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ENERGY EFFICIENT COMMERCIAL BUILDING DESIGN STRATEGIES

Baharuddin[1)]

ABSTRACT

This paper explores some of design strategies in designing energy efficient commercial buildings. It describes energy efficient terms in relating to the occupant's comfort such as thermal, visual comfort and air quality. Therefore, this paper tries to present several strategies that can be applied in designing energy efficient buildings especially commercial buildings. These strategies include building form and orientation; building envelopes: windows and shading, insulation, air leakage, colour and surface properties; lighting design: daylighting, advanced glazing, innovative side-lighting, energy-efficient artificial lighting, heating, ventilating and cooling: energy-efficient HVAC systems, mixed or hybrid ventilation, night ventilation, and thermal mass; and building integrated photovoltaic (BIPV).

Keywords: Energy Efficient, Commercial Building, Daylighting, Design Strategies

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INTRODUCTION

This article describes some of the factors that should be taken into account in order to improve commercial building design. One way to improve commercial building design is to apply energy-efficient design. Energy-efficient buildings are the buildings that consume low energy without sacrificing the occupants' comfort such as thermal comfort, air quality and visual comfort. In order to achieve these goals, the building should be designed using integrating design method.

1) PhD candidate, Hongkong University, Hongkong. Lecturer at Department of Architecture Faculty of Engineering Hasanuddin University, Indonesia. E-mail: baharsyah@yahoo.com

To support this design integration, this paper will describe several strategies, which are used to achieve energy-efficient and comfortable commercial buildings. These strategies include building form and orientation; building envelopes: windows and shading, insulation, air leakage, colour and surface properties; lighting design: daylighting, advanced glazing, innovative side-lighting, energy-efficient artificial lighting, heating, ventilating and cooling: energy-efficient HVAC systems, mixed or hybrid ventilation, night ventilation, and thermal mass; and building integrated photovoltaic (BIPV).

ENERGY-EFFICIENT DESIGN

Prasad (1995) points out that commercial buildings consume more than 50% of the energy in order to satisfy occupants' thermal and visual comfort. To reduce this energy consumption energy efficient design should be applied. The benefit of energy-efficient buildings not only for the owner/tenant but also for utilities in managing their peak demand and for the society at large through minimising the ecological impact of energy use (such as greenhouse gases).

Nowadays, two equal important criterions are becoming the standard of building design practice. Firstly, the building design must provide a comfortable environment for the occupants. Secondly, the building must be designed to achieve energy-efficient building. As Haves (1992) points out that the priority of design is to meet the needs of the building owner or occupants by providing a design that will provide a comfortable and productive environment which consume less energy and require low maintenance. Daylighting and natural ventilation have a great possibility to be integrated in energy-efficient design in order to achieve these objectives. There are a lot of studies have been done regarding these requirements over more than twenty years.

Wong et al. (2000) state that the understanding of the interactions between various aspects of building performance and also their implication on building control systems is one of the challenges in design process. The over-reliance on mechanical systems to achieve required levels of comfort and health also obscured the inherent performance implications of other critical building design decision. Similarly, Papamichael (1999) points out that design decision are based on the comparison of several alternatives with respect to variety of performance consideration, such as, comfort, aesthetic, economic and environmental impact, etc.

Balcomb (1998) stressed that understanding building behaviour is an important first step in designing to reduce energy and at the same time improve indoor comfort and improve indoor air quality.

Chiogioji and Oura (1982) present two methods of reducing the use of energy in building. Firstly, it involves changes in the way we operate existing systems such as raising thermostat setting in room air conditioning, lowering of hot water temperature setting, better HVAC systems, and reduction of the use of artificial lighting in commercial building. Secondly, improvement of efficiency of equipment used in building and building structure such as using insulation.

COMFORT REQUIREMENTS

Pidcock & Cowdroy (1996) states that comfort is a balance of complex biological and psychological responses of individuals to their immediate environment and to conditioning and experience. Discomfort is an imbalance in the complex responses to the environment and may be due to either biological or psychological imbalance, or both. As a result of this inherent complexity, the conditions that are required to achieve comfort for each individual are not constant. Control of the environment to the level necessary to achieve real (perceived) comfort therefore requires an inside-to-outside approach and balanced relationships between the whole, sensory person and the environment. This approach contradicts the conventional outside-in approaches characterised by anthropometric modelling of comfort conditions. Achievement of real comfort therefore requires the development of a more comprehensive brief, increased selectivity in the application of performance and design criteria and a more flexible, humane set of response systems.

Thermal comfort

Thermal comfort is a subjective judgment of the influence of temperature surrounding a person. It is a state of the mind that expresses satisfaction with the thermal environment in the absence of intrusive thermal sensation (ASHARE standards 55-1981 cited in Lim and Teh, 1999). Thermal comfort is achieved when there is equilibrium between the skin temperature and the core temperature of the body. This is when the heat produced by the body's metabolism is in equilibrium with the heat loss from the body (Lim and Teh, 1999).

According to Pidcock and Cowdroy (1996) thermal comfort can be determined by environmental factors such air temperature, thermal radiation, air speed, and humidity; and personal factors such as activity/metabolic rate, and clothing/thermal resistance.

In order to maintain comfort during the occupancy and prevent damage of fabrics outside occupancy the temperature should be controlled. Building envelope has a major contribution in controlling the indoor temperature. In order to control the room temperature, according to Haves (1992) we need to vary: (1) solar gain (2) natural ventilation rate (3) conductive heat flow through the building envelope (4) the temperature or flow rate air introduced into space by mechanical equipment (5) the temperature or flow rate of water in radiators.

In the energy efficient design book of United Nation (1991) it is stated that temperature levels that acceptable for individual needs and comfort must be maintained by heating and ventilating systems. Temperature levels are usually set between limits defined by statutory legislation or best practice guide.

Air quality

On the alert of sick building syndrome (SBS) since 1980, indoor air quality (IAQ) has become another equally important design factor. Air quality influenced by a number of factors namely, thermal behaviour of building envelope, space air movement, occupant activities, HVAC systems and its own control and management scheme (Chow, 1998).

Ventilation must provide adequate supplies of fresh air, while maintaining comfortable humidity levels and minimizing pollutants. Certain type of buildings, room and task require mechanical ventilation or air conditioning, with attendant energy demands (United Nation, 1991). Similarly, Cooper (1995) states that maintaining indoor air quality at acceptable level is one of the purposes of building ventilation.

Visual comfort

Guzowski (1999) points out that even though IAQ may be a primary component in resulting SBS, many researches and designers suggest that there may be another important issue. Some researches and designers recognise lighting as SBS contributor. To support this statement Guzowski cited the perspective of Gardner and Hannaford that “Poor lighting can be a major, but unrecognised, cause of workers to make more mistakes, or to take more time to read written material, and to work slower, Employees’ health may even be affected; badly designed, poorly specified lighting can cause stress and its often associated with glare, eye strain, migraines and other features of what known as ‘Sick Building Syndrome’.” Guzowski also cited the statement of Alan Hedge, associate professor of the College of Human Ecology at Cornell University that support Gardner and Hannaford’s perspective: “SBS complaints seem to be the result of the interaction of multitude of environmental, occupational, and psychological factors, and they probably are not caused by poor indoor air quality alone.” Hedge found that the quality of the lighting environment correlates directly to the frequency of vision-related symptoms such as headache, eyestrain, and visual discomfort.

In order to optimise visual comfort, daylighting should be integrated with artificial lighting. Two key factors that determine visual comfort according to Guzowski (1999) are ‘user controls’ and ‘flexibility’. These mean that the occupant can modify the amount of light, response to the changing of light, and control the reflection of light from windows or skylights.

Similarly, Balcomb (1998) argue that one way to achieve the visual comfort is to apply daylighting in building environment. This is because daylight adds variety, character, sparkle, and vibrancy to indoor spaces. Daylighting is most often designed into a building for its own sake. Good architecture required the intelligent use of daylight.

ENERGY-EFFICIENT DESIGN STRATEGIES

Building form and orientation

According to Todesco (1998) “the most efficient building encloses the largest volume for the least surface area because heating and cooling energy use is affected by the amount of exposed wall area. The building form with the minimum surface to floor area (S/F) is a cube.”

In terms of orientation, energy use can be minimised by limiting building’s exposure to the east and west. When possible, building should be oriented with a long axis running in east-west direction (Todesco, 1998).

Building envelopes

Building envelope is one of the major aspects that must be paid attention in designing energy-efficient building. This is because, according to Energy Victoria (1994), building envelope has a great impact on the energy performance of building. A potential reduction up to 50% of energy costs can be achieved by a well design building envelope.

Window areas, orientation, type and shading

Todesco (1998) explains that “limiting windows area in the east and west facades and using shading techniques such as deep window recess or window overhangs can control glare. Similarly, heat gain and heat loss can be minimised using high performance glazing that improves occupant comfort."

According to Verma and Suman (2000) shading is used to reduce heat gain while allowing the light enter the rooms. Shade factor of shading devices plays a very important part in reducing the heat gain inside the building. Sharma (1972) cited in Verma and Suman (2000) present three different shading devices: (1) External shading devices such as louvers, sun breaks, verandah etc. (2) Internal shading devices such as curtain, Venetian blinds, etc. (3) Double glass, heat reflecting and heat absorbing glass.

Insulation levels

Insulation is needed to reduce heating and cooling loads by making the building fabric more resistant to heat transfer. All the different types of external wall elements in a building require insulation. These include the various materials used in the roof, wall elements such as masonry, timber, brick veneer, fibre-cement and tilt-up concrete, and floors. A wide range of insulation products is available to suit all these different needs. Naturally, each product has to be correctly installed to achieve best possible results (Energy Victoria, 1994).

Insulation products vary widely – the most commonly used include fibreglass, rockwool, natural wool, polystrene, various rubber types and reflective foil. In order to choose the right insulation materials, the designers should compare the R (resistance) value of each (Energy Victoria 1994).

Hastings (1993) describes new insulating systems using transparent insulation. This material provides distinct advantages particularly in mild or cold and sunny climates. Hastings describes the difference between the characteristic of walls insulated by opaque and transparent insulation. Solar radiation is absorbed by a layer of plaster on the exterior. Insulation under the plaster impedes solar thermal gains by the masonry wall. On the other hand, with transparent insulation, solar radiation is partially transmitted through the insulating layer to absorb at the exterior surface of the wall behind the insulating layer. Transparent insulation permits a large part of the absorbed energy to be conducted into the wall. Therefore, in order to reduce the amount of winter heat loss and summer heat gain, insulation of walls, roof, and floors and sealing of window and door openings must be accurate.

Air leakage

Unwanted air movement will lose or gain heat unnecessarily. Draughts mostly occur through small gaps and openings in the building envelope such as around doors and windows. Air leaks usually mean increased heating and cooling energy and cause occupants' discomfort (Energy Victoria, 1994).

Infiltration of outside air through crack around doors, windows, and other elements of exterior cause one of the major loads on any building. Infiltration, which in a particularly bad building can account for up to 25% of the entire energy conservation in commercial building (Chiogioji and Oura, 1982).

Colour of building envelopes

According to Energy Victoria (1994), in well-insulated materials, colour is less of a concern. However with poorly insulated materials, colour is very important. Dark surface of metal window, for example, can significantly affect the annual energy use.

A study done by Akbari et al (1999) proved that there was a potential cooling energy savings can be achieved when using a reflective (light colour) roofs in residential and commercial building in the United States, especially for single story building in hot and sunny climates.

Lighting design

Daylighting

Daylighting become one of a major consideration among architects and designers in dealing with better building design. Balcomb (1998) points out the important of daylighting as a design strategy. He states that among design strategies daylighting, which is the use of natural light to replaced artificial light, fulfills a unique role. It can be argue that the most important reasons to daylight a building are:

- to improve the aesthetics of indoor environment
- to enhance the productivity of the occupants
- to decrease peak electric loads
- to reduce emission of pollutant (CO_2, SO_2, NO_x)
- to save energy and operation cost

So if the focus only on energy saving, according to Balcomb (1998) the most critical factors are missed. Daylighting design is challenged, sophisticated and complex.

Daylighting has been shown to be an important element in energy efficient building design, particularly in passive solar design. The buildings with daylighting will always consume less energy than the same building without it. The design of daylighting scheme depends on attending to subtle interaction of a large number of design factor. Detailed hourly building energy simulation technique have proved useful in understanding the thermal and energy performance of buildings and the impact of all related factors on building energy use due to daylighting. The proper use of daylighting technique can be use to reduce the electricity consumption and peak cooling load (Lam et al., 1998).

However, the application of daylighting strategy can result in some problems. According to Hastings (1994) "some daylight strategies may decrease quality of light, glare, contrast ratios, veiling reflections and light colour and variation with time all to be considered; improvements in energy use at the cost of human comfort and productivity are worthless gains. The strategies considered in any design application must always be considered with an overall perspective. It is not just a question of illumination available on horizontal surface, but the interaction between light quality, climate, building function and orientation, and building materials and equipment for overall usage and occupant comfort."

Hastings (1993) describes the two daylight strategies, they are classical strategies, which is includes window, clerestories, light shelf, monitors, sawtooth, and skylight; and new strategies, which is includes advanced glazing, innovative side-lighting, and core daylighting system (atrium). Energy Victoria (1994) describes some of these strategies:

- Windows

  Use vertical windows and clerestories to illuminate the interior of buildings. The distribution of light can be direct from the window or indirect via light selves that reflect light onto the ceiling and down to the work plane. In most cases, light will only penetrate 4-6 m into the room from one side. Rule of thumb states that daylight can penetrate back into the room a distance 2.5 times the distance between the work plane and the top of window.
- Skylights

  Skylights are apertures cut through the roof of the building. There is a difficulty in controlling the direct beam radiation, but skylight give excellent daylight. Skylights unfortunately tend to gain and lose heat in great amount than other types of window. As a result can cause comfort problem to the occupants.
- Sawtooth

  Sawtooth apertures are a top-lighting technique that includes a vertical glazed surface and slopping roof. The distribution system can be baffles as well as the slopping ceilings.
- Monitors

  The monitor aperture is similar to the sawtooth but has two opposing vertical glazed surfaces above the general roof line. The distribution system can also be baffles.

Advanced glazing

Highly-glazed designs become more popular especially in commercial buildings. However, they can lead to major design problems that are energy wastage and discomfort

In order to minimise these problems, according to Hastings (1993) the building should use the new glazing systems, which can improve daylighting design strategies such as the possibility to reduce the energy wastage and discomfort. He classified glazing on two major categories, which are superinsulating glazing and glazing with control capabilities:

- Superinsulating glazing reduces the heating penalties normally associated with fenestration and thus enables an increase of daylight apertures, giving more daylight to deep perimeter areas. Recent innovation in glazing have a successfully in insulating window with multiple glazing layers with low emissivity coatings and inert gas cavity.

- Switchable glazing, that is, glasses capable of dynamically varying the transmission of light and radiation can adjust automatically to outside condition and control the admission of daylight and solar energy. By reducing the transmission, switchable glazing can also reduce glare and overheating, which is particularly useful in the perimeter close to the window where daylight illumination often exceeds design values. Switchable glazing falls into three categories:
  - Electrochromatic glazing whose transmission is changed by applying an electric field.
  - Photometric glazing whose transmission depends on a change in light level, and
  - Thermochromic glazing whose transmission can change with a change in temperature.

Among these options, electrochromic glazing appears to offer the best control and the largest potential for saving energy.

Similarly, Prasad (1995) describes the new glazing systems than can be used for solar controls. This is relate to the development of absorptance, transmittance, reflectance and emittance of the glazing systems. *Low-E Glass* Low-emittance glass, which has a metal coating which reflects radiant heat back to the source, should prove beneficial in most climates. *Chromogenic Glass* These new ‘smart’ glazings respond dynamically to heat, light or electrical impulses and can change their transmissive properties from high (80-90%) to low (20-30%) within seconds while changing their colour as well.

Innovative side-lighting

According to Hastings (1993) the challenges in using daylighting in sidelit interiors are controlling daylight levels and solar gain in the zone closest to the windows, enhancing daylight levels in the deeper zone, and extending the depth to which daylight may replace artificial lighting. Conventional light shelves can solve some of these problems by reducing the daylight levels and insulation close to the window and perhaps by increasing daylight levels to a small degree at the back of space.

Hastings (1993) also describe the new side-lighting systems include solar shading which admits diffuse light and sunlight to the back of the room. Systems which redirect sunlight to deeper zones inherently work also as shading systems for the zone close to the windows. Several technological options exist for such applications: (1) prismatic glazing or prismatic panels (2) reflective blinds, mirror panels (3) holographic glazing, and (4) lens systems

Core daylighting systems (Atrium)

According to Energy Victoria (1994), atrium is a core lighting technique that can be used in multi-story buildings. The centre of the building is opened up and glazed at the top. Windows light the outside perimeter of the building. The ratio of height to width of the light well in the atrium should not exceed 2:1. Sometimes reflectors can be used to bounce light well back into the building.

In the commercial building, atrium can be used not only to provide light for the building but also can acts as a heating system – a buffer reducing transmission losses from adjacent spaces to ambient and may also provide heat to adjacent spaces, and can acts as a cooling system – induce natural ventilation and avoid undesirable solar gains (Hastings, 1993).

Energy-efficient artificial lighting

The basic purpose of lighting is to enable vision. McLean (1995) points out that "energy efficient lighting is not merely lighting that uses less than its predetermined power consumption. It is lighting that creates the desired visual environment by the most energy efficient method. The energy effect of lighting is not confined to the energy consumption of light fittings. Lighting is also a significant source of heat load for the building. In an air conditioned building this affects the initial plant size and the running cost of the system. In a passive design it may cause the summer performance of the building to fall short of that predicted."

Chiogioji and Oura (1982) cited the Illuminating Engineering Society's recommendations for saving energy in illumination systems, without sacrificing visual comfort:

- Design lighting for expected activity.
- Design with more effective luminaires and fenestration.
- Use efficient light source.

- Use more efficient luminaires.
- Use thermally controlled luminaires.
- Use care in choosing the finish on ceilings, walls, floors, and furnishings.
- Use efficient incandescent lamps.
- Provide flexibility in the control of lighting.
- Design fenestration to control heat-producing radiation entering space.
- Design fenestration to use daylighting as practicable to produce the required illumination, either alone or with an electric lighting.
- Select luminaires with good cleaning capability and lamp with good lumen maintenance.
- Post instructions covering operation and maintenance.

The adequacy of lighting in a task, in terms of visual performance criteria and the perception of the user can be influenced by a number of factors. If the users' perception of the lighting falls short of their expectation, even though the illuminance may be adequate, they will add light to compensate or at least complain about inadequate lighting. The key to energy efficient lighting is to create an environment that meets the needs of the users (McLean, 1995).

Heating, ventilating and air-conditioning (HVAC) systems

Energy-efficient HVAC systems

In designing HVAC system, some important considerations should be taken into account. They are the types of HVAC systems that efficient to be used, the size of HVAC system, and the HVAC control systems.

In terms of distribution, according to Energy Victoria (1994), there are two type of HVAC systems available. They are centralised plant and packed plant. Centralised plant has some advantages over packed plant. Centralised plant is more efficient than packed plant. It is also generally cheaper to buy and to run for the cooling and heating loads 100 kW or more than packed plant.

Energy Victoria (1994) presents some features of modern HVAC systems that should be consider in HVAC design:

- *Controls and Energy management.* These systems measure various conditions concerning HVAC and lighting by using electronic system and can be automatic system. The system control HVAC and lighting system such as room temperature, outside air temperature, light levels in room, etc, and then direct the appropriate equipment to adjust to the specific condition.
- *Economy air cycles.* This part of HVAC system draws in outside air for space cooling when the outside air temperature of the air returning from the building. This system can be easily integrated into centralised plant.
- *Variable air volume (VAV).* This type of HVAC system uses varying volumes of air delivered to different room spaces according to changing requirements for cooling. All the air in the building is therefore at a constant temperature. This is contrast to a Constant Air Volume that uses varying air temperature to cope with the changing conditions in each room space. VAV systems are more energy efficient because their fans can operate at much lower speeds for much of the time.

Todesco (1998) suggests that "HVAC equipment should be sized as closely as possible to design loads by taking into account any load reductions from an improved building envelope, use daylighting strategies and any other efficient measures. It is also important to use appropriate values for lighting loads, office equipment/plug loads and occupant densities that reflect actual condition or are based on measured data rather than suggested guidelines, accepted practice or nameplate ratings."

Mixed or Hybrid ventilation

The implications of comfort have for energy consumption is important. The Sydney University experiments use a variety of individually operated mixed mode climate control devices. They are indicating energy savings in the order of 40% (Rowe 1996 cited in Pidcock & Cowdroy, 1996). A major concern of this experiment is the recognition of the importance of the individual and their ability to easily adapt their immediate environment to suit their own perceptions of comfort.

Rowe and Dinh (2001) concluded that the hybrid ventilation system could significantly improve perception of thermal comfort and air quality with very significant energy savings over the requirements of conventional air conditioning. This system allows people to operate supplementary mechanical cooling and heating equipment when they perceive the need of them. Also allows the people to operate windows and doors for ventilation in mild weather.

‘Mixed mode’ or ‘hybrid’ HVAC system is the system which combine natural ventilation and air-conditioning. This system is increasingly being specified. In such buildings the peak demand is met with air-conditioning while the majority of the heating and cooling is met naturally. Where the natural ventilation system includes Task Ambient Conditioning (TAC) through the use of occupant operable windows, automatic interlock devices are frequently specified on the windows to ensure that the mechanical HVAC is switched off if windows are opened within conditioned zones. Mixed mode systems also frequently incorporate more sophisticated zoning to allow better tailoring of the systems’ response to occupant needs (Shipworth, 1999)

Night ventilation

According to Kolokotroni and Aronis (1999) the requirements of cooling energy can be reduced by using low-energy technologies. From some of available technologies, night ventilation is particularly suited to office buildings because these buildings are usually not occupied during the night. This strategy can also be applied for some other commercial buildings, which are not occupied in the night.

Furthermore, Kolokotroni and Aronis (1999) state that night ventilation can affect internal conditions during the day in four ways:

- reducing peak air-temperatures;
- reducing air temperatures throughout the day, and in particular during the morning hours;
- reducing slab temperatures; and
- creating a time lag between the occurrence of external and internal maximum temperatures.

Night ventilation becomes one of main researches in Europe. This technique combined with thermal mass regarded as one of the most appropriate techniques for hot, cold and temperate climates. This combination techniques benefit in reducing the need for air conditioning and improving the internal thermal conditions. It can be claimed that thermal mass and night ventilation has started to be implemented as one of the default design options for 'green' office buildings (Kolokotroni and Aronis 1999).

Thermal mass

Baggs and Mortensen (1995) describe that "thermal mass is the ability of a material to store heat and is a function of its *specific heat* (kJ/kg.K) – the amount of heat required to increase 1 kg of material by 1°K - and its density. Materials suitable for thermal mass are heavy (or dense) materials with the ability to store large amounts of heat energy to provide warmth in winter and coolth (the opposite of warmth) in summer, within a relatively small volume."

Furthermore, Baggs and Mortensen (1995) state that "while the ‘greenhouse’ effect can trap large amounts of heat during the day, this heat can also be quickly lost unless materials with ‘thermal mass’ (which act as a storage medium for the heat) are used. In summer, the thermal mass effect is the most important of only three commonly possible means of ‘actively’ cooling a structure without the use of fuel. The others are ventilation and evaporation. In many climatic conditions, the thermal mass effect is the only means of cooling a building. Thermal mass influences bodily comfort by providing heat source and heat sink surfaces primarily for the radiative heat exchange processes."

Prasad (1995) presents several design considerations regarding the application of thermal mass in building design. These can be explained as follows:

- where mass is used for warmth, it should be exposed to incident solar radiation;
- where mass is required for coolth, it may be better placed in a shaded zone;
- buildings may be pre-heated using electric or hot water tubing embedded in the mass (mostly floors);
- buildings may be pre-cooled by night-flushing using night time cool outside air, although this requires significant amounts of exposed mass, and may be necessary only at certain times of the year in most Australian locations (where little thermal mass is used, night purge cooling removes warm indoor air and replaces it with cool air from outside); and
- in buildings with extended hours of use, thermal mass heated during the day can also be a cause of discomfort during the night when the heat is released.

Building integrated Photovoltaics (BIPV)

Prasad and Byrnes (1999) describe the term ‘building-integrated photovoltaics’ is loosely applied to any application of photovoltaics mounted on or within a building envelope. Additionally, it refers to projects where the photovoltaics are used to enhance the design concept of a building and where there is consideration of integration at physical, environmental and aesthetic levels. This integration can be achieved according to Guzowski (1999) by the integration of Photovoltaic (PV) with daylighting, architectural design. This technology enables the integration of PV on or within roofs, claddings, glazing, skylight and shading devices.

There are several advantages of the integration between PV and architectural design. Three of them according to Guzowski (1999):

- As energy producer, photovoltaic is used to produce electricity that can be used to fulfill the demand of the building.
- Aesthetic advantage, the building envelope can be more aesthetic than just put PV as attachment on building roof.
- Ecological advantage, this system shows the intention of the owner in the ecological problems.

Beside those advantages, according to Prasad and Byrnes (1999) "the integration of photovoltaics into buildings offers a number of potential advantages over freestanding applications of photovoltaics. It eliminates the need for separate support structures or additional land use; it can save materials and produce cost incentives for the adoption of photovoltaic technology. By increasing the appearance and desirability of a property, BIPV can improve rental or sales returns and enhance the built environment."

CONCLUSION

From above explanations we can conclude that:

- Energy efficient design is the design that use the minimum of energy requirement without reduces occupant's comfort such as thermal comfort, air quality and visual comfort.
- There is several design strategies available that can be use to design energy-efficient commercial building. However, the application of one or several of them should be see in integrated way.
- The choice of one strategy than another will depend on the microclimatic condition of the building site.

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