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Design Feature for Net Zero Energy Efficient Building: A Case of Office Building

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1. Introduction

A significant environmental problem emanates from the construction industry. Buildings account for at least 40% of energy consumption worldwide. Global warming is one of the environmental issues that the construction industry in India is also facing (Ministry of New and Renewable Energy, 2010).

Throughout their lifetime, buildings have a significant impact on the environment: the comfort of their occupants is provided by energy-intensive lighting, air conditioning, and water heating systems.1 To be energy conscious, climate-smart design must be paired with usable building design.

Buildings that use less energy are another approach to combating climate change. (ZHANG ZHU, 2013) studied the energy consumption of four energy efficient office buildings in four different climates in China. They found that cooling and lighting are the largest contributors to energy consumption in office buildings.

One of the best ways to reduce energy consumption and carbon emissions in the construction industry is to make existing buildings more energy efficient. Numerous studies have shown that heating, ventilation and air conditioning systems account for the majority of energy consumption in buildings.

As a result, much research has been conducted to increase the efficiency of HVAC systems and reduce energy consumption (Sun, Gou, & Siu, 2018).

Retrofitting lighting systems in existing buildings also offers significant potential to reduce energy consumption.

This work not only provides an active and passive approach to upgrading existing buildings in a composite environment, but also evaluates the quality of new energy-efficient buildings.

1.1 Need of the study

Energy efficiency retrofit strategies can generally be divided into passive and active solutions. Passive solutions aim to provide more resource-efficient architectural components (such as building envelopes and roofs) to minimise reliance on active solutions (Sadineni, Madala, & Boehm, 2011). Active solutions optimise heating, ventilation, HVAC systems, lighting, and all other building services applications.

It has been shown that lighting is often the second largest energy consumer in office buildings. Daylighting optimization (Campo, 2010) and lighting system replacement are two relevant methods for renovating older buildings.

Therefore, the renewal of glazing and lighting offers great potential to increase the energy efficiency of the current structure.

1.2 Aim

The aim of this study is to design and analysis of a building which using passive strategies to achieve thermal comfort. Integration of passive strategies into the building spaces for achieving thermal comfort.

1.3 Objective

Analyzing and evaluating the energy performance of building through energy simulation software tool.

Understanding the improved efficiency through each individual design strategy. Retrofitting of energy efficient building through exterior glazing and artificial lighting.

1.4 Research Question

Do energy-efficient lighting systems make a major contribution to reducing an office building's energy consumption and cost-effectiveness?

1.5 Research Hypothesis

The strategy of retrofitting of the lighting system will lead individually to a greater reduction in the overall energy consumption of energy-efficient building.

2. Methodology

In terms of thermal design of buildings, India can be divided into five climatic zones, namely hot and dry, warm and humid, mixed, temperate, and cold, of which the mixed zone covers the largest area of India (BEE, 2011). The mixed zone covers the largest area of India. Based on the rating system, energy consumption patterns and design strategies for energy efficient buildings, the case of an existing building was selected. A literature review was used to collect data on the selected building and evaluate various criteria by which energy efficient buildings perform. The performance of the building is compared with the effectiveness of the different design strategies used in the buildings. A building model simulation was performed to determine the appropriate design measure to reduce the building's energy consumption through an efficient lighting system.

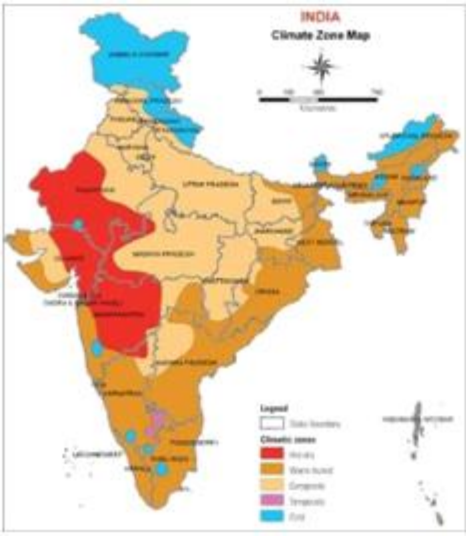

Figure 1.1: Map of India (climate zones)
(source:https://www.researchgate.net/figure/Map-showing-climatic-zones-in-India-Source-National-Building-Code-of-India-2005_fig1_221901881/actions#embed)

1) Selection of case study
- Assessed using one of the rating systems or high-performance building standards.
- Availability of energy performance data related to building.

2) Introduction
- Aim
- Objective
- Research question
- Research Hypothesis

3) Analysis
- Active Strategies
- Passive Strategies
- Renewable Energy Source

4) Literature Review
- Terms and Definition
- Analysis of literature Review

5) Case Study
- Site Study
- Analysis of case study
- Comparative analysis of Buildings

6) Data Evaluation
- Quantifying Parameters
- Simulation Of Building Model
- Evaluation Of Simulation data

7) Recommendations and Solutions

Scope
- This work will provide retrofitting options to reduce energy consumption in existing buildings.
- The work will provide approaches to how energy reduction in the existing building stock could be accomplished.
- The study will integrate active and passive strategies.

Limitation
- The study was conducted specifically for the composite climate. It is limited to an office building. The study will focus on only two parameters selected:
- Exterior glazing
- Artificial lighting

3. Literature Review

3.1 Definition

Energy-efficient buildings are buildings that essentially have energy consumption reduction measures compared to conventional buildings of similar size and occupancy.This efficiency is achieved by:

Design elements (Landscaping, building form, orientation, building envelope and fenestration, materials and construction techniques etc.). Specific strategies for passive, active and renewable energy.

3.2 Parameters of Energy Efficient Buildings

- Passive systems provide thermal and visual comfort by using natural energy sources and sinks, such as solar radiation, outdoor air, sky, moist surfaces, vegetation, and internal gains. This reduces the load on conventional systems (heating, cooling, ventilation, and lighting). Passive solar systems change based on climate.
- Create HVAC (heating, ventilation, and air conditioning) and lighting systems that use less energy. When passive solar architecture principles are incorporated into a design, the need for traditional systems (HVAC and lighting) decreases.
- Use renewable energy technologies to meet some of the building load, such as solar water heating or photovoltaic systems.
- Use energy-efficient building materials and construction techniques while reducing energy demand for transportation. - Strive for efficient construction and use less energy-intensive building materials (such as glass, steel, and aluminium) and more low-energy ones.
- An energy efficient building provides an optimal mix of passive solar techniques, energy efficient technology, and renewable energy sources to balance all aspects of energy use in a building, including lighting, air conditioning, and ventilation. An energy efficient building design (TERI) also relies heavily on the use of low energy materials.

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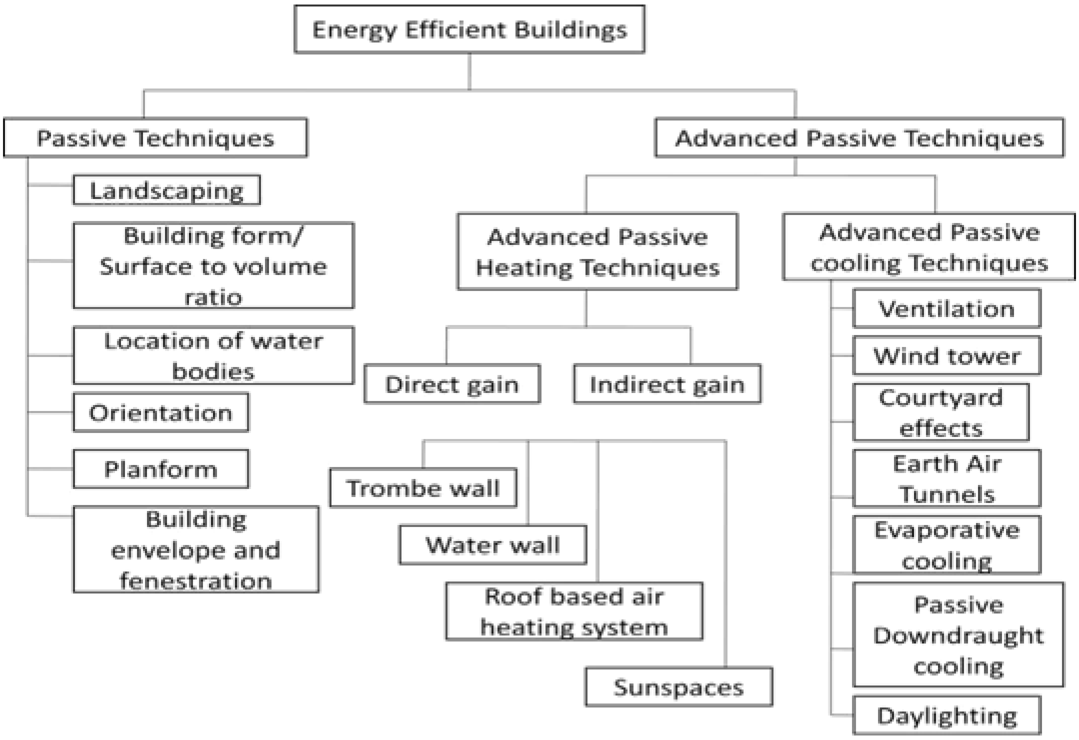

3.3 Terms and Definitions

3.3.1 Passive Design Strategies

Considering the building's geographical and meteorological conditions, passive approaches to reduce the building energy demand are implemented during construction layout. Factors that are considered in passive design strategies are (USAID):

3.3.2 Form and Orientation

Form and orientation are two of the most important passive development techniques to reduce energy consumption and improve the thermal comfort of a building's occupants.The design of the building varies depending on its location and environment (USAID).

The form of the building determines the volume of space that needs to be heated or cooled inside a building (USAID).

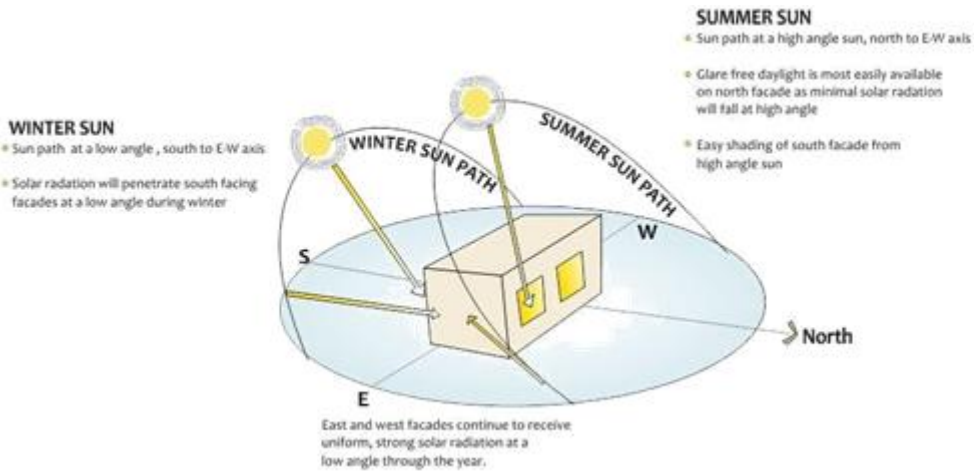

Figure 2.1: Form and orientation
(source: https://nzeb.in/wp-content/uploads/2015/06/form_orientation_1.gif)

Shading

External shading systems, for example, are important structural measures that either prevent or greatly minimise the need for mechanical heating and cooling to provide thermal comfort in buildings by limiting heat absorption through openings. Consequently, external and internal shading systems can be used as a necessary option to achieve energy efficiency. Opening proposals (USAID, Net-zero buildings)

Consequently, shading of south-facing openings must allow sunlight to pass through for heat gain in winter, but block it in summer. According to the USAID Net-Zero Energy buildings, shading is only appropriate for north-facing openings to block high solar gain in summer.

Cool roofs

Just as light-colored clothing can help keep a person cool on a sunny day, cool roofs use solar-reflective surfaces to keep temperatures down on the roof. Highly reflective and light colored roofs are now an integral part of a building's energy efficiency measure(USAID, Net Zero Energy Buildings).

Traditional dark roofs reach temperatures of 660C (150oF) or higher in the summer sun, while a cool roof could remain more than 280C (50 ° F) cooler under the same conditions (USAID, Net Zero Energy Buildings).

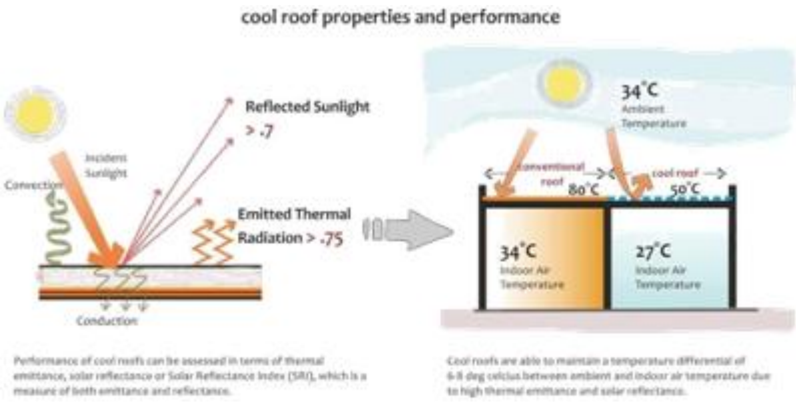

Figure 2.2: Cool roofs

(source: https://nzeb.in/wp-content/uploads/2015/07/Coolroof.jpg)

Fenestrations

- When required, fenestrations (windows, skylights, and other openings in a building, etc.) allow sunshine and the prevailing wind within the building.
- Fenestrations often influence the capacity for daylight harvesting by minimizing lighting charges without compromising the visual and thermal comfort of occupants of buildings.
- Windows position, width and glazing can be used wisely to reduce the cooling load and, as a result, smaller cooling systems for buildings.
- In terms of both quantity and duration, solar radiation intensity is minimal on openings or walls facing north, followed by façades facing south. The openings (or walls) facing east and west receive a large amount of solar radiation all year round (USAID, Net zero energy buildings).

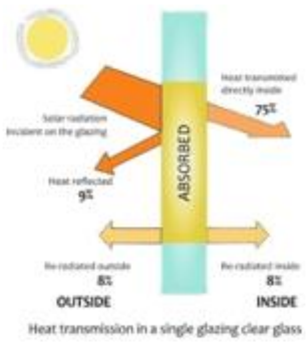

Figure 2.3: Fenestration

(source: https://nzeb.in/wp-content/uploads/2015/07/glazing-properties.jpg)

Insulation

- In walls and roofs, thermal insulation reduces heat transfer from inside to outside and helps to maintain comfortable indoor temperatures. This creates a healthier environment, improves noise safety, and reduces electricity bills most significantly. Insulation helps keep indoor space cooler in summer months and warm during winters.
- Various materials can be selected including fiber glass, mineral wool, rock wool, expanded or extruded polystyrene, cellulose, urethane or phenolic foam boards and cotton.
- Higher R-values mean better insulation and turn into more energy savings, much needed to meet the development goals of the energy efficient buildings (USAID, Net zero energy building).

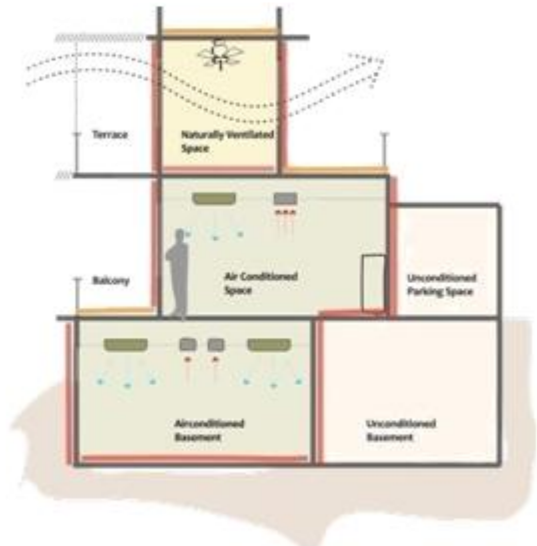

Figure 2.4: Insulation

(source: https://nzeb.in/wp-content/uploads/2015/07/insulation_2.jpg)

Daylighting

- Daylighting is a technique for building design to use daylight. The presence of natural light in an occupied space provides a sense of well-being, raises awareness of one's surroundings and also increases energy saving potential with reduced reliance on artificial light.
- Appropriate use of windows, skylights, clerestories, and other building apertures provides means for daylight harvesting (USAID, Net zero energy buildings).

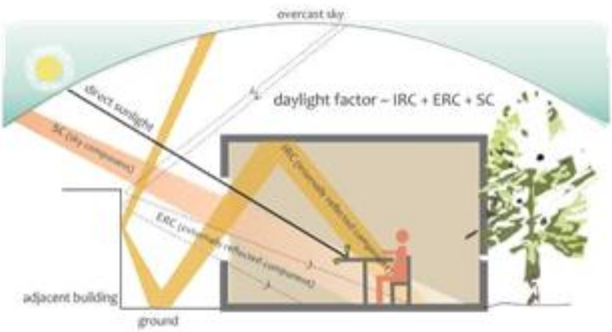

Figure 2.5: Day lighting
(source:https://nzeb.in/wp-content/uploads/2015/07/daylight-factor.jpg)

Natural Ventilation

- Fresh air in a building provides health benefits to its residents and increased levels of comfort. The supply of fresh air is considered an effective and safer solution because it eliminates the need for mechanical ventilation of a house.
- Passive design measures can be used to influence the movement of outside air into a built space by bringing fresh air in order to achieve an Efficient Design goal.
- Different forms such as correct orientation and shape, building envelope openings (windows, doors and ventilators), operating windows, internal space design, etc. are different natural ventilation techniques that can be implemented.Other advanced ventilation techniques are the effect of the courtyard, the effect of the stack, the wind tower or tunnels on the air earth (USAID, net zero energy buildings).

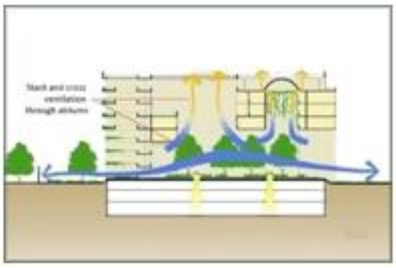

Figure 2.6: Natural Ventilation
(source: https://nzeb.in/wp-content/uploads/2015/10/passive_IPB2.jpg)

Thermal Mass

- Thermal mass helps to retain heat and moderate variations in the indoor temperature within the building structure. The building material heat storage capacity helps by providing time delay in achieving thermal comfort for occupants.
- Building material mass and density influence the ability for heat storage in buildings. High density materials like concrete, bricks and stone have high thermal mass, whereas materials like wood or plastics have low thermal mass.The effectiveness of direct sun irradiation depends on the placements of these components(USAID, net zero energy buildings).

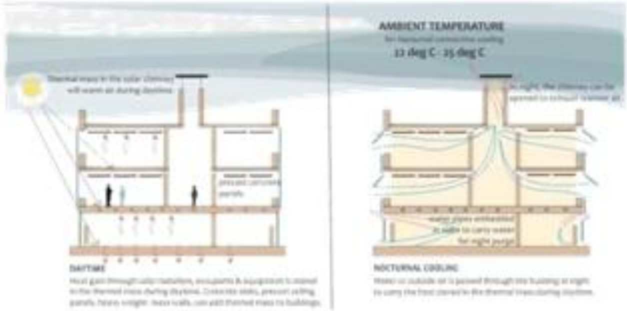

Figure 2.7: Thermal mass
(source: https://nzeb.in/wp-content/uploads/2015/07/thermal-mass-1.jpg)

Evaporative cooling

- Over the years, traditional wisdom has supported the idea of a water body like pond, lake or fountain to give the surrounding environment a cooling effect. This effect reduces the temperature of indoor air-an evaporative cooling phenomenon that is widely known. This phenomenon is witnessed in most Indian households in systems such as desert coolers.
- Evaporative cooling reduces the temperature of the indoor air, thereby reducing the cost of power in building air conditioning. Reduced energy load leads to achieving the goals of efficient design(USAID, Net zero energy buildings).

Thermal Comfort

- Ultimately, buildings are designed to provide shelter and comfortable habitats. Significant amounts of energy are expended as buildings are cooled or heated by mechanical equipment to maintain the optimal thermal comfort conditionsIt is important to understand what thermal comfort is and how, with the least amount of energy expended, it can be accomplished.
- Thermal comfort is an evaluation of the environment's thermal condition. ISO 7730 states that thermal comfort is described as "a condition of mind expressing satisfaction with the thermal environment"(USAID, Net zero energy buildings).

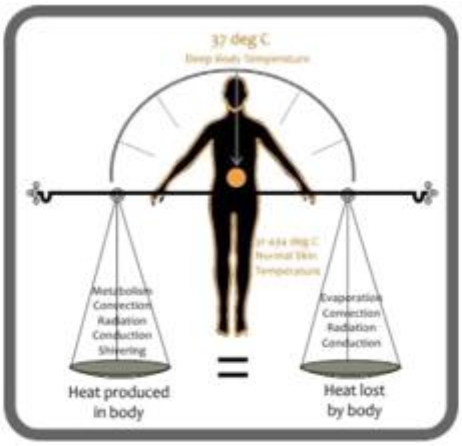

Figure 2.8: Thermal comfort
(source: https://nzeb.in/wp-content/uploads/2015/07/thermal-comfort.jpg)

Human body needs to maintain its core temperature at 37 ºC. In order to do so, it must constantly exchange heat with the surroundings. People feel comfortable when this process is sufficiently supported by the surrounding thermal environment of a building (USAID, Net zero energy buildings).

Vegetation

Different air circulation patterns are produced by trees and shrubs, providing shade and keeping the surrounding area warmer. Vegetation can be used in buildings to conserve energy in the following ways:

- Shading of buildings and open spaces through landscaping.
- Roof gardens (or green roofs).
- Shading of vertical and horizontal surfaces (green walls).
- Buffer against cold and hot winds.
- Changing direction of wind.
- Vegetation is a dynamic control system for the penetration of solar and wind into buildings. This prevents direct sun from hitting and heating building surfaces and decreases the outside air temperature which in turn affects the heat transfer from outside to the exterior and interior of the building.
- Green roofs or roof gardens can also be used to help lower heat loads in a building. Extra thermal insulation is given by the additional thickness of the growing medium (USAID, Net zero energy buildings).

Active Design Strategies

HVAC

a) Comfort systems contribute almost 40% of the energy used in India by commercial buildings. There are many types of comfort systems on the market that range from low-energy comfort systems to conventional systems.
b) Reducing heating / cooling loads through passive design strategies and enhancing HVAC systems efficiency are essential steps for any energy efficiency building policy.
c) The system type are broadly categorized into two types:
    - Centralized system: central cooled water system (air-cooled and water-cooled system
    - Distributed system (DX system): VRF, duct-capable system, separated air-conditioners, unit systems.

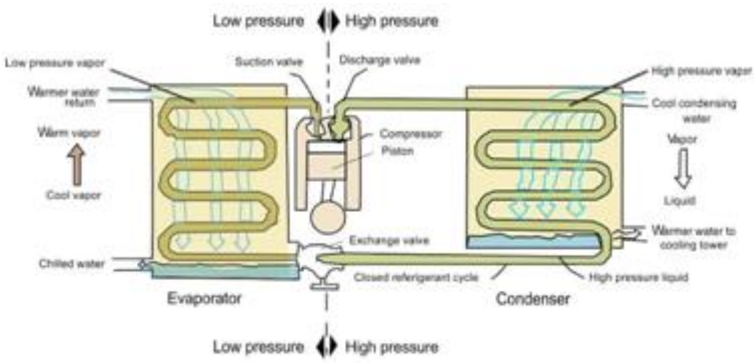

Figure 2.9: HVAC

(Source: https://nzeb.in/wp-content/uploads/2015/08/hvac-intro-image.jpg)

HVAC design and equipment selection majorly depends on:

- Building functional use, type, and operational schedule.
- Variation in operational schedule and potential of system controls
- System complexity
- Commissioning – pre occupancy and post occupancy Design (USAID, Net zero energy buildings).

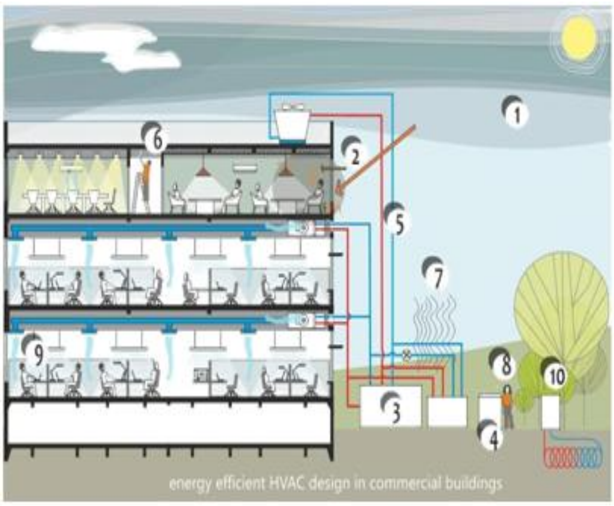

Figure 2.10: Energy efficient HVAC design in commercial building

(source: file:///C:/Users/ANSHU/Desktop/reference/HVAC_landing3 11.gif)

Lighting

- Lighting is designed based on user activity and usable space requirements. To meet the goal, choose possible lamps available on the market.
- Lighting is one of building design's most complex parts. A variety of issues regarding lamp engineering and luminaires, lighting design philosophy, energy efficiency, and aesthetics have to be juggled by the lighting designer.
- Designer should target an LPD reduction of at least 50% of the value stated in ECBC for an energy-efficient design (USAID, Net zero energy buildings).

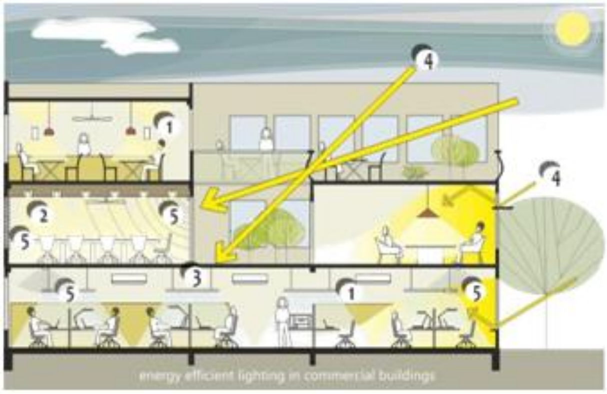

Figure 2.11: Lighting
(Source: file:///C:/Users/ANSHU/Desktop/reference/Lighting3.gif)

Efficient appliances

Solar and off grid appliances

- Renewable energy-based devices will go a long way towards saving customer money by decreasing energy bills and increasing reliance on the electricity grid.
- For controlling external lighting, small photovoltaic modules can be used.

Solar Water heaters use energy from the rays of the sun for domestic and commercial purposes to heat water. There are two types of closed loop and open loop solar water heaters.

Standards and Labelling

Energy Efficiency Standards & Labelling (S&L) systems in many countries have been active in increasing the supply and performance of energy-efficient goods. In India, the S&L appliance system was launched by the Bureau of Energy Efficiency (BEE) in 2006.

Refrigerator

In particular in residential buildings, refrigerators account for a significant fraction of the annual energy usage. There are two main types of refrigerators in the market, Direct Cool and Frost Free, based on the process of circulating cooling and defrosting.

Room Air Conditioners

Air Conditioners are designed to offer comfort to humans by reducing room temperature and humidity. While air conditioners consume large amounts of electricity, their popularity is increasing among the general public.Two types of air conditioners are present in the market:

- Window Type
- Split Type

Distribution Transformer

This type of transformer is the final step in the electrical distribution system's voltage transformation. This reduces the voltage obtained from the distribution lines to a rate that is expected by the end consumer.The standard ratings covered by the program are 16, 25, 63, 100, 160 and 200kVa and 16 to 200kVa non-standard ratings.

Tubular Fluorescent Lamps (TFLs)

TFLs are typically low-pressure mercury vapor gas discharge lamps that produce light by using fluorescence. The labeling scheme for BEE Star covers 4-foot TFLs with up to 40W wattages.

Ceiling Fans

For 1200 mm sweep and a total air supply of 210 cu. m / min, the BEE star labeling system for ceiling fans is applicable

Electric Geysers

Efficient computer system (USAID, Net zero energy buildings)**.**

Renewable Energy

Solar Photovoltaic

- Solar photovoltaics are a combination of panels that contain a number of solar cells that transform the solar energy incident into usable electricity.
- These panels can be mounted anywhere they receive plenty of sunlight.
- Solar cells consist of semiconductor materials such as crystalline silicon, which includes monocrystalline silicon, polycrystalline silicon, ribbon silicon, and mono-like multi-silicon, and thin films like cadmium telluride, copper indium gallium selenide, silicon thin film, and thin film gallium arsenide.

Factors affecting generation of electricity:

- Location, tilt, and orientation
- Over shading
- Temperature
- Panel efficiency (USAID, Net zero energy buildings)

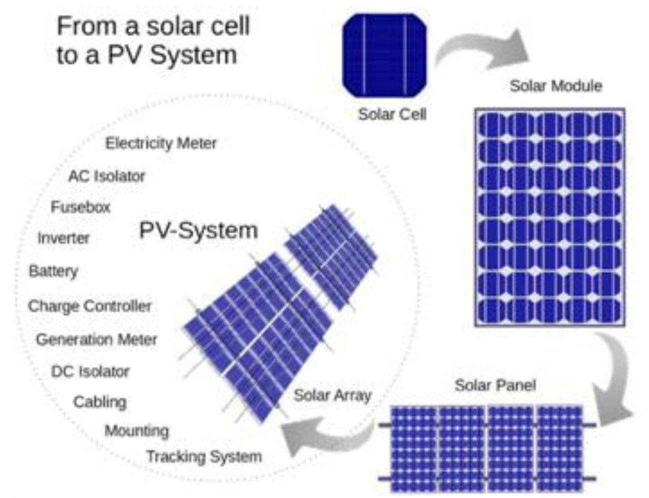

Figure 2.12: Solar Panel Detail
(source: https://nzeb.in/wp-content/uploads/2015/10/From_a_solar_cell_to_a_PV_system.svg_.png)

Wind Energy

- By using wind turbines to harness the wind's kinetic energy, wind power is generated. Wind blowing across a wind turbine's rotors causes it to spin.
- Rotator spinning transforms a part of the wind's kinetic energy into mechanical energy. The mechanical power is further transformed into electricity by a generator (USAID, Net zero energy buildings).

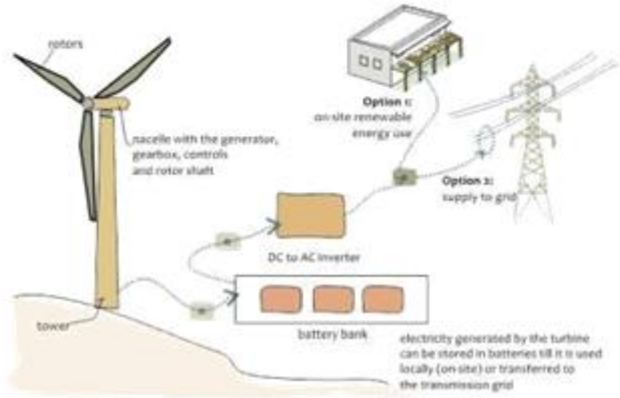

Figure 2.13: Diagram showing wind energy *(source: https://nzeb.in/wp-content/uploads/2015/08/wind-energy_2.jpg)*

Biomass

Biomass fuel is the energy from plants or products derived from plants. Wood is the most widely used source of energy from biomass. Certain biomass sources include: land and aquatic plants, agricultural waste, industrial waste, sewage sludge, animal and municipal waste.

To transform biomass into useful energy, three main technologies are used:

- Bio Gastification
- Biogas
- Biofuels (USAID, Net zero energy buildings)

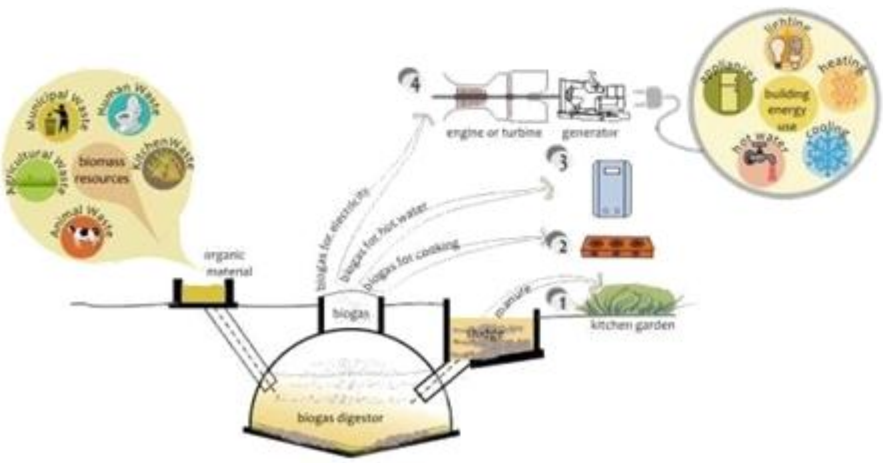

Figure 2.14: Biomass
(source: https://nzeb.in/wp-content/uploads/2015/08/biogas-system.jpg)

Hydro

- Hydro energy is power generated from running or falling water energy on an energy conversion (turbine or wheel) equipment.
- These energy conversion devices transform the kinetic energy into mechanical energy, which is further converted to electrical energy through a generator(USAID, Net zero energy buildings)

4. Literature Review Analysis

Table 2.1: Literature review

Authors	Design Variables	Analysis Target	Simulation tool/ method	Country	Main Finding
(Su & Zhang, 2009)	WWR, orientation, glass type (e.g., single, hollow)	Environmental impact	Life cycle environmental analysis	China	WWR is the most important factor in the environmental impact of the life cycle.

(Ma, Wang, & Guo, 2015)	WWR(i.e., 10~100% with interval 10%), U-value	Recommended WWR	Mathematical model	USA	The optimum WWR is determined not only by the amplitude of the temperature but also by the U value of the building envelope.
(G.Zeng inis & Kontoleon, 2017)	WWR, building aspect ratio(i.e., length and width dimensions)	Heat gain and loss	Mathematical model	Greek	The orientation of the façade and the design aspect ratio with WWR have a huge impact on heat fluxes through the building.
(Wen, Hiyama, & Koganei, 2017)	WWR(i.e., 10~70%, interval:10 %), orientation	Total CO2 emission, recommended WWR	Energy Plus	Japan	This research proposed the optimum WWR of all Japanese regions by taking into account the environment and window properties

5. Case Study

Indira Paryavarn Bhawan

- Geographic coordinates: 28°N, 77°E;
- Location: New Delhi;
- Typology: new construction;
- Climate type: composite;
- Project area: 9565 m2;
- Grid connection: Grid connection; EPI43.75 kWh/m2/year; Type of use: office (MoEF);

Figure 3.1: Indira Paryavaran Bhawan
(source: https://nzeb.in/wp-content/uploads/2015/10/Intro_IPB.jpg)

Background
Indira ParyavaranBhawan, the new Ministry of Environment and Forests (MoEF) building, is the first major building in the country to receive the Net Zero and Energy Positive marks, and the first government building to do so.The building is located in Aliganj on JorBagh Road in South Delhi and includes the minister's office and various administrative areas of the ministry.This project was undertaken at all levels by the Central Public Works Department (CPWD) and Dependra Prashad, Dependra Prashad, Architects and Planners (DPAP) Sustainable Design Consultants to design a building that is not only energy efficient, but also capable of generating more energy on site than it consumes over the course of a functional year (Prashad & Chetia, 2014).

Developing Indira Paryavaran Bhawan

Figure 3.2: Indira ParyawaranBhawan Plan
(source:https://mnre.gov.in/file-manager/akshay-urja/november-december-2014/EN/26-31.pdf)

- The design of the building went through various iterations with a twin North-South facing blocks with a large open space court in the middle being the final design.
- To keep the building height in tune with the surroundings, the maximum permitted ground coverage was used.

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- Permission to cut 46 trees was granted, the design and measures proposed helped to reduce chopping to just 19 trees.
- The landscaping project was planned not only to serve as a climate change agent, but also to highlight the country's plant diversity (Prashad & Chetia, 2014).

Introduction

- The new office building of the Ministry of Environment and Forests (MoEF), Indira ParyavaranBhawan, represents a fundamental departure from conventional construction methods.
- The project team paid special attention to strategies to reduce energy demand by providing adequate natural light, shade, landscaping to reduce ambient temperatures, and energy-efficient, effective building systems. - Several energy conservation measures were taken to reduce the building's electricity loads, and the remaining demand was met by generating energy from on-site high-efficiency solar panels to meet net-zero requirements. By reclaiming wastewater from the site, the proposal incorporated sustainable building principles such as water optimization and conservation.The Indira ParyavaranBhawan is now India's top-rated green building. The project received a GRIHA 5-star rating and LEED Platinum.
- The building has already received recognition for its remarkable demonstration of renewable energy technology integration, including the MNRE's Adarsh/GRIHA award (net zero energy building).

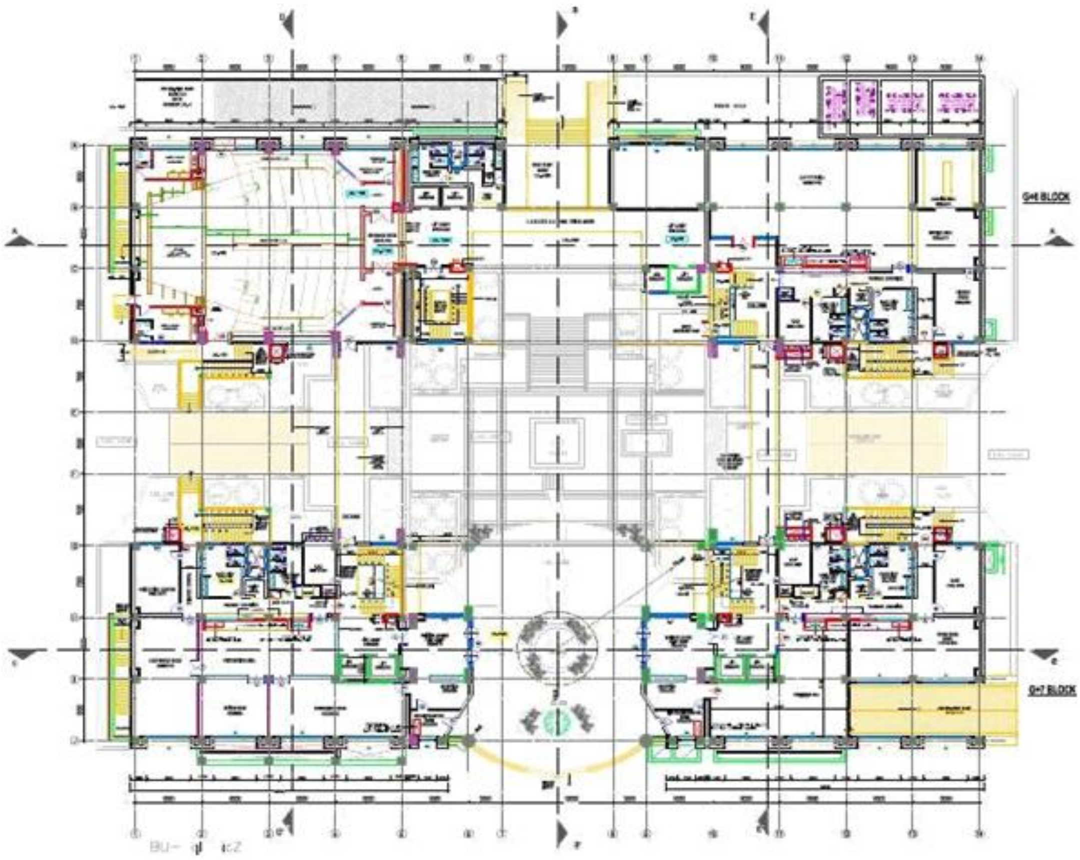

Figure 3.3: Plan
(Source: author)

Passive Design Strategies

Orientation

The building is oriented north-south, with separate blocks connected by corridors and a huge central courtyard. Orientation reduces heat intake. Optimal ratio between window and wall.

Figure 3.4: Orientation
(Source: https://nzeb.in/wp-content/uploads/2015/10/RE_IPB2.jpg)

Landscaping

About 50% of the land outside the building is covered by forest. Circulation roads and paths are paved softly to allow drainage of groundwater.

Figure 3.5: Landscaping
(Source: author)

Daylighting

75% of the building floor space is daylight, reducing reliance on artificial lighting sources. The courtyard inside serves as a bright light.

Figure 3.6: Daylighting
(source: author)

Ventilation

As natural ventilation occurs due to the stack effect, the central courtyard aids in the air movement. Cross ventilation is supported by windows and jaalis.

Figure 3.7: Ventilation
(Source: https://nzeb.in/wp-content/uploads/2015/10/passive_IPB1.jpg)

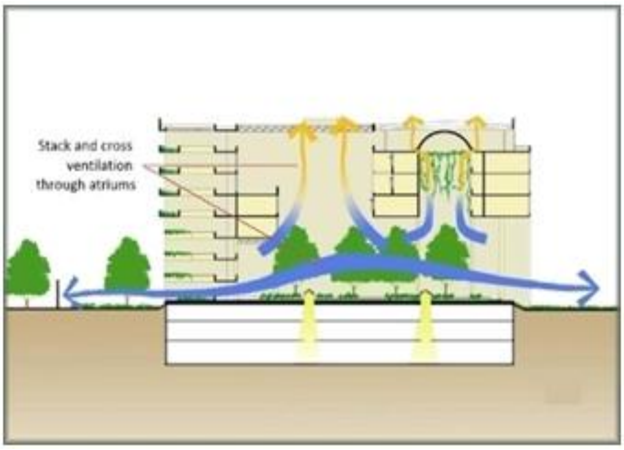

Figure 3.8: Stack effect
(Source:https://nzeb.in/wp-content/uploads/2015/10/passive_IPB2.jpg)

Figure 3.9: Cross ventilation through jails
(Source: Author)

Building Envelope and Fenestration

- Optimized building envelope -window installation (U-value 0.049 W/m2K), VLT 0.59, SHGC 0.32
- Double-glazed, hermetically sealed windows made of UPVC with low thermal transmittance glass Insulation made of rock wool
- High-efficiency glass
- Cool roofs: use of highly reflective terrace slabs for heat absorption, high resistance, durable

Figure 3.10: Fenestrations with double glazing
(Source: Author)

Figure 3.11: Door with high efficiency glass
(Source: Author)

Figure 3.12: Terrace garden with high reflective tiles
(Source:https://mnre.gov.in/file-manager/akshay-urja/november-december-2014/EN/26-31.pdf)

Materials and construction techniques - AAC blocks with fly ash

- Plaster and mortar based on fly ash
- Jaalis made of stone and ferrocement - Floor coverings made of local stone
- Doors, frames and flooring made of bamboo-jute composite material
- High-efficiency glass, high VLT, low SHGC and low U-value, optimized by appropriate shading

- Light shelves for diffuse sunlight (USAID, net zero energy building)

Figure 3.13: Stone and Ferro cement jails
(Source: Author)