ENERGY EFFICIENT BUILDING

PREPARED

BY

MARYWAN MAHMOOD QURBANY

A LICENCENED

MECHANICHAL ENGINEER

ENERGY EFFICIENT BUILDING

Introduction:

Social and environmental conditions have given more attention to conservation of natural resources and sustainable living. Economic changes have also caused consumers to revaluate how they use energy, with attention on maximizing efficiency.

Using more efficient building methods in new construction and in renovation of old buildings could reduce the amount of energy consumed, thereby saving money and reducing electric load growth and air emissions resulting from electric generation.

Energy efficient buildings can be defined as buildings that are designed to provide a significant reduction of the energy need for heating and cooling, independently of the energy and of the equipment that will be chosen to heat or cool the building. This can be achieved through the following elements:

1. Bioclimatic architecture:

   Includes shape and orientation of the building,solar protections, passive solar systems.

2. High performing building envelope:

   Which is achieved thorough insulation, high performing glazing and windows, air-sealed construction, avoidance of thermal bridges.

3. High performance controlled ventilation:

   Which is achieved thorough mechanical insulation, heat recovery. Only when the building has been designed to minimize the energy loss, we should start looking at the energy source (including renewable energy) and at the heating and cooling equipment.

Design approach:

The design of an energy efficient building is performed through the following steps :

A**rchitectural climatic design** which takes into account climate and environmental conditions to help achieve thermal and visual comfort inside. Bioclimatic design takes into account the local climate to make the best possible use of solar energy and other environmental sources, rather than working against them. Bioclimatic design includes the following principles:

a. The shape of the building has to be compact to reduce the surfaces in contact with the exterior; the building and especially its openings are given an appropriate orientation preferably towards the south in our region; interior spaces are laid out according to their heating requirements ;

b. Appropriate techniques are applied to the external envelope and its openings to protect the building from solar heat in winter as well as in summer; passive solar systems collect solar radiation, acting as “free” heating and lighting systems; the building is protected from the summer sun, primarily by shading but also by the appropriate treatment of the building envelope.

Thermal insulation which is a low-cost, widely available, proven technology that begins saving energy and money, and reducing emissions the moment it is installed. Well installed insulation ensures reduction of energy use in every part of the building envelope including ground slabs, roofs, walls and facades. It is also well suited for pipes and boilers to reduce the energy loss of a building’s technical installations. Insulation is as relevant in cold regions as in hot ones. In cold/cool regions, insulation keeps a building warm and limits the need for energy for heating whereas in hot/warm regions the same insulation systems keep the heat out and reduce the need for air conditioning. An exterior wall is well insulated when its thermal resistance (R value) is high, meaning the heat losses through it are small (reduced U value). Insulation is a key component of the wall to achieve a high R value (or a low U value) for the complete wall. The thermal resistance R of the installed insulation products has to be as high as possible. To limit the thickness of the insulation within acceptable dimensions, improve the thermal conductivity of materials thus allowing increased thermal resistance within the same space.

Air tightness which reduces air leakage – the uncontrolled flow of air through gaps and cracks in the construction (sometimes referred to as infiltration, exfiltration or draughts). Air leakages need to be reduced as much as possible in order to create efficient, controllable, comfortable, healthy and durable buildings, air tightness is an increasingly important issue. Details that are necessary to achieving good air tightness need to be identified at early design stage. Careful attention must be paid to sealing gaps and ensuring the continuity of the air barrier. It is far simpler to design and build an airtight construction than to carry out remedial measures in a home which is not air tight. Appropriate installation of the insulation must guarante excellent air tightness and allowing proper moisture management

Consequences of air leakages : cold outside air may be drawn into the home through gaps in the walls, ground floor and ceiling (infiltration), resulting in cold draughts. In some cases, infiltration can cool the surfaces of elements in the structure, leading to condensation. Warm air leaking out through gaps in the building’s envelope (exfiltration) is a major cause of heat loss and, consequently, wasted energy.

Most existing buildings, are far from being airtight and because of unwanted air infiltration generate high costs to owners and occupants, in environmental, financial and health terms. A leaky residential building will result in higher CO_2 emissions. The additional heat loss will mean that a correctly sized heating system may not be able to meet the demand temperature. Draughts and localized cold spots can cause discomfort. In extreme cases, excessive infiltration may make rooms uncomfortably cold during cooler periods. Excessive air leakage can allow damp air to penetrate the building fabric, degrading the structure and reducing the effectiveness of the insulation. Air leakage paths often lead to dust marks on carpets and wall coverings that look unsightly.

Ventilation is the intended and controlled ingress and egress of air through buildings, delivering fresh air, and exhausting stale air through purpose-built ventilators in combination with the designed heating system and humidity control, and the fabric of the building itself. If you do not insulate properly and ventilate too little, you can risk warm humid air condensing on cold, poorly insulated surfaces which will create moisture that allows for moulds and fungi to grow. A controlled ventilation strategy will satisfy the fresh air requirements of an airtight building. Air infiltration or opening of the window cannot be considered an acceptable alternative to designed ventilation.

Rules for energy – efficient building:

RULE 1: Seal all joints in the building shell. It doesn't make sense to invest in well insulated walls and ceilings yet do little to block air flow around and through the insulated cavities. Figure [1] shows where these sealing products are needed in conventional residential construction. Since buildings are always moving in response to changing moisture, and temperature conditions, it is critical that air-sealing products last as long as the structure and be capable of withstanding movement. Stabilized polyethylene films can provide reliable interior air-control in cold or temperate climates provided the wall or roof is designed to prevent vapor condensation.

RULE 2: Eliminate unnecessary holes and seal all those that are unavoidable. Locate electrical outlets and switch boxes on interior walls wherever possible, and try to use surface-mounted lights instead of recessed fixtures on insulated ceilings. Where electrical work on exterior walls and ceilings is unavoidable, tightly seal all box edges and wiring holes. Seal plumbing stacks with sheet-rubber gaskets slid over the pipes and mechanically clamped around the edges. Insulate and gasket attic (betoona) access doors or replace them with air-sealed versions. Build removable gasketed lids for whole-house fans, or better yet, don't install this type of fan in an unheated space. Avoid air leakage through unsealed spaces behind bathtubs, showers, staircases, and other construction adjacent to exterior walls.

RULE 3: Block heat conduction pathways. Completely fill all cavities with insulation. Even the smallest gaps between insulation and framing can cause a significant loss of insulation performance, Insulation should completely fill all wall and ceiling cavities and should be installed flush with the interior surfaces.

RULE 4: Insulate foundations adequately, preferably on the exterior. Basements are rarely insulated to the same standards as upper floors, even though basement walls often have a similar exterior exposure. When an uninsulated or poorly insulated basement is later converted to living space, it is often difficult to retrofit sufficient insulation, and many basement insulation techniques can create condensation problems that can lead to mold and rot. Basements should be properly insulated during the initial construction process, preferably on the exterior. Exterior insulation reduces the chance of condensation and eliminates the extreme thermal cycling that causes foundations to crack.

RULE 5 : Buildings cannot be designed solely for energy-efficiency: they must also be designed for durability, comfort, and health. Failure to consider the impact of air-tightening on indoor comfort and air quality has led to serious moisture and air-quality problems:• In the past, buildings had little insulation, so there was plenty of air circulation in cavities to promote drying. Today, buildings have walls and roofs filled with insulation that blocks most air circulation in the cavities.• In the past, buildings had leaky single-pane glass windows that let in plenty of dry outside air and caused excess interior moisture to condense as water in cold climates, dehumidifying the air. Today, buldings have tight insulated glass units that let in little air and cannot provide winter dehumidification by condensation because their interior surfaces are too warm. • In the past, foundations could be economically backfilled with gravel and good soil. Today, buildings are usually backfilled with the same material that was excavated which often drains poorly and allows water pressure to build against the foundation.• In the past, buildings had small, simple bathrooms. Today's buildings have elaborate baths equipped with multiple sinks, whirlpools, hot tubs, and saunas, all of which generate moisture.• In the past, the average building contained a few potted houseplants. Today, many buildings contain a rainforest of plants, and some have integral sunspaces, greenhouses, waterfalls, pools, and other moisture generators.Today, most building products and furnishings are made of plastics and composition materials emitting a bewildering assortment of chemicals. Combined with the dozens of new chemical-laden cleansers, paints, glues, and personal hygiene products, the emission of indoor air pollutant risen enormously. All this is a formula for disaster, so it should not be surprising that problems with uncomfortably high moisture levels, interior mold and mildew, and high levels of indoor air pollution have appeared. The issue is how to prevent these problems without reducing the level of interior thermal comfort we have come to expect.

RULE 6: Block all pathways for moisture to enter walls and ceilings from the exterior. Figure [2] shows the many ways in which moisture can get into a wall or ceiling from the building exterior. One common problem is the direct flow of water though roof and walls, such as when wind-driven rain manages to pass. Below ground, water enters through floor slabs and foundation walls by capillary wicking, moisture diffusion, and by direct flow through cracks. Wicking and diffusion through floor slabs can be eliminated by using polyethylene and gravel under floor slabs. Wicking and diffusion through foundation walls can be eliminated by exterior dampproofing or waterproofing. Gravel or synthetic drain materials can relieve hydrostatic pressure against both floor slabs and foundation walls if a drain line carries water to daylight or to a sump. It is also important to provide capillary breaks at footings and between the foundation wall (polyethylene sheet or rubber) to prevent moisture from rising up the foundation wall and into the framing.

RULE 7: Block all pathways for moisture to enter walls and ceilings from the interior. Figure [3] shows the many ways in which moisture can get into a wall or ceiling from the building interior either by transmission in air that flows through holes and cracks or by diffusion through drywall and other building materials. Of these two mechanisms, air-carried moisture is the most significant. In cold or moderate climates, air-carried moisture can be stopped by an airtight seal at the inner surface of the wall. An exterior seal would not be as effective in preventing the entry of warm, moisture-laden air into the wall where the water might condense. The methods for creating interior air seals have already been identified (seal all building joints and holes with rubber gaskets, continuous sheets of air-impermeable materials, etc.).Moisture movement through diffusion can be easily stopped with vapor barrier films, paints, or other materials with low moisture permeability. It is generally not necessary to have a perfect diffusion barrier unless, as can be done with a quality polyethylene film, it is desirable to have one product serve as both an air transmission and vapor-diffusion barrier simultaneously.

RULE 8: Design walls and roofs so that water and moisture that enters can't do any damage. Regardless of how effective a defense is built to keep water and moisture out of walls and roofs, some will always get in. Good design provides a way for this water to drain or diffuse outward without jeopardizing the integrity of the wall or roof system. Using a thick layer of insulating sheathing is one of the best precautions: if the insulation is thick enough, its interior surface will not be cold enough for the moisture to condense as water. In cold climates where the required sheathing thickness might be unmanageable, floor-to-floor transitions and flashings can be designed so that any water that does condense will drain out of the wall harmlessly.

RULE 9: Ventilate adequately with a continuously running mechanical ventilation system. All homes built today are too airtight and should have mechanical ventilation. Intermittent bathroom and kitchen exhaust fans do not constitute an effective ventilation system because they may not be used enough: water vapor and indoor air pollutants are produced on a continuous basis, not just when we cook or take a shower. Every building should have a continuously operating mechanical ventilation system that draws a small controlled air flow from bathrooms and kitchens A major benefit of this type of system is that it helps create negative indoor air pressure, just as inefficient gas and oil furnaces have always done (unlike modern sealed-combustion furnaces and heat pumps that do not use interior combustion air and have no effect on air pressures). Negative pressure encourages dry outdoor air to move inward to dry out walls and ceilings and prevents indoor air from entering the walls and ceilings where moisture can condense and do damage.

RULE 10: Control air pollution and moisture at the source. It's often very easy to reduce the amount of moisture and air pollution that is emitted into the interior of a building at a very low cost. Major moisture sources such as sunrooms containing hot-tubs or large numbers of plants or indoor swimming pools can be carefully isolated from the remainder of the house. Laundry and bathroom exhausts should always be vented outdoors, never into attics. Since building materials such as concrete and drywall contain enormous amounts of water and can take a year or more to dry, it should not be surprising that the worst indoor moisture problems such as mold and mildew are often seen in the first year. Wise practice would dictate that every new building should have a dehumidification system for at least the first year.

Methods To Increase Energy Efficiency Building Design and Construction

In general, highly energy-efficient buildings use less energy, cost less to operate, use less in the way of natural resources, and produce less environmental impact than conventional buildings. But the process of designing, constructing, or renovating a high-performance building is different from traditional design/build methods. In the whole-build approach, a building's architectural design is considered with its energy design. The capacity of mechanical and electrical systems can be minimized by incorporating passive solar technologies to help meet indoor space-conditioning requirements and lighting loads. Building simulation software can guide decisions to achieve this strategy. All suggested design changes should be re-evaluated through simulation before implementation to ensure they will not detract from meeting building design goals.

Currently employed methods of increasing energy efficiency in building design and construction include a variety of measures. They range from proper site selection and building orientation that allows newly constructed buildings to take greater advantage of passive solar heat gain, to simple steps such as sealing air leaks around doors and windows. Renewable energy systems, such as solar water pre-heaters, active solar space heating systems, and solar electric (photovoltaic) panels used to offset some of a building's electric usage through self-generation and net metering, are also becoming more popular. Some of the most common measures currently employed to achieve these goals are detailed below.

Passive Solar Design Techniques

In building planning and design, passive solar techniques are those that take advantage of solar heat and light to offset the need for gas or electric heating, air conditioning, and lighting. They are different from active solar systems, such as photovoltaic solar panels, which transform solar rays into electricity for home use. Common passive solar tactics include south-facing building orientations that absorb and store solar heat during the winter and deflect solar heat during the summer, and "day lighting," or maximizing the use of windows and full-glass exterior walls, often covered in a heat-deflecting glaze, to allow natural lighting into the building's interior work spaces, while minimizing the heat gain that might normally result.

New construction offers the greatest opportunity for incorporating passive solar design features. New construction and retrofit projects may also incorporate day lighting strategies that include skylights and light-sensing controls that reduce artificial lighting in response to changing levels of daylight, heat control techniques such as exterior shades or overhangs, and passive solar heating strategies to allow for reduced use of HVAC systems. Passive solar design provides the opportunity to integrate various building components such as exterior walls, windows, and building materials to collect, store, and distribute solar energy .

Thermal Storage

Thermal storage may be implemented in individual building projects in many ways. Some of the most common strategies include strategic window placement and day lighting design, selection of appropriate glazing for windows and skylights, appropriate shading of glass to prevent undesirable heat gain, use of light-colored materials or paint for building envelopes and roofs, careful siting and orientation, and appropriate landscaping. Shading strategies may include overhangs and porches, trees and other vegetation, removable awnings, exterior roll-down shades, or shutters. Passive solar heating systems in a building with south-facing orientation can be combined with solar heat-storing trombe walls or floors made with concrete, tile, brick, stone, or masonry that absorb solar heat, store it, and then slowly release the heat into the building.1 Due to the angle at which solar rays reach the earth's surface during winter, a south-facing building with a large overhang will be able to absorb the heat of the sun, lessening the need for energy-consuming heating systems. During summer months when solar rays arrive at a much higher angle, the overhang shades the building, eliminating much of the heat gain that would otherwise result and reducing air conditioning use.

Cooling Strategies

During the summer months, air conditioning systems consume much electricity. Alternative passive cooling strategies, especially when used in conjunction with thermal storage techniques that prevent heat absorption, may reduce the need for heavy air conditioning. Such cooling techniques include the use of natural ventilation, ceiling fans, atria and stairwell towers, evaporative cooling systems for dry climates, dehumidification systems, and geothermal cooling and heat pump systems. These methods can effectively remove heat from the interior of a building without the use of energy-intensive conventional air conditioning systems.

Day lighting

Day lighting techniques involve the incorporation of natural daylight into the mix of a building's interior illumination. When properly designed and integrated with electric lighting, day lighting can offer significant energy savings by offsetting a portion of the electric lighting needed. A side benefit of daylighting is that it also reduces the internal heat gain from electric lighting, thereby reducing required cooling capacity. Results of recent studies imply improved productivity and health in daylighted schools and offices. Windows—the principal source of daylight—also provide visual relief, a visual portal on the world outside the building, time orientation, and a possible source of ventilation and emergency egress ,Other sources of daylight include light pipes with mirrored inner surfaces that bring natural light deep into a building interior, skylights, skydomes, and reflective devices and surfaces that spread daylight more evenly in occupied interior spaces. A light shelf is a reflecting overhang set above eye-level with a transom window above it. View windows can be glazed to minimize glare ultraviolet rays while more intense light can be permitted through the transom windows and reflected farther into the building's interior spaces.

If not integrated with electric lighting systems, a building designed for daylighting will be a net energy loser because of increased heat absorption. The electric lighting load must be reduced to realize savings in electrical and cooling loads. The benefits of daylighting are the greatest when occupancy and lighting sensors along with electronic dimmers are used to control the electric lighting system, adjusting it as the needs of the occupants and the available light outdoors changes.

Occupancy sensors use passive infrared, ultrasonic, or a combination of the two. Sensors detect body heat or movement. If neither is detected after a preset delay, the sensor will signal the room lights to turn off. Used alone, occupancy sensors are ideal for low- or intermittent-use areas such as storage rooms, restrooms, and some corridors. Light sensors have a photoelectric sensor that measures room illumination and can be set to respond to specific lighting conditions. The sensors can turn individual lights on or off and can also operate a continuous dimming system that makes changes in lighting levels less noticeable to occupants. The coordination of daylighting with an electrical lighting system requires careful planning for a successful system. The layout and circuiting should correspond to the available daylight.

High-performance Insulation

A type of super-insulating material increasingly used for residential and light commercial buildings is structural insulated panels used in floors, walls, and roofs. The panels are manufactured by forming a sandwich of rigid foam plastic insulation between two panels of plywood. The panels generally cost about the same as building with wood-frame construction, but labor costs and job-site waste are reduced (Structural).

Methods To Decrease Energy Use by Building Operating Systems

Most large, multistory buildings employ sophisticated, computer-based building control systems that integrate key subsystems such as lighting, security, fire protection, heating and air conditioning, occupancy sensors, and large networks of programmable thermostats. Such operating and control systems afford a high degree of fine-tuning capability and operating flexibility for differential environmental control in various locations of a building, depending on their exposure to daylight and weather conditions. Other methods include rooftop wind turbines and geothermal heat pumps.

An understanding of building occupancyand activities can lead to building designs that not only save energy and reducecosts, but also improve occupant comfort andworkplace performance. The proposed building is carefully sited and its programmed spaces are carefully arranged to reduce energy use for heating, cooling,and lighting. Its heating and cooling loads are minimized by designing standard building elements—windows, walls, and roofs—so that they control, collect, and store the sun's energy to optimum advantage. These passive solar design strategies also require that particular attention be paid to building orientation and glazing.

Some conventional building envelope materials can be replaced by energy-producing technologies. For example, photovoltaics can be integrated into window, wall, or roof assemblies, and spandrel glass, skylights, and roof become both part of the building skin and a source of power generation.

Low-Energy Building Design Guidelines

Application Domain : The application domain for low-energydesign is not so much a case of wherethe technology should be *installed*, butwhere it is *integrated* with the otherelements of the project to produce anenergy-efficient building that servesboth the environmental and functionalneeds of its users. When thinking aboutwhole buildings, it is important to considernot only the discrete components and materials but how the various partscan best work together to achieve thedesired results. That is what is meant bythe phrase "integrated, whole-buildingdesign."

Energy-Saving Mechanisms: low-energy design mechanisms range from a few high-profile architectural features that are solar responsive to the application of more conventional, and often less conspicuous,energy conservation technologies.Many applications are reconfigurations of typical building components, such asa change from flat façades and roofs tothose that are articulated and have surfaces designed to bounce or block directsolar rays.For most non-residentialbuildings, an energy-use reduction of 30% below what is required by codes and standards can usually be achieved with little, if any, increase in construction cost.

Evaluating a specific project for selecting and integrating low-energy design strategies starts with an understandingof the following factors:

1. ClimateNot just is it hot or cold, but how humidis it? Is it clear or cloudy,and during what times of the year? Clearwinter climates are well matched with spaces that incorporate passive solar heating strategies. In contrast, spaces (and buildings) in clear summer climates generally require a high degree of suncontrol. Clear climates also make the best use of light shelves—horizontal surfaces that bounce daylight deeper into buildings. Even the site-specific and seasonal nature of the wind needs to be understood if natural ventilation strategies are to be incorporated into abuilding design.

2. Internal Heat Gains: The heat gains from building occupants,lights, and electrical equipment can be thought of as the interior climate andshould not be generalized. Instead, during the early programming of the project,the heat gains anticipated from the sesources should be quantified for the various spaces where they apply. In some cases, such as in storage buildings and other areas with relatively few occupantsand limited electrical equipment,these heat gains will be minor. In other instances, the presence of intensive andenduring internal heat gains may be a determining factor in HVAC systemdesign. Examples of intensive and enduring influences include activity based gains, such as those produced by cafeterias and laundry facilities and technological or industrial gains, such as the heat produced by main frame computers or heavy machinery.

3. Building Size and Massing: In a low-energy building, both the indoor and outdoor climates exert a powerful influence on all aspects of building design. Sometimes, they complement one another, such as the case of a building with a lot of internal heat gains sited in a very cold climate. At other times, however, the two climates are antagonistic, such as when there area lot of internal heat gains in a very hot climate. Understanding the implications of these factors is fundamental to determining appropriate low-energy design strategies for a particular building project.Under hot/hot conditions, buildings with large footprints and a large amount of floor space far from the exterior of the building will require heat removal in the interior zones (generally by mechanicalcooling) all or much of year.The other basic planning approach is to position all spaces that can benefit from connection to the outdoors in proximity to exterior walls. To achieve this, buildings become much narrower, with a maximum width of about 70 feet. Such an approach to building massing must,by necessity, be introduced very early in the design process.

4. Lighting Requirements: The lighting needs of a building's various spaces need to be identified, both quantitatively and qualitatively, as part of the environmental programming conducted early in the project. Many spaces, including lobbies and circulation areas, requiregeneral ambient lighting at relatively low foot-candle levels (10 foot-candles or less). Such spaces are ideal candidates for daylighting. In contrast, some spaces are used for demanding tasks that require high light levels (50 foot-candles or more) and a glare-free environment. Here thedesign team's attention may shift from daylighting to a very efficient electricallighting system with integrated occupancysensors and other controls.

5. Hours of Operation :Intensive building use increases the need forwell-controlled, high-efficiency lighting systems. Hours of use can also enhancethe cost effectiveness of low-energy design strategies.In contrast, buildings scheduled for operations during abbreviated hours (including seasonal occupancy facilities,like some visitor centers), should bedesigned with limited use clearly inmind.

6. Energy Costs:The cost for energy, particularly electricalenergy, for most non-residential buildingsis a critical factor in determiningwhich design strategies will not onlyconserve energy, but will also be costeffectiveFor example, increasing the glassarea and the commensurate daylightentry can save expensive electrical use

7. Building-Appropriate Site Selection*:* This process involves choosing a site that fully supports the energy reduction strategies contemplated forthe project. During site selection, locate buildings that do not require extensive exterior exposure on shaded or confined urban sites. Buildings that will benefit from a greater degree of exterior exposure should be located on open sites.

8. Perimeter Circulation Space*:* This passive solar strategyuses circulation (corridors) and casual meeting spaces as buffers between the façade and the interior conditioned spaces. Because perimeter circulation plans generally require slightly more total floor area, it is necessary to examine user needs and evaluate the strategy in light of the overall budget. If the strategy is acceptable, look for buffer spaces that can be located along the building's exterior, particularly along the south façade.

9. Direct-Gain Passive Solar Heating*:* Installing south-facing glazingin an occupied space enables the collectionof solar energy, which is partiallystored in the walls, floors, and/or ceilingof the space, and later eleased. Glazing must face within15 degrees of true (solar) south, and theaffected areas must be compatible withdaily temperature swings..

10. Induced (Stack-Effect) Ventilation*:* Heated air rises within amid- or high-rise building to the top(often below a glazed roof in an atrium),where it exits through roof openings. This process induces ventilation of the adjoining spaces below. Incorporate air inlets, generallyin the form of operable windows,at the building perimeter. For best results, use open-office space planning andavoid partitions that inhibit air movement.Consider complementing natural ventilation with controllable passive ventilators located in the upper portions of the building. Carefully coordinate the implementation of this strategy with building HVAC system and controls.

11. Landscape Shading*:* The use of existing or planned trees and major landscaping elements to provide beneficial shading. Study planting plans of existing site landscaping to determine whether existing trees can be retained and incorporated into the planning process. Perform shading analyses of plants in both immature and mature forms to estimate energy savings during plants' anticipated life span. When ever possible, avoid or remove plantings that would compromise useful solar gain.through Windows.

12. Earth-Protected Space *:* Bermed, or partially buried,construction can moderate building temperature, save energy, and preserve open space and views above the building. Berm against walls or earth cover roofs (in severely hot or cold climates) or combine high horizontal windows with light shelves located above earth-sheltered walls. In some cases,using "invisible" earth-protected buildings can help counter community resistance to bulky new construction.

13. Solar Water Heating*:* Solar water heating uses flat-plate solar collectors to preheat domestic hot water. Design an array of flat-plate solar collectors that include an absorber plate (usually metal), which heats when exposed to solar radiation. Most common among these are indirect systems that circulate a freeze-protected fluid through a closed loop and then transfer heat to potable water through a heat exchanger.Typically roof-mounted, solar collectors should face south and tilt at an angle above horizontal, approximately equal to the latitude of the project location. This configuration will provide optimum year-round performance. Provide a pipe chase to a mechanical room. The room needs to be large enough for storage tanks.

14. Building-Integrated Photovoltaic Systems*:* Photovoltaic (PV) arrays arenow available that take the place of ordinary building elements (such as shingles and other roofing components), converting sunlight into electrical energy without moving parts, noise, or harmful emissions. Commercially available systems include thick, crystal, circular cells assembled in panels and thin-film products deposited on glass or metal substrates. To be cost effective, BIPV must intercept nearly a full day's sun, so it isoften most effective as a replacement for roof or atrium glazing. BIPV also works well as spandrels that are fully exposed to the sun.

15. Glazing for Walls*:* Glass products are now available with a wide range of performance attributes that allow designers to carefully select the amount of solar gain,visible light, and heat that they allow to pass through. Solar heat is measured by the properties of shading coefficient (SC) and solar heat gain factor (SHGF). An SC of 1.0 applies to clear 1/8-inch thickglass with other glasses that admita lesser amount of solar heat having alower SC.

16. Shading Devices*:* Fixed or movable (manual or motorized) devices located inside or outside the glazing are used to control direct or indirect solar gain. A wide range of shading devices are available, including overhangs (on south façades), fins (on east and west façades), interior blinds and shades, louvers, and special glazing (such as fritted glass). Reflective shading devices can further control solar heat gain and glare.

17. Daylighting through Windows*:* Using day lighting through building windows can displace artificial lighting, reduce energy costs, and is associated with improved occupant health, comfort, and productivity. Place much of the façade glazing high on the wall, so that daylight penetration is deeper. Considerthe enhanced use of day lighting by installing light shelves on south façades. Recognize the inter dependencies in glazing, light fixtures and controls,and HVAC systems. When ever possible, electrical lighting should be considered a supplement to natural light.

18. ***Extended Daylighting through Windows—Light Shelves****:* Ahorizontal device or "shelf"that bounces direct sun light off the ceiling and deeper into the interior spaces.Light shelves are also used to provide shading and suppress glare. Light shelves are located above vision glazing (up to and slightly above eye level), but below high glazing above. They may be positioned inside or outside , or both . Integrate the light shelves with façade design, office layout, lighting design, lighting controls, glazing, and shading devices. They tend to workbest with moderately high ceilings and openplanning.

19. Natural Ventilation through Windows*:* User-controlled operation of windows provides outdoor air for ventilation and cooling, and should improve indoor air quality.

Locate windows that will serve as air inlets to face prevailing winds. During the cooling season, this strategy can be enhanced by landscaping features and projecting building features (such as fins). This strategy tends to work best in residential-type occupancies,where the user already has control over HVAC.

20. Window Geometry: Windows should be shaped and located in a manner that minimizes glare and unwanted solar gain and maximizes useful daylight and desirable solar heating. Make window decisions based on occupant activities and low energy performance rather than simply for aesthetic purposes. Having said this,reduce glass area whenever possible. To minimize glare and enhance daylighting benefits, substitute horizontal strips of high windows for "punched" windows, and scattered small windows in lieu of a few large ones.

21. ***Differentiated Façades:*** In this strategy, the designer creates variations in the façade designin response to changes in orientation, the use of space behind the façade, and the low-energy design strategies being employed. Select a design consultant who can work with the concept that the appearance of a building's various façades will likely differ in esponse to variations in their environmental loads.To that end, pursue a building style that is compatible with functionally varied façade elements.

22. Insulation: A well-insulated building envelope reduces energy use, controls moisture, enhances comfort, and protects the energy-saving potential of passive solar design.

23. ***Air Leakage Control:*** Air retarder systems areused to reduce air leakage into or out of a building. Install air-impermeable components that are sealed at the joints and penetrations to create a continuous,air tight membrane around the building. Note, however, that air retarders placed on the winter/cold side of the insulation must be vapor-permeable to avoid trapping moisture within the walls.

24. Roof Monitors: Roof monitors are windows installed at roof level, typically verticalor steeply sloped. South-facing roof monitors should use vertical glass and be shaded by overhangs to provide daylight and useful solar heating . By contrast,north-facing roof monitors need not be concerned with glare or the unwanted entry of direct solar rays. North-facing glazing can be inclined some what to access the over head sky better,which provides a much greater level of diffuse daylight than does the sky near the horizon. As a general rule of thumb,avoid east- and west-facing roof monitors. Also avoid horizontal glazing, which typically over heats the building, thereby dramatically increasing cooling loads.Minimize the amount of glass required to achieve desired illumination levels,and avoid narrow slots with glazing on opposite sides.

25. Scattered Skylights: Small, individual spot-located skylights. Generally achieved with prefabricated elements that have flat or domed glazing, spot-located skylights should be used with care, except in cases where potential glare and direct sun penetration is of little concern within the building. Use sparingly—large numbers of separate skylights are expensive in comparison to glazed roofs.

26. Glazed Roofs: Glazed roofs are large-area skylights typically found over atrium spaces. Consider installing a clear span glazed roof between buildings or building sections to create a covered“street.” Solar heat gain can be controlled through use of fritted glass or louvers.

27. Non-Absorbing Roofing: Roofs covered by light coloredor reflective membranes are aviable passive solar strategy, as they tend to absorb less heat. Use roofing systems with light-colored or reflective top layers.

28. Lighting Controls: Lighting controls automatically adjust lighting levels in response to daylight availability. Other controls automatically turn lights off in response to unoccupied space. Automatic daylight dimming controls either provide light levels in discrete steps or through continuous dimming, based on light levels sensed. Occupancy sensors are used to turn off lights and some times HVAC in unoccupied areas. They are made with multiple activation technologies, including thosethat sense body heat (infrared) as well as those that detect motion (ultrasound).

30. High-Efficiency Heating, Ventilation, and Cooling Equipment: This category of equipment offers operating efficiencies far greater than those afforded by systems designed to simply meet applicable codes or standards. There are various types of efficient heating and cooling equipment that can readily address the specific needs and operating patterns of a given building. Computer analyses are required along with some form of rigorous life-cycle cost analysis.Consider using modular equipment (e.g., three small boilers instead of one large one or a dual compressor chiller) and variable-speed equipment (modulating burner or variable-speed chiller) for greater flexibility in achieving targeted reductions in energy use..

31. Exhaust Air Heat Recovery: This process involves the recovery of useful heat from the air being dispelled from a building. Various types of heat exchangers are in use today, including heat wheels, plate and fin air-to-air heat exchangers, and heat pipes. Heat pipes are very simple devices that consist of a highly conductive tube filled with refrigerant which, when vaporized, transfers heat from the outgoing to the incoming air stream.

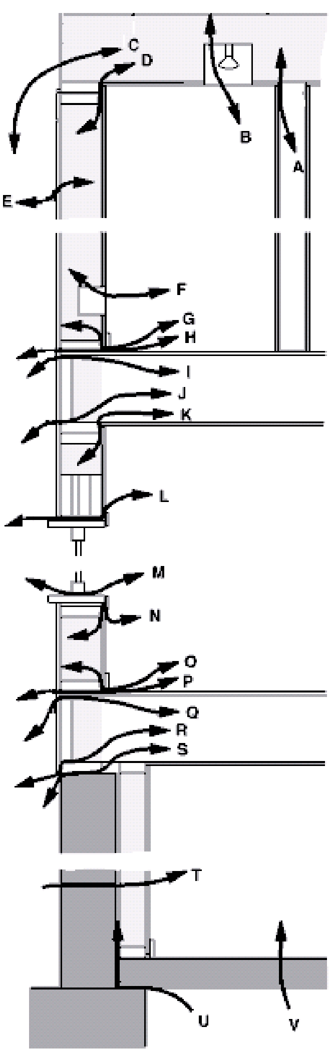
Because heat exchangers obstruct the air passage of both intake and exhaust ducts, by pass dampers should be installed to facilitate operation during mild or warm weather.

32. Economizer Cycle Ventilation*:* Contributing to both energy reduction and good indoor air quality,this strategy introduces a varying amount of ventilation air to cool the building in combination with normal air conditioning (AC).

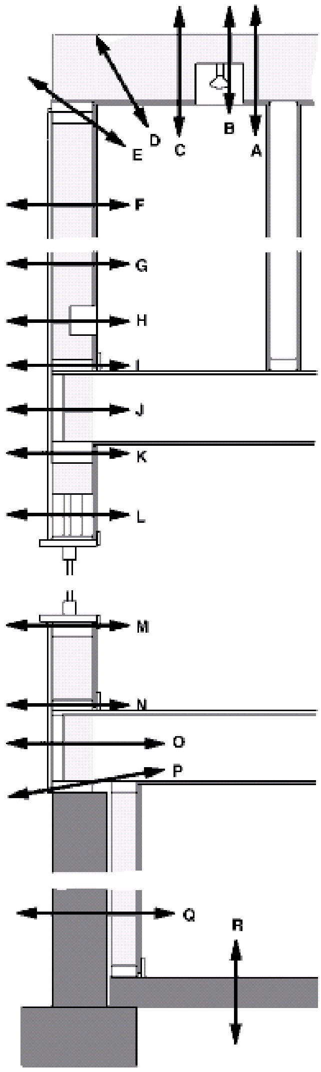
33. ***Night time Cooling Ventilation****:* High-volume, fan-powered ventilation of large areas during cool,dry nights. This strategy relies on moving large quantities of air in an economical manner and requires a secure source of intake ventilation that can be directed into spaces to be cooled.

34. HVAC Controls*:* Specify controls that maintain intended design conditions, including temperature, humidity, and air flow rate in terms of cubic feet per minute (cfm) throughout the building. Keep control systems as simple as possible. Avoid controls that offer little in the way of improved operations or energy savings, especially if they complicate the system and add features that require frequent maintenance or are subject to malfunction. Evaluate the use of variable-speed drives (VSD) on all large pumps and fans serving loads that only occasionally function at peak capacity. In large spaces with varying occupancies (auditoriums, large meeting rooms,cafeterias), investigate control strategies (e.g., the use of carbon dioxide monitors) that regulate the amount of outside air in accordance with actual occupancy.Consider using set back thermostats in all building types. However, avoid setting temperatures back in spaces where a large amount of exposed thermal mass will make it difficult to reestablish comfortable temperatures.

Air leakage pathways



Heat conduction pathways



Moisture transmission pathways