



Research Component: Day lighting Integration in Commercial Buildings

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Abstract: Day lighting is defined as the natural maximum light used in a commercial building to illuminate the interior space of the building. The strategy has numerous benefits including energy saving, enhancing interior space, and aesthetics in the structure. Daylighting can be achieved in commercial buildings by the orientation of building windows opening and the material used.

Keywords: Illuminate, Orientation of the Building.

1. INTRODUCTION

Light commonly refers to electromagnetic radiation it can be seen by human eyes. The electromagnetic spectrum is extremely broad, ranging from low-energy radio waves with wavelengths measured in meters to high-energy gamma rays with wavelengths less than 1×10^{-11} meters. Electromagnetic radiation is the type of energy that travels in the waves and it's produced by the movement of electrically charged particles. It counts in wavelengths, from radio waves to gamma rays.

Natural light refers to the direct light source of the sun. Natural light has a great impact on space and can produce light and shadow to make space becoming strong and vibrant, it can also make the space composition and building space environment feel clear. The modern architectural design uses natural light reasonably and effectively, reduces energy consumption, reduces the operation and maintenance of the building, becoming a modern and final architectural design method when building buildings. Human dwellings have evolved from primitive wooden structures to nests and dwellings in caves to today's intelligent skyscraper buildings, which has undergone a fundamental change. . At present, 20% of the world's population consumes 80% of the world's energy and at the same time creates a corresponding amount of pollution. 50% of the energy consumption is used for the



production and operation of buildings. The idea of sustainable development has become the serious issue of mankind. In the face of increasingly serious environmental problems, the use of renewable resources is very important.

1.2 Objectives of the Study

- To study the working of Daylighting
- To understand daylighting strategies and techniques used in Buildings.

1.3 Daylighting

Daylighting refers to the practice of utilizing natural sunlight to illuminate interior spaces within buildings. This involves the strategic design and placement of openings, such as windows, skylights, and glazed surfaces, to allow sunlight to enter indoor spaces and provide illumination. Daylighting is a fundamental aspect of architectural and interior design, offering numerous benefits in terms of energy efficiency, human well-being, aesthetics, and sustainability.

1.4 Methods of Daylighting

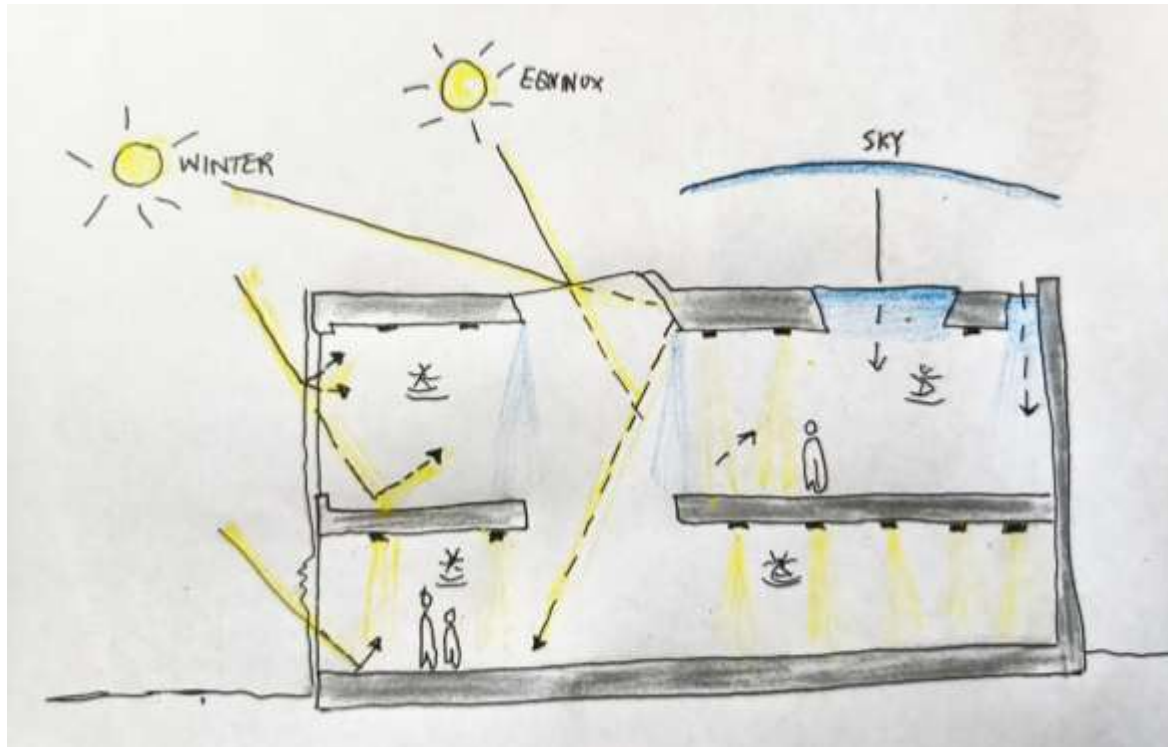
Building Orientation: Building orientation refers to the direction in which a building's major axes are aligned. A well-considered building orientation can significantly impact energy efficiency, occupant comfort, and daylighting. Here are some factors to consider:

1. **Solar Exposure:** Orienting the building's main facades (south, east, west, north) strategically can maximize or minimize solar exposure based on the climate. In colder climates, south-facing facades capture more sunlight, while in warmer climates, minimizing western exposure can reduce afternoon heat gain.
2. **Daylighting:** Proper orientation can allow for effective daylight penetration, reducing the need for artificial lighting during the day. Design spaces to take advantage of northern and southern light, while minimizing eastern and western light exposure.
3. **Views and Context:** Consider how building orientation enhances views of natural features, landmarks, or important surroundings. It can also create outdoor spaces that are sheltered from prevailing winds.
4. **Cross-Ventilation:** Aligning the building's layout to prevailing winds can facilitate natural cross-ventilation, promoting passive cooling and improving indoor air quality.
5. **Shading and Glare Control:** Design overhangs, shading devices, and fenestration to prevent excessive solar heat gain and glare. These elements should be adjusted based on the building's orientation.
6. **Privacy and Noise Mitigation:** Orient spaces to optimize privacy from neighboring structures and to minimize exposure to noise sources.
7. **Accessibility:** Consider universal design principles and ensure that the building orientation allows for accessible entrances and paths of travel.

1.4.1 Concentrating Daylighting

Daylight harvesting or daylight redirection, is a concept and technique used in architecture and building design to maximize the utilization of natural sunlight for interior lighting purposes. The goal is to reduce the dependency on artificial lighting during the daytime,

leading to energy savings and improved indoor environmental quality. The process of concentrating daylighting involves the strategic placement of reflective or refractive elements, such as mirrors, lenses, prisms, or light tubes, to capture, redirect, and distribute sunlight into deeper areas of a building that might not have direct access to windows or openings. This technique is particularly useful in spaces like the core of a building or areas that are distant from exterior walls.



1.4.2 Daylight Availability and Climatic Factors

- a) **Latitude:** Higher latitudes receive less intense sunlight, which will cause to shorter daylight hours in winter and longer days in summer.
- b) **Cloud Cover:** Cloudy skies reduce direct sunlight, resulting in lower daylight levels on overcast days.
- c) **Altitude:** Higher altitudes can intensify sunlight due to thinner atmospheres, leading to potentially brighter and more direct daylight.
- d) **Air Quality:** Airborne particles and pollution can scatter sunlight, affecting its quality and intensity.
- e) **Seasons:** The tilt of the Earth's axis causes varying angles of sunlight throughout the year, impacting the duration and angle of daylight.
- f) **Topography:** Mountains, valleys, and urban structures can cast shadows, influencing the distribution of daylight.
- g) **Climate Type:** Different climates (e.g., temperate, tropical) affect the amount of available daylight and its variability.



- h) **Daylighting Strategies:** Architectural elements, like windows and light shelves, can optimize daylight entry while minimizing heat gain.
- i) **Building Orientation:** Proper orientation can maximize daylight penetration, improving interior illumination.
- j) **Reflective Surfaces:** Light-colored surfaces can reflect and distribute daylight deeper into spaces.

1.5 Advantages of Daylighting

- a) **Energy Savings:** Reduces reliance on artificial lighting, lowering energy consumption.
- b) **Health Benefits:** Improves mood, boosts productivity, and supports circadian rhythms.
- c) **Visual Comfort:** Provides even and natural illumination, reducing eye strain.
- d) **Aesthetics:** Enhances architectural features and creates dynamic, visually appealing spaces.
- e) **Connection to Nature:** It gives a sense of connection to the outdoors, promoting well-being.
- f) **Sustainability:** Aligns with green building practices, reducing carbon footprint.
- g) **Cost Efficiency:** Decreases lighting-related expenses over the building's lifespan.
- h) **Market Value:** Buildings with effective daylighting can be more attractive to tenants and buyers.
- i) **Regulatory Compliance:** Supports adherence to daylighting standards and certifications.
- j) **Positive Learning Environments:** Enhances educational spaces, aiding concentration and learning.

1.6 Disadvantages of Solar Energy

- a) **Glare:** Excessive sunlight can cause uncomfortable glare, affecting visibility.
- b) **Heat Gain:** Sunlight can lead to increased indoor temperatures, requiring additional cooling.
- c) **Uneven Lighting:** Improper design can result in unevenly lit spaces.
- d) **Privacy Concerns:** Transparent openings can compromise privacy in certain settings.
- e) **Daylight Variability:** Changing sunlight angles require constant adjustments to lighting.
- f) **Design Complexity:** Effective daylighting demands intricate design considerations.
- g) **Weather Dependency:** Cloudy days reduce available natural light.
- h) **Aesthetic Challenges:** Integrating daylighting with aesthetics can be challenging.
- i) **Initial Investment:** Advanced daylighting technologies may involve higher costs.
- j) **Maintenance:** Large windows need regular cleaning to maintain clarity.

1.7 Daylighting Strategies and Techniques in Sustainable Design

Building Orientation: Properly orienting a building can significantly impact the amount of natural light it receives. For example, in the northern hemisphere, maximizing south-facing windows can capture more sunlight throughout the day.

- **Window Placement and Sizing:** Carefully positioning windows and choosing appropriate sizes can optimize the entry of natural light into interior spaces. This involves considering the path of the sun throughout the day and the building's internal layout.



- **Skylights and Clerestory Windows:** Incorporating skylights and clerestory windows in the roof design allows light to penetrate deeper into the building's core, providing natural illumination to areas that may not have access to external windows.
- **Light Shelves:** Light shelves are horizontal surfaces (e.g., shelves, louvers) designed to bounce natural light further into the interior of the building. They can prevent direct sunlight from causing glare while providing a more even distribution of light.
- **Solar Tubes (Sun Tunnels):** Solar tubes are small tubular devices that capture sunlight from the roof and redirect it into interior spaces, particularly useful in areas with limited access to windows.
- **Interior Design Considerations:** Use of reflective surfaces, light-colored finishes, and open floor plans can help distribute natural light more effectively throughout the building.
- **Automated Lighting Controls:** Incorporating smart sensors and automated lighting controls can help manage artificial lighting levels based on the amount of available natural light, further reducing energy consumption.
- **External Shading Devices:** Employing shading devices like overhangs, fins, and exterior louvers can control the amount of direct sunlight entering the building, preventing overheating and reducing cooling loads.
- **Dynamic Glazing:** Smart or dynamic glazing technologies can adjust the tint or transparency of windows in response to changing external conditions, optimizing the balance between natural light and solar heat gain.
- **Light Diffusers and Redirectors:** Light diffusers and redirectors help spread and redirect natural light deeper into a space, creating a more evenly lit environment.
- **Natural Ventilation:** Introducing operable windows and ventilation systems that rely on natural air circulation can improve indoor air quality while reducing the need for mechanical cooling systems and artificial lighting.
- **Balancing Glazing Ratios:** Striking the right balance between the amount of glazing (windows) and the building's overall thermal performance is essential to avoid excessive heat gain or loss while still maximizing natural light.

1.8 Basic Components of Daylighting

- a) **Windows and Openings:** These are the primary entry points for natural sunlight. Windows come in various sizes, types (e.g., fixed, operable), and orientations to control the amount and direction of light entering a space.
- b) **Glazing:** The glass or transparent material used in windows that allows sunlight to pass through while providing insulation and protection from the elements.
- c) **Window Treatments:** These include shades, blinds, curtains, and other coverings that can be adjusted to control the amount of daylight and glare entering a room.
- d) **Reflective Surfaces:** Interior surfaces, such as walls, ceilings, and floors that are designed to reflect and distribute daylight deeper into the space enhancing illumination.
- e) **Light Shelves:** Horizontal surfaces placed outside or inside a window to bounce sunlight onto the ceiling, providing indirect and balanced illumination.
- f) **Skylights and Roof Openings:** These provide overhead natural light, particularly useful in areas where traditional windows might not be feasible.

- g) **Clerestory Windows:** Windows positioned high on walls, allowing daylight to enter deep into the interior while maintaining privacy.
- h) **Light Tubes (Solar Tubes or Sun Tunnels):** Tubular devices with reflective interiors that capture sunlight from the roof and transport it into interior spaces, often used in areas with limited access to exterior walls.
- i) **Daylight Redirecting Films and Panels:** These materials are applied to windows or other surfaces to diffuse and redirect sunlight, preventing glare and distributing light more evenly.
- j) **Automated Controls:** Sensors and motorized systems that adjust artificial lighting levels based on available daylight, ensuring consistent illumination and energy savings.
- k) **Light Diffusers:** Elements that spread and scatter direct sunlight, preventing harsh contrasts and creating a more diffused and comfortable lighting environment.
- l) **Side lighting and Atriums:** Architectural features that bring light in from the sides or from a central atrium, helping illuminate larger and deeper spaces.
- m) **Exterior Shading Devices:** Louvers, fins, and other external elements that block direct sunlight during peak hours to control heat gain and glare.



Figure 1 buildinggreen.com

1.9 Day lighting Design Strategies

Building Orientation: Building orientation refers to the direction in which a building's major axes are aligned. A well-considered building orientation can significantly impact energy efficiency, occupant comfort, and day lighting. Here are some factors to consider:

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1.10 Electricity saving by daylighting

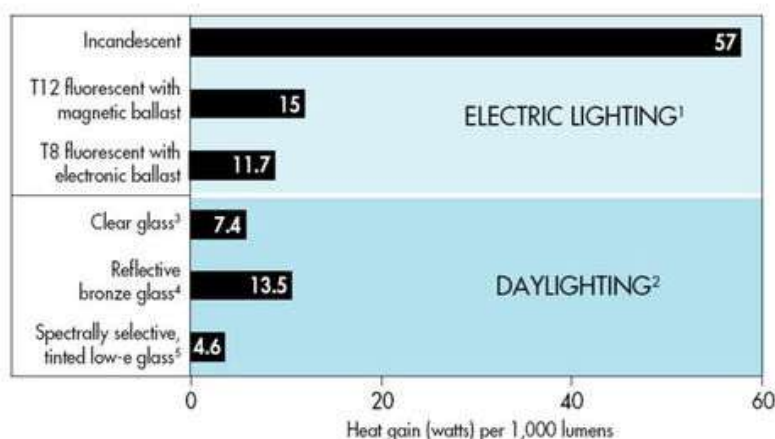


Figure: buildinggreen.com

Day lighting can save energy in commercial buildings when used in conjunction with electric lighting. It's important to have a well-planned strategy that turns off or dims electric lights

when sufficient daylight is available. This can save money on electricity usage and demand charges, especially during peak usage times. Lighting accounts for 20% to 25% of total electricity consumption nationwide.

1.11 Calculation of illuminance

Calculate the illuminance at a point in a room given the daylight factor of 5% if the external illuminance is 9500 lux

Area	Average Daylight factor	Minimum daylight factor
Commercial Buildings:		
General office	5%	2%
Classroom	5%	2%
Dwellings:		
Kitchen	2%	
Living room	1%	
Bedroom	0.5%	

Sources : NBC 2

Therefore

$$\text{Internal illuminance} = (\text{Daylight factor} \times \text{External Illuminance}) / 100 \%$$

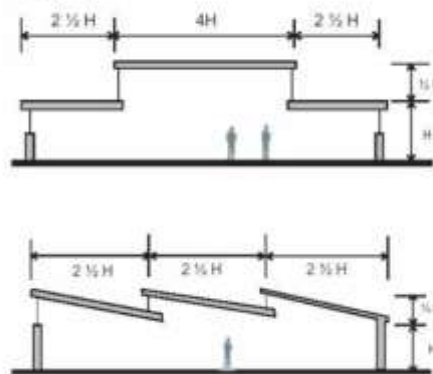
$$\text{Internal Illuminance} = (5 \times 9500) / 100\%$$

$$\text{Internal Illuminance} = 475\text{lux}$$

1.12 Clerestories

Clerestories

Space clerestories according to building height. The recommended spacing for clerestories and monitors is shown below.



Clerestory Spacing as a Function of Building Height

1.12.1 Percentage of Units Saved towards Electricity Consumption by using daylighting in commercial building

To calculate the percentage of units saved towards electricity consumption by using daylighting in a commercial building, some assumed data.



1. Total electricity consumption without daylighting (in units).
2. Total electricity consumption with daylighting (in units).
3. The difference between these two consumption values.

Calculate the percentage of units saved:

- Total electricity consumption without daylighting: 1500 units
- Total electricity consumption with daylighting: 1200 units

To calculate the percentage of units saved towards electricity consumption by using the daylighting feature, formula:

Percentage Saved = $\frac{\text{Electricity Saved with Daylighting}}{\text{Total Electricity Consumption without Daylighting}} \times 100$

Percentage Saved = $\frac{\text{Total Electricity Consumption without Daylighting} - \text{Electricity Saved with Daylighting}}{\text{Total Electricity Consumption without Daylighting}} \times 100$

First, let's calculate the electricity saved:

Percentage Saved = $100 \times (1 - 1500/1200)$

Percentage Saved = $100 \times (1 - 0.8)$

Percentage Saved = $100 \times 0.2 = 20\%$

So, using the daylighting feature in the commercial building results in a 20% reduction in electricity consumption.

1.12.2 Calculate the percentage of units saved towards daylighting compared to artificial lighting consumption

Suppose you have:

- Energy consumed using daylighting: 2000 units
- Energy consumed using artificial lighting: 3000 units

Using the formula:

Percentage Saved = $\frac{3000 - 2000}{3000} \times 100 = 66.67\%$ Percentage Saved = $\frac{3000 - 2000}{3000} \times 100 = 66.67\%$

So, in this example, using daylighting resulted in a 66.67% reduction in energy consumption compared to using artificial lighting alone.

Chart (b): Percentage of Units Saved towards Electricity Consumption by using daylighting feature in commercial building.

Calculation for daylighting in a commercial building located in Nashik, Maharashtra, India. We'll calculate the potential energy savings and cost savings in rupees.

Assumptions:

- Building Area: 500 square meters
- Percentage of Glazed Area (Windows and Skylights): 15%
- Percentage of Light Transmission Through Glazing: 75%



- Average Daily Sunlight Duration: 8 hours
- Electricity Cost: ₹8 per kWh

Step 1: Calculate Total Daylight Illuminance: Total Daylight Illuminance = Glazed Area × Percentage of Light Transmission × Average Sunlight Illuminance
Total Daylight Illuminance = $500 \text{ m}^2 \times 0.15 \times (8,000 \text{ lux}) = 6,000 \text{ lux-hours}$

Step 2: Calculate Energy Savings from Daylighting: Energy Savings = Total Daylight Illuminance × Building Area
Energy Savings = $6,000 \text{ lux-hours} \times 500 \text{ m}^2 = 3,000,000 \text{ lux-hour m}^2$

Step 3: Convert Lux-Hour m² to kWh: Assuming 1 lux-hour m² is approximately 0.00001163 kWh:

Energy Savings (kWh) = Energy Savings (lux-hour m²) × Conversion Factor
Energy Savings (kWh) = $3,000,000 \text{ lux-hour m}^2 \times 0.00001163 \text{ kWh/lux-hour m}^2 = 34.89 \text{ kWh}$

Step 4: Calculate Cost Savings: Cost Savings = Energy Savings (kWh) × Electricity Cost
Cost Savings = $34.89 \text{ kWh} \times ₹8/\text{kWh} = ₹279.12$

In this scenario, the estimated cost savings from using daylighting strategies in the commercial building in Nashik would be approximately ₹279.12 per day.

1.13 Recommendations

The following are suggested for improvement of Solar energy power technology:

- Choose energy-efficient glazing materials that allow ample visible light transmission while minimizing heat gain and glare.
- Explore the use of dynamic glazing technologies that can adjust tint or opacity based on the intensity of sunlight by using AI.

2. CONCLUSION

Daylighting is a sustainable way to use natural light. Industries moved to fossil fuels because setup costs were high. But technology has made daylighting cheaper and eco-friendly. It's a cornerstone of modern architecture and design. Daylighting enhances well-being, reduces energy use, and promotes sustainability. Integrating natural light into built environments is crucial for human comfort and ecological balance.

Daylighting plays a pivotal role in enhancing the sustainability and energy efficiency of commercial buildings. This abstract delves into the multifaceted aspects of daylighting strategies, focusing on their integration into the architectural design process. With the global emphasis on green building practices and the pressing need to reduce carbon emissions, this study explores innovative methods to harness natural light effectively while ensuring occupant comfort, well-being, and energy conservation.

The abstract begins by discussing the fundamental principles of daylighting, highlighting its influence on building aesthetics, energy consumption, and occupant satisfaction. It underscores the significance of a comprehensive approach that encompasses architectural



design, site orientation, window placement, shading devices, and advanced lighting control systems. The study investigates innovative technologies, such as smart glass and sensors, which optimize daylight penetration and mitigate glare, thus creating a harmonious indoor environment.

Furthermore, the abstract explores case studies of exemplary commercial buildings worldwide, analyzing their daylighting strategies and the resultant impact on energy savings and user experience. It also emphasizes the economic advantages of incorporating daylighting solutions, including reduced electricity costs and increased property value. The research considers the psychological and physiological benefits of natural light, underscoring its influence on productivity, mood, and overall well-being of building occupants.

Additionally, the abstract delves into the challenges faced during the implementation of daylighting strategies, ranging from design complexities to variable climatic conditions. It discusses innovative design tools and simulation techniques that aid architects and engineers in optimizing daylighting designs, ensuring maximum efficiency and occupant comfort.

In conclusion, this abstract advocates for a change in basic assumptions in commercial building design, urging architects, engineers, and policymakers to prioritize daylighting as a cornerstone of sustainable architecture. By embracing advanced technologies, interdisciplinary collaboration, and informed decision-making, commercial buildings can evolve into energy-efficient, environmentally responsible, and occupant-friendly spaces, thereby contributing significantly to the global sustainability agenda.

3. BIBLIOGRAPHY

1. <https://www.slideshare.net/AbdultawabQahtan/daylighting-77804592>Kumar, V. (2016). Solar Energy Potential. Policy and Forecasting - A Review.
2. <https://www.buildinggreen.com/feature/daylighting-energy-and-productivity-benefits>
3. <https://www.sciencedirect.com/topics/engineering/daylight-factor>