Heat enters the building through windows and is captured and stored in thermal mass (e.g. water tank, masonry wall) and slowly transmitted indirectly to the building through conduction and convection. Efficiency can suffer from slow response (thermal lag) and heat losses at night. Other issues include the cost of insulated glazing and developing effective systems to redistribute heat throughout the living area.

Isolated solar gain

Isolated gain involves utilizing solar energy to passively move heat from or to the living space using a fluid, such as water or air by natural convection or forced convection. Heat gain can occur through a sunspace, solarium or solar closet. These areas may also be employed usefully as a greenhouse or drying cabinet. An equator-side sun room may have its exterior windows higher than the windows between the sun room and the interior living space, to allow the low winter sun to penetrate to the cold side of adjacent rooms. Glass placement and overhangs prevent solar gain during the summer. Earth cooling tubes or other passive cooling techniques can keep a solarium cool in the summer.

Measures should be taken to reduce heat loss at night e.g. window coverings or movable window insulation

Examples:

- Thermosiphon
- Barra system
- Double envelope house
- Thermal buffer zone[22]
- Solar space heating system
- Solar chimney

Heat storage

The sun doesn't shine all the time. Heat storage, or thermal mass keeps the building warm when the sun can't heat it.

In diurnal solar houses, the storage is designed for one or a few days. The usual method is a custom-constructed thermal mass. These include a Trombe wall, a ventilated concrete floor, a cistern, water wall or roof pond. It is also feasible to use the thermal mass of the earth itself, either as-is or by incorporation into the structure by banking or using rammed earth as a structual medium.[23]

In subarctic areas, or areas that have long terms without solar gain (e.g. weeks of freezing fog), purpose-built thermal mass is very expensive. Don Stephens pioneered an experimental technique to use the ground as thermal mass large enough for annualized heat storage. His designs run an isolated thermosiphon 3m under a house, and insulate the ground with a 6m waterproof skirt.[24]

Insulation

Thermal insulation or superinsulation (type, placement and amount) reduces unwanted leakage of heat.[10] Some passive buildings are actually constructed of insulation.

Special glazing systems and window coverings

The effectiveness of direct solar gain systems is significantly enhanced by insulative (e.g. double glazing), spectrally selective glazing (low-e), or movable window insulation (window quilts, bifold interior insulation shutters, shades, etc.).[25]

Generally, Equator-facing windows should not employ glazing coatings that inhibit solar gain.

There is extensive use of super-insulated windows in the German Passive House standard. Selection of different spectrally selective window coating depends on the ratio of heating versus cooling degree days for the design location.

Glazing selection

Equator-facing glass

The requirement for vertical equator-facing glass is different from the other three sides of a building. Reflective window coatings and multiple panes of glass can reduce useful solar gain. However, direct-gain systems are more dependent on double or triple glazing to reduce heat loss. Indirect-gain and isolated-gain configurations may still be able to function effectively with only single-pane glazing. Nevertheless, the optimal cost-effective solution is both location and system dependent.

Roof-angle glass / Skylights

Skylights admit harsh direct overhead sunlight and glare[26] either horizontally (a flat roof) or pitched at the same angle as the roof slope. In some cases, horizontal skylights are used with reflectors to increase the intensity of solar radiation (and harsh glare), depending on the roof angle of incidence. When the winter sun is low on the horizon, most solar radiation reflects off of roof angled glass (the angle of incidence is nearly parallel to roof-angled glass morning and afternoon). When the summer sun is high, it is nearly perpendicular to roof-angled glass, which maximizes solar gain at the wrong time of year, and acts like a solar furnace. Skylights should be covered and well-insulated to reduce natural convection (warm air rising) heat loss on cold winter nights, and intense solar heat gain during hot spring/summer/fall days.

The equator-facing side of a building is south in the northern hemisphere, and north in the southern hemisphere. Skylights on roofs that face away from the equator provide mostly indirect illumination, except for summer days when the sun rises on the non-equator side of the building (depending on latitude). Skylights on east-facing roofs provide maximum direct light and solar heat gain in the summer morning. West-facing skylights provide afternoon sunlight and heat gain during the hottest part of the day.

Some skylights have expensive glazing that partially reduces summer solar heat gain, while still allowing some visible light transmission. However, if visible light can pass through it, so can some radiant heat gain (they are both electromagnetic radiation waves.

You can partially reduce some of the unwanted roof-angled-glazing summer solar heat gain by installing a skylight in the shade of deciduous (leaf-shedding) trees, or by adding a movable insulated opaque window covering on the inside or outside of the skylight. This would eliminate the daylight benefit in the summer. If tree limbs hang over a roof, they will increase problems with leaves in rain gutters, possibly cause roof-damaging ice dams, shorten roof life, and provide an easier path for pests to enter your attic. Leaves and twigs on skylights are unappealing, difficult to clean, and can increase the glazing breakage risk in wind storms.

"Sawtooth roof glazing" with vertical-glass-only can bring some of the passive solar building design benefits into the core of a commercial or industrial building, without the need for any roof-angled glass or skylights.

Skylights provide daylight. The only view they provide is essentially straight up in most applications. Well-insulated light tubes can bring daylight into northern rooms, without using a skylight. A passive-solar greenhouse provides abundant daylight for the equator-side of the building.

Infrared thermography color thermal imaging cameras (used in formal energy audits) can quickly document the negative thermal impact of roof-angled glass or a skylight on a cold winter night or hot summer day.

The U.S. Department of Energy states: "vertical glazing is the overall best option for sunspaces."[27] Roof-angled glass and sidewall glass are not recommended for passive solar sunspaces.

The U.S. DOE explains drawbacks to roof-angled glazing: Glass and plastic have little structural strength. When installed vertically, glass (or plastic) bears its own weight because only a small area (the top edge of the glazing) is subject to gravity. As the glass tilts off the vertical axis, however, an increased area (now the sloped cross-section) of the glazing has to bear the force of gravity. Glass is also brittle; it does not flex much before breaking. To counteract this, you usually must increase the thickness of the glazing or increase the number of structural supports to hold the glazing. Both increase overall cost, and the latter will reduce the amount of solar gain into the sunspace.

Another common problem with sloped glazing is its increased exposure to the weather. It is difficult to maintain a good seal on roof-angled glass in intense sunlight. Hail, sleet, snow, and wind may cause material failure. For occupant safety, regulatory agencies usually require sloped glass to be made of safety glass, laminated, or a combination thereof, which reduce solar gain potential. Most of the roof-angled glass on the Crowne Plaza Hotel Orlando Airport sunspace was destroyed in a single windstorm. Roof-angled glass increases construction cost, and can increase insurance premiums. Vertical glass is less susceptible to weather damage than roof-angled glass.

It is difficult to control solar heat gain in a sunspace with sloped glazing during the summer and even during the middle of a mild and sunny winter day. Skylights are the antithesis of zero energy building Passive Solar Cooling in climates with an air conditioning requirement.

Angle of incident radiation

The amount of solar gain transmitted through glass is also affected by the angle of the incident solar radiation. Sunlight striking glass within 20 degrees of perpendicular is mostly transmitted through the glass, whereas sunlight at more than 35 degrees from perpendicular is mostly reflected[28]

All of these factors can be modeled more precisely with a photographic light meter and a heliodon or optical bench, which can quantify the ratio of reflectivity to transmissivity, based on angle of incidence.

Alternatively, passive solar computer software can determine the impact of sun path, and cooling-and-heating degree days on energy performance. Regional climatic conditions are often available from local weather services.

Operable shading and insulation devices

A design with too much equator-facing glass can result in excessive winter, spring, or fall day heating, uncomfortably bright living spaces at certain times of the year, and excessive heat transfer on winter nights and summer days.

Although the sun is at the same altitude 6-weeks before and after the solstice, the heating and cooling requirements before and after the solstice are significantly different. Heat storage on the Earth's surface causes "thermal lag." Variable cloud cover influences solar gain potential. This means that latitude-specific fixed window overhangs, while important, are not a complete seasonal solar gain control solution.

Control mechanisms (such as manual-or-motorized interior insulated drapes, shutters, exterior roll-down shade screens, or retractable awnings) can compensate for differences caused by thermal lag or cloud cover, and help control daily / hourly solar gain requirement variations.

Home automation systems that monitor temperature, sunlight, time of day, and room occupancy can precisely control motorized window-shading-and-insulation devices.

Exterior colors reflecting - absorbing

Materials and colors can be chosen to reflect or absorb solar thermal energy. Using information on a Color for electromagnetic radiation to determine its thermal radiation properties of reflection or absorption can assist the choices.
See Lawrence Berkeley National Laboratory and Oak Ridge National Laboratory: **"Cool Colors"** [29]

Landscaping and gardens

Energy-efficient landscaping materials for careful passive solar choices include hardscape building material and "softscape" plants. The use of landscape design principles for selection of trees, hedges, and trellis-pergola features with vines; all can be used to create summer shading. For winter solar gain it is desirable to use deciduous plants that drop their leaves in the autumn gives year round passive solar benefits. Non-deciduous evergreen shrubs and trees can be windbreaks, at variable heights and distances, to create protection and shelter from winter wind chill. Xeriscaping with 'mature size appropriate' native species of-and drought tolerant plants, drip irrigation, mulching, and organic gardening practices reduce or eliminate the need for energy-and-water-intensive irrigation, gas powered garden equipment, and reduces the landfill waste footprint. Solar powered landscape lighting and fountain pumps, and covered swimming pools and plunge pools with solar water heaters can reduce the impact of such amenities.

- Sustainable gardening
- Sustainable landscaping
- Sustainable landscape architecture

Other passive solar principles

Passive solar lighting

Passive solar lighting techniques enhance taking advantage of natural illumination for interiors, and so reduce reliance on artificial lighting systems.

This can be achieved by careful building design, orientation, and placement of window sections to collect light. Other creative solutions involve the use of reflecting surfaces to admit daylight into the interior of a building. Window sections should be adequately sized, and to avoid over-illumination can be shielded with a Brise soleil, awnings, well placed trees, glass coatings, and other passive and active devices.[20]

Another major issue for many window systems is that they can be potentially vulnerable sites of excessive thermal gain or heat loss. Whilst high mounted clerestory window and traditional skylights can introduce daylight in poorly oriented sections of a building, unwanted heat transfer may be hard to control.[30][31] Thus, energy that is saved by reducing artificial lighting is often more than offset by the energy required for operating HVAC systems to maintain thermal comfort.

Various methods can be employed to address this including but not limited to window coverings, insulated glazing and novel materials such as aerogel semi-transparent insulation, optical fiber embedded in walls or roof, or hybrid solar lighting at Oak Ridge National Laboratory [32].

Interior reflecting

Reflecting elements, from active and passive daylighting collectors, such as light shelves, lighter wall and floor colors, mirrored wall sections, interior walls with upper glass panels, and clear or translucent glassed hinged doors and sliding glass doors take the captured light and passively reflect it further inside. The light can be from passive windows or skylights and solar light tubes or from active daylighting sources. In traditional Japanese architecture the Shōji sliding panel doors, with translucent Washi screens, are an original precedent. International style, Modernist and Mid-century modern architecture were earlier innovators of this passive penetration and reflection in industrial, commercial, and residential applications.

Passive solar water heating

There are many ways to use solar thermal energy to heat water for domestic use. Different active-and-passive solar hot water technologies have different location-specific economic cost benefit analysis implications.

Fundamental passive solar hot water heating involves no pumps or anything electrical. It is very cost effective in climates that do not have lengthy sub-freezing, or very-cloudy, weather conditions. Other active solar water heating technologies, etc. may be more appropriate for some locations.

It is possible to have active solar hot water which is also capable of being "off grid" and qualifies as sustainable. This is done by the use of a photovoltaic cell which uses energy from the sun to power the pumps.

Comparison to the Passive House standard in Europe

There is growing momentum in Europe for the approach espoused by the Passive House (*Passivhaus* in German) Institute in Germany. Rather than relying solely on traditional passive solar design techniques, this approach seeks to make use of all passive sources of heat, minimises energy usage, and emphasises the need for high levels of insulation reinforced by meticulous attention to detail in order to address thermal bridging and cold air infiltration. Most of the buildings built to the Passive House standard also incorporate an active heat recovery ventilation unit with or without a small (typically 1 kW) incorporated heating component.

The energy design of Passive House buildings is developed using a spreadsheet-based modeling tool called the Passive House Planning Package (PHPP) which is updated periodically. The current version is PHPP2007, where

2007 is the year of issue. A building may be certified as a 'Passive House' when it can be shown that it meets certain criteria, the most important being that the annual specific heat demand for the house should not exceed 15kWh/m^{2}a.

Design tools

Traditionally a heliodon was used to simulate the altitude and azimuth of the sun shining on a model building at any time of any day of the year.[33] In modern times, computer programs can model this phenomenon and integrate local climate data (including site impacts such as overshadowing and physical obstructions) to predict the solar gain potential for a particular building design over the course of a year. GPS-based smartphone applications can now do this inexpensively on a hand held device. These tools provide the passive solar designer the ability to evaluate local conditions, design elements and orientation prior to construction. Energy performance optimization normally requires an iterative-refinement design-and-evaluate process. There is no such thing as a "one-size-fits-all" universal passive solar building design that would work well in all locations.

Levels of application

Pragmatic

Many detached suburban houses can achieve reductions in heating expense without obvious changes to their appearance, comfort or usability.[34] This is done using good siting and window positioning, small amounts of thermal mass, with good-but-conventional insulation, weatherization, and an occasional supplementary heat source, such as a central radiator connected to a (solar) water heater. Sunrays may fall on a wall during the daytime and raise the temperature of its thermal mass. This will then radiate heat into the building in the evening. This can be a problem in the summer, especially on western walls in areas with high degree day cooling requirements. External shading, or a radiant barrier plus air gap, may be used to reduce undesirable summer solar gain.

Annualised

An extension of the "passive solar" approach to seasonal solar capture and storage of heat and cooling. These designs attempt to capture warm-season solar heat, and convey it to a seasonal thermal store for use months later during the cold season ("annualised passive solar.") Increased storage is achieved by employing large amounts of thermal mass or earth coupling. Anecdotal reports suggest they can be effective but no formal study has been conducted to demonstrate their superiority. The approach also can move cooling into the warm season.

Examples:

- Passive Annual Heat Storage (PAHS) - by John Hait
- Annualized Geothermal Solar (AGS) heating - by Don Stephen
- Earthed-roof

Minimum machinery

A "purely passive" solar-heated house would have no mechanical furnace unit, relying instead on energy captured from sunshine, only supplemented by "incidental" heat energy given off by lights, computers, and other task-specific appliances (such as those for cooking, entertainment, etc.), showering, people and pets. The use of natural convection air currents (rather than mechanical devices such as fans) to circulate air is related, though not strictly solar design.

Passive solar building design sometimes uses limited electrical and mechanical controls to operate dampers, insulating shutters, shades, awnings, or reflectors. Some systems enlist small fans or solar-heated chimneys to improve convective air-flow. A reasonable way to analyse these systems is by measuring their coefficient of performance. A heat pump might use 1 J for every 4 J it delivers giving a COP of 4. A system that only uses a 30 W fan to more-evenly distribute 10 kW of solar heat through an entire house would have a COP of 300.

Zero Energy Building

Passive solar building design is often a foundational element of a cost-effective zero energy building.[35][36] Although a ZEB uses multiple passive solar building design concepts, a ZEB is usually not purely passive, having active mechanical renewable energy generation systems such as: wind turbine, photovoltaics, micro hydro, geothermal, and other emerging alternative energy sources.

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External links

- www.solarbuildings.ca (http://www.solarbuildings.ca/) - Canadian Solar Buildings Research Network
- www.eere.energy.gov (http://www.eere.energy.gov/de/passive_solar_design.html) - US Department of Energy (DOE) Guidelines
- www.climatechange.gov.au (http://www.climatechange.gov.au) - Australian Dept of Climate Change and Energy Efficiency
- www.ornl.gov (http://www.ornl.gov/sci/btc/apps/) - Oak Ridge National Laboratory (ORNL) Building Technology
- www.FSEC.UCF.edu (http://www.FSEC.UCF.edu) - Florida Solar Energy Center
- www.ZeroEnergyDesign.com (http://www.ZeroEnergyDesign.com) - 28 Years of Passive Solar Building Design
- (http://www.kezarhomes.com) - Prefabricated Passive Solar Home Kits
- Passive Solar Design Guidelines (http://nmsea.org/Curriculum/Courses/Passive_Solar_Design/Guidelines/Guidelines.htm)
- http://www.solaroof.org/wiki
- www.PassiveSolarEnergy.info (http://www.PassiveSolarEnergy.info) - Passive Solar Energy Technology Overview
- www.yourhome.gov.au/technical/index.html (http://www.yourhome.gov.au/technical/index.html) - Your Home Technical Manual developed by the Commonwealth of Australia to provide information about how to design, build and live in environmentally sustainable homes.
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