Technical Manual for Green Building Design

Introduction

Building green can promote energy and water efficiency, encourage recycling and use of recycled-content products, add to the local economy, and protect the natural resources. Education, training, and creating a sustainable marketplace in the community are vital in developing and utilizing green materials and products. Many opportunities to use green building materials and products exist in today's marketplace.

Green building practices reduce negative environmental impacts, while using the features of the site to enhance human comfort and health. Preserving site resources and conserving energy and materials in construction and building operations are important benefits. Planning can greatly reduce construction, utility, and maintenance costs.

Designing a resource-efficient home is an integrative process. It involves site selection and evaluation, building design, construction, operation, maintenance, and deconstruction. All parties including contractors, architects, landscape designers, owners, engineers, government agencies, suppliers, and utility companies should be involved in planning and design for the most effective integration of components. A green home designs waste and pollution out of the process by combining site characteristics, materials, mechanical systems, and design elements to maximize resources.

Selecting environmentally preferable building materials is one way to improve a building's environmental performance. To be practical, however, environmental performance must be balanced against economic performance versus economic performance.

Building Shape and Orientation

Choose the most compact building footprint and shape that work with requirements for daylighting, solar heating and cooling, and function. The greater the amount of building skin in relation to the volume of space enclosed, the more the building is influenced by heat exchanges at the skin. Excluding consideration of window openings and glazing choices, if two building designs under consideration enclose the same volume, the one with the more compact plan will have greater thermal efficiency. A square floor plan is more thermally efficient than a rectangular one because it contains less surface area over which to lose or gain heat. However, this may not be the most efficient or desirable form when other considerations such as daylighting, passive solar heating and cooling, need for temperature variation, and occupant use patterns are included.

The Building Envelope

The building envelope, or "skin," consists of structural materials and finishes that enclose space, separating inside from outside. This includes walls, windows, doors, roofs, and floor surfaces. The envelope must balance requirements for ventilation and daylight while providing thermal and moisture protection appropriate to the climatic conditions of the site. Envelope design is a major factor in determining the amount of energy a building will use in its operation. Also, the overall environmental life-cycle impacts and energy costs associated with the production and transportation of different envelope materials vary greatly.

Openings are located in the envelope to provide physical access to a building, create views to the outside, admit daylight and/or solar energy for heating, and supply natural ventilation. The form, size, and location of the openings vary depending upon the role they play in the building envelope. Window glazing can be used to affect heating and cooling requirements and occupant comfort by controlling the type and amount of light that passes through windows.

Decisions about construction details also play a crucial role in design of the building envelope. Building materials conduct heat at different rates. Components of the envelope such as foundation walls, sills, studs, joists, and connectors, among others, can create paths for the transfer of thermal energy, known as thermal bridges, that conduct heat across the wall assembly. Wise detailing decisions, including choice and placement of insulation material, are essential to assure thermal efficiency.

Construction Process

The construction process can have a significant impact on environmental resources. Environmentally conscious construction practices can markedly reduce site disturbance, the quantity of waste sent to landfills, and the use of natural resources during onstruction. It can also minimize the prospect of adverse indoor air quality in the finished building. In addition to yielding environmental benefits, all of these actions can lower project costs.

In many cases, construction clears and disturbs the site's existing natural resources like native vegetation and wildlife, natural drainage systems, and other natural features and replaces them with artificial systems such as non-native vegetation and artificial drainage.

When approaching construction from a sustainable perspective, a builder should ensure that the construction contract and specifications address the design and construction teams' environmental requirements for the construction process. Construction projects typically use large quantities of material, energy, and water resources. Environmental performance improvements can reduce waste, increase efficiency and water conservation, and reduce consumption of natural resources. Potential improvements include the following:

- Efficiently satisfying temporary power and water requirements;
- Reducing waste production with less packaging;
- Reducing waste production through use of materials with recycled content;
- Reducing waste by reusing building materials and demolition debris on the construction site;
- Recycling demolition debris off-site;
- Recycling construction debris; and

- Developing overall efficiency guidelines.
- Use energy-efficient lamps and ballasts.

Use of solar energy in Building Planning and Design

Buildings designed for passive solar and day-lighting use features such as large south-facing windows and materials that absorb and slowly release the sun's heat. No mechanical means are employed in passive solar heating. Passive solar designs can reduce heating bills as much as 50 percent. These solar designs can also include natural ventilation for cooling.

The solar home systems offer a quick and convenient means for electrification of households in remote and difficult villages in the country. Besides providing lighting facility, such systems also provide electricity for operating television, radio and fans and other small items. Five models of home lighting systems are covered under the subsidy program. Typically, a solar home system can have an 18/37/74 Wp PV module and a 20/40/75 AH-12 V tubular plate battery and is designed to work for 3-5 h each day. The program also supports deployment of streetlights, which operate from dusk to dawn. A typical solar street lighting system has a 74 Wp PV module and a 80 AH-12 V battery with appropriate electronics and a pole.

Passive Solar Design

Passive solar designs are simple and of greater reliability, lower costs, and longer system life times. Passive solar heating and cooling of buildings seem to be cost effective, when appropriate techniques suited to the regional and micro climate of the place and site are chosen. Climate conscious and energy efficient designs should supplement the passive solar designs. Passive systems when effectively designed, would perform effortlessly and quietly, without mechanical and electrical assistance. They do not require special construction skills and much can be accomplished using locally available common building and insulating material. The additional financial investment may range from nil to 10 percent. Passive solar systems save fuel bills for the house owner and the nation.

Passive solar design uses sunshine to heat and light homes. It is usually part of the design of the building itself, using certain materials and placement of windows or skylights. A successful passive solar building needs to be very well insulated in order to make best use of the sun's energy. The result is a quiet and comfortable space, free of drafts and cold spots. Passive solar design can also achieve summer cooling and ventilating by making use of convective air currents which are created by the natural tendency of hot air to rise.

Orientation

In order for passive solar systems to work effectively, care must be take to ensure that the building is oriented to take advantage of year-round energy savings. The ideal orientation for solar glazing is within 5 degrees of true south. This orientation will provide maximum performance. Glazing oriented to within 15 degrees of true south will perform almost as well, and orientations up to 30 degrees off—although less effective—will still provide a substantial level of solar contribution. The warmer the climate, the more east and west-facing glass will tend to cause overheating problems. In general, southeast orientations present less of a problem than southwest. In the ideal situation, the house should be oriented east-west and so have its longest wall facing south. But as a practical matter, if the house's short side has good southern exposure it will usually accommodate sufficient glazing for an effective passive solar system, provided that the heat can be transferred to the northern zones of the house.

Solar Control

To minimize the exposure of wall and window areas of the building, to the direct solar radiation by shading them is the basic approach of solar control. By treating the exposed wall and roof surfaces with white, off white, or light colour surface finishes, as much as 60 to 70 percent of solar energy can be rejected. . However shading of. windows is far more important as unshaded. clear window glasses, when exposed to direct solar radiation, transmit more than 85 percent. Once the sunlight hits the window glass, half the cooling battle is lost. South facing windows admit less sun in summer than in winter and it is also easy to shade them with overhangs. East and west window glasses are difficult to shade with overhangs alone. Vertical fins are the best means of shading such glasses. We all know that the sun path varies during the day from season to season and from place to place.

Passive Solar Design starts with consideration of siting and daylighting opportunities and the building envelope; then building systems are considered. Almost every element of a passive solar design serves more than one purpose. Landscaping can be aesthetic while also providing critical shading or direct air flow. Window shades are both a shading device and part of the interior design scheme. Masonry floors store heat and also provide a durable walking surface. Sunlight bounced around a room provides a bright space and task light.

Passive solar design is based on optimizing the “whole-building” concept by integrating site conditions, building materials, and mechanical equipment. Energy efficiency is related to whole-building performance and depends on the efficient design and operation of integrated systems in keeping with the specific function of the building. Building system components include the building envelope, heating and air conditioning, lighting, plumbing, and ventilation. These are affected by the operational requirements of the occupants. A lighting system that employs energy-efficient lighting designs is ineffective if it does not meet the needs of occupants.

Thermal Efficiency

Determine the building function and amount of equipment that will be used. The type of activity and the amount of equipment in a building affect the level of internal heat generated. This is important because the rate at which a building gains or loses heat through it skin is proportional to the difference in air temperature between inside and outside. A large commercial building with significant internal heat loads would be less influenced by heat exchanges at the skin than a residence with far fewer internal sources of heat generation.

In general, build walls, roofs, and floors of adequate thermal resistance to provide human comfort and energy efficiency.

Heat transfer across the building envelope occurs as either conductive, radiant, or convective losses or gains. Building materials conduct heat at different rates. Metals have a high rate of thermal conductance. Masonry has a lower rate of conductance; the rate for wood is lower still. This means that a wall framed with metal studs compared to one framed with wood studs, where other components are the same, would have a considerably greater tendency to transmit heat from one side to the other. Insulating materials, either filled in between framing members or applied to the envelope, resist heat flow through the enclosing wall and ceiling assemblies.

Thermal Storage

Thermal mass in a passive solar building is intended to meet two needs. It should be designed to quickly absorb solar heat for use over the diurnal cycle and to avoid overheating. It should provide slow release of the stored heat when the sun is no longer shining. Depending upon the local climate and the use of the building, the delayed release of heat may be timed to occur a few hours later or slowly over days. Careful selection of the thermal storage medium, its location in the building, and its quantity are important design and cost decisions. Venting, another solution for handling stored heat, can rid the building of late afternoon heat or exhaust heat when the building's thermal mass is already saturated. Venting can also be viewed as a form of economizer cooling, using outside air to cool the building when the outside air is cooler than the building's thermostat setting 3 Venting requires an exhaust fan tied to a thermostatic control or flushing using natural ventilation.

The following considerations should be taken into account, depending on the climate type.

1. A building material with high thermal mass and adequate thickness will lessen and delay the impact of temperature variations from the outside wall on the wall's interior. The material's high thermal capacity allows heat to penetrate slowly through the wall or roof. Because the temperature in hot/dry climates tends to fall considerably after sunset, the result is a thermal flywheel effect—the building interior is cooler than the exterior during the day and warmer than the exterior at night.

2. In hot/moist climates use materials with low thermal capacity. In hot/moist climates, where nighttime temperatures do not drop considerably below daytime highs, light materials with little thermal capacity are preferred. In some hot/moist climates, materials such as masonry, which functions as a desiccant, are common. Roofs and walls should be protected by plant materials or overhangs. Large openings protected from the summer sun should be located primarily on the north and south sides of the envelope to catch breezes or encourage stack ventilation.

3. In temperate climates, select materials based on location and the heating/cooling strategy to be used. Determine the thermal capacity of materials for buildings in temperate climates based upon the specific locale and the heating/cooling strategy employed. Walls should be well insulated. Openings in the skin should be shaded during hot times of the year and unshaded during cool months. This can be accomplished by roof overhangs sized to respond to solar geometries at the site.

– Consider masonry or concrete walls insulated on the outside. Many buildings, especially low-rise commercial buildings, are constructed with concrete or masonry walls that can provide excellent thermal mass to absorb excess solar heat and stabilize indoor temperatures. Insulated masonry also adds extra width to a wall, making it difficult to finish at the edges of windows, roofs, and doors.

Increasing the thickness of all of the wall surfaces can raise the thermal capacity of the building for little additional material cost and practically no labor cost. It has the added benefits of increasing the fire safety and acoustic privacy of interior spaces. This diffuse thermal mass approach depends on effective convective airflows since room air is the heat-transfer medium.

– Consider water-storage containers for thermal mass. Water has a very high thermal capacity, about twice that of common masonry materials. Water also has the advantage that convection currents distribute heat more evenly throughout the medium.
Passive solar designers have experimented with a wide variety of water-storage containers built primarily into walls. Creative solutions include enclosing water containers in seating boxes under south windows or using water as an indoor feature such as a large tropical aquarium, pond, or pool.

Natural Ventilation

Ventilation cooling has a dual role to play, Firstly to promote human comfort directly and secondly to cool the structure. Air movement across the human body causes a cooling sensation because it enhances the removal of body heat by convection and by evaporation of perspiration .

In hot dry climate evaporative cooling concept works very well. 'This works on the principle, when moisture .changes from liquid to vapor state, the sensible heat, required (for the adiabatic process of cooling), is extracted from the evaporating surface and thus its surface temperature falls. The rate of evaporation and hence the drop in surface temperature depends, on how low is the humidity in the atmosphere, and the air velocity across the surface.

Experimental studies were made on three roof cooling methods, namely Roof Pond with movable insulation roof spray and roof covered with a wet pad, on a concrete roof base, at CBRI Roorkee. It is shown that on a typical summer day in the month of May, the ceiling temperature was maintained in a narrow range of 30°C (max) and 24°C (min) for these evaporative cooled roofs. While the bare untreated concrete roof temperatures were 45°C (max) and 20^0C (min). Of the three methods the wet pad treatment performed slightly better.

Radiant gains can have a significant impact on heating and cooling loads. A surface that is highly reflective of solar radiation will gain much less heat than one that is adsorptive. In general, light colors decrease solar gain while dark ones increase it. This may be important in selecting roofing materials because of the large amount of radiation to which they are exposed over the course of a day; it may also play a role in selecting thermal storage materials in passive solar buildings.

Size and position doors, windows, and vents in the envelope based on careful consideration of daylighting, heating, and ventilating strategies. The form, size, and location of openings may vary depending on how they affect the building envelope. A window that provides a view need not open, yet a window intended for ventilation must do so. High windows for daylighting are preferable because, if properly designed, they bring light deeper into the interior and eliminate glare.

Vestibules at building entrances should be designed to avoid the loss of cooled or heated air to the exterior. The negative impact of door openings upon heating or cooling loads can be reduced with airlocks. Shade openings in the envelope during hot weather to reduce the penetration of direct sunlight to the interior of the building.

The use of earth berms to bury part of a building will minimize solar gain and wind-driven air infiltration. It will also lessen thermal transfer caused by extremely high or low temperatures.

Passive Solar Heating, Cooling, and Thermal Storage

Integration of passive solar heating, cooling, and thermal storage features, along with daylighting, into a building can yield considerable energy benefits and added occupant comfort. Incorporation of these items into the building design can lead to substantial reduction in the load requirements for building heating and cooling mechanical systems. Passive solar cooling strategies include cooling load avoidance, shading, natural ventilation, radiative cooling, evaporative cooling, dehumidification, and ground coupling. Passive design can minimize the need for cooling through proper selection of glazings, window placement, shading techniques, and good landscaping design. However, incorrect daylighting strategies can produce excessive heat gain.

Thermal mass and energy storage are key characteristics of passive solar design.They can provide a mechanism for handling excess warmth, therefore reducing the cooling load, while storing heat that can be slowly released back to the building when needed. The thermal mass can also be cooled during the evening hours by venting the building, reducing the need for cooling in the morning.

Integrate passive solar heating with daylighting design. A passive solar building that makes use of sunlight as a heating source should also be designed to take advantage of sunlight as a lighting source However, each use has different design requirements that need to be addressed. In general, passive solar heating benefits from beam sunlight directly striking dark-colored surfaces. Daylighting, on the other hand, benefits from the gentle diffusion of sunlight over large areas of light-colored surfaces. Integrating the two approaches requires an understanding and coordination of daylighting, passive design, electric lighting, and mechanical heating systems and controls.

Identify appropriate locations for exposure to beam sunlight. Overheating and glare can occur whenever sunlight penetrates directly into a building and must be addressed through proper design. A “direct-gain” space can overheat in full sunlight and is many times brighter than normal indoor lighting, causing intense glare.

Generally, rooms and spaces where people stay in one place for more than a few minutes are inappropriate for direct gain systems. Lobbies or lounges can be located along the south wall where direct sun penetrates. Choose glazings that optimize the desired heat gain, daylighting, and cooling load avoidance Avoid glare from low sun angles. In late morning and early afternoon, the sun enters through south-facing windows. The low angle allows the sunbeam to penetrate deep into the building beyond the normal direct-gain area. If the building and occupied spaces are not designed to control the impact of the sun’s penetration, the occupants will experience discomfort from glare. Careful sun-angle analysis and design strategies will ensure that these low sun angles are understood and addressed. For example, light shelves can intercept the sun and diffuse the daylight. Workstations can be oriented north-south so that walls or high partitions intercept and diffuse the sun.

Passive Solar Cooling

Minimization of cooling loads should be carefully addressed for both solar building and conventional energy-efficient building design. Design strategies that minimize the need for mechanical cooling systems include proper window placement and daylighting design, selection of appropriate glazings for windows and skylights, proper shading of glass when heat gains are not desired, use of light-colored materials for the building envelope and roof, careful siting and orientation decisions, and good landscaping design.

Choose one or more shading strategies.

– Install fixed shading devices, using correctly sized overhangs or porches, or design the building to be “self-shading.” Fixed shading devices, which are designed into a building, will shade windows throughout the solar cycle. They are most effective on the south-facing windows. The depth and position of fixed shading devices must be carefully engineered to allow the sun to penetrate only during predetermined times of the year. In the winter, overhangs allow the low winter sun to enter south-facing windows. In the summer, the overhangs block the higher sun.

– Plant trees and/or bushes to shade the windows at the right time of day and season Vegetation and groundcover also contribute to evaporative cooling around a building.

– Consider exterior roll-down shades or shutters. An enormous variety of vertical shading devices are readily available. Wooden shutters are the most traditional. Also available are many exterior-grade fiberglass and plastic fabrics that cut out a significant amount of sunlight but still allow a clear view through the window. However, they do not prevent the glare problems caused by low-angle sun. Opaque steel or plastic roll-down shutters have proved reliable and long-lasting. Although expensive, they can also provide additional storm and vandalism protection.

– Limit east/west glass. Glass on these exposures is harder to shade from the eastern morning sun or western evening sun. Vertical or egg-crate fixed shading works well if the shading projections are fairly deep or close together; however, these may limit views. North-facing glass receives little direct solar gain, but does provides diffuse daylight.

Consider other cooling strategies.
– Design the building to take advantage of natural ventilation. Natural ventilation uses the passive stack effect and pressure differentials to bring fresh, cooling air through a building without mechanical systems. This process cools the occupants and provides comfort even in humid climates. Buildings using this design will incorporate operable windows or other means of outdoor air intakes. Wing walls are sometimes used to increase the convective air flow. Other features include fresh air inlets located near floor level, use of ceiling fans, and the use of stairwell towers to enhance the stack effect. Caution should be used not to increase the latent load (i.e., the increased cooling load resulting from condensation) by bringing in moist outside air.

– Consider radiative cooling in appropriate climates. Radiative cooling, also known as nocturnal radiative cooling, uses design strategies that allow stored heat to be released to the outside. This strategy is particularly effective in climates and during seasons of the year when the daytime-nighttime temperature differences are meaningful. Night flushing of buildings uses radiative cooling principles. Building thermal storage serves as a heat sink during the day, but releases the heat at night, while being cooled with night air.

– Consider ground coupled cooling. Ground coupling is achieved by conductive contact of the building with the earth. The most common strategy is to cool air by channeling it through an underground tunnel. Another strategy provides cool air by installing a tube in the ground and dripping water into the tube. This reduces the ground temperature through evaporation.

– Consider evaporative cooling strategies. This cooling method works when water, evaporating into the atmosphere, extracts heat from the air. Evaporative cooling is most appropriate in dry climates.

– Use dehumidification in humid climates. Dehumidification is required in climates having high humidity levels, and therefore latent loads, during portions of the year. Common strategies include dilution of interior moisture by ventilating with less humid air, condensation on cooled surfaces connected to a heat sink, and desiccant systems.

Daylighting

Daylighting is the practice of bringing light into a building interior and distributing it in a way that provides more desirable and better-quality illumination than artificial light sources. This reduces the need for electrical light sources, thus cutting down on electricity use and its associated costs and pollution. Daylighting can cut peak electric loads by as much as two-thirds in new construction and nearly half in major retrofit projects. Daylighting is not only the coolest source of light available to building designers, but potentially the least ex-pensive as well. As energy consumption in commercial buildings is dominated by the need to light and cool interior spaces, reducing the amount of heat-producing electric lighting per square foot reduces cooling loads as well. Architects are becoming increasingly aware that buildings with properly controlled natural lighting are more pleasant spaces to work or learn than conventional buildings.

Daylighting significantly reduces energy consumption and operating costs. Energy used for lighting in buildings can account for 40 to 50 percent of total energy consumption. In addition, the added space-cooling loads that result from waste heat generated by lights can amount to three to five percent of total energy use. Properly designed daylighting strategies can save 50 to 80 percent of lighting energy.

Greater use of daylighting can also provide advantages for the environment by reducing power demand and the related pollution and waste byproducts from power production. Daylighting requires the correct placement of openings, or *apertures,* in the building envelope to allow light penetration while providing adequate distribution and diffusion of the light. A well-designed system avoids excessive thermal gains and excessive brightness resulting from direct sunlight, which can impair vision and cause discomfort. To control excessive brightness or contrast, windows are often equipped with additional elements such as shades, blinds, and light shelves. In most cases, the daylighting system should also include controls that dim or turn off lights when sufficient natural light is available to maintain desired lighting levels. It is also often desirable to integrate daylighting systems with the artificial lighting system to maintain required task or ambient illumination while maximizing the amount of lighting energy saved

Recent daylighting innovations offer a wide range of advanced, highly efficient, and, in some cases, highly engineered systems. The benefits of daylighting include improved visual quality, better lighting-color rendition, reduced solar heat gain, and improved visual performance and productivity. These benefits can make any increased engineering and installation costs a worthwhile investment for the building owner or employer.

General Daylighting Principles

Avoid direct sunlight on critical tasks and excessive brightness.

Direct sunlight in certain non-task areas can be helpful because it provides building occupants with information about outside weather conditions and the time of day. These factors can actually relieve the stress associated with being in a windowless space for long periods of time. However, when a critical task is performed in direct sunlight, the light can cause unacceptable contrast ratios, disability glare, or veiled reflection. In this situation, the work surface or computer screen reflects the light source so that it is difficult to see the intended task. The recommended maximum background-to-task ratio is 10 to one; the recommended maximum light source-to-background ratio is 40 to one

Bring the daylight in at a high location.

The four basic types of daylight apertures are windows, skylights, roof monitors, and clerestories. Skylights, roof monitors, and clerestories tend to be more effective than windows because their high location in a building affords penetration of light into the building core. Windows, unless fitted with light shelves or venetian blinds, can sometimes cause unacceptable brightness levels and excessive contrast ratios of background to foreground, thereby creating visual problems.

Size and position doors, windows, and vents in the envelope based on careful consideration of daylighting, heating, and ventilating strategies. The form, size, and location of openings may vary depending on how they affect the building envelope. A window that provides a view need not open, yet a window intended for ventilation must do so. High windows for daylighting are preferable because, if properly designed, they bring light deeper into the interior and eliminate glare.

Vestibules at building entrances should be designed to avoid the loss of cooled or heated air to the exterior. The negative impact of door openings upon heating or cooling loads can be reduced with airlocks. Shade openings in the envelope during hot weather to reduce the penetration of direct sunlight to the interior of the building.

Filter the daylight. Trees, plants, draperies, screens, translucent shades, and light-scattering glazings diffuse and distribute light while reducing its intensity.
Bounce daylight off of surrounding surfaces. Light shelves, louvers, blinds, and vertical baffles reflect and distribute light throughout a building interior. In general, the larger and softer the light source, the better the visual quality, the less the resulting eye strain, and the easier it is to function and perform a given task. In addition, when the light is nondirectional—that is, reflected from countless surfaces—shadows are avoided or eliminated, again improving visual quality.

Traditional Daylighting Strategies

Side lighting
Maintain a favorable room aspect ratio—the ratio of ceiling height and window height to depth of room from window
In this strategy, which combines sidelighting and toplighting, vertical windows in a higher space are positioned adjacent to other windows, creating in a sense a "clear story. This method provides an excellent means of delivering daylight deep into an interior space.

Top lighting
A sawtooth roof uses a series of repetitive clerestories to provide uniform illumination over a large area and is best designed in concert with passive solar heating and cooling strategies. The glazed openings in the sawtooth commonly face north, thereby providing a diffuse and uniform source of daylight. Overhangs, diffuse glazing materials, interior or exterior baffles, louvers, blinds, and shades are all effective means of accomplishing the required solar control.

Skylights, horizontal openings in a roof, are the most common daylighting strategy in single-story buildings. When used judiciously, they offer the most efficient means of bringing light into a building because they generally have a 180-degree view of the sky.

They are usually laid out on a grid so that the distance between the skylights is roughly 1.5 times the distance between the floor and ceiling planes. Optimal skylight-to-floor ratios may range from 5 to 10 percent or higher depending on the transmittance of the glass, the efficiency of the skylight design, the required illuminance level, the ceiling height, and whether the space is mechanically air conditioned.
Some problems with skylights include the potential for water leakage, the loss of some thermal insulation at the skylight locations, and the generally higher cost of the roof structure. The finished vertical surfaces below the skylight opening are known as the "light well." As the depth of the construction or the distance from the roof to the ceiling plane increases, it becomes more important that the light well be angled to prevent loss of efficiency of the skylight system.

– Use baffles below the skylight to reflect some of the incident light up onto the ceiling surface. This technique reduces the ratio of source-to-background contrast by making the ceiling a relatively large indirect light source.

– Consider roof design. When a skylight is used in conjunction with a sloped roof surface, the efficiency of the skylight is reduced in proportion to the slope of the roof, and the light distribution pattern becomes more like that of a side lighting strategy. If the slope of the roof is to the north, solar control is less of a concern; if it is to the east, south or west, it is more of a concern.

Light Distribution Strategies

Ceiling shape is the simplest mechanism for distributing light in a space. Sloping the ceiling from a high point at the window or skylight essentially has the same impact as maintaining a high ceiling throughout the space. Curving the ceiling can produce dramatic effects. The light from the window or skylight can be focused or collimated in the case of a concave surface or further diffused and spread in the case of a convex surface.

Although usually necessary to exclude light and solar gain at unwanted times, overhangs always reduce the overall amount of daylight in the space and should therefore be designed with care, including an analysis of their year-round effect.
Incorporate light shelves with windows where appropriate.

The light shelf is an extremely useful tool when used in conjunction with sidelighting strategies. This mechanism, a horizontal surface at or above eye level, serves to reflect light falling above the vision window up onto the ceiling and therefore deeper into the room . At the same time, it reduces illumination immediately adjacent to the window, where illumination levels are typically too great to work comfortably. This has the effect of creating more even illumination throughout the space, even though the overall amount of light flux into the space is reduced. Employ baffles, louvers, and reflectors as appropriate in conjunction with any of the above mentioned strategies for solar control.

Active Solar Systems

Active solar collector systems take advantage of the sun to provide energy for domestic water heating, pool heating, ventilation air preheat, and space heating. Active solar systems should be integrated with a building's design and systems only after passive solar and energy-conserving strategies are considered.

Water heating for domestic use is generally the most economical application of active solar systems. The demand for hot water is fairly constant throughout the year, so the solar system provides energy savings year-round. Successful use of solar water heating systems requires careful selection of components and proper sizing. Major components of a system include collectors, the circulation system that moves the fluid between the collectors and storage, the storage tank, a control system, and a backup heating system.

An active solar water heating system can be designed with components sized large enough to provide heating for pools or to provide a combined function of both domestic water and space heating. Space heating requires a heat-storage system and additional hardware to connect with a space heat distribution system. An active solar space heating system makes economic sense if it can offset considerable amounts of heating energy from conventional systems over the life of the building or the life of the system. The system equipment, which can be costly, should be evaluated on a life-cycle basis, using established project financial criteria acceptable to the building owner.

General Considerations

Determine if the climate and building usage is appropriate for an active solar collection system. The energy savings for active solar systems depend upon the amount of available solar radiation, projected uses of the system, and the proper system design.
Determine the financial feasibility of an active solar system.

A life-cycle cost analysis should be carried out for the up-front and operational costs, and expected energy savings, of an active solar system compared with conventional systems. The financial analysis should be performed over the projected life of the system—a minimum of 10 years. Based on the resulting estimated calculations, the project owner can make a determination of the financial feasibility of investment in the active solar system.

Photovoltaic (PV) technology .

Photovoltaic (PV) technology is the direct conversion of sunlight to electricity using semiconductor devices called solar cells. Photovoltaics are almost maintenance-free and seem to have a long life span. The photoelectric conversion process produces no pollution and can make use of free solar energy. Overall, the longevity, simplicity, and minimal resources used to produce electricity via PV systems make this a highly sustainable technology.

The most common technology in use today is single-crystal PVs, which use wafers of silicon wired together and attached to a module substrate. Thin-film PV, such as amorphous silicon technology, is based on depositing silicon and other chemicals directly on a substrate such as glass or flexible stainless steel. Thin-film PV materials can look almost like tinted glass. They can be designed to generate electricity from a portion of the incoming light while still allowing some light to pass through for daylighting and view. Thin films promise lower cost per square foot, but also have lower efficiency and produce less electricity per square foot compared to single-crystal PVs. PV panels produce direct current, not the alternating current used to power most building equipment. Direct current is easily stored in batteries; a device called an inverter is required to transform the direct current to alternating current. The cost of reliable batteries to store electricity, and the cost of an inverter, increase the overall cost of a system.

Watershed Protection

Every building site is in a watershed, and everything people do on a site has an impact on the watershed's condition. Sustainable development can solve watershed problems at the source. Its purpose is to

(1) restore the infiltrating, cleansing, and storing functions of soils, plants, and groundwater by preserving natural systems;
(2) restore the permeability of constructed pavements; and
(3) capture and treat excess runoff by means of natural soil and biological processes.

Water conservation, efficiency, and management arise from preserving, restoring, taking advantage of, and working with the site's natural systems.

Water Harvesting

Collect and use "harvested" water. Water harvesting means collecting runoff from the soil's surface, paved surfaces, and other sources, and storing it for future use such as irrigation. Harvested water can include storm water and irrigation runoff

Rainwater Harvesting

Collecting and using precipitation from a roof or other catchment area is an excellent way to take advantage of natural site resources, to reduce site runoff and the need for runoff-control devices, and to minimize the need for utility-provided water.
The capacity of rainwater harvesting to meet water needs depends on the amount of rainfall in an area, the size of the collection area, the size of the storage area, and water needs. Basic components of a rainwater collection system include the catchment area (usually the roof), conveyance system (guttering, downspouts, piping), filtration system, storage system (tank), and distribution system. The highest cost in most rainwater-collection systems is for water storage.
– Use appropriate roofing materials. The best roof materials for catchment are metal, clay, and concrete-based (such as tile or fiber cement). Asbestos roof materials are not suitable for potable collection because grit can enter the system. Use of asbestos roof materials may not be permitted under local building codes. Lead-containing

materials such as flashing should not be used in catchment roofs.
– Install gutters and downspouts sized for the roof size and rainfall intensity. Install screening so that leaves and debris do not enter the tank, as well as a "roof-washer" device to divert the first flush of water after a rainfall, preventing it from entering the tank.
– Construct tank storage. Tanks may be constructed from a wide variety of materials. Prefabricated tanks in steel or fiberglass are available, but tend to be quite expensive. Tanks also may be constructed on site from concrete, ferro-cement, stone, or compressed earth. Tank interior surfaces must, of course, be watertight and should be covered to prevent mosquito breeding and contamination.
To prevent algae growth, which occurs with exposure to sunlight, use opaque materials only. Filter and/or treat rainwater to use it as an irrigation source.

Landscaping
Plant native or well-adapted species.

Typical urban landscapes consist of non-native or unadapted plant species, lawns, and a few trees. Non-native plants increase demands for water, especially during the growing season, thereby depleting local water supplies and driving the need for larger-capacity centralized facilities that may lie dormant during periods of low water use.

Native plants have become adapted to natural conditions of an area such as seasonal drought, pest problems, and native soils. Landscape designs that emphasize native trees, vines, shrubs, and perennials also help maintain the biological diversity of a region and preserve the character of regional landscapes.

Minimize use of high-maintenance lawns. Most turfgrasses typically require more inputs of water, maintenance, and chemicals than other types of plants. Native or drought-tolerant turf species or beds planted with shrubs, groundcover, and perennials can replace non-native lawns. In order to irrigate lawns efficiently, design them with relatively small perimeter areas and in flowing, rounded shapes. Long, skinny, or oddly shaped turf areas are difficult to negotiate with most irrigation equipment.

Diverting or reusing wastewater before it enters the centralized wastewater stream minimizes loading of municipal water treatment plants. As an added benefit, the resulting treated effluent can be utilized on-site as an irrigation source that contains valuable plant nutrients or as part of a design feature in an attractive landscape.

Indoor Water Conservation
Reducing overall water use reduces wastewater. Water-efficient fixtures and appliances are readily available. Faucet bubblers, lowflow showerheads, and flow restrictors further reduce water consumption. Perform a water budget analysis to project the amount and configuration of daily wastewater flows.

Estimate water usage and wastewater generation based on standard use patterns and the number of building occupants, then analyze the figures to determine opportunities for conservation.

Wastewater Systems

Usually, irrigation with wastewater is required to be subsurface, although some areas permit above-ground irrigation. Factors affecting the approval and use of wastewater irrigation systems include soil depth and characteristics as well as drainage and flooding patterns.

Two pipe system separates wastewater from latrine waste. Dual plumbing is not difficult to install, but is most-cost effective if done during initial construction. If dual plumbing lines are not installed initially, adding a wastewater treatment system later can be quite expensive. For this reason, install dual distribution lines in new facilities if a wastewater system may be incorporated in the future.

Utilize wastewater for nonpotable purposes.
Recycle wastewater via a dual distribution system, for such nonpotable water uses as toilet-flushing, thereby avoiding unnecessary use of high-quality potable water. Another major use of wastewater is for irrigation landscapes and turf areas. A separate tank, filter, and special emitters are necessary in wastewater irrigation systems. Types of irrigation systems that can utilize wastewater include shallow trench systems, which utilize distribution pipes placed close enough to the surface to allow for irrigation of plant roots In some areas, above-ground or spray irrigation is possible.

– Utilize biological systems such as constructed wetlands for treating septic tanks effluents.. Constructed wetlands are artificial wetlands used for waste treatment. As wastewater flows through the wetland, plants and naturally occurring microbes remove waste. This technology can be used at a variety of scales, from wastewater treatment for an individual building to treatment for entire communities. Two types of systems, the surface-flow wetland, and the subsurface-flow wetland, can be utilized. Surface flow wetlands, also called wastewater lagoons, usually use a tiered system of ponds with wetland plants to treat wastewater. Subsurface-flow wetlands, also called microbial rock plant filters, are soil-less, and utilize a gravel medium to anchor plants. Wastewater flows through the gravel and is not visible at the surface. Effluent from both types of systems must be handled through irrigation or other methods.

Indoor Air Quality
With potentially hundreds of different contaminants present in indoor air, identifying indoor air quality (IAQ) problems and developing solutions is extremely difficult. The study of indoor air quality is a relatively recent endeavor. Although much is known about the health effects of poor design and ways to overcome them through good design, a tremendous amount of research is needed in this complicated field The quality of indoor air results from the interaction of many complex factors each contributing different effects.

There are many sources of potentially harmful air contaminants in buildings. Contaminants may originate indoors, outdoors, from occupants, and from within the mechanical system of the building. VOCs and MVOCs may be emitted into the air from building materials, products, equipment, and furniture. Since moisture and condensation allow molds and bacteria to start growing on the surface of indoor materials, finishes, products, ventilation ducts, and insulation materials, the primary methods to control microbial growth are controlling the interior temperature and humidity and removing the source of potential contamination. Source control can be achieved by the use of simple design and specification techniques
– Specify materials that are resistant to microbial growth especially in areas where moisture can support the growth of fungi.
– Provide adequate ventilation for the building population;

Building Materials and their effect on Indoor Air Quality

1. Concrete
Making portland cement for concrete requires substantial energy, causing a significant amount of carbon dioxide emissions. Because concrete is such a high-mass material and is used in buildings in large quantities, considering alternatives is important. If the selection is based on life-cycle assessment principles, other materials may be preferable.
Resource-efficient options
– Use fly-ash concrete, available in many regions, as an alternative to conventional mixes. Fly ash is a waste material from coal-burning power plants. It can be used to replace up to about 30 percent of the portland cement in conventional mixes. It is also mixed with ground blast-furnace slag, a waste from metal smelting. Fly ash produces a superior concrete with excellent finishing characteristics; however, only some types of ash are appropriate for certain applications, and the proportions are restricted.
– Recycled aggregates and lightweight aggregates are available for some concrete applications. Recycled aggregate may contain crushed concrete, brick, and other masonry waste; or it may contain crushed glass. Lightweight concrete is made with expanded volcanic materials such as pumice and perlite in place of part of the usual stone aggregate. These materials place less load on structures (particularly when used on wood or lightweight steel floors) and provide some thermal insulation value.
– Anticorrosion agents such as epoxy coating extend the life of steel reinforcement, especially for applications such as parking slabs where salt is used in winter. These agents have been found to extend the life of slabs substantially, avoiding repair and replacement costs.
Concrete additives such as water reducers or superplasticizers may produce odors and risk of skin and bronchial irritation. Form-release agents are sometimes made from diesel oil or other odorous petroleum oils that produce emissions. Wax- or mineral oil-based products are available substitutes.

2. Masonry
Masonry products are made from concrete, sand, clay, and various types of standard and

lightweight aggregates. Quarried stone is also used. Most masonry products are installed with mortar made from portland cement, sand, and lime.
– Consider lightweight concrete blocks and bricks made with expanded aggregates to reduce weight and add insulating value.
– Other options are brick and block products with waste and recycled contents, such as sewage sludge and ash from incinerators and coal-burning plants. However, such ash should be tested for pollutants that could cause unacceptable health or environmental exposures. Native stone or lightweight cultured stone made from cement and recycled aggregates are appropriate for some uses.
– Overall, masonry products produce minimal air pollution.

3. Metals

Steel is the most common metal used in building products. It is highly recyclable, and its scrap has value. Aluminum, the second most common metal, is probably the most recyclable material in buildings. Stainless steel and brass products are alloyed metals that are recyclable if carefully separated by type. Copper is also a highly valued recyclable. Metal plating is common in building products, especially in architectural metals, door hardware, and office systems and furniture. Chromium, cadmium, brass, and nickel plating is often carried out by electroplating plants, sometimes resulting in high levels of pollution.
Emissions such as hexavalent chromium and cadmium and acid wastes are environmentally toxic. Plastic polymer coatings and "powder coatings" are alternatives; however, the use of plated metal versus plastic polymer coatings should only be evaluated by comparable life-cycle assessments.
– Indoor air pollution is a minimal problem with metal products. The only exceptions are products that may require polishing, cleaning, or repainting in place.

4. Wood and Plastic

Woods used in construction and interior finishing are primarily domestic species. Woods used in furniture, doors, and specialty millwork are often imported tropical varieties. Appropriate forest management is vital to more sustainable wood sources in many cases. Most plastics are made from "nonrenewable" petroleum or natural gas feedstocks. Their production may involve use of toxic and potentially hazardous substances. Plastics are sometimes used in building systems as claddings and panels, but most often in interior finishes.

Construction materials, furnishings, and equipment may emit odor, particles, and volatile organic compounds (VOCs), and adsorb and desorb VOCs. Individual VOCs from a specific material may combine with VOCs from other materials to form new chemicals. VOCs and particulates can cause health problems for occupants upon inhalation or exposure. In the presence of adequate heat and moisture, some materials provide nutrients that support the growth of molds and bacteria, which produce microbial volatile organic compounds (MVOCs).

Lack of maintenance allows dirt, dust, mold, odors, and particles to increase. The use of high-VOC cleaning agents pollutes air. The number of occupants and the amount of equipment contribute to indoor air pollution. People and pets are major sources of microorganisms and airborne allergens in indoor environments. Occupant activities also can pollute the air. Poor indoor air quality can cause human illness. It can also lead to lost productivity of building occupants, resulting in economic Health problems that can result from poor indoor air quality may be short term to long-term, and range from minor irritations to life-threatening illnesses.

Pollutant sources can be controlled, reduced, or eliminated to produce a healthier indoor environment. Strategies for source control are listed below.

– Determine the emission factor and rate of the product VOCs to use as a potential indication of health concerns that may be associated with the use of the product.
– Determine the odor characteristics of the priority material, product, or furniture item. While odors may indicate a health-related IAQ problem, not all odors present a health risk. Nevertheless, be cautious initially about specifying products that emit strong odors, as they may indicate a potential and perceptual IAQ problem.
Take steps to control the MVOC contribution to the indoor air from materials, products, and furniture.

Design for improved indoor air quality involves four interrelated principles that should be implemented as a whole: source control, ventilation control, occupant activity control, and building maintenance.

Acoustics
Acoustics have a significant impact upon the overall indoor environmental quality of modern buildings and the amount of noise emission or pollution discharged to the outdoors. The levels of background noise, privacy, and separation between particular types of spaces have important implications for the work environment of building occupants.
In open office spaces, for instance, background noise that is too loud or has tonal qualities can distract occupants and reduce productivity. Other types of office spaces such as executive suites, conference rooms, and boardrooms have particular privacy requirements.
. Selecting the correct balance between hard, acoustically reflective materials and soft, absorptive ones facilitates the projection of speech to intended areas and prevents echoes or the excessive buildup of unwanted sound in other areas.

Energy Audit of Buildings
An energy audit is a periodic examination of an energy system to ensure that energy is being used as efficient as possible in a building. This guideline is particular written in simplified version to encourage energy self-auditing by owners or users of smaller buildings.

By identifying and minimising wasted energy through an energy audit, you can achieve the following results:

- Conserve non-renewable energy resources which are gradually running out;
- Protect the environment by burning less fossil fuels, e.g. by reducing power generating requirement, thus lessening carbon dioxide emissions which contribute to global warming; and
- Save energy and reduce running costs.

General Self-auditing Procedure

1. Collect up-to-date information for the following

Form 1

Building Information and Historical Energy Consumption

1 Name of Building: ____

2 Type of Premises: *Office/Shop/Restaurant/Workshop/Warehouse/Residential/Other please specify ____

3 Address: ____

4 Gross Floor Area of Building: ____________________ m^2

5 Year Built: ___________________________________

6 Building details

7 Approximate number of occupants: _______________

8 Hours of Operation:

Monday - Friday Hours/day

Saturday Hours

Sunday Hours

Annual Total Hours Hours/year

8 Energy bills for electricity for the present and past 2 to 5 years

Electricity Consumption (kWh)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2001													
2002													
2003													
2004													
2005													
2006													
Total													

2. Carry out a walk-through of the premises to identify obvious areas of energy wastage and opportunities for energy saving. Form 2 with a detailed checklist is prepared to assist recording results of the survey.

Form 2

Check List for Energy Management Opportunities (EMO)

1. Lighting Equipment:
    - a) Use of daylighting
    - b) Use of low energy Lighting devices
    - c) Lighting turned on unnecessarily
    - d) Tungsten Filament Lamps
    - e) One switch controlling two or more luminaries that are not required to be turned on simultaneously for a task
    - f) Area that is over-provided with lighting
2. Air Conditioning:
    - a) Doors or windows are open when air conditioning is operating
    - b) Temperature setting is unnecessary low for summer and high for winter
    - c) Air filter is not cleaned regularly
    - d) Condensation outside air duct
    - e) Chilled water leakage
3. Appliances:
    - a) TV is left turned on when the room is vacant 3a
    - b) Ventilation fan is turned on unnecessarily
4. Water
    - a) Use of solar water heaters
    - b) Hot water piping not properly insulated
    - c) Leakage in shower head or water tap
    - d) Water heater turned on unnecessarily

2.3 Implement energy saving opportunities identified in the survey. The opportunities could be implemented with practically no cost implication, e.g. through good housekeeping, or with some capital cost investment, e.g. retrofit fluorescent luminaires with electronic ballasts.

Form 3 is prepared to assist planning of the implementation program.

Form 3

Check List for Implementation of Energy Management Opportunities

Location EMO

Reference No.

Date of Completion
Remark