# Exploring Energy Conservation Strategies in Residential Buildings in Composite Climate

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**Abstract: Thermal comfort is essential in a tropical climate and building air conditioning offers better thermal comfort compared to other systems. But the air conditioning system in the building consumes a lot of energy to meet the needs of thermal comfort in a tropical climate. Research has proved that excessive use of air conditioners is detrimental to the environment as the refrigerants are a major source of global warming. An effective thermal insulation system in the building can increase energy efficiency by reducing consumption for cooling systems, but it can also decrease the lighting comfort of natural light. This research aims to study the effectiveness of different energy saving strategies and to find the best compromise between visual comfort and thermal comfort in the building in composite climate by taking a building as a case study, and subjecting it to thermal and lighting simulations.**

**Keywords- Energy conservation, thermal comfort, residential buildings, Composite climate**

## 1. INTRODUCTION -

Global energy consumption is foreseen to be increased by 53% within the next ten years from the International Energy Agency (IEA) prediction, which is as the result of the significant increase in industrial and urban activities due to the intensive country development and dramatic increase of population size in the recent times. The rising energy demand is expected to be more severe, especially in developing countries due to the rapid growth of new buildings while the use of energy efficiency technologies is often not gaining sufficient attention.

As the consequence of the energy demand upsurge, environmental issues are becoming more apparent. As the consequence of the energy demand upsurge, environmental issues are becoming more apparent. Carbon dioxide ($CO_2$), an instance of the pollutant, has widely known as a harmful substance to human health. Carbon dioxide plays a strong contribution in the greenhouse gas effect. The couple leads to the rising of average global temperature. If no necessary steps are taken to reduce the emissions of $CO_2$ and other greenhouse gases, the Earth's average surface temperature is predicted to rise about 1.1– 6.4 °C by the end of 2100. A 2 °C increase of the global average temperature would cause irreversible impacts on the environment, severe issue on human health, huge damage on natural ecosystems as well as affecting global agriculture sustainability.

As one sector that consumes a vast amount of energy to provide thermal comfort, construction sector in general (residential, industrial and commercial buildings) could contribute to lower its energy consumption through proper, effective insulation strategies. An effective insulation conserves energy and consequently requires less energy for space cooling in summer and less heat to keep the house warm in winter. The chain effect of implementation of this energy efficiency technique reduces the use of natural resources (petroleum and gas reserves) that are used for power generation, and it slows down their depletion rate. Thus, it lowers the greenhouse gases production.

Energy conservation techniques in residential buildings constitute the irreplaceable pillars of the reduction of energy consumption and the increase in sustainability. Many studies have emphasized that introducing an energy-savings approach in residents' buildings is the key for economies and the society at the large. Illustrated here is that although behavioral energy conservation in industrial facilities could be more perpetual than that in dwellings. Strategies for residential building energy conservation and emission reduction have been engaged, including the patterns exploration and effects factors discussion. Energy management in the installation must using the instant recognitions algorithms-the devices to monitor electrical appliances will play a vital role for the home-based building energy system.

Adding to this, regulations often have limitations and focussing on developing countries' building energy policies emphasizes the role of the policies in reducing energy consumption. The most important part of residential building retrofitting, especially when it comes to energy efficiency through enhanced window retrofits, has a significant place in the energy conservation strategies of different climatic zones. The local governments are known to be closely linked to energy conservation ambitions that propel green policies in the old housing sites, reflecting the impact policy-making has on this issue.

On one hand, a suite of energy conservation policies agreed worldwide, like the Dutch government's goal for reduced energy use in the case of prewar housing stock, is another demonstration of the seriousness of the issue and that energy efficiency is a solution, not just an option. Applying the Analytical Hierarchical Process (AHP) as a method for evaluating clean energy services use in rural residential buildings becomes necessary for popularizing energy-efficient improvements and saving energy. Ecotect is a software application that features custom design options for its users; its ability to use energy efficiently for houses has been assessed.

## 2. LITERATURE REVIEW –

### 2.1 Characteristics of Composite Climate Regions

Climate regions mixing distinct climatic conditions can be acknowledged as 'composite' climate regions, in which case it calls for an effective energy-efficient design and a residential energy conservation model. The domestic consumption of energy of various regions is a specific issue that requires of a design of specific strategies to minimize its use.

2.1.1 Temperature Extremes: Composite climates are characterized by both hot summers and extremely cold winters, and, in many cases, there are major temperature changes during the seasons. Summers are usually a period of high humidity and heat, whereas winters tend to be dry and cold, and as a result, there is a need for different heating and cooling systems.

2..1.2 Precipitation Patterns: Precipitation in compose climates oscillates tremendously and goes from massive downfall of rain during the monsoon season to patterns that hardly have precipitation. Regulations on rainwater collection and stormwater retention might just be the missing piece in sustainable water utilization.

2.1.3 Wind Patterns: The prevailing wind flow patterns in monsoon regions may alter with relation to local terrain. The correct placement of a building concerning wind direction and careful planting is done for positive or negative influence on the building energy performance.

2.1.4 Humidity Levels: Consequently, climates, such as composite ones, can show relevant weather parameters, like high humidity values, during summer period, that can make the heat even more unbearable and the cooling demand increasing. Air flow and dehumidification are the core components of creating an indoor environment in which we feel comfortable.

### 2.2 Passive Design Strategies

Passive design strategies exploit inert elements of the building environment such as nature toreduce energy consumption for heating, cooling, and lighting of a building. The strategies designed to achieve the maximum comfort, the natural heat gain efficiency and the minimization of the reliance on the mechanical systems are these ones. Some buildings are exposed to composite climates- where one both hot summers and cold winters are present. At the same time, the passive design means a lot when designers are considering energy efficiency.

### 2.3 Active Energy Conservation Technologies

On one hand, passive conservation techniques use natural factors which reduce energy consumption, and on the other hand, extra energy-saving systems that are mechanical and electrical, take energy conservation to a different level in residential buildings In complicated climate regions where there is heating and cooling demands in high quantities, active means along with passive strategies have to work in a coordinated way to keep optimal performance regarding the energy efficiency.

### 2.4 Renewable Energy Integration

The option to integrate renewable energy sources into residential buildings may be the way forward to lower demand for fossil fuels, reduce greenhouse emissions and enhance the resilience of existing energy systems. In composite climate regions where weather conditions carrying high degree of variation cause significant power demand fluctuations, integrating renewable energy is the most important factor to meet sustainable energy objectives.

## 3. CASE STUDIES –

### 3.1 Indira Paryavaran Bhawan, New Delhi

- Location New Delhi
- Geographical coordinates 28° N, 77° E
- Occupancy Type Office (MoEF)
- Climate Type Composite
- Project Area 9,565 $m^2$
- Grid Connectivity Grid connected
- EPI 44 $kWh/m^2/yr$

Indira Paryavaran Bhawan, the new office building for Ministry of Environment and Forest (MoEF) sets is a radical change from a conventional building design.

The project team put special emphasis on strategies for reducing energy demand by providing adequate natural light, shading, landscape to reduce ambient temperature, and energy efficient active building systems. Several energy conservation measures were adopted to reduce the energy loads of the building and the remaining demand was met by producing energy from on-site installed high efficiency solar panels to achieve net zero criteria. Indira Paryavaran Bhawan uses 70% less energy compared a conventional building. The project adopted green building concepts including conservation and optimization of water by recyclingwaste water from the site.

Indira Paryavaran Bhawan is now India's highest green rated building. The project has received GRIHA 5 Star and LEED Platinum. The building has already won awards such as the Adarsh/GRIHA of MNRE for exemplary demonstration of Integration of Renewable Energy Technologies.

**Passive Design Strategies:**

- Orientation**:** Building is north south oriented, with separate blocks connected through corridors and a huge central court yard. Orientation minimizes heat ingress. Optimal window to wall ratio.
- Landscaping**:** More than 50% area outside the building is covered with plantation.Circulation roads and pathways are soft paved to enable ground water recharge.
- Daylighting**:** 75% of building floor space is day lit, thus reducing dependence on artificial sources for lighting. Inner courtyard serves as a light well.
- Ventilation**:** Central courtyard helps in air movement as natural ventilation happens due to stack effect. Windows and jaalis add to cross ventilation.
- Building Envelope and Fenestration**:**
  1. Optimized Building Envelope – Window assembly (U-Value 0.049 W/m$^2$K),VLT 0.59, SHGC 0.32
  2. uPVC windows with hermetically sealed double glazed using low heat transmittance index glass
  3. Rock wool insulation
  4. High efficiency glass
  5. Cool roofs: Use of high reflectance terrace tiles for heat ingress, high strength, hard wearing.

Materials and construction techniques:

1. AAC blocks with fly ash
2. Fly ash based plaster & mortar
3. Stone and Ferro cement jaalis
4. Local stone flooring
5. Bamboo jute composite doors, frames and flooring
6. High efficiency glass, high VLT, low SHGC & Low U-value, optimized by appropriate shading
7. Light shelves for diffused sunlight.

**Active Strategies:**

Lighting Design

1. Energy efficient lighting system ( LPD = 5 W/m$^2$) , nearly 50% more efficient than Energy Conservation Building Code 2007 requirements ( LPD = 11 W/m$^2$) reduces energy demand further.
2. Remaining lighting load supplied by building integrated photovoltaic (BIPV).
3. Use of energy efficient lighting fixtures (T5 lamps).
4. Use of lux level sensor to optimize operation of artificial lighting.

**Renewable Energy:**

1. Solar PV System of 930 kW capacity
2. Total Area: 6,000 m$^2$

3. Total Area of panels: 4,650 $m^2$
4. No of panels: 2,844
5. Annual Energy Generation: 14.3 lakh unit

**3.2 Unnati Office Greater NOIDA, Uttar Pradesh**

- Location Greater NOIDA
- Coordinates 29° N, 78° E
- Occupancy Type Office, Private
- Climate Type Composite
- Project Area 3,740 $m^2$
- Date of Completion 2018
- EPI 60 $kWh/m^2/yr$

The Unnati Office Building is the regional headquarter (North) for Gainwell Commosales Pvt. Ltd., part of a larger 5 acre campus. It is the first building in India to be certified Platinum under LEED v4 BD+C : NC rating in 2018. The building performs 59% better than a conventional office building in the region, and 40% of the building energy consumption is met through on site renewable energy generation.

**Passive Design Strategies:**

- Orientation: The three-storey building is a cuboid with a central courtyard. It is oriented northeast-southwest, with the core areas distributed in the east and the west orientations. Passive design strategies have been integrated with the building design.
- Landscaping: The landscape is a mix of existing and new vegetation. 30% of the site is un-built, of which 25% is covered with shrubs and trees. Only native vegetation has been planted to reduce irrigation water volume as well as pump energy. Treated waste water is used for irrigation.
- Daylighting: 90% of the office spaces, including the core and service areas, receive uniformly distributed daylight. This can be attributed to the form, central courtyard, shallow floor plates, appropriate sizing and distribution of openings. All the windows have box shading that prevents glare.
- Ventilation: A design ventilation rate of 30% additional outdoor air over ASHRAE Standard 62.1-2010 enhances indoor air quality and occupant comfort. Passive design features reduce the total diversified AC load to 208 kW for 3740 $m^2$ (80 tons for 33,500 $ft^2$).

**Active Strategies:**

- Lighting Design: An energy-efficient lighting system with daylighting controls is used.Energy-efficient fixtures and ballasts contribute to a 66% reduction in lighting energy compared to Standard 90.1-

2010.Occupancy sensors in normally unoccupied areas like storage areas, toilets and mechanical rooms minimize lighting use.Lighting controls ensure minimum internal heat gain and reduced air-conditioning load in those spaces.Approximately 90% of total regularly occupied spaces in the building have an illuminance level of 300-3000 lux measured on the clearest sky conditions. A lighting power density (LPD) of 3.6W/$m^2$ in all occupied spaces is significantly lower than the Standard 90.1-2010 baseline of 10.9 W/$m^2$.The building uses energy-saving technologies associated with the electrical power supply system/building management system.

- Indoor Air Quality**:** Dry outdoor ventilation air is supplied through an externally mounted unit that dehumidifies the air before it is supplied to occupied space. This dry outdoor air acts as primary air to the chilled beams.The air quality is monitored inside the entire building with help of $CO_2$ sensors which provide an audible alarmThe DOAS system starts at 8 a.m. to remove moisture that builds up during unoccupied hours and brings down the temperature to desired level before office start-up.

**Renewable Energy:**

1. The building draws 40% of its energy from the roof-top PV plant.
2. The installed 100 kW solar PV generates 146 MWh/yr.

**3.3 Jaquar Headquarters Manesar, Haryana**

- Location Manesar, Haryana
- Coordinates 28° N, 77° E
- Occupancy Type Occupancy Type
- Climate Type Composite
- Project Area 48,000 $m^2$
- Date of Completion 2016
- Architect Gayathri & Namith Architects
- Energy Consultants Environmental Design Solutions (EDS)

The Jaguar Headquarters located at Manesar is not only a beautiful building but a meticulously designed facility featuring cutting-edge technology solutions resulting in a net zero campus with a certified LEED Platinum (USGBC) rating. This project is reputed for being a visual treat with challenging organic design and space planning.The design redefines a corporate space by making it a memorable experience though its iconic wing-shaped architecture. The horizontal glass building is topped by the sweeping wings of a metaphorical eagle, ready to take flight, symbolizing a company with global ambitions.Designed by a Bengaluru based firm – Gayathri & Namith Architects (GNA) – the structure is a fine amalgamation of contemporary design sensibilities, biophilic inspiration and a brand vision of soaring high.

**Passive Design Strategies:**

- Site Layout & Planning: The initial zoning of the site involved placing the factory block at the back and corporate office in the front. But this was not using the site to its full potential. Instead, stacking of the two into a single structure was proposed.The final design houses the corporate office on top and the factory below. The landscape is berm shaped and raises the drop off point by 8 meters, providing space for an elaborate, planned landscape with water features.
- Climate Responsive Design**:** To ensure minimal dependence on artificial lighting and air conditioning, the three levels of the building were staggered, and the floor plate rotated at each level.This permitted the right amount of natural light to the internal spaces while also providing shading and reduced the cooling load.The three levels open on to a massive sky-lit atrium, the white fluted ceiling at each level merging into the skylight, ushering in the sense of infinity into the work-spaces. The atrium also brings in light to the building core.
- Form and Massing: The form has been derived from the span of a bird's wings. The wing-shaped form of the building maximizes the external surface area. Staggered floor plates not only give an iconic appeal to the building but also help in channeling the surrounding air movement.
- Biophilic Design: Water being at the core of the Jaquar's products, the multiple characteristics related to it are subtly brought into each level through use of demarcating colours. Each floor is marked with a specific colour, the green, grey and blue silently connecting to the grand 'Sangam' of the three oceans while the brown roots the water to earth.

**Active Strategies:**

- Cooling Systems: All areas are served by a central air conditioning plant. The HVAC system comprises of a conventional cooling system, radiant cooling, heat pump, VRF indoor/outdoor, and ventilation mechanism.
- Ventilation System: As an energy efficient measure, the facility has commissioned heat recovery units to utilize the cool return air to lower the temperature of outdoor air. These units are installed on the terrace level. Exhaust fans are commissioned in the facility. For maintaining required pressure in lifts and staircases, axial fans are installed.
- Lighting Design: All installed lighting are LEDs. In all the regularly occupied spaces there is provision for automatic lighting shut-off that results in power saving. General lighting in each space is controlled separately. Occupancy sensors too shut off lights when offices and meeting rooms are unoccupied.

**Renewable Energy:**

Crystalline high-powered cells are used in the solar photovoltaic module. Solar module has been laminated using lamination technology using established polymer (EVA) and Tedlar / Polyester laminate. SPV module efficiency is greater than 13%.

The total no. of solar panel modules installed are:

- 566kwp: 1872 modules
- 6kwp: 808 modules
- 148kwp: 486 modules
- 54kwp :180 modules

## 4. ENERGY CONSERVATION STRATEGIES –

**4.1 Passive Cooling Techniques:** Passive cooling processes capitalize on natural elements and physical conditions to keep indoor air conditions tolerable with little or no support from mechanical cooling devices. In passive regions, where heat waves often occur, especially in the summer, it would be advisable to implement efficient cooling techniques as well as undertaking conservation strategies to avoid diminishing energy consumption and improve popular comfort.

Building Orientation and Shading:

- Proper Orientation: Orientate buildings to minimize of the solar head coming in at the high noon hours. Since orienting the longitude of the building at east-west may be helpful in enduring minimum sunlight exposure towards the east and west sides.
- Shading Devices: Put up trellis, awnings, and external blinds to block direct sunlight and minimize heat gain due to sunlight. Design the gardens with deciduous trees or climbing plants that trellis as natural shade during the summer while light can penetrate during winter wear.

Natural Ventilation:

- Cross-Ventilation: Create buildings with strategic placement of windows and doors for catching, natural breeze from the prevailing wind is to introduce good air circulation. Instead of occupying the center of the building to keep squirrels at bay, consider the availability of opposite sides as a natural air opening and refreshment with air flow for cooling instead.

- Stack Effect: Exploit the stack effect by incorporating high windows or vents near the ceiling to allow hot air to escape, while lower openings draw in cooler air from outside.

Thermal Mass:

- High Thermal Mass Materials: Use materials like concrete, brick or rammed earth, which had high thermal mass in the structure's walls to absorb and store the sun's heat during the day and gradually release them at night. By achieving this kind of balance, the temperature inside does not fluctuate so much and the need for mechanical cooling is reduced.

**4.2 Passive Heating Techniques:** Passive heating strategy employs the naturally occurring energy sources and some structural concepts to extract, accumulate and distribute the heat within the residential structures without the necessity of mechanical heating systems. Composite climate regimes that have cold winter months unavoidable having effective methods of passive thermal comfort is a crucial measure that will lead to reduced energy consumption and maintenance of comfort inside a structure.

Solar Gain Optimization:

- South-Facing Windows: Window orientation to the southern direction is the option of choice, in order to take advantage of the winter sun gain. Glazing, which faces the south direction, lets in the sun and warms up the interior surfaces of the building, as a consequence.
- Thermal Mass: Include solar heat absorber and storing devices near windows, thus windows will be south facing, using such materials as concrete floors or masonry walls which will absorb and store solar heat. Thermal mass during the course of the day it acts to moderate temperature variations and release accumulated heat shell slowly as the temperatures drop.

Insulation and Air Sealing:

- Enhanced Insulation: Increase insulation to levels of walls, roofs and floors so there will be minimum heat loss and a comfortable thermal condition will be maintained. Buildings' insulation reduces the poll ratio and boosts the performance of the natural heating systems.
- Air Sealing: Seal any openings on the rigorous outer shell including gaps, cracks, and penetrations that let air leak and allow desired interior temperatures to escape. Air tightness measures add success to the works of interior spaces heating through blocking of air leaking from these spaces.

**4.3 Active Energy Efficiency Measures:** Energy efficiency can be seen in a housing system as the more popular approach hard measures that use mechanical or electrical systems. Unlike passive strategies that include exploitation of the natural resources and design principles, active ones will have an aim at technological improvements and controls designed to enhance the energy saving and its reduction. Energy efficiency in which cooling and heating demands are also significant is highly important for the combined climate region that results in the best possible energy efficiency outcome.

High-Efficiency HVAC Systems:

- Variable-Speed Heat Pumps: Introduce heat pumps of variable speed with the ability to fine-tune their output closely based on the demand of either cooling or heating, allowing maximum control over the indoor temperature and optimal energy efficiency.
- Geothermal Heat Pumps: Use the ground-source heat pumps, which are also referred to as he geothermal heat pump systems, which transfer heat through the building and the ground, to respectively achieve high levels of space heating in the winter and energy efficient cooling in summer through entire year.

Energy-Efficient Lighting and Appliances:

- LED Lighting: Substitute the market share of inefficient incandescent or fluorescent bulbs with their high-efficient LED lighting fixtures so as to curb the wattage consumption for lighting without sacrificing its long-lasting and quality brightness.
- Smart Appliances: Invest in smart appliances, capable of saving energy and connectivity options to enable remote access, control or optimization of energy usage possibly for more efficiency.

**4.4 Renewable Energy Integration:** Renewable energy integration is the way to introduce energy, green and environmentally-friendly into residential buildings, so that one can get rid of burning of fossil fuels, contributing to carbon dioxide emissions lowering and better energy reliability. In pooled climate areas the heating and cooling demands are generatiin at the same time. To achieve the best sustainability practice and ensure the enviromenter is safe from impacts, integration of renewable energy system is essential.

Solar Photovoltaics (PV):

- Rooftop Solar Panels: Developing solar PV panels on roofs to convert solar energy into electricity would offer a green and renewable source of energy for residential houses.
- Solar Microgrids: Use solar microgrid systems that would be entirely powered by battery storage and be either above the powerline or underneath it, consequently guaranteeing the continuation of power supply and raising energy resilience even during intervals in the supply of power due to outages or disruptive events.

Wind Energy:

- Small-Scale Wind Turbines: Find out the practicality of mounting mini wind turbines for homes on the ground so as to acquire wind power and improve electricity generation.
- Wind Energy Cooperatives: Take part in community participatory energy cooperatives where joint investments and distributing the profits from wind power generation are the objective.

**5. CONCLUSION –**

It is therefore possible to reduce the energy balance of an existing building by incorporating correct strategy. The paper has focussed on active and passive strategy to reduce the electrical energy consumption of a building, by taking a hotel as a case study. The active strategy involved changing of existing luminaires with more efficient LED based luminaires and setting the thermostat of HVAC system to 26 degree Celsius. The passive strategy, which can be incorporated into the building, included a change in the window glazing having a better thermal insulation. Through these recommendations, it was observed that a reduction of 12.53 % in electrical energy consumption can be achieved. The solutions are multiple and inexpensive and can subsequently install less green energy input systems than if they had been applied to the building base.

Consider the value of passive design solutions, active energy saving measures, and renewable energy integration methods in decreasing energy consumption, delivering comfortable living experience, and bringing about increased sustainability. Cite the observed decrease in gas usage for heating, cooling, lights and appliances during the implementation of an energy conservation plan as compared to the actual beginning time. Identify future research directions, for instance: examining the scope of futuristic technologies, improving building systems integration, and conducting long-range performance monitoring.

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