



# GUIDELINES FOR FORMULATING A SUSTAINABLE AND ECO FRIENDLY BUILDING

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*Abstract:* Our concern for the environment and for sustainability has dramatically increased in recent decades. This is why, we see more of our everyday items and even construction projects being completed using sustainable building materials. These materials offer a number of advantages, both economic and environmental. Sustainability is meant to make something last. A cost reduction and extended life-span seem reason enough to convince anyone into building a sustainable home. Being innovative and creating sustainable building goals is an essential part of the construction industry. Eco-housing is energy and resource efficient building practice. Eco-housing, therefore, recognizes two meanings: an environmentally appropriate dwelling and an economically acceptable dwelling. Buildings use resources (energy, water, raw materials, and etc.), generate waste (occupant, construction and demolition), and emit potentially harmful atmospheric emissions.

This research aims at introducing the specific architectural design elements of the existing residential buildings according to the surrounding environmental elements while balancing costs with ecological benefits to develop rules and knowledge methods for climate-responsive design and introduce them to the design process in such a way that it assists architects in their design practice. Next to making the architect aware of the energy and comfort impact of their (climate-responsive) design decisions, an important aspect is the identification of the structural and architectural impact of the implementation of climate-responsive building elements to create a satisfying and healthy atmosphere in which we can deploy our activities, whether these activities are residential, recreational, educational, or work related. The design of a comfortable indoor climate is of great influence on occupant's health.

*Index Terms* - Environmental sustainability; Eco-friendly, thermal performance; acoustic insulation, agricultural waste

## I. INTRODUCTION

Eco-housing is an integrated design process with the objectives to create minimum disturbance to an existing site and minimize the requirements of natural resources, energy and water with the help of its bio-climatic features. A more challenging eco-housing target is to enhance the existing site features and even be net producers of energy, water etc, within the traditional framework of economic-efficiency.

An ecological house modelled on the energy and material flows of natural ecosystems, and thus enhances rather than corrupts the environment. An ecological house conserves resource (energy, water, food and materials). It also produces resources or gathers and stores more of them than it uses. In an ideal ecological house, there is no waste because the resource flow is circular (Roaf, 2001).

Eco-housing therefore, integrates several disciplines and design objectives to be applied during the entire lifecycle of a housing project: design, construction, maintenance and end-of-life activities. It merges traditional and modern day architectural practices. Many concepts of eco-housing have been used by humans for centuries to ensure comfort conditions in habitats. The guidelines provided by the UNEP (2005) on eco-housing have given priority to five major areas of construction. These include:

**1. Passive and Active Solar Design**

In Passive solar design maximum use of the sun’s light with features like south facing windows and strategic shading to illuminate rooms during the day without too much heat, reducing the need for artificial light and HVAC systems.

**a. Energy Efficient Landscaping**

Large deciduous trees can provide shade and summer cooling and then allow the sun’s warm rays to enter the house during winter months. Deciduous trees are most effective on the east, Taking advantage of “nature’s heating and cooling system” through the effective use of landscaping is an important way to cut energy costs by as much as 10-25%. Landscaping is a natural and beautiful way to block the sun and provide protection from winter winds.

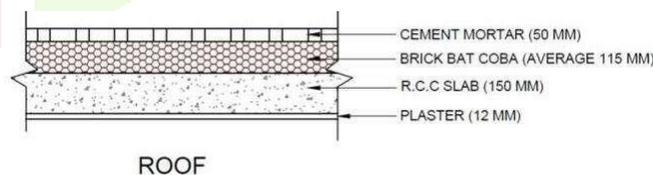
Strategically planted or preserved trees around your home can reduce solar heat gains during the summer by 40-80% depending on the density of the trees. It is important to use plants native to your area that survive with minimal care and (once they are established) without watering.

A well planned landscape can reduce an un-shaded home’s air conditioning costs in summer by 15-50%. In the winter, a house with windbreaks on the windward side can average 25% less fuel consumption.

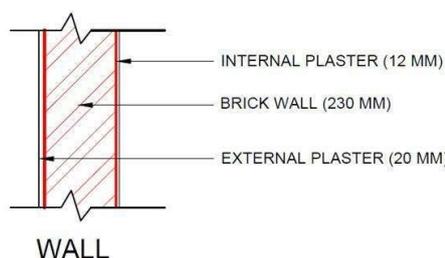
Trees not only help conserve energy but also help the environment in other ways. They absorb carbon dioxide, release oxygen, moderate storm water runoff and soil erosion, provide wildlife food and shelter, lessen local temperature extremes, buffer against noise and dust, and mitigate the glare of urban and suburban lighting.

a. Shading Reduction in solar radiation by shading windows can reduce the heat gain and consequently increase the comfort. An increase of 12.6% in the number of comfortable hours can be achieved, if windows are shaded by 50% throughout the year.

b. Roof type Insulating the roof using polyurethane foam insulation (PUF) increases performance by 2.2% as compared to a roof with brick -bat-coba waterproofing. However, an uninsulated roof i.e. plain RCC roof having a higher U-value decreases the n umber of comfortable hours by about 16.8%



c. Color of the external surface White and cream colors are desirable compared to puff shade (base case) or dark grey. The percentage increases in comfortable hours compared to the base case are 4 .8 and 3.0 respectively.



**2. Energy performance:** Submissions shall demonstrate strategies, which have been adopted to reduce energy demand for air and water heating, cooling, and lighting. Consider primary energy sources and recycled sources.

### **a. Energy – Lighting**

Typically rural households use electricity for lighting purposes on an average of four hours. Even though electricity from grid is cheaper than using alternative sources such as solar panels, most of the rural households are not connected to the grid. Therefore, solar panels provide an attractive alternative to provide these households with electricity. The following is a diagram showing the typical components of a solar energy system:

The rural units (as well as the urban type 1) are supplied with 40 watts solar PV (12V, 55AH@10HR Battery) array which would light two small fluorescent tubes and two light emitting diodes or alternatively, 1 fluorescent tube, 1

LED and one Black and White Television. The devices would run for an average of four hours thereby, meeting the minimum lighting requirements of rural households and decreasing the use of kerosene – a fossil fuel.

### **b. Energy – Cooking**

In addition to lighting and operating electronic devices, another major energy demand in households is for cooking.

To supplement this, the units are equipped with bio-gas plants. The diagram below shows the essential components of the bio-gas plants of capacity 100 CFT that have been used. Each of the dwelling units of rural type have been provided with cow-shed to provide feed for the plants.

Since it is not convenient to supply human generated bio-waste in digestors to produce bio-gas in urban locations, it has been assumed that such plants will not be suitable for the urban type- Instead it has been assumed that bio-gas plants can be set up at suitable locations within the city to supply to specific localities and to supplement other natural gas resources.

### **c. Energy – Water Pump**

Overall, this is a more efficient housing practice in terms of resource and energy use; moreover, it takes into consideration environmental wellbeing, thereby, the technology is cleaner than conventional ones. In order to raise water from ground level to overhead water tanks by using two windmills. The tower is built using pre-cast concrete and the turbine is imported. The combination will provide a windmill giving sufficient energy daily to raise ground water to water reservoirs at a height to supply daily water to the households.

A diagrammatic representation of the eco-housing is given below.

## **3. Water management-**

To reduce water use demand, the units will use rain water harvesting system. A first hand calculation shows that using only one storage tank, 1/5th of the water demand can be met. This capacity can be increased by using underground reservoirs, if needed.

Metering and measuring facility water use help to analyze saving opportunities. This also assures the equipment is run correctly and maintained properly to help prevent water waste from leaks or malfunctioning mechanical equipment. Replace Restroom Fixtures should be smart For example, toilets used 3.5 gallons per flush (gpf). Nearly all EPA laboratories have since installed water-efficient fixtures, for efficiency and performance. These include:

- New toilets with flow rates of 1.28 or 1.6 gpf.
- WaterSense labeled urinals flushing at 0.5 gpf or less.
- WaterSense labeled showerheads flowing at 2.0 gallons per minute (gpm) or less.

Faucet aerators flowing at 0.5 gpm, well below the 2.2 gpm federal standard, have also been installed in most laboratories.

Use Water-Smart Landscaping and Irrigation- Planting native and drought-tolerant plant species minimizes the need for supplemental irrigation. Landscape water use can also be reduced 10 to 20 percent by having an irrigation water audit. EPA selects audit professionals certified through a Water Sense labeled program. Water Sense labeled weather-based irrigation controllers or soil moisture sensors are used to water only when plants need it. Several EPA laboratories require water for aquatic culture research. In some cases, culture water is pumped into laboratory specimen tanks from local bodies of water, such as lakes or bays. It is then discharged into the sewer or treated and returned to the body of water. Recovery systems capture rainwater from the roof and redirect it to a storage tank. This water is used for flushing toilets, supplying cooling towers and irrigating the landscape.

#### 4. Renewable energy generation

Alternatively, one could benefit from the ubiquitous renewable energy resources in the immediate environment such as direct solar radiation, daylight, natural air flows and the earth's high thermal storage capacity. By using the energy potential of the immediate environment, a comfortable and healthy environment can be created that contributes to the reduction of energy consumption and, by banning out fossil fuels, eliminates undesired side-effects of pollution and waste generation.

##### a. Solar panels

Roofs are often angled toward the sun to allow photovoltaic panels to collect at maximum efficiency. To maximize efficiency in winter, the collector can be angled above horizontal Latitude  $+15^\circ$ . To maximize efficiency in summer, the angle should be Latitude  $-15^\circ$ . However, for an annual maximum production, the angle of the panel above horizontal should be equal to its latitude.

##### b. Wind turbines

A small wind turbine can be installed on a roof. Small-scale rooftop wind turbines have been known to be able to generate power from 10% to up to 25% of the electricity required of a regular domestic household dwelling. Turbines for residential scale use are usually between 7 feet (2 m) to 25 feet (8 m) in diameter and produce electricity at a rate of 900 watts to 10,000 watts at their tested wind speed. Building integrated wind turbine performance can be enhanced with the addition of an aerofoil wing on top of a roof mounted turbine.

##### c. Earth-coupling

The general idea behind earth-coupling is to take advantage of the earth's large thermal storage capacity. Ground temperatures are quite stable at relatively small depths and are quite similar to the local annual average ambient temperature. Near the surface ground temperatures are more influenced by dynamic ambient conditions. evaporative cooling.

Evaporative cooling is based on the fact that energy is needed for the evaporation of water. If this energy is withdrawn from the building, it will instant cool down the building. Just the presence of groundwater or surface water will bring about a cooling effect on its direct surroundings. Due to its high thermal capacity, water has great potential as a heat sink.

#### **d. Thermal buffering**

Thermal buffering is the capacity of a material to store heat, either from direct solar radiation or from passing air flows. As the result of this buffering behaviour indoor temperature swings are smoothened. In addition, energy is stored during the day and released during the night. This will lower the temperature drop during the night and thus the desired amount of heat required for the next day.

#### **5. Material selection:**

As architects, our decision regarding selection of appropriate materials can bring a substantial impact on the environment. Application of low embodied energy materials, low ongoing maintenance levels, and potentially recyclable selection. People have three shelters to survive the first one is skin, the second is clothes and the third is the building. So buildings should protect from the outdoor elements such as climate condition. (Roaf, 2001)

##### **a. Earthen structures**

Earthen architecture can be defined as a building where the main constructional material is unfired earth. Loadbearing walls, in the filling of walls, roof structures, roof finishes, and furniture can be constructed from the earth. It is a versatile material with many construction techniques that range from mudbrick (adobe), rammed earth, wattle-and-daub, cob walls, etc Today, it is well known for its good environmental properties of recyclability and low embodied energy along the production process.

The earth buildings successfully last for decades in almost all types of regions and climates and also with proper care and maintenance when it's done with suitable architectural design, structural techniques, and proper stabilization measures and care in sitting.

For all types of earth construction, the important properties are compressive strength, water absorption, and weather resistance.

When compared to the many commonly used contemporary building materials the production and construction of earth materials do not have any health hazards and no pollution.

Each region has its systems and they could be adapted to diverse needs. The basic earthen material can be improved with the use of local natural reinforcement products which are often waste materials, which can get recycled easily.

Earth balances the air humidity, stores the heat, saves energy & reduces pollution, is always reusable, saves the material & transportation costs, preserves organic materials, absorbs pollutants & is ideal for do it yourself construction, contributes to reducing energy or water consumption, or it helps to improve air quality.

##### **b. Straw bale**

Straw is basically an agricultural by-product which comprises only of the plant stalks (mostly cereals) after removal of grain and chaff. Rice straw has the highest silica content making it the toughest amongst all other cereal straws. Straw is considered as an environmental problem as its burning causes breathing problems. Straw and Straw bale have a huge scope in India as it is one of the largest producers of straw bale. 46% of total land (32, 87,590 sq.km) of India is agricultural land and out of a total population of 1, 17, 09, 38,000 people 58.4% are solely dependent upon agriculture as a means of livelihood. So straw has high potential as an alternate building material. It is also fire resistant as it does not support combustion, is thermally insulated, has sound and moisture insulation and is not toxic.

In recent days many researchers have explored the possibilities of using the natural fiber obtained from different plants, which includes bagasse, cereal straw, corn stalk, cotton stalk, rice husk/rice straw etc as an alternative building material. Due to the light weight, high strength to weight ratio, corrosion resistance and other advantages, natural fiber based composites are becoming important alternatives for building materials

for use in civil engineering fields. The superior properties comprise of better workability, resistance to cracking, lighter weight, high fracture toughness and a higher degree of flexibility. These properties make it a suitable material for use in low cost construction.

Straw bale buildings provide significant benefits in terms of costs, human health, and environmental sustainability. Combining straw bale walls with a render or any type of high-density layer can improve both the thermal and acoustic properties of straw bale constructions. Finally, a quantitative assessment of the most significant properties, such as thermal resistance and acoustic insulation, is necessary to reduce the gap between straw bales and traditional building materials.

Straw bale as a material in construction is the most appropriate answer in handling all issues as it is a recycled material and is nontoxic, low-cost and carbon-sequestering in nature. The buildings offer excellent insulation and sound deadening properties. They are surprisingly resistant to fire due to the inability of air to flow through the straw bales.

Straw bales can provide significant benefits in terms of costs, human health, and environmental sustainability. Due to their advantages, straw bales were mainly utilized in traditional rural buildings to improve environmental sustainability.

**c. Insulated concrete forms (ICF)** Insulating concrete forms result in cast-in-place concrete walls that are sandwiched between two layers of insulation material. These systems are strong and energy efficient. Common applications for this method of construction are low-rise buildings, with property uses ranging from residential to commercial to industrial. Traditional finishes are applied to interior and exterior faces, so the buildings look similar to typical construction, although the walls are usually thicker. The concrete has a very high embodied energy relative to most building materials, many consider it a green material for its longevity and durability.

**d. Structural insulated panels**

**(SIPS)**— SIPS are large panels (4' x 8' up to 24' x 8') typically constructed at a factory. They are composed of foam insulation sandwiched between two sheets of oriented strand board (OSB). You can consider SIPS green because of their superior insulation and air-sealing qualities, but they often must be set in place with a crane. SIPS construction is typically slightly more expensive than conventionally built structures.

**e. Wood**

While wood is the most common residential building material, there are now greener versions of wood available, as well as several alternatives. Two types of wood are gaining traction among green builders — engineered wood and wood certified by the authority of various countries like FSC in America. Engineered wood is very common on both green and conventional homes. It uses wood scraps and smaller trees to produce framing that's stronger than traditional sawn logs. Engineered wood allows the builder to use less wood per structure and make use of wood scraps that would otherwise go to waste, wherever conventional sawn timbers are used.

**f. Exterior Siding**

Like roofing, exterior siding helps provide the distinction between indoors and outdoors, but, unlike roofing, siding can play a significant role in the appearance of the structure.

**Wood** — Wood is a traditional siding choice and, when properly designed and detailed, remains a reliable green building choice. Reclaimed and recycled wood are all popular choices with green builders or architects.

**Fiber cement** — This material is made from wood, sand, and Portland cement. Fiber cement offers excellent durability and fire resistance and is less expensive than many common wood choices.

**Composites** — Composite materials such as plastics and vinyl are not inherently green materials, but some consider them green because of their long lifetime and low maintenance requirement.

**Composites**— Manufacturers often make composites from plastics and rubber, and they mimic the appearance of natural materials such as slate and wood. They have the advantage of being lighter than their natural counter

## **g. Green Insulation**

Insulation is critical for any building. Whether the builder is trying to keep the heat out or in, the amount of insulation will indicate how resistant a building is to losing energy.

The stuff doesn't need to be pretty or pleasant, since it's essentially wall filler. Green insulation uses recycled materials to line our walls. Cotton insulation is a great example: The soft blue insulation is primarily composed of recycled denim old jean scraps. Cellulose insulation takes an equally common product and recycles it. Recycled paper insulation comes in several forms, but one of the most common is blow-in cellulose, which can be sprayed into walls or attics rather than being laid out in sheets. Even fiberglass insulation can include recycled glass, but there's a downside: Melting down the glass and forming fiberglass insulation is far more energy-intensive than producing cellulose insulation from paper. Cellulose insulation often consists of 75 to 85 percent recycled material, higher than fiberglass' 30 to 40 percent, and cellulose is even better at preventing airflow than fiberglass. Cellulose and cotton are definitely better choices when it comes to green insulation, and neither poses the discomfort or health concerns of fiberglass. Cellulose made from recycled paper, cellulose is the second most common insulation material and is considered a very green choice when used properly. Also, it is relatively inexpensive, with costs similar to fiberglass.

Polystyrene and isocyanurate foams are typically installed as preformed sheets. Builders commonly use them to insulate below grade, such as beneath a slab, but also use them as exterior-mounted insulation in some applications.

## **Roofing**

Keeping the weather out of a structure is not only key to making it a comfortable environment but is also critical to making it last. Like the variety of choices for other building components, there are now numerous ways to cover a building. The color of the material can also have an impact. Light colors are preferable for all types of roofing, as they reflect more energy away from the structure and thus reduce the cooling load.

**a. Polyurethane**— Expanding and shingles) is an increasingly spray-on polyurethane foams are quickly becoming very popular. They offer the highest insulation value for a given thickness and, because of their expansion during installation, are excellent at eliminating air leakage.

**b. Slate/stone**— These natural materials are excellent green choices but are very expensive due to both material and labor considerations but can be cheap at the places where they are easy available. They have a very long life parts. Composites are frequently made from recycled materials and so have a lower embodied energy than materials that must be mined.

## **c. Cool Roofs**

Cool roofs are specially designed to offer increased solar reflectance and decreased thermal emittance. In other words, they reflect more of the sun's rays than your average shingle roof, and prevent the warm or cool air inside from escaping through the top of a building. Under the intense heat of the summer sun, dark shingle roofs can reach temperatures of 150 degrees Fahrenheit (65.5 degrees Celsius). The reflectance of a cool roof can cut that down by more than 50 degrees.

Lowering the temperature of the roof itself is an advantage, of course, but the real savings are inside. A cool roof improves the interior temperature of a building, either by reflecting intense heat or trapping the air inside. That reduces the strain placed on air conditioning systems, thereby reducing the emissions that result from powering our heating and cooling. Cool roofs can be constructed with a number of materials, including special reflective paint and cool roof shingles and tiles. If you need an environmental reason to believe in the cool roof, look no further: Their reflectance can help lower the heat island effect of urban and suburban areas, which causes dramatically higher temperatures under harsh sunlight compared.

d. **Green roofs** represent a promising adaptation strategy for facing climate changes, and the

number of green roof studies has consequently increased in recent years. The thermal effects of a green roof mainly result from the shading, insulation, evapotranspiration and thermal mass of the plants and their substrate, with the additional contribution of the high specific heat of the water contained in the substrate. In addition, evapotranspiration from a green roof brings a cooling effect, since experiments demonstrate that latent heat can override sensible heat on a green surface, and leaf transpiration accounts for almost 30% of rooftop cooling.

Moreover, the insulation role of green roofs can mitigate indoor peak temperatures, saving both cooling and heating loads, and decreases the heat flux entering the roof by 60% according to the roof design.

They found out that during the warm period (1-7 March 2008), the green roof reduced heat gain by 92%-97% in comparison to ceramic and metallic roofs respectively, and enhanced the heat loss to 49% and 20%. During the cold period (25-31 May 2008), the green roof reduced heat gain by 70% and 84%, and reduced the heat loss by 44% and 52% in comparison to ceramic and metallic roofs, respectively. From the derived data, it has been confirmed that green roof contributes to the thermal benefits and energy efficiency of the building in temperate climate conditions. The thermal effects of a green roof mainly result from the shading, insulation, evapotranspiration and thermal mass of the plants and their substrate, with the additional contribution of the high specific heat of the water.

In addition, evapotranspiration from a green roof brings a cooling effect, since experiments demonstrate that latent heat can override sensible heat on a green surface, and leaf transpiration accounts for almost 30% of rooftop cooling. Moreover, the insulation role of green roofs can mitigate indoor peak temperatures, saving both cooling and heating loads, and decreases the heat flux entering the roof by 60% according to the roof design.

In fact, during summer – with the soil in almost dry conditions – the green roof allows an attenuation of the thermal gain entering the underneath room of about 60% with respect to a traditional roofing with an insulating layer.

That is due to the higher solar reflection of the greenery, while the evapotranspiration contribution is quite limited. When the soil is in a wet condition, not only the entering flux is cancelled, but also a slight outgoing flux is produced so that the green roof works as a passive cooler, thanks to the cooling effect of evapotranspiration. During winter, the evapotranspiration process is driven above all by the air vapor pressure deficit, able to produce an outgoing thermal flux from the roof that is 40% higher than the corresponding one of a high solar absorbing and insulated roof.

### **Summary & Conclusions**

This research paper provides guidelines where energy and environmental concerns are adopted in the development and design process to create comfortable and healthy buildings that make use of the energy potential of their environment. By doing so, the need for non-renewable energy sources can be eliminated. As a result, such buildings gain in environmental performance; significantly lowering waste production, pollution and greenhouse gas emissions and making path to sustainable energy housekeeping for buildings is transitional and embraces improving existing techniques, presenting new innovative solutions and thinking in whole new concepts where energy and environmental concerns are adopted in the development and design process to provide several material and energy benefits as compared to typical and conventional building practices in the country.

These benefits can be summarized as below

**a. Enjoy of better health**

Provides improved comfort conditions

Provides intelligent landscaping to modulate site climate and improve energy performance and comfort. Sustainable material products and green buildings can be beneficial to health. Therefore, opting for less toxic products and more sustainable materials can help with air purification. This means reduced exposures to chemicals that are linked to indoor health problems such as sick building syndrome, headaches, asthmatic reactions, communicable and respiratory disease. Indoor air quality can also affect the overall experience of a building's occupants by impacting cognitive function and work performance. Thus, the choice of materials can play a significant role in health outcomes.

**b. Boost your productivity**

Improves energy performance by using passive cooling design techniques and site treatments. Additionally, several studies have reported that environmentally friendly workspaces help employees perform better while reducing absenteeism. The better the environment, the easier it is to concentrate and work effectively toward the completion of tasks.

**c. Reduce the amount of waste you deal with**

Requires less water than conventional buildings as rainwater is used to supplement water need

Needs less energy for lighting & cooking than conventional buildings thereby reduces demand on piped gas supply and grid electricity. Green buildings minimize waste with their lower environmental impact and use of renewable sources and materials. Products such as demolition debris, sand and burnt coal can be used with excellent environmental and aesthetic results.

**Reduce noise around you**

Noise can have a significant effect on a person's well-being. In 2011, the World Health Organization (WHO) released a report that shows how exposure to prolonged or excessive noise may cause a range of health problems ranging from stress, poor concentration, productivity losses in the workplace, and communication difficulties and fatigue from lack of sleep, to more serious issues such as cardiovascular disease, cognitive impairment, tinnitus and hearing loss.

**d. Improve your comfort, satisfaction, and wellbeing**

Efforts to improve your comfort and satisfaction every day are important because discomfort has negative consequences for your work effectiveness, job satisfaction, and quality of work life. Natural and sustainable materials, appear to have positive psychological and social benefits. The benefits of using sustainable materials include reduced stress, improved emotional functioning, increased communication, and an improved sense of belonging.

**e. Better and longer use of materials**

Provides material efficiency by innovative design, recycling of waste & promotion of traditional indigenous materials.

Additionally, when sustainable materials are used in buildings, they manage water in a more effective and environmentally friendly manner. Sustainable buildings can be equipped with systems that recycle water, such as collecting rainwater for toilet cleaning. Sustainable buildings can collect and preserve natural energy, such as solar or wind energy, storing it and reusing it accordingly.

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