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Strategies to Improve the Performance of Energy Efficient Office Building towards a Net Zero Building (A Retrofitting Case of Composite Climate)

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Abstract: ***The U.S energy information administration (EIA) states that building sector consumes about 47% of energy, which is almost half of the total energy produced.74.9% of all the electricity produced in the U.S is used just to operate building. Energy consumption through commercial sector contributes to 19% of the total energy consumed by the building sector. Energy consumption in buildings for operating building i.e. heating, cooling, and lighting is required to be reduced. Literature study has been done to understand different design strategies which should be considered in the early stages of designing of an office building. This paper initially focuses on the strategies which should be considered to reduce the overall energy consumption of an office building and then meeting the net zero energy goal by covering the minimized energy demand by applying the renewable energy source. This approach is simulation based which has been done by design builder software. Firstly, the energy consumption demand of the building has been estimated. Subsequently, sustainable building approaches for energy conservation have been integrated to reduce the overall energy demand of the building. Finally, renewable energy sources are implemented in order to offset the minimized energy demand of the building. Thus having a net zero energy IT office building.***

Keywords: Sustainable design strategies, energy consumption, Energy Performance Index (EPI), Renewable energy sources

1. Introduction

The construction sector poses a major challenge to the environment. Globally buildings are responsible for at least 40% of energy consumption. India too faces the environmental challenges of the construction sector in the form of global warming (Ministry of New and Renewable energy, 2010)

Buildings have huge impacts on the environment throughout their lifespan. Energy-consuming lighting, air-conditioning and water heating systems provide comfort to their occupants. Energy-conscious design requires climate-responsive design to be combined with building usability.

Energy-efficient buildings are also one of the ways of addressing climate change issues. (ZHANG & ZHU, 2013) analyzed four energy efficient office buildings in four climatic zones of China and determined the breakdown of the energy consumption of those buildings. They reported that lighting and cooling account for the largest proportion of energy consumption in office buildings.

Improving the energy efficiency of existing building stocks is one of the most efficient measures in the construction sector to reduce energy consumption and carbon emissions. It has been widely demonstrated that HVAC (Heating, Ventilation and Air-conditioning)is the largest source of energy consumption in buildings.

Therefore, a huge proportion of research has been done for improving the performance of HVAC systems and reducing energy consumption by enhancing HVAC efficacy (Sun, Gou, & Siu, 2018). In addition to HVAC, lighting retrofits have great potential to reduce existing building's energy consumption.

This work assesses the quality of new energy-efficient buildings and offers an active and passive approach for upgrading existing buildings in a composite environment.

2. Need of the Study

In general, retrofitting approaches for energy efficiency can be classified as passive and active solutions: active solutions involve optimizing heating, ventilation, HVAC systems, lighting and any other building services applications; while passive solutions seek to provide more resource-efficient architectural components (such as building envelopes and roofs) to minimize dependency on active solutions(Sadineni, Madala, & Boehm, 2011)

It has been commonly demonstrated that lighting in office buildings is the second largest energy source. Relevant approaches to update existing buildings include the improvement of the lighting system(R.Benya & Leban, 2011) and optimizing day lighting (Campo, 2010)

Glazing and lighting retrofitting therefore has a great potential to improve the existing building's energy efficiency.

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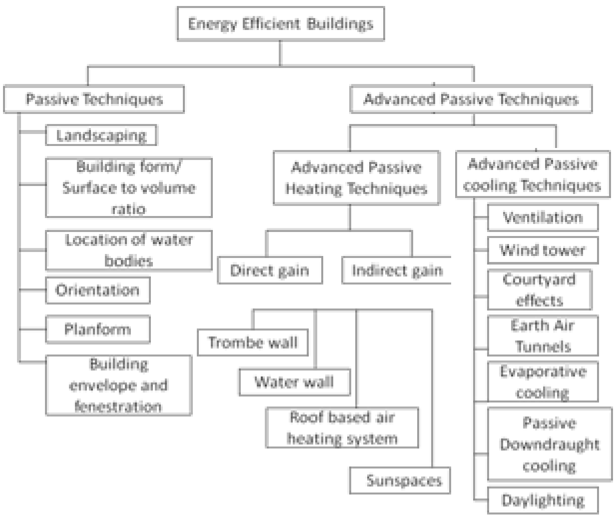
3. Parameters of Energy Efficient Buildings

- Incorporate solar passive techniques in a building design to minimize load
- on conventional systems(heating ,cooling, ventilation and lighting)-**Passive systems provide thermal and visual comfort by using natural energy sources and sinks , e.g. Solar radiation, outside air, sky, wet surfaces, vegetation, and internal gains. The solar passive systems vary from one climate to the other.**
- Design energy efficient lighting and HVAC (heating, ventilation and air conditioning systems)-**Once the passive solar architectural concepts are applied to a design, the load on conventional systems (HVAC and lighting) is reduced.**
- **Use renewable energy systems (solar PV systems/solar water heating systems etc.) to meet a part of building load-**The pressure on earth's non-renewable sources can be alleviated by judicious use of earth's renewable resources.
- **Use low energy materials and methods of construction and reduce transportation energy-**Efficient structural design should also be aimed, reduced use of transportation energy and high energy building material (glass, steel etc.) and use of low energy building material should be used.
- An **energy efficient building** balances all aspects of energy use in a building-**lighting, space-conditioning, and ventilation,** by providing an optimized mix of **passive solar strategies, energy efficient equipment, and renewable sources** of energy. Use of **materials with low embodied energy** also forms a major component in energy efficient building design (TERI).



4. Case Studies

Indira Paryavarn Bhawan

- Location-New Delhi
- Geographical coordinates28°N, 77°E
- Occupancy Type-Office (MoEF)
- Typology-New Construction
- Climate Type-Composite
- Project Area-9565 m^2
- Grid Connectivity-Grid connected
- EPI43.75 $kWh/m^2/yr$

Figure1: Indira Paryavaran Bhawan
(Source: Author)

- Indira ParyavaranBhawan, the new Ministry of Environment and Forest (MoEF) office building collection, is a radical shift from traditional construction style.
- Through providing adequate natural light, shade, landscape to minimize ambient temperature, and energy-efficient effective building systems, the project team placed special emphasis on strategies to reduce energy demand.
- Many energy conservation measures have been taken to reduce the building's power loads and the remaining demand has been met by generating energy from on-site installed high-efficiency solar panels to meet net zero requirements.
- Indira Paryavaran Bhawan uses less energy than a conventional building by 70 percent. The plan implemented sustainable building principles including water conservation and optimization by extracting waste water from the site.
- Indira Paryavaran Bhawan is the highest rated green building in India today. GRIHA 5 Star and LEED Platinum earned the venture.
- The building has already won awards for outstanding demonstration of Renewable Energy Technology Integration such as MNRE's Adarsh / GRIHA (USAID, Net zero energy buildings).

ITC Green Centre
Location: 10, Institutional Area, Sector 32,Gurgaon, India
Floor Area: 1, 70,000Sq.Ft(15,793Sq.Mtr.)
Architect: Rajender Kumar & Associates, New Delhi, India
Significance: Platinum Rated green building

Energy consumption Statistics

- Conventional building of similar area – 35,00,000 kWh/year
- ITC Green Centre – 20,00,000 kWh/year
- Annual Energy Savings Rs. 9 Million
- % increase in initial cost - 15%

ITC social & ecological commitment

- ITC tries to reduce the direct and indirect effect of its business operations on the environment.
- 'Carbon Positive' Corporation-the use of environmentally friendly fuels, renewable energy and large-scale

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afforestation has enabled the company to sequester the carbon dioxide emitted by its operations.

- 'Water Positive' , Zero Water Discharge & Solid Wastes corporation(Khatri).

Green Materials

The first challenge was the procurement of green materials from sustainable forests such as green wood and low-volatility organic compounds for building that were not readily available in the country at the time. Many energy awareness programs had to be carried out with ITC design and architecture consultants and staff to sensitize them with environmental conservation issues (Khatri).

Use of Glass

The aim was to significantly reduce energy consumption over a typical building during the project design. Energy consumption at the ITC Green Center has been reduced by as much as 51 percent by design integration alone. The glazing of the building was designed to maximize the effect of natural light, eliminating the need for artificial light in large part. At the same time, though allowing light inside, the window glass does not allow heat.

With advanced high-performance glazing solutions, ITC could achieve the twin proposal of lending in ample natural light while increasing the energy gain in the interiors (Khatri).

Design Intent

- High façade energy efficiency with optimal transmission of light.
- On the northern side, due to the building's orientation, the glass solution was needed to provide a higher light transmission.
- The principles of Green Building emphasize sunshine (natural lighting) and unlimited vision as both are related to a quality of human health. Glass is the only product that can help to fulfill these needs.

Figure 2: Site Plan Of ITC Green Centre

5. Analysis of Selected buildings

Parameters	Indira Paryavaran Bhawan	ITC Green Centre
Passive Strategies		
Orientation	NS oriented	NS oriented
	Seprate block connected by corridors	Two office wings are held together by a central atrium
	Optimal WWR	Optimal WWR
Landscaping	More than 50% plantation	Hardscaping
	Circulation roads and pathways soft paved	
Day lighting	75% of building floor space is day lit	
	Inner courtyard serves as a light well	
Ventilation	Central courtyard provides natural ventilation due to stack effect.	
	Windows and jaalis add to cross ventilation	
Building Envelope and Fenestration	• Window assembly (U-Value 0.049 W/m^{2}K),VLT 0.59, SHGC 0.32	U value 1.9 w/m2 K
	• uPVC windows with hermetically sealed double glazed using low heat transmittance index glass	• Glass by Saint Gobain
	• Rock wool insulation	No uPVC windows
	• High efficiency glass	No cool roofs.
	• Cool roofs: Use of high reflectance terrace tiles for heat ingress, high strength, hard wearing.	
Material and Construction Techniques	• AAC blocks with fly ash	• AAC blocks 55% Flyashcontent PortlandPozzolana cement Ready Mix Concrete (RMC)
	• Fly ash based plaster & mortar	Fly ash (3.36%)
	• Stone and Ferro cement jaalis	• Medium Density Fibre board (MDF) 85% rapidly renewable materials (eucalyptus which is grown within ten years life cycle) 15% recycled material
	• Local stone flooring	
	• Bamboo jute composite doors, frames and flooring	
	• High efficiency glass, high VLT, low SHGC & Low U-value, optimized by appropriate shading	
	• Light shelves for diffused sunlight	
Terrace Garden and Water Bodies	• The terrace garden utilizes preserved top soil extracted during the initial excavation	
	• Water bodies in central courtyard	

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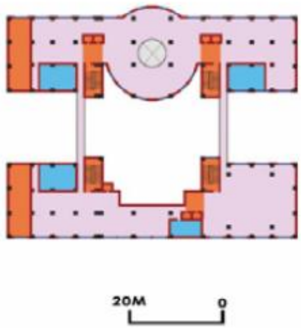
Parameters	Indira Paryavaran Bhawan	ITC Green Centre
Active Strategies		
Efficient Lighting Design	• Energy efficient lighting system	• Energy efficient lighting system
	• Building integrated photovoltaic (BIPV)	• No BPV
	• Use of energy efficient lighting fixtures (T5 lamps)	• T5 lamps with electronic ballast, high efficient luminaires)
	• Use of lux level sensor to optimize operation of artificial lighting	• No lux level sensors
Optimized Energy Systems/Hvac Systems	• Chilled beam system/ VFD/ Screw Chillers	• No chilled beam system
	• Geothermal heat exchange system	• CO^2 monitoring systems in AHU
Renewable Energy		
Solar PV System	• Solar PV System of 930 kW capacity	
	• Total Area of panels : 4650 m^2	
	• No of panels : 2,844	
Water Efficiency	• Zero water discharge	• Zero water discharge
	• Extracted water supplied to NDMC	

Parameters		
	ITC Green Centre, Gurgaon	IPB, New Delhi
Year of completion	2004	2014
Significance	Platinum-rated by LEED 52/69	Platinum-rated by LEED Five star-rated by GRIHA
Open plan/Cellular office	60% Cellular office + 40% Open plan	Open + Cellular
Building configuration		
Orientation	Long axis of the building oriented NE–NW	N–S orientation
Placement of core	Central, East, and West	Central and West
Typical floor area (m^2)	2047	3150
Total floor area (m^2)	15,799	31,400
No. of floors	6 (2B + G + 5)	8 (G + 7)
Floor-to-floor height (m)	3.6	3.9
Plan depth (m) overall	24	15

6. Data Analysis

Window paraeters		
Overall WWR (%)	33	20
Shading device	Few windows shaded with horizontal louvers	Box
Sill level (m)	0.3	0.8
Window height (m)	2.1	1.8
Building envelope materials		
Wall assembly U-value in W/m^2K	250-mm AAC block with 70-mm stone cladding and 12.5-mm plaster inside U-value: 0.607	AAC block masonry wall and fly-ash-based plaster and mortar U-value: 0.34 Stone and ferrocementjaalis used in the circulation area
Roof assembly U-value in W/m^2K	120-mm RCC roof with a 76-mm ISO board in the interior U-value: 0.335	150-mm RCC slab with insulation and local stones U-value: 0.5
Glazing type U-value in W/m^2K	Double-glazing window (6-12-6), SC = 0.26, and U-value = 1.81 W/m^2K	Double-glass windows with a high efficiency, visible light transmission (VLT = 0.59), and U-value (0.049)
		Light shelves for allowing the entry of diffused sunlight
Occupancy& energy consumption		
Working hours	9am-5pm(per day)	09am–10:30 pm (5 days per week)
	48 hours per week	42.5 hours a week
	Sunday closed	Saturday and Sunday closed
HVAC type and capacity ECBC recommends COP: 5.4	Central, 2850 kW capacity, 18 m^2/TR COP: 6.1	Chilled beam system of HVAC, geothermal technology for heat rejection, 563 kW capacity, 45 m^2/TR COP: 6.7
Lighting fixtures	T5 and CFL lamps (daylight sensors)	Light shelves, T-5, and LED fixtures (daylight sensors)

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LPD ECBC recommends 10.8 W/m^2	7.2 W/m^2	5 W/m2
HVAC performance index ($kWh/m^2/year$)	64	27
Renewable energy (kWp)	Photovoltaic cells for emergency lighting	930 kWp SPV panels

7. Building Simulation

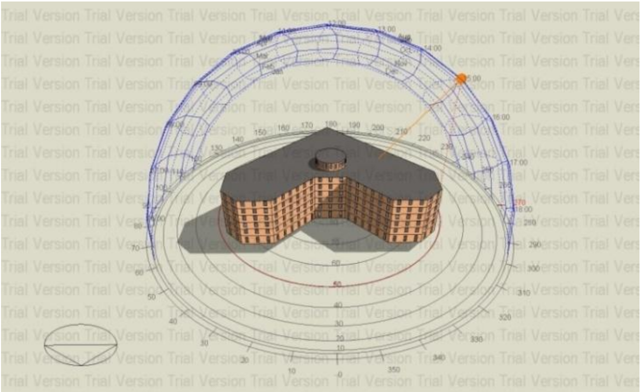


Figure 3: Sunpath Analysis
(Source: Design builder)

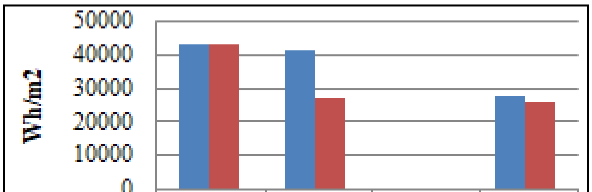
WWR 33%

Pre-Retrofit of Window Glazing and lighting fixture

Glazing type-Double Glazing Window(6-12-6)
U-value -1.81/m2k
Lighting Fixture-T5 CFLS

Post-Retrofit of Window Glazing and lighting fixture

Glazing type-Double Glazing Window(6-13-6)
U-value -0.049/m2k
Lighting
Fixture-LEDS



	Electricity	Lighting	Heating	Cooling
Pre-Retrofit	43342.98	41342.4	199.38	27959.6
Post Retrofit	43342.98	27316.16	236.29	25986.86

The annual consumption by lighting of the existing building model is 121301kwh. WWR of existing building is 33% with fenestration glazing(windows) with SC value-0.26,U value of glass-1.81W / m2 Using building simulation, after replacing the fenestration(windows) glass material with U-value-1.81W / m2 K with U-value 0.049 as applied in the building used as a comparison benchmark (Indira paryavarn Bhawan), the reduction in electricity consumption is found to be 7% due to the reduction in cooling load and 33.9 % due to the reduction in lighting load.

After replacing the lighting fixtures (T5 and CFL's) and the glazing material of window(U-value-1.81/m2k) applied in the existing building model with the fixtures used in the benchmark building (LED's and T8lights), it was found that there is a total reduction of 5.64 % in total electricity consumption through lighting and cooling.

8. Conclusion

Indoor and outdoor lighting system consisted primarily of T5 fluorescent tubes. Although T5 lighting has been considered a relatively energy-efficient solution, advances in lighting technology have pushed the boundaries further, especially with the introduction of LED lighting (light emitting diode).The T5 lights have been replaced by energy-saving LEDs along with the fenestration (windows) glass material change.

The current building's annual consumption (lighting) was found to be 121301kwh and fell to 80179.97 after installing LED lights in November 2019.This indicates a 33.9% reduction in energy based on office usage.

9. Recommendations

For building envelope insulated walls with low U-value, high performance dual pane glass in fenestrations, insulated roof, and shaded windows should be integrated in design for effective reduction in HVAC load of a building in composite climate.

Lower WWR reduces the cooling load. However, it also reduces the availability of natural light hence increasing the lighting and cooling load. So WWR should controlled according to the building direction and orientation.

Energy efficient LED lighting can reduce the overall lighting load of a building upto 40%.Hence reducing the overall Energy Performance Index Of the building.

Author Profile

Anshu Verma had done his B.Arch. degree from Bundelkhand university, Jhansi in 2018 and currently pursuing M. Arch degree from Faculty of Architecture & Planning, Lucknow (Dr. APJ Abdul Kalam Technical University Lucknow, India.). From last one-year author is busy in completing his research project on the topic “Strategies to improve the performance of an energy efficient office building towards a net zero building”. The main aim of her research is to provide information about Net zero energy buildings and their importance in the sustainable building design.

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