ACHIEVING ENERGY EFFICIENCY IN BUILDINGS DESIGN THROUGH INNOVATIVE PLANNING AND DESIGN SOLUTIONS

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Abstract

The idea that the, earth is a finite planet in the mathematical sense is commonly accepted today. In 1972, both the Club of Rome, in its report, (Meadows et al, 1972), and the first Earth summit in Stockholm expressed this idea. This amounts to all its resources including fossil energy being limited. Renewable resources, already partially tapped, will only replace a portion of this energy. This substitution will be difficult to accomplish since the level of predation of human beings on the planet is causing serious malfunctioning of the biosphere.

The building sector does not escape from today's spotlight on the environmental impacts of human activities. Buildings are major energy consumer during both construction and 'usage, and also generate large quantities of waste. Built up structures are consumers of 40% of the global primary energy and generator of 24% co_2 emission. As such, criticality of buildings and their role in minimizing energy consumption and promoting sustainability of human habitat assumes importance. The options relating to building materials, building technologies, landscaping, heating and cooling system etc have already been explored.

It is logical to apply the principles of energy costing to building prospects and look for ways to minimize energy consumption during their entire lifetime. Accordingly, the paper focuses on design strategies for making building highly energy efficient and sustainable in terms of site planning, macro and micro climatic conditions, landscaping, orientation, fenestration and shading and building materials. It discusses two case studies from India incorporating innovative design solutions to achieve energy efficiency.

Key Words- *Building Design, Site and Building Orientation, Internal Layout, Ventilation, Courtyards*

1 Introduction

Considering the role and importance of energy as the major driver of economic growth and physical development coupled with limited availability of conventional and non-renewal sources of energy and ever rising demand and spiraling market prices, issues related energy consumption, energy conservation and promoting non-conventional and alternate sources of energy have assumed global concerns. Considering the fact that existing built up structures account for 40% of the global primary energy consumption and generator of 24% of CO_2 emission, criticality of buildings and their role in minimizing energy consumption and promoting sustainability of human habitat assumes importance. With rapid urbanization and growth of population, more and more buildings would be required to be constructed to meet the increasing demand of shelter, trade and commerce, industries, entertainment, institutions etc. and accordingly level of energy consumption are likely to rise on a compounded pattern. Making buildings energy efficient have distinct advantages in terms of not only saving money on energy costs but also reduction of adverse impact on the environment through the reduced use of fossil fuels, increased comfort levels achieved through effective use of natural light and ventilation.

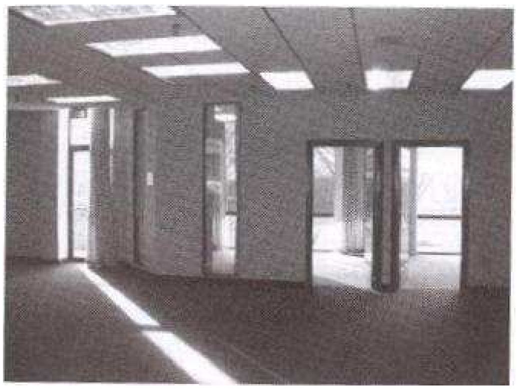

Fig. 1: *Optimum use of natural light reduce energy consumption*

2 Building Design

Buildings as they are designed, constructed and used have enormous energy implications. With number of people and institutions rushing towards urban centres, energy requirements of cities due to buildings is going to rise sharply in future. Looking at the high degree of energy consumption by built environment, which has been placed at 300 Kwh for every square meter on annual basis, there appears to be enough options to bring it down to the level of 140 Kwh with proper design. Thus built environment is the sector which would require close scrutiny and monitoring for effecting overall economy in the levels of energy consumption. Experience has shown that buildings can be designed to meet the occupant's needs for thermal comfort at reduced level of energy consumption by adopting an integrated approach to building design. The integrated approach could include orientation, shape and size of the building, built form, surface to volume ratio, building efficiency, ratio between length and depth of the building, using simple techniques of building structure, efficient structural design, principles of solar passive techniques in building design, using energy efficient equipment, control and operation strategies for lighting, heating, ventilation etc. using solar energy for meeting the energy needs of buildings, replacing energy intensive materials with low energy components etc.
Main features of energy efficient buildings would essentially revolve around

- Site and Building Orientation
- Internal Layout of Buildings
- Window placement, sizing and shading
- Insulation
- Ventilation
- Courtyard
- Landscaping
- Building Materials
- Use of energy efficient appliances

2.1 Site and Building Orientation

Orientation has the greatest impact on the energy consumption by buildings. The issue of energy in context of building, has to be viewed in the dual context of planning of plots/sites and the actual designing of the buildings. To make sure that the building makes best use of the solar and wind energy, it would be essential that the majority of the buildings should have the site advantage. Accordingly town planners have important role cast for themselves while preparing the layout plan, so that maximum number of plots have best orientation. Once this is ensured at the planning level, it would be much easier for the Architects to evolve a design which would be energy efficient.

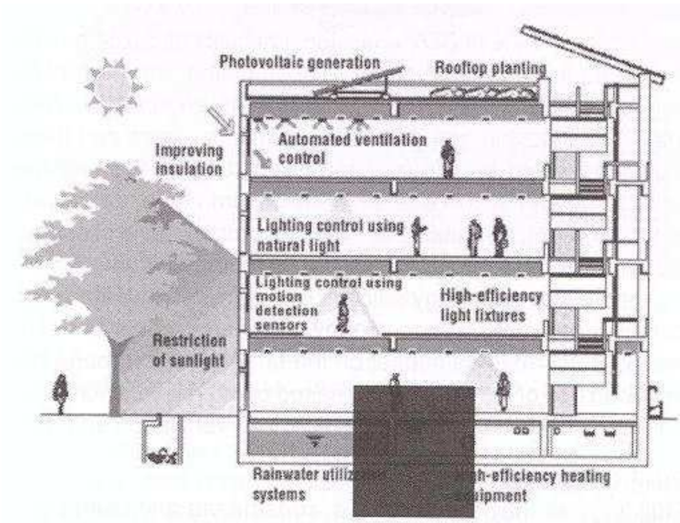

Fig. 2: *A few features of energy efficient building.*

Further the planners should ensure that ratio of plot width and depth is fixed in a manner that the entire depth of built up area allowed on a plot should have access to natural light, minimizing the requirement of artificial lighting. This would be particularly important in case of row housing where the plots have the option to draw light from front and rear only.

Orientation needs to be effectively used in order to evolve energy efficient building design by making use of solar radiation and the wind. However requirements of building design would vary from region to region, state to state and within regions in states. Accordingly, buildings with regards to sun and wind will have to be oriented differently in different regions. Architects can ensure high degree of energy efficiency both in construction and operation by critically studying the macro and micro climate, applying bio-climatic architectural principles and making optimum use of desirable conditions.

Artificial heating and cooling are biggest consumers of energy in buildings, which is placed at 26% of average household energy consumption. Accordingly, it will be critical to minimize the energy load on building due to heating and cooling. A major principle of energy efficient building design would be to orient the building in a manner that maximizes sun heat gain into building during winter while excluding it during the hot long days of summer. This can be made possible due to the fact that the angle of sun changes from season to season. In summer, sun rises early in North-East and climbs high in the South before setting in North-West and heat gain is mainly through roof, east and west windows of buildings. In winter sun rises later in South of East, stay low in South before setting in South of West. South windows and walls receive the maximum winter sun and warmth. To achieve the design goal of optimum energy efficiency, basic rule of a building would be to have North and South facing walls 1.5 to 2.00 times the length of East and West facing walls in order to allow reasonable access to morning and late afternoon sun on the East and West whereas maximum sun during winter through the southern walls. However small projection on the southern wall will help in cutting the vertical sun and avoiding the heat trickling into the buildings during summers.

Fig. 3: *A perfect orientation for summer and winter.*

2.2 Internal Layout of Buildings

Not only placing of external walls is critical but also rational allocation of internal spaces in the buildings for achieving the desired level of energy efficiency. Spaces can be classified and grouped considering their energy requirements. Space requiring ambience temperatures should be grouped and planned in the best orientation whereas spaces having little relevance to living, etc. can be placed in directions considered as adverse from the point of view of orientation. Accordingly, indoor living and entertainment spaces can be placed on the Eastern and Southern sides for having bright and warm areas during winters and cool spaces in the summers. Thus placing bedrooms on the East and South will be more comfortable for sleeping during both summers and winters. Mechanism of grouping rooms with similar uses together for creating different zones and using doors to separate them would help in evolving appropriate design solutions. Closed design offers distinct advantages in terms of energy efficiency as compared to open designs. However, where ever the specific needs of planning re-quires open plans then use of glass doors would be appropriate to define different zones. Kitchen, laundry, bathrooms can be grouped to minimize the need for long hot water pipes. Garages and stores can be kept on the western side of the house so as to seal the living areas from the intense summer heat.

2.3 Windows Placement, Sizing and Shading

For evolving energy efficient design solutions appropriate placement, sizing and shading of buildings would be critical. Windows have multiple functions to perform including solar collectors trapping heat from the sun which is useful in winter but not during summers, acting as ventilators during summers., funneling cool late afternoon and night time breeze to reduce heat accumulated during the day and to let in daylight to make spaces bright. A balance need to be made between controlling sun access, allowing adequate cross-ventilation and natural light to enter. Accordingly 1/3rd to ½ of the southern face of the building can be put under glass for trapping winter sun and shading from summer sun with correctly designed eaves. An overhang of 0.4 times the distance from eaves to bottom of windows will be sufficient to save it from the heat of the sun during summers. Use of solar pergola can also be made to regulate the impact of the sun in the building. However, it would be critical that shading devices do not block the sun's access to the interior of the building during winter. Eastern and Western windows provide warmth in winter from early morning and afternoon sun, but they pose difficulty from sun in summer. It makes rooms on East and West comfortably warm, in particular those on the West. Accordingly it would be critical to keep area of Eastern and Western windows minimum and wherever provided should have vertical screens, louvers, blinds, shutters to block the sun. North facing windows can be made large to facilitate good ventilation and light without losing much of heat.

Tinted glass and reflective films absorb and reflect heat leading to reduction of heat and light. They can be used on East and West where glazing is unavoidable due to design/site reasons. Double glazing can be used to reduce winter heat loss. However, during summer, they require full shading minimize heat gains/transfer.

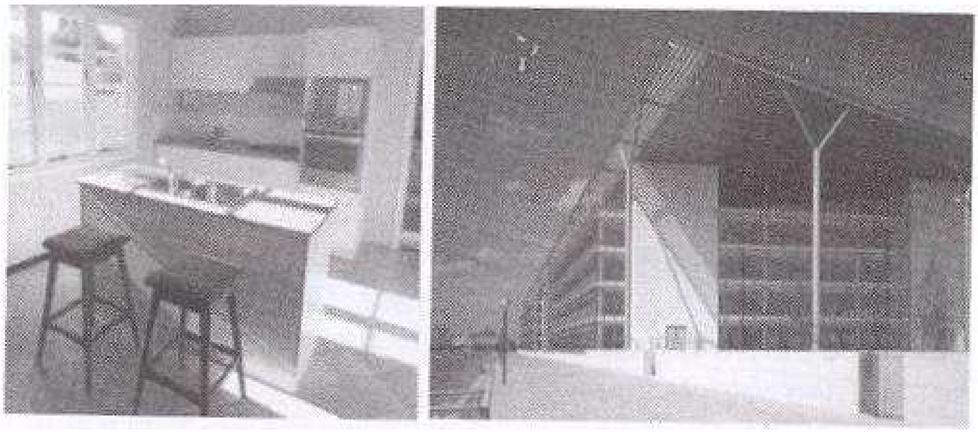

Fig. 4: *Orientation of windows and use of solar pergola*

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2.4 Internal Windows

The internal windows are important for reducing winter heat loss. Windows can lose heat five to ten times faster than an equivalent area of wall. Heat loss can be minimized by keeping warm air inside the room away from cold windows, closed curtains covering entire window up to ground made of heavy fabrics are considered effective in minimizing heat loss.

2.5 Insulation

Acting as barriers, insulation makes spaces more comfortable by reducing the heat loss in winter and heat gain in summer. Insulation of ceilings, roof, external walls and air gaps would be critical to achieve the desired objectives of energy efficiency. Bulk and reflective are two major kinds of insulations used. Bulk insulation works by trapping small cells or layers of air within the insulating materials which are effective in retarding heat transfer whereas in case of effective insulation, reflection of light and heat are used as mechanism to reduce the heat transfer.

Effective use of thermal insulation, treating roof for regulating solar radiation, using cavity walls, locating, sizing and detailing properly windows and shading devices help in evolving design solutions which are bio-climatic and ultimately help in reducing energy requirement of the building. However advanced techniques of passive heating and ventilation like trombe wall, water wall, roof based air heating system, wind towers, courtyard, earth-air tunnels, evaporating, cooling, etc. can be effectively used for evolving low energy building designs.

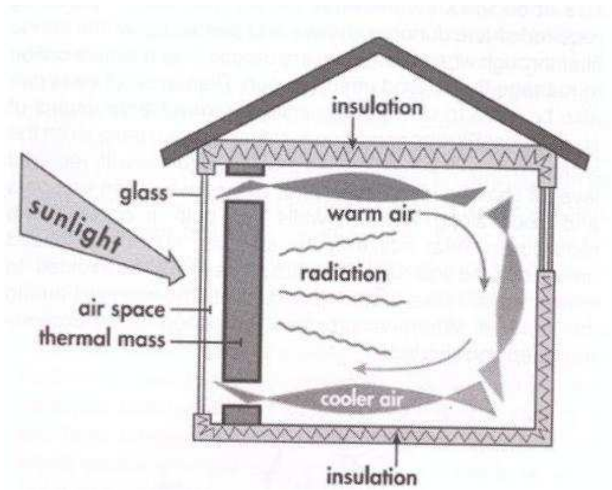

Fig. 5: *Illustration of insulation.*

2.6 Ventilation

Natural ventilation is considered an essential part of energy efficient structures. For achieving cross ventilation correct positioning of the doors and windows would be critical. A large opening on the leeward side of the building will maximise the air flow through room's facilitating the removal of heat accumulated during the day. Ventilation is very critical in hot and humid zones for creating climate sensitive design solutions for buildings.

2.7 Courtyards

Courtyards have been considered critical in promoting energy efficiency in buildings. They facilitate not only natural air and light into inner areas but also high degree of cross ventilation. Courtyards make buildings safe from large heat intake and glare. Acting as large evaporator, cooler during summers, courtyards promote enormous cooling without mechanical aids. Landscaped courts are great moderators of micro-climate within buildings. Acting as great heat dump, courtyards minimize heat loss during winters.

Courtyards with water column fountains have been considered as great environmental moderators. Looking at the distinct advantages, courtyards should be considered as valued partners in building designs. Building and zoning laws should leverage courtyards for evolving energy efficient building solutions.

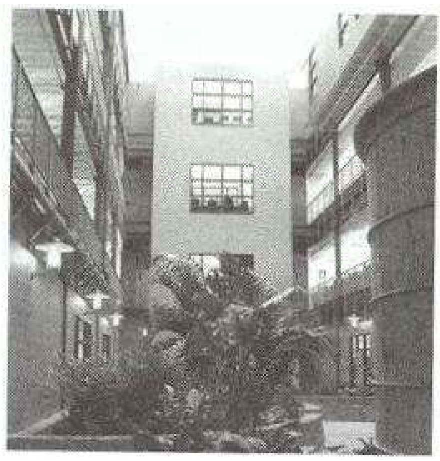

Fig. 6: *Use of courtyards.*

2.8 Landscaping

Effective use of landscaping as part of building design can help considerably in lowering energy consumptions in the buildings. Gardens can act as significant climate moderators. Use of deciduous trees / vines in West can help in providing required shade during summers and permit winter sun to filter through when the leaves are dropped, as a simple option to manage the good effects of the sun. Plantation of trees can also be used to shield the buildings from the adverse impact of some trees. Shrubs or creepers grown on an open pergola on the southern face of a building can provide windows with required level of shading in summers. Use of evergreen creepers and trees along western walls can help in considerable reduction of heat intake in the summer. Use of unshaded paving on the South and Western sides should be avoided to minimize the intake of heat reflected into the windows during the summer. Wherever provided they need to be properly designed and shaded.

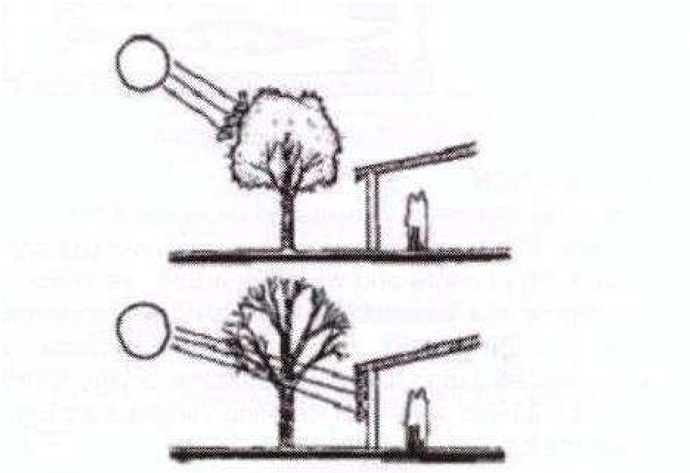

Fig. 7: *Deciduous trees provide shade from summer sun and allow winter sun.*

2.9 Building Materials

Choice of building materials has important bearing on energy consumption level of the buildings. Using low energy materials, efficient structural design and reduction of energy used for transportation can help in achieving high degree of energy efficiency. Choice of locally available materials and innovative construction techniques has clearly demonstrated their usefulness in reduction of energy consumed by the buildings during construction and operation. In addition, using dense materials such as brick, stone, concrete and rammed earth which heat up and cool down slowly (having high thermal mass) are critical for adequately storing winter daylight warmth and gradually releasing at night. In summers thermal mass can also help in keeping buildings cooler during the day when provided with proper ventilation, allowing the night air to cool down the inside mass resulting in more comfortable conditions next day.

For evolving energy efficient buildings, role of building industry would be critical. Government should encourage the industry which produces energy efficient materials. Industry must evaluate and monitor every material in terms of energy. Industry should be encouraged to promote R&D with support from building material agencies to ensure that energy requirement of each material is thoroughly studied before the material is allowed to be marketed. Specification should also include the energy component in order to make Architects/builders understand the energy implication of material being used.

Fig. 8: *A Small structure created using locally available material-saves cost.*

2.10 Colours of External Building Finishes

External finishes of buildings need careful choice in order to regulate the heat gain/loss by walls/roof. As a general rule, light colours have a tendency to reflect sun's heat, while darker colours absorb it. This fact can be made use of for identifying colours for roofs and walls. During summer's, choice of light colour would be critical to minimize heat gain and to keep inside spaces cooler by reflecting heat from the sun and for heat gain during winter, the colours will have to be darker. This would call for repeatedly changing the colours of walls and roof. Better option will be to keep the building properly insulated which is an effective mechanism of controlling and regulating heat transfer.

2.11 Use of Energy Efficient Appliances

80% of the energy consumed by any building over its entire life cycle is during the operational phase of the building whereas 20% energy is consumed during construction. Accordingly, it would be critical that energy consumed after the buildings are made operational should be minimized. Substantial portion of energy is consumed by the electrical gadgets which are used for lighting, heating and cooling which can be reduced considerably provided energy efficient appliances are used. CFL lights, evaporative coolers, rated kitchen gadgets, etc. would be critical to minimize the energy consumption. With careful design and planning only low energy light fittings should be used along with dimmers placed strategically to have maximum impact.

Roof areas can be used for installing series of photo-voltaic solar panels which can generate enough electricity to cater to the entire electricity needs of the building making it a zero energy building. Excess power, if available can be returned to the main power grid. Buildings have large facades can be used for installing solar panels to generate electricity to met its energy requirements.

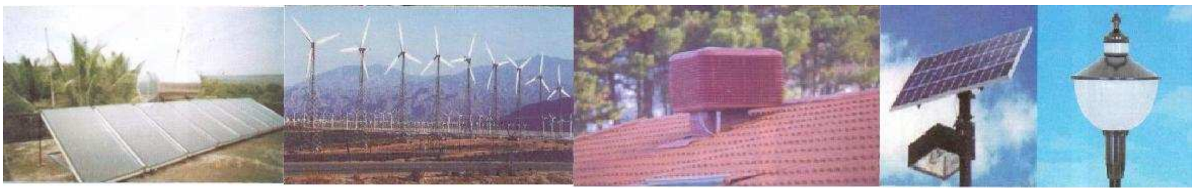

Fig. 9: *Solar water heater, wind mill, evaporative coolers, solar lighting and C.F.Lamps.*

3 Case Studies in India

3.1 Himuruja Office Building,Shimla

Fig. 10: *Himruja office building, Shimla*

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Design Features

- Air heating panels designed as an integral part of the south wall provide effective heat gain. Distribution of heat gain in the building through a connective loop that utilizes the stairwell as a means of distributing heated air
- Double-glazed windows with proper sealing to minimize infiltration
- Insulated RCC diaphragm walls on the north to prevent heat loss
- Solar chimney
- Specially designed solarium on south for heat gain
- Careful integration of windows and light shelves ensures effective daylight distribution
- Solar water heating system and solar photovoltaic system

3.2 Retreat, Resource efficient TERI retreat for environmental awareness and Training, Gurgaon

Fig. 11: *RETREAT; Resource efficient TERI retreat for environmental awareness and training, Gurgaon*

Design Features:

- Wall and roof insulation
- Building oriented to maximise winter gains; summer gains offset using shading
- East and west walls devoid of openings and are shaded
- Earth air tunnel for rooms – four tunnels of 70-m length and 70-cm diameter each laid at a depth of 4 m below the ground to supply conditioned air to the rooms
- Four fans of 2 hp each force the air in and solar chimneys force the air out of rooms
- Ammonia absorption chillers for the conference block
- Hybrid system with 50 kW biomass gasifier and 10.7 kW solar photovoltaic with Inverter and battery backup to power the building
- 2000 lpd building integrated solar water heating system
- Energy-efficient lighting provided by compact fluorescent lamp, high efficiency fluorescent tubes with electronic chokes.
- Day lighting and lighting controls to reduce consumption
- Waste water management by root zone system
- Building monitoring and management

4 Conclusion

Looking at the existing scenario, accelerated urbanization in the Indian context imposes immense pressure on the dwindling energy resources. However, the resource crunch confronting the energy sector can be effectively alleviated if we plan, design and develop human settlements and buildings by using appropriate strategies and incorporating sound concepts of energy efficiency and sustainability.
Appropriate knowledge and technology is available for creating energy efficient buildings but behavioral, organizational and financial barriers would require immediate demolition for achieving the desired results. Adopting holistic and integrated approach, shared accountability and responsibility towards improved energy performance, making energy more valued by educating and motivating professionals involved in building industry would be critical to promote energy efficient buildings. Efficiency gains in buildings are likely to provide the greatest energy reduction globally. It is estimated that demand reduction measures could almost halve expected growth in global electricity demand and CO_2 emissions from building energy use can be reduced by 29% at no net cost by 2020. however, creating energy efficient buildings would involve design community producing energy efficient building designs, financial community supporting investment in energy efficiency, building industry offering product and services for supporting designs economically, building owners and operators supporting designs financially and utilities supporting intelligent distribution and sustainable content of energy to and from building. Making all stakeholders work together would require effective policies and programme to be put in place on priority.

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