International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 1, January - 2014

Solar Energy for Passive House Design

Dr. Amit Kumar

Assistant Professor, Department of Mechanical Engineering, National Institute of Technology Patna - 800005, Bihar, India,

Abstract

Solar energy from the sun has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar radiation, along with secondary solar-powered resources such as wind and wave power, hydroelectricity and biomass accounts for most of the available renewable energy on earth. The Earth receives 174 petawatts (PW) of incoming solar radiation at the upper atmosphere and only a minuscule fraction of the available solar energy is being used. A partial list of solar applications includes space heating and cooling through solar architecture, potable water via distillation and disinfection, day lighting, solar hot water, solar cooking. Solar technologies may be broadly characterised as either passive or active depending on the way they capture, convert and distribute sunlight. Sunlight has influenced building design since the beginning of architectural history. The common features of passive solar architecture are orientation relative to the Sun, compact proportion (a low surface area to volume ratio), selective shading (overhangs) and thermal mass. When these features are tailored to the local climate and environment they can produce well-lit spaces that stay in a comfortable temperature range. The paper presents various aspects of passive solar building design concept and design elements for residential buildings in temperate climate. If passive solar building design is adopted on large scale, it is likely to restrict the formation of Urban Heat Island.

Keywords:Passive house design, Solar energy, Insulation, Landscaping, Solar gain, Air tightness

1.0 INTRODUCTION

There has been a close correlation between economic growth and environmental degradation. As communities grow, consequently, the environment declines. This trend is clearly demonstrated on graphs of human population numbers, economic growth, and environmental indicators. Unsustainable economic growth has been starkly compared to the malignant growth of a cancer because it eats away at the Earth's ecosystem services which are its life-support system. A major driver of human impact on Earth systems is the destruction of biophysical resources, and especially, the Earth's ecosystems. The total environmental impact of a community or of humankind as a whole depends both on population and impact per person, which in turn depends in complex ways on what resources are being used, whether or not those resources are renewable, and the scale of the human activity relative to the carrying capacity of the ecosystems involved. Utilisation of solar energy for passive house design is step towards preservation of ecosystem.

2.0 SOLAR ENERGY

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar radiation, along with secondary solar-powered resources such as wind and wave power, hydroelectricity and biomass accounts for most of the available renewable energy on earth. Only a minuscule fraction of the available solar energy is being used.

Solar powered electrical generation relies on heat engines and photovoltaic. Solar energy's uses are limited only by human ingenuity. A partial list of solar applications includes space heating and cooling through solar architecture, potable water via distillation and disinfection, day lighting, solar hot water, solar cooking and high temperature process heat for industrial purposes. To harvest the solar energy, the most common way is to use solar panels.

Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

Sunlight, in the broad sense, is the total frequency spectrum of electromagnetic radiation given off by the Sun on earth. The sunlight is filtered through the Earth's atmosphere and solar radiation is obvious as daylight when the Sun is above the horizon.

When the direct solar radiation is not blocked by the clouds, it is experienced as sunshine, a combination of bright light and radiant heat. When it is blocked by the clouds or reflects off of other objects, it is experienced as diffused light.

2.1 Energy From The Sun

The Earth receives 174 petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere [1]. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet [2]. Earth's land surface, oceans and atmosphere absorb solar radiation, and this raises their temperature. Warm air containing evaporated water from the oceans rises, causing atmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the Earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anticyclones. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14^0C [3]. By photosynthesis green plants convert solar energy into chemical energy, which produces food, wood and the biomass from which fossil fuels are derived [4].

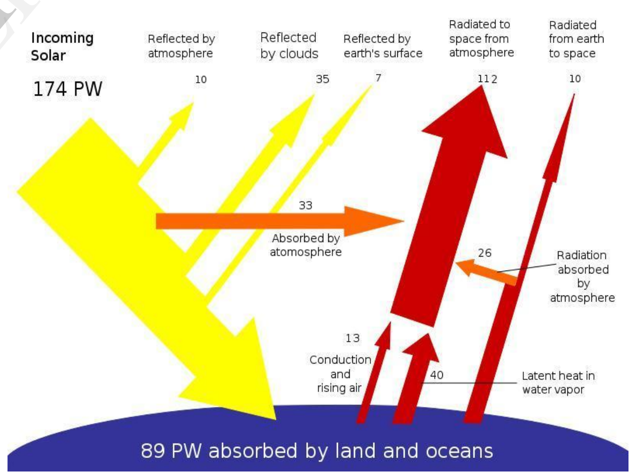

Fig. 1, About half the incoming solar energy reaches the Earth's surface.

2.2 Application of Solar Technology

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand side technologies [5].

2.3 Architecture and Urban Planning

Sunlight has influenced building design since the beginning of architectural history [6]. Advanced solar architecture and urban planning methods were first employed by the Greeks and Chinese, who oriented their buildings toward the south to provide light and warmth [7].

The common features of passive solar architecture are orientation relative to the Sun, compact proportion (a low surface area to volume ratio), selective shading (overhangs) and thermal mass. When these features are tailored to the local climate and environment they can produce well-lit spaces that stay in a comfortable temperature range. Socrates' Megaron House is a classic example of passive solar design. The most recent approaches to solar design use computer modeling tying together solar lighting, heating and ventilation systems in an integrated solar design package [8]. Active solar equipment such as pumps, fans and switchable windows can complement passive design and improve system performance.

Urban heat islands (UHI) are metropolitan areas with higher temperatures than that of the surrounding environment. The higher temperatures are a result of increased absorption of the Solar light by urban materials such as asphalt and concrete, which have lower albedos and higher heat capacities than those in the natural environment. A straightforward method of counteracting the UHI effect is to paint buildings and roads white and plant trees. Using these methods, a hypothetical "cool communities" program in Los Angeles has projected that urban temperatures could be reduced by approximately 3 °C at an estimated cost of US$1 billion, giving estimated total annual benefits of US$530 million from reduced air-conditioning costs and healthcare savings [9].

3.0 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.

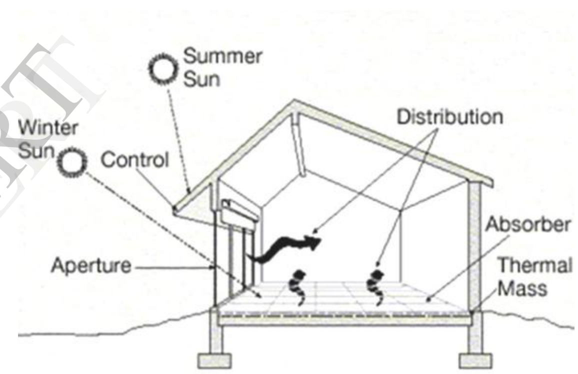

Fig. 2. Elements of passive solar design, shown in a direct gain application

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 solar technologies use sunlight without active mechanical systems (as contrasted to active solar). Such technologies convert sunlight into usable heat (water, air, and thermal mass), cause air-movement for ventilating, 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, 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 thermo-siphon or geyser pump, 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.

3.1 Sun Path

Sun path refers to the apparent significant seasonal-and-hourly positional changes of the sun as the Earth rotates, and orbits around the sun. The relative position of the sun is a major factor in the heat gain of buildings and in the performance of solar energy systems. Accurate location-specific knowledge of sun path and climatic conditions is essential for economic decisions about solar collector area, orientation, landscaping, summer shading, and the cost-effective use of solar trackers.

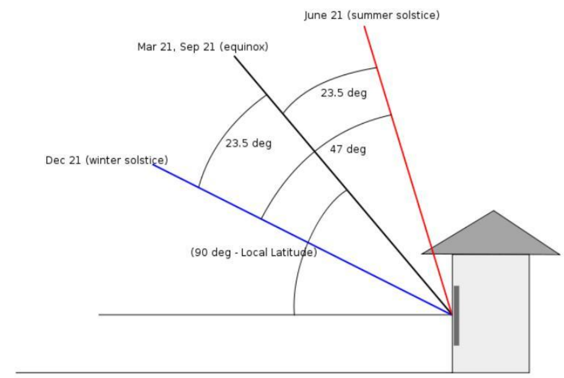

Fig. 3, Solar altitude over a year; for latitude based on New York.

3.2 Passive Solar Thermodynamic Principle

Personal thermal comfort is a function of personal health factors (medical, psychological, sociological and situation), ambient air temperature, mean radiant temperature, air movement and relative heat transfer in buildings occurs through convection, conduction, and thermal radiation through roof, walls, floor and windows [10].

3.3 Convective Heat Transfer

Convective heat transfer can be beneficial or detrimental. Uncontrolled air infiltration from poor weatherisation / weather-stripping / 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.

3.4 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]. Windows are a ready and predictable site for thermal radiation 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.

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 louvers during summer. The amount of radiant heat received is related to the location latitude, altitude, cloud cover, and seasonal / hourly angle of incidence.

Another passive solar design principle is that thermal energy can be stored in certain building materials and released again when heat gain eases to stabilise 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.

4.0 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

4.1 Design Elements for Residential Buildings In Temperate Climate

- 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)
- 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
- Erecting correctly sized, latitude-specific roof overhangs, or shading elements

(shrubbery, trees, trellises, fences, shutters, etc.)

- 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)

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
- 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 weatherisation leading to high air infiltration
- Lack of, or incorrectly installed, radiant barriers during the hot season.
- Insulation materials that are not matched to the main mode of heat transfer (e.g. undesirable convective/conductive/radiant heat transfer)

4.2 Efficiency and Economics of Passive Solar Heating

Technically, PSH is highly efficient. Direct-gain systems can utilise (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.

4.3 Passive Solar Building Design Concept

There are six primary passive solar energy configurations [15]:

- direct solar gain
- indirect solar gain
- isolated solar gain
- heat storage
- insulation and glazing
- Landscaping and gardens

4.3.1 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 design as it imparts to a direct gain.

The cost effectiveness of these configurations is currently being investigated in great detail and is demonstrating promising results.

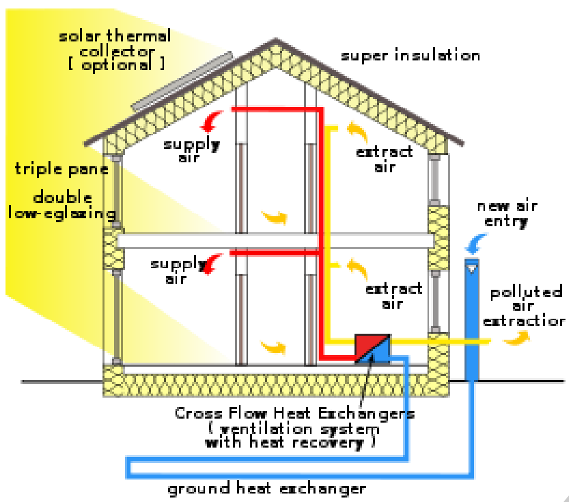

Fig. 4, The Passive house using a combination of low-energy buildings techniques and technologies.

4.3.2 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.

4.3.3 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:

- Thermo-siphon
- Barra system
- Double envelop house
- Thermal buffer zone
- Solar space heating system
- Solar chimney

4.3.4 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.

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 thermo-siphon 3m under a house, and insulate the ground with a 6m waterproof skirt [16].

4.3.5 Insulation

Thermal insulation or super-insulation (type, placement and amount) reduces unwanted leakage of heat. Some passive buildings are actually constructed of insulation.

5.0 GLAZING SYSTEMS AND WINDOW COVERINGS

The effectiveness of direct solar gain systems is significantly enhanced by insulative (e.g. double glazing), spectrally selective glazing, or movable window insulation (window quilts, bi-fold interior insulation shutters, shades, etc.) [17].

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.

5.1 Glazing Selection

5.1.1 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.

5.1.2 Roof-Angle Glass / Skylights

Skylights admit harsh direct overhead sunlight and glare [18] 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 and 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.

"Saw-tooth 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." 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.

5.1.3 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 [19]. 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 energyperformance. Regional climatic conditions are often available from local weather services.

5.1.4 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.

5.1.5 Exterior Colours Reflecting - Absorbing

Materials and colors can be chosen to reflect or absorb solar thermal energy. Using information on a colour for electromagnetic radiation to determine its thermal radiation properties of reflection or absorption can assist the choices.

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 organicgardening 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.

6.0 LANDSCAPING AND GAEDENS

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.

Widespread tree planting and climate appropriate landscaping offer substantial environmental benefits. Trees and vegetation control erosion, protect water supplies, provide food, create habitat for wildlife, and clean the air by absorbing carbon dioxide and releasing oxygen.

Advantages of a well-designed landscape are:

- Cut your summer and winter energy costs dramatically
- Protect your home from winter wind and summer sun.
- Reduce consumption of water , pesticides, and fuel for landscaping and lawn maintenance
- Help control noise and air pollution.

.

Carefully positioned trees can save up to 25% of a household's energy consumption for heating and cooling. Some of the landscaping strategies are listed by region and in order of importance
Below [20]:

6.1 Temperate

- Maximize warming effects of the sun in the winter.
- Maximize shade during the summer,
- Deflect winter winds away from buildings.
- Funnel summer breezes toward the home.

6.2 Hot-Arid

- Provide shade to cool roofs, walls, and windows.
- Cool the air around the home by plant evaporation and transpiration.
- Allow summer winds to access naturally cooled homes.
- Block or deflect winds away from air-conditioned homes.

6.3 Hot-Humid

- Channel summer breezes toward the home.
- Maximize summer shade with trees that still allow penetration of low-angle winter sun.
- Avoid locating planting beds close to the home if they require frequent watering.

Cool

- Use dense windbreaks to protect the home from cold winter winds.
- Allow the winter sun to reach south facing windows.
- Shade south and west windows and walls from the direct summer sun, if summer overheating is a problem.

A well designed landscape provides enough energy savings to return your initial investment in less than 8 years.

7.0 CONCLUSIONS

- The Earth receives 174 petawatts (PW) of incoming solar radiation and only a minuscule fraction of the available solar energy is being presently used. Attempt should be made to use freely available solar energy to compensate for dwindling biomass source of energy.

- Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun and unlike active solar heating systems, it doesn't involve the use of mechanical and electrical devices.

- Passive Solar Heating is highly efficient. Direct-gain systems can utilise 65-70% of the energy of solar radiation that strikes the aperture or collector.

- The following general principles are followed in passive house design:
  (a) Insulation
  (b) Air Tightness
  (c) Solar Gain
  (d) Heat Exchange
  (e) Thermal Bridging Minimised
- A well designed landscape provides enough energy saving to return your initial
  investment in less than 8 years.
- A passive house design for urban planning is need of the hour and if required, active solar energy can be also utilised as a supplement to it.

REFERENCES

1. ^ Smil (1991), p. 240
2. ^ "Natural Forcing of the Climate System". Intergovernmental Panel on Climate Change. Retrieved 2007-09-29.
3. ^ Somerville, Richard. "Historical Overview of Climate Change Science" (PDF). Intergovernmental Panel on Climate Change. Retrieved 2007-09-29.
4. ^ Vermass, Wim. "An Introduction to Photosynthesis and Its Applications". Arizona State University. Retrieved 2007-09-29.
5. ^ *a b* Philibert, Cédric (2005). "The Present and Future use of Solar Thermal Energy as a Primary Source of Energy". IEA. Archived from the original on 2011-12-12.
6. ^ *a b c* Schittich (2003), p. 14
7. ^ Butti and Perlin (1981), p. 4, 159
8. ^ Balcomb(1992)
9. ^ Rosenfeld, Arthur; Romm, Joseph; Akbari, Hashem; Lloyd, Alan. "Painting the Town White -- and Green". Heat Island Group. Retrieved 2007-09-29.
10. ^ *a b* Your Home - Insulation
11. ^ "BERC - Airtightness". Ornl.gov. 2004-05-26. Retrieved 2010-03-16.
12. ^ Your Home - Passive Cooling
13. ^ "EERE Radiant Barriers". Eere.energy.gov. 2009-05-28. Retrieved 2010-03-16.
14. ^ *a b c d* "Glazing". Archived from the original on December 15, 2007. Retrieved 2011-11-03.
15. ^ *a b* Chiras, D. The Solar House: Passive Heating and Cooling. Chelsea Green Publishing Company; 2002.
16. ^ Annualized Geo-Solar Heating, Don Stephens- Accessed 2009-02-05
17. ^ Shurcliff, William A.. *Thermal Shutters & Shades - Over 100 Schemes for Reducing Heat Loss through Windows 1980*. ISBN 0-931790-14-X.
18. ^ "Florida Solar Energy Center - Skylights". Retrieved 2011-03-29.
19. ^ "Solar Heat Gain Through Glass". Irc.nrc-cnrc.gc.ca. 2010-03-08. Retrieved 2010-03-16.
20. The National Renewable Energy Laboratory and US Department of Energy National Laboratory. Document produced on Landscaping for Energy Efficiency, April 1995.