Urban Energy Technical Note

Daylighting

It is estimated that buildings use more than 40% of the total energy generated for heating, cooling and lighting, among other uses. Many people still depend on artificial light during the day. This may be due to inefficient design and construction using climate inappropriate materials, combined with poor understanding of thermal comfort, passive building principles and energy conscious behaviour. All these factors contribute to tremendous energy wastage.

Fossil fuels, which are the main sources of energy generation, are limited, diminishing and unsustainable in the long term. Due to these limitations, it is necessary to reduce the electricity load in buildings. By planning for daylighting right from the onset of the design process, significant energy savings can be achieved.

Therefore, this technical note describes how a building can use natural light effectively to reduce the reliance on artificial lighting during the day.

What is daylighting?

Daylighting is the practice of using natural light to illuminate building spaces thus enabling buildings to consume less energy. This in turn helps in a reduction in the use of fossil fuels and carbon dioxide emissions, which are associated with global warming and climate change.

Benefits of daylighting

- It can improve the quality of light within a space, reducing dependency on artificial lighting during the day, leading to substantial energy and cost savings;
- It provides psychological benefits to occupants, ensuring their good health and increased well-being;
- It results in increased user productivity and occupants' comfort as well as satisfaction with the indoor environment.

Challenges of daylighting

- Glare is experienced when direct sunlight penetrates into buildings and reflects off surfaces, causing visual discomfort. It can be mitigated by correct orientation and positoning of windows and use of shading devices;
- Undesirable heat gains and consequently increased cooling loads. The use of sun shading devices and use of window treatments such as window films can help in minimising heat gains and thermal discomfort.
- Fluctuations in availability, as the little amount of light varies with the time of day, the latitude, the weather conditions and the seasons.
- The building's shape and features such as roofs, shading devices etc. can also prevent daylight from illuminating a space.

Daylight availability

The source of daylight is the sun and it may reach the building in the following ways as illustrated by Figure 01.

- Direct sunlight along a straight path from the sun, through an opening to a given point;
- Diffuse light through the sky and clouds;
- Reflected light – either externally by the ground and surrounding buildings or internally by walls, ceilings and other internal surfaces

These factors determine the illuminance level at any point in the room.

Performance Metrics

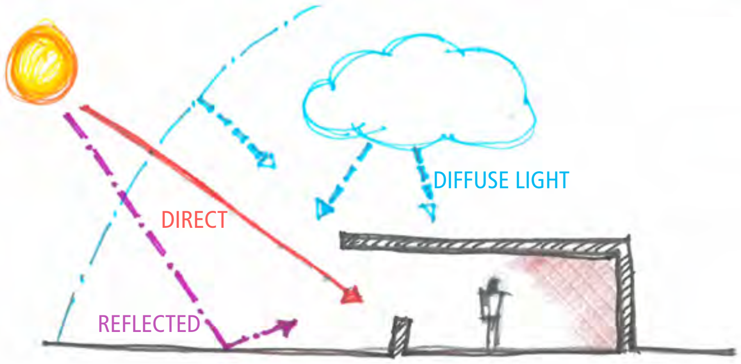
The quantity of light / illuminance level indoors varies depending on the distance from the opening through which light is coming in. Indoor illuminance (E_{int}) on a working plane is given by (Fig. 02):

DF = (inside illuminance)/(outside illuminance) x 100

DF = SC + ERC + IRC :

SC - Sky component
ERC - Externally reflected component
IRC - Internally reflected component

Fig. 01: **Sources of light**



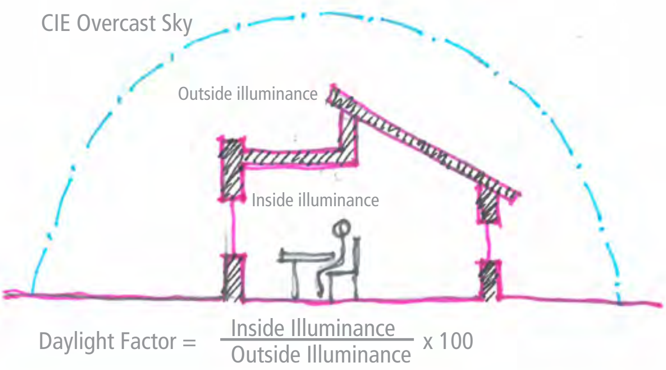


Fig. 02: **Daylight Factor**

When determining the illuminance levels within a space, the following aspects are considered:

- **Daylight Factor (DF)** is a measure of the daylight available in a space. It is expressed as the ratio of illumination at a point indoors to the illumination outdoors on a horizontal plane of a height between 0.7 – 1.0 m from the floor, without obstructions. It depends on: window size, shape and location; room depth; shading devices; obstructions and colour of internal and external surfaces.
- **Daylight Autonomy (DA)** corresponds to the percentage of the occupied time when the illuminance at a point in a space is met by daylight. Unlike the Daylight Factor, it considers all sky conditions and therefore is useful in overcoming the over sizing derived from using DF alone.

Daylighting solutions

For daylighting to be successful, an integrated design approach is necessary as it involves various aspects, such as the following:

Siting / orientation

The building orientation, taking into account the sun's movement, must be considered at the onset of the design process in order to ensure maximum availability of useful natural light to the interior. Adjacent buildings as well as their finishes, surrounding landscape features and the amount of daylight available on site should also be considered.

Form of building

The form of the building determines the quality of daylight experienced within the space (Fig. 03).

- **Linear forms** present long and relatively narrow widths and have a greater potential for daylighting through side lighting than square shaped plans.
- **Centric forms** have a central core around which other spaces are organised. They offer good opportunities to incorporate courtyards, atria, or light wells that help in the distribution of daylighting to the inner spaces.
- **Clustered forms** consist of a variety of smaller masses in a mixture of configurations that offer extensive surface area for top lighting and side lighting.

Aperture:

Toplighting strategies (Fig. 04) permit daylight into a space generally from above via glazed openings in the roof, which protect the interior space from the elements. They are applicable in single storey buildings or the top floor of a multi-storey building and they include:

- Skylights, which are suitable with diffuse light;
- Atria, which increase access to daylight within the building;
- Clerestories, sawtooths and monitors, which deliver daylight deeper into the space.

Problems associated with the above strategies include: potential leaks (in the case of poor detailing); exposure to direct solar radiation (hence heat gains if not properly shaded) and limitation of visual connection between indoors and outdoors.

Sidelighting strategy uses vertical fenestrations located in walls to introduce daylight into spaces. It improves the occupants' comfort by creating a visual connection to the outdoors. However, depending on orientation, siting and glazing properties, direct solar radiation may introduce heat gain and glare issues within the space. The use of shading elements is therefore necessary to prevent excessive glare and minimise heat gains.

Fig. 03: **Examples of building plans with good access to natural light**

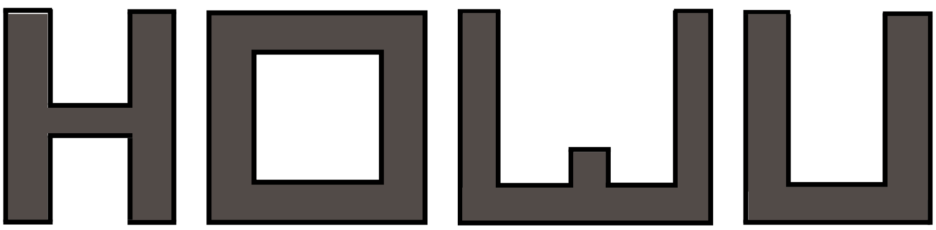


Fig. 04: **Top lighting strategies**

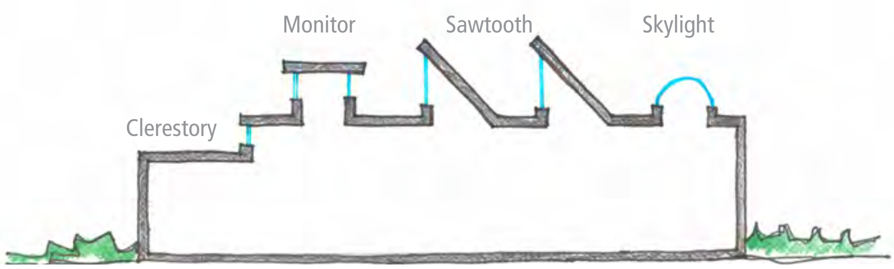


Fig. 05: **Side lighting via clerestory windows**

Coca-Cola building, Nairobi ©UN-Habitat / Jerusha Ngungui

Fig. 06: **Top lighting via sawtooths**

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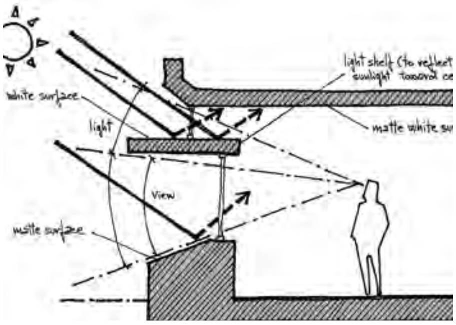
Fig. 07: **Vertical openings into a courtyard lit via an atrium**

New Office Facility, United Nations Office Nairobi © UN-Habitat / Julius Mwelu

Additional innovative daylighting strategies:

- **Light shelves** have a dual purpose, providing shade and indirect lighting – light bounces off the reflective surface of the shelf onto a ceiling, which bounces it into the room thereby increasing the amount of daylight penetration.
- **Light-pipes** collect light through a heliostat located at the rooftop, and channel it through a reflective tube of prismatic glass or mirrors. At the end of the light pipe, diffuse light is distributed within the space.
- **Anidolic ceilings** use parabolic concentrators to collect diffuse daylight which is distributed to the back of a room through a specular light duct located above a ceiling plane.
- **Venetian blinds** with a reflective upper surface may be used to reflect the sun's rays onto a light-coloured ceiling to provide diffuse lighting in the building's interior.
- **Translucent materials** may be used in place of glass to admit diffused light into a space with no direct sun.
- **Solar bottle bulbs** made from plastic bottles filled with water and encased in a galvanised iron sheet provide an environmentally friendly daylighting solution to houses with non-existent or typically small windows as in the case of informal settlements.

Fig. 08: **Typical section through a light shelf (left)**



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RMi2 Building, Colorado © Andrew Michler

Glazing ratio

The larger the glazed area, the more daylight and heat gain will enter – but the larger the heat losses will be. Recommended glazing ratios are generally between 25-50% of the external wall of the daylight space.

Glazing specification

Clear glass allows a high transmission of daylight as well as a high transmission of solar radiation if it is not properly shaded. Tinted or reflective glass reduces solar heat gains but limits the amount of visible light.

Fig. 09: **Solar bulbs in use in an informal settlement in Nairobi**

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Daylight penetration

The depth to which natural light penetrates into a room is influenced by the window head height. Light penetration is twice the head height of the window (with shading) as illustrated in Fig. 11.

Fig. 10: **Typical section through a light-pipe (left). Light-pipe installation on the roof (centre) and as seen from inside the building (right).**

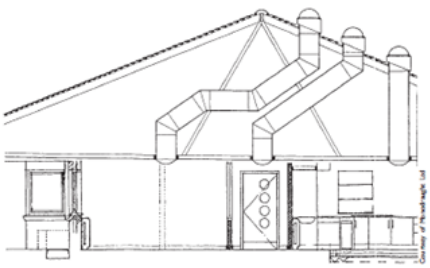

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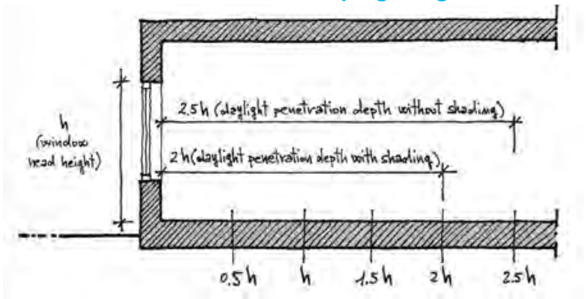
Fig. 11: **Combination of side and top lighting**



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RULE OF THUMB

Daylight penetration in a space varies linearly with window head height. The relationship factor varies depending on whether or not a shading device is used.

Finishes

- Light-coloured surfaces reflect light and therefore the highest practical room reflectance should be specified so as to achieve the best overall efficiency of the daylighting. Dark coloured surfaces absorb light therefore reducing the daylight quality.
- Rough textures create diffuse light while smooth or glossy surfaces create reflected light. They also have the potential to create glare.

Daylighting in the tropics

Hot-arid and Savannah climates

Buildings in these climates tend to be small to minimise heat gain and reduce glare. Therefore, daylighting can be achieved in the following ways:

- Use of internally reflected light;
- High level windows to admit reflected light on the ceiling;
- Light coloured ceilings to ensure sufficient and well diffused interior light through a high level window;
- Low level windows opening onto a shaded / planted courtyard;
- Use of non-reflective shading devices to avoid glare.

Hot-humid and Great lakes climate

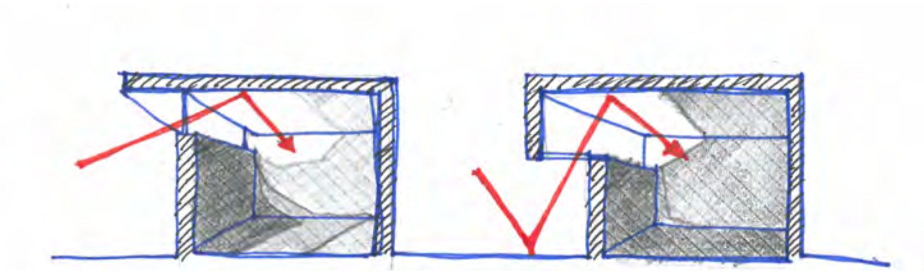
Buildings in these climates have large openings to ensure cross ventilation and air movement. They are also provided with wide overhanging eaves or shading devices.

- Bright sky could provide sufficient light – but its high illuminance would cause glare and therefore, the view of the sky should be screened by shading devices / plants.
- Daylight should be reflected from the ground and louvres onto the ceiling – the ceiling should be light coloured.

Fig. 12: **Light coloured interior finishes**

Strathmore University ©UN-Habitat / Jerusha Ngungui

Fig. 13: **Opening types allowing the reduction of glare in a hot-arid climate**



Adapted from UN-Habitat (2015)

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The purpose of this Technical Note is to call reader's attention to new technical issues in the field of sustainable human settlements development. They are not meant to be final or exhaustive. For more information, contact the Urban Energy Unit. Prepared by Vincent Kitio and Jerusha Ngungui.