JAKARTA GREEN BUILDING USER GUIDE

VOL. 3

LIGHTING SYSTEM

The Government of the Province of
Jakarta Capital Special Territory

In cooperation with:

IFC International Finance Corporation
World Bank Group

IFC in partnership with:

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs,
Education and Research EAER
State Secretariat for Economic Affairs SECO

CODE REQUIREMENTS

Lighting System (LT)
LT01 Photosensor Control of Lights
LT02 Maximum Lighting Power

The calculation should be done using the calculator available on this website
http://greenbuilding.web.id

Checklist for all code requirements lists the required documents is also available on this website
http://greenbuilding.web.id

JAKARTA GREEN BUILDING USER GUIDE

VOL. 3

LIGHTING SYSTEM

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Lighting System:
An Introduction

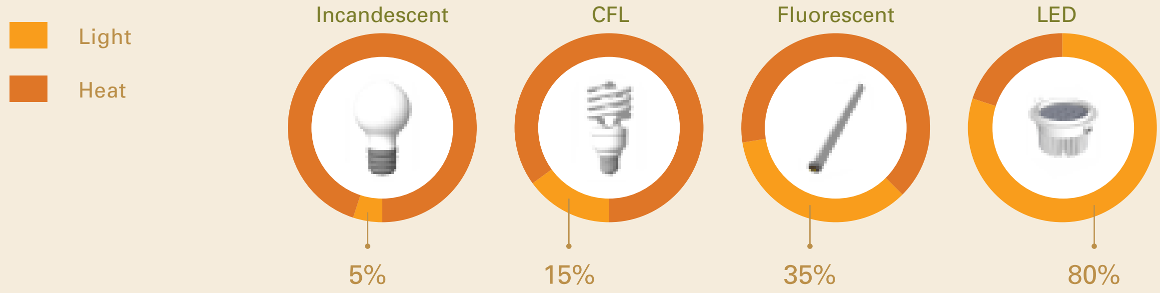
Light is a necessity for performing tasks and for creating visual comfort. Light from the sun and sky have been the primary sources of light till recent times. Even now, most of our lighting needs can be met by diffused natural light (daylight) if the building is designed accordingly. However, electric lighting cannot be avoided during hours when daylight is not available, or in spaces without daylight access.

Lamps typically use electricity to create light, but also waste a lot of it as heat. This decreases the efficiency of the lighting system while also increasing the cooling load in the building. **As a rule of thumb, every 3 watts of lighting energy saved results in 1 watt of cooling energy reduction**. This ratio can vary depending on the building type, design and operation.

FIGURE. 01

Output Characteristic of Typical Lamps

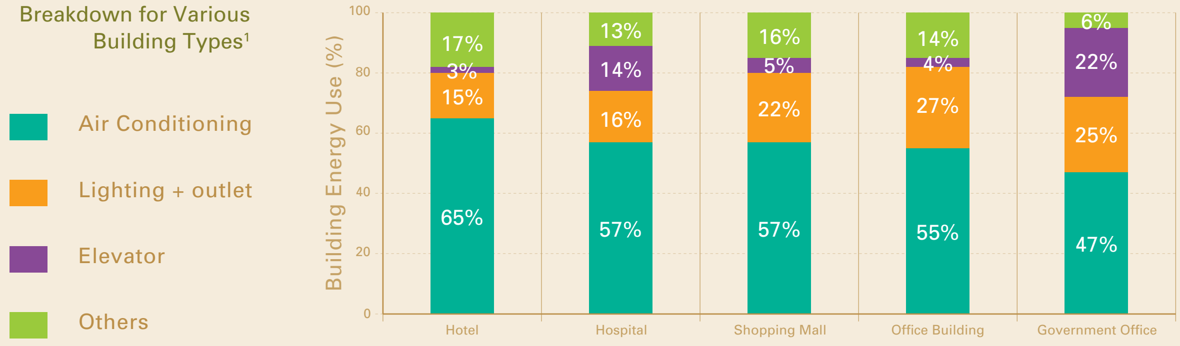
*Typical lights waste **72%** of input energy as heat. **28%** of typical cooling energy is used just for dissipating heat from lights.*



Typically in Indonesian buildings, lighting forms one of the biggest energy consumption after cooling.

FIGURE. 02

Energy Consumption Breakdown for Various Building Types[1]



Careful design, efficient fixtures and good controls have the potential to reduce the total energy in Jakarta buildings by up to **10%**[2].

Implementation of the code requirements are expected to save lighting as well as cooling energy, while improving the visual environment inside the buildings.

1 Japan International Cooperation Agency (JICA). 2009. A Study of Electricity Use in Multiple Jakarta Buildings.
2 Energy simulation analyses done by IFC for typical Jakarta buildings, 2011.

01 *code requirement*

REFERRING TO ARTICLE 10

1. Lights in following areas should have photo sensor control:
   a. perimeter open office larger than 100 m^2 and with windows
   b. perimeter conference/meeting rooms larger than 100 m^2 and with windows
   c. perimeter lobby/waiting rooms larger than 100 m^2 and with windows

   Lighting zone to be controlled by photo sensors should have a depth of 1.5 times the floor to ceiling height.

2. Design interior electric lighting to not exceed the maximum installed lighting power for each space type per **SNI 03-6197**.

02 code requirement details

This code is applicable for all interior spaces that use electric lighting, except for cases where specialized lighting is needed. Such cases may include areas devoted for theatrical productions, television broadcasting, audio-visual presentations and those portions of entertainment facilities, public monuments, specialized manufacturing facilities etc. For more exemptions, the approving government department should be contacted.

REQUIREMENT 1

All perimeter spaces larger than 100 m^2 and having windows with the following function:

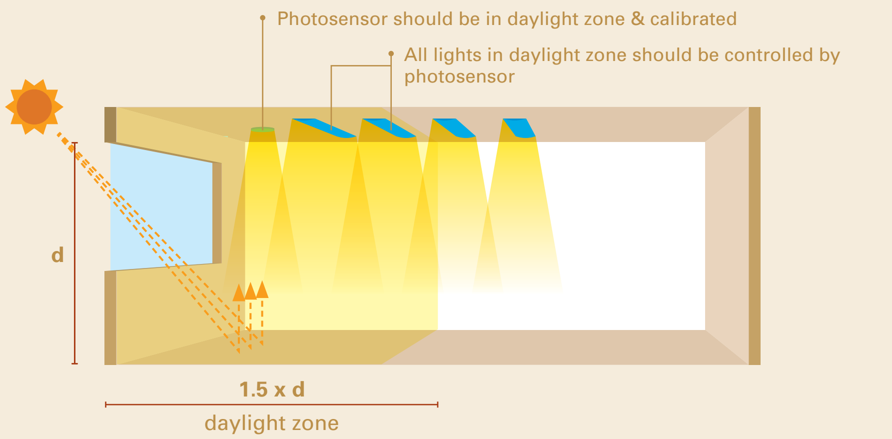
- open offices
- conference/ meeting rooms or
- lobby/waiting rooms

should have perimeter lighting zones with a minimum depth of 1.5 times the floor to ceiling height. Ceiling height near the windows should be used for this calculation. All the permanent lighting fixtures within this zone (with the exception of exit and emergency lights) should be controlled by a photosensor. The photosensor should be placed in the perimeter daylight zone and calibrated to accurately measure the light levels.

*More guidance on effective daylight design is provided in the "**Design Principles**" section of this document.*

FIGURE. 03

Perimeter Lighting Zone that should be Controlled by Photosensor



REQUIREMENT 2

Design interior electric lighting to not exceed the maximum installed lighting power per SNI 03-6197 2011 as shown in table below. Please note that the overall building wide lighting power (watts) should not exceed the allowed lighting power calculated using the table below. Trades off between individual spaces is allowed as long as the total wattage does not exceed the requirement.

TABLE. 01

Maximum Lighting Power Density

ROOM FUNCTION	MAXIMUM LIGHTING POWER (W/M2) Including Ballast Losses
RESIDENCE	
Terrace	3
Guest Room	7
Dining Room	7
Working Room	7
Bedroom	7
Bathroom	7
Kitchen	7
Garage	3
OFFICE	
Receptionist Room	13
Director Room	13
Working Room	12
Computer Room	12
Meeting Room	12
Drawing Room	20
Archives Storeroom	6
Active Archives Room	12
Emergency Staircase	4
Parking Room	4
EDUCATION INSTITUTE	
Classroom	15
Library	11
Laboratory	13
Computer Practice Room	12
Language Laboratory Room	13
Teacher Room	12
Sports Room	12
Drawing Room	20
Canteen	8
HOTELS AND RESTAURANTS	
Receptionist Room & Cashier	12
Lobby	12
Multipurpose Room	8
Meeting Room	10
Dining Room	9
Cafetaria	8
Bedroom	7
Corridor	5
Kitchen	10

ROOM FUNCTION	MAXIMUM LIGHTING POWER (W/M2) Including Ballast Losses
HOSPITALS	
Emergency Room	15
Action Room	15
Recreation &	15
Rehabilitation Room	10
Recovery Room	
Corridor Room (Day)	8
Corridor Room (Night)	9
Staff Office Room	3
Restroom & Patient's	10
Restroom	7
SHOP/SHOWROOM	
Showrooms with Large Objects (For Example: Cars)	13
Small Sale Area	10
Large Sale Area	15
Cashier Area	15
Bakery & Food Market	9
Florist	9
Book & Stationery Store	9
Jewelry & Watch Store	15
Leather Goods & Shoes Store	15
Clothes Store	15
Supermarket	15
Toy Store	15
Electricity Equipments Store (TV, Radio/Tape, Washing Machine, Etc)	9
Music & Sports Equipment Store	9
INDUSTRY (GENERAL)	
Warehouse	5
Menial Job	7
Medium Job	15
Fine Job	25
Very Fine Job	50
Color Checking	20
HOUSE OF WORSHIP	
Mosque	10
Church	13
Monastery	10

Lighting code compliance calculations should be done using the following steps:

Determine allowed lighting power:

A. Calculate space area for each space type (example office, lobby, classrooms).
B. Determine allowed watt per square meter from table above.
C. Calculate allowed lighting power for each space type (A x B)
D. Add allowed lighting power for all spaces to get the allowed lighting power budget.

Determine designed lighting power:

E. Determine lamp wattage for all designed lamp types.
F. Determine Fixture wattage (lamp wattage x number of lamps per fixture).
G. Calculate Total space wattage (add all fixtures wattages for the space).
H. Add up all space wattages in building to get the total designed lighting power.

A spreadsheet calculator is available on DPPB website to do the above calculation.

Code requires that H (total design lighting power Watts) should be equal to or less than D (total allowed lighting power Watts).

03 *design principles*

The design principles and best practices discussed in this section illustrate different ways of meeting the code, and exceeding its requirements to get additional benefits.

Energy use in lighting is mainly dependent on:

- **How much does the design take utilize natural light?**
- **How many lamps are installed to provide the required light level?**
- **How efficient are the lamps and fixtures in converting the electricity to usable light and delivering it at the work surface?**
- **How long are the lights kept on?**

Lighting energy can be significantly reduced by:

1. Utilizing natural light (daylight)
2. Reduction of installed lighting
3. Use of efficient lamps and fixtures
4. Use of lighting controls

UTILIZING NATURAL LIGHT (DAYLIGHT)

The most significant and logical way of reducing lighting energy is to use naturally available daylight as much as possible.

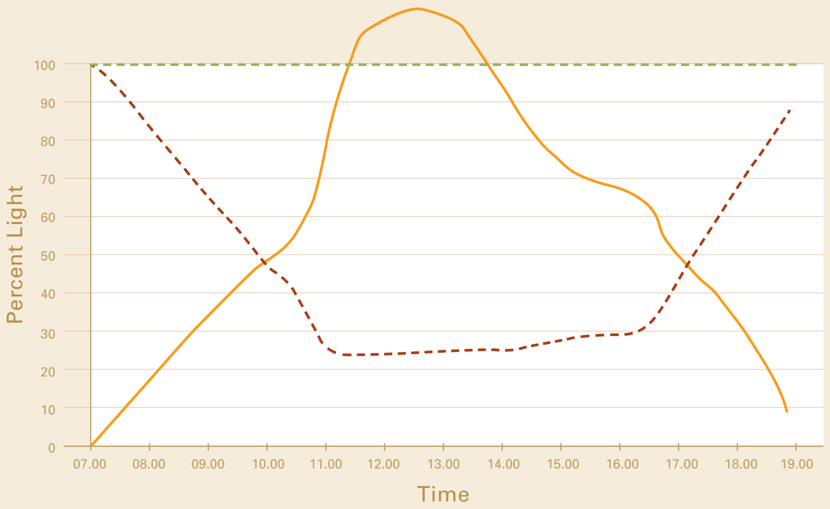
FIGURE. 04

Electric Lighting and Daylight Integration in a Well Ballanced Lighting System[3]

Maintained Light Level

Electric Illumination

Daylight



Daylighting used in concert with existing lighting control technologies can save up to 50% of the energy used for lighting in offices.[4]

A well daylit building not just looks more vibrant and spacious but also has been shown to increase worker productivity and health. Two recent studies have shown that significant positive impacts of daylighting include increased retail sales[5] and higher student test scores.[6]

In a study, it was shown that people in windowed offices spent significantly more time (15%) on work-related tasks than people in interior offices without windows.[7]

Optimum benefits of daylighting can be achieved in two distinct steps, daylight design and daylighting control.

DAYLIGHT DESIGN

Daylight design involves designing the building envelope and layout such that large parts of the building have access to usable natural daylight.

[3] Smart Energy User. Saving Dollars Through Lighting Control. 1997. (*http://www.wisdompage.com/SEUhtmDOCS/3SE11.htm*)

[4] LRC, 1994; Rubenstein et al., 1984; Nilsson et al., 1991; Zonneveldt et al., 1998.

[5] Heschong L, Wright R, Okura S. 2001a. Daylighting impacts on Retail Sales Performance. Conference Proceedings of the Illuminating Engineering Society of North America.

[6] Heschong L, Wright R, Okura S. 2001b. Daylighting impacts on Human Performance in Schools. Conference Proceedings of the Illuminating Engineering Society of North America.

[7] Daylight and Productivity—A Field Study. (*http://eec.ucdavis.edu/ACEEE/2002/pdfs/panel08/06_15.pdf*)

A. Orientation of Windows

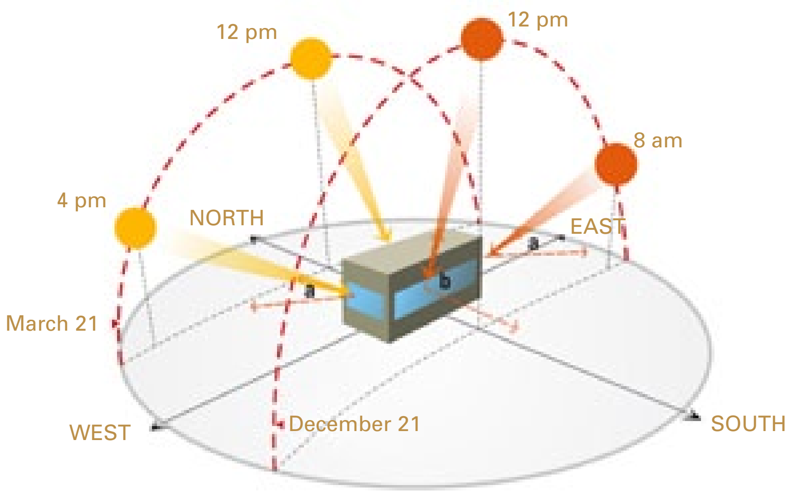
As the **Figure 5** shows, the low sun angle in the morning and evening is very difficult to block using horizontal shades. When the sun is higher up in the sky during the day, horizontal shades work very well especially in the equatorial locations such as Jakarta. Therefore, well shaded south and north facing windows will allow diffused daylight penetration without too much direct sun.

FIGURE. 05

Sun Path Diagram

a Low Vertical Shadow Angle

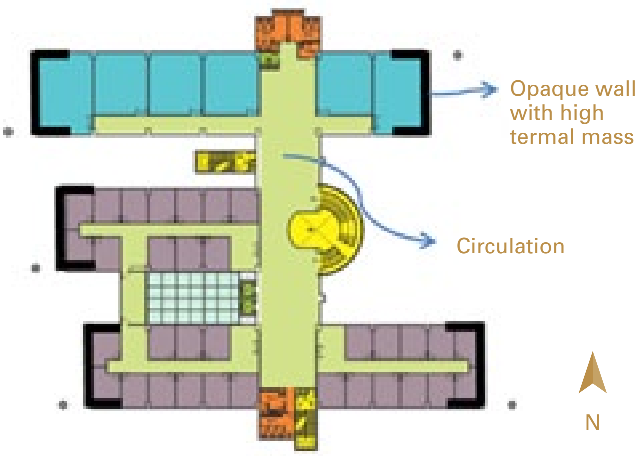
b High Vertical Shadow Angle



An example of optimum daylight design is presented in **Figure 6**. In this case, although the main road is located at the west side of the site, most of the windows are oriented to north and south. Using a system of shading and lightshelves, these windows admit sufficient daylight without excessive heat gain, allowing electric lights to remain shut for most part of the day. In addition, walls with high thermal mass are dominated the east and west facades to mitigate the problems of high intensity solar radiation at low altitude angles.

FIGURE. 06

Faculty of Social and Political Science, UIN Jakarta[8]



[8] Jatmika Adi Suryabrata

B. Window/Skylight Size

Building envelope opening provide daylight but are also one of the biggest sources of heat coming into the space, causing a significant increase in cooling load. However, shaded daylight is still a much cooler source of lighting as compared to other common light sources. Graph below shows the added air conditioning load in a typical building due to various lighting sources needed to provide 100,000 lumens of light in the space.

FIGURE. 07

Air Conditioning Load for 100.000 Lumen of Light[9]

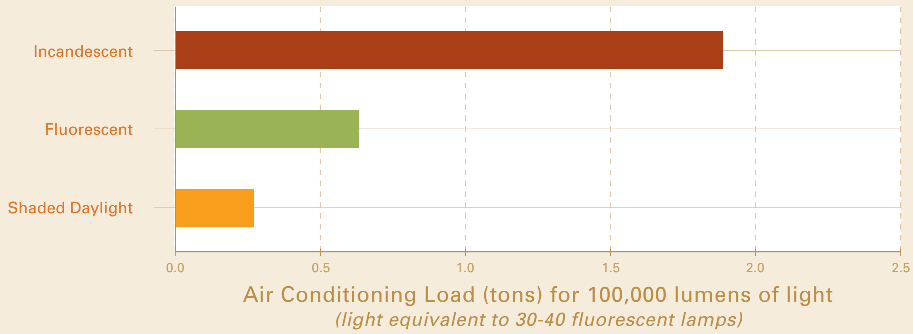


FIGURE. 08

Typical Jakarta Buildings with Their Window to Wall Ratios[10]

Optimizing window size for daylighting saves operational energy as well as capital costs, since walls are usually less expensive than glass. Many global standards set a maximum threshold of window to wall area ratios (WWR) between 25% and 50%.

Approx. 30% Window to Wall Ratio

Approx. 70% Window to Wall Ratio

[9] Horn, Abby Vogen. Energy Center of Wisconsin. Daylighting Design "...light every building using the sky." (*http://www.daylighting.org/usgbc2008presentation.pdf*)
[10] Jatmika Adi Suryabrata.

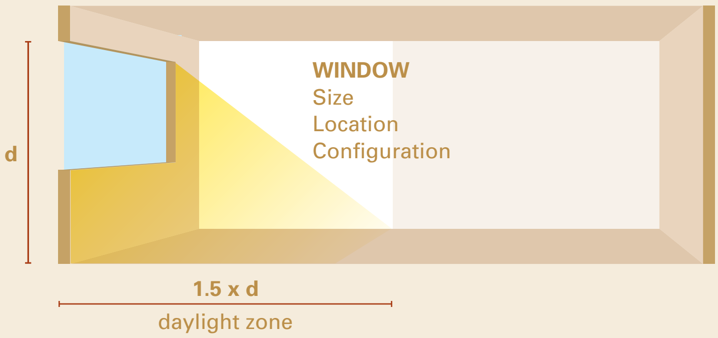
Even a "high performance" insulating low-e double glazed glass (R-0.5 Km2/W) has similar thermal performance as a standard uninsulated brick wall (R-0.4 Km2/W). However, thermal transfer from a window is much higher than that of a wall as direct radiation through the glass can be more than 90% of the total heat gain from a window.

*The "**Building Envelope**" section of this user guide has more guidelines on figuring out the appropriate Window to Wall Area ratio.*

The code emphasizes that design and location of windows and skylights should be planned such that a large portion of the building receives sufficient daylight, without causing a big increase in cooling load and visual discomfort.

FIGURE. 09

Daylight Penetration Relationship to Window Configuration



The referred standard SNI 03-2396 provides some design guidelines for well daylit buildings. Additional guidance including recommended daylight factors are presented in **Table 1**, **2**, and **3** of this standard.

C. Glass Properties

Visible transmittance (VT) indicates the percentage of visible light that the glass allows to pass through. Increasing visible transmittance also typically increases the solar heat gain coefficient (SHGC) of the glass, thus allowing more solar heat to come in to the space. Therefore, the VT and SHGC of the glass should both be considered while selecting a glass product. A suitable glass selection for large buildings in Jakarta should have a high visible transmittance and a low SHGC.

D. Glass Shading

Daylighting has a dynamic nature because of the location of the sun and clouds in the sky and configuration of the window or skylight. As a result, the amount and direction of daylight in a space can vary significantly. Since direct sunlight is not desirable in most buildings, the most logical design approach is to shade the windows such that they direct sun is blocked from coming in for most part of the year. Generally speaking, exterior shades save more cooling energy than interior shades, as they stop solar heat from entering the conditioned space.

Interior shades (blinds, roller shades) are efficient for stopping glare, but the tendency of most occupants is to leave the shades closed even when the glare is not present. This causes usable daylight to be blocked as well, and often lights are turned on despite it being quite bright outdoors.

If Horizontal blinds are used for glare control, they can be positioned in such a manner that they bounce off light on to the ceiling of the space.

FIGURE. 10

Horizontal Blinds for Redirecting Light

Source: Jatmika Suryabrata

More guidance on window shading is provided in the ***"Building Envelope"*** *section of the user guide.*

An efficient way of blocking direct sun while allowing usable daylight in the space is through the use of light shelves. Light shelves are interior horizontal shades of reflective material that are placed.

As shown in the example below, light shelves on north and south windows can block direct sunlight and reflect it deeper into the space, thus producing a brighter environment without the glare.

FIGURE. 11

South and North Light Shelves in a Classroom[11]

[11] Jatmika Adi Suryabrata.

FIGURE. 12

If light shelf is used, the daylight penetration could be 2d

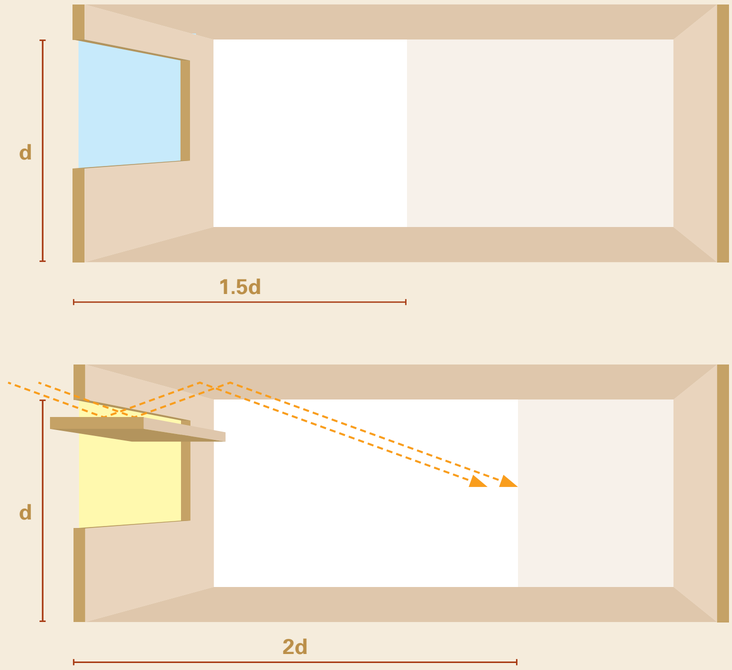


FIGURE. 13

Efficient Integrated Daylight and Electric Lighting System[12]

Note that the perimeter lighting is off due to sufficient daylight level

An effective way to distribute light is to bring it in high in the space so that it illuminates and bounces off the ceiling. A good design practice that builds on this principle is to divide the window into two parts vertically, using a mullion or a light shelf. The upper "daylight" window uses a glass with higher visible transmittance, whereas the lower "vision" window has lower visible transmittance and solar heat gain coefficient. Both windows have their separate shades. When glare and direct sun control is needed, the lower shades could be closed and upper ones left open. In some cases, fixed angle blinds could be used for the upper shades. Alternatively, depending on solar angles, the daylight window could be used without any shades.

[12] Jatmika Adi Suryabrata.

FIGURE. 14

Window Design Options for Daylight

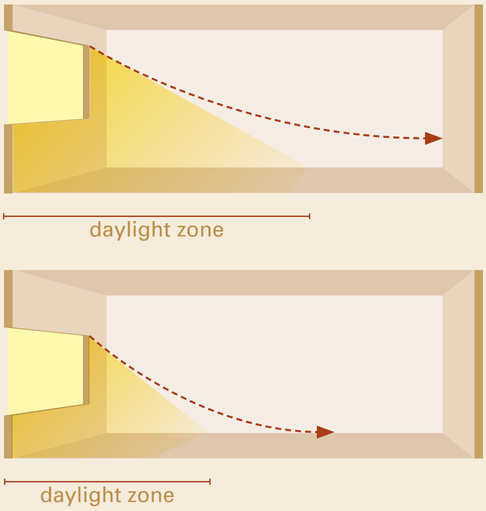
(effectiveness is higher for the windows on the right)

E. High Head Heights

Daylight penetration is closely linked to the head height of the window. As a rule of thumb, usable daylight is able to reach inside the space at a depth of 1.5 times the head height of the window. On the other hand, glass below 80 cm does not typically contribute to usable daylight and should be avoided as much as possible.

FIGURE. 15

Window Height and Daylight Penetration



F. Floor Layout and Space Layout

*A list of tools available for designing and testing daylighting designs is available at Daylighting Collaborative, Daylighting Design Aids (**http://www.daylighting.org/designaids.php**)*

Thinner floor plates which allow daylight access to most of the space can save significantly on lighting energy.

In office spaces, placing the open offices next to the perimeter windows, and the private offices further back in the space allows daylight access to more area. Having transparent or translucent interior partitions also helps in daylight penetration.

FIGURE. 16

Graphic Plan Drawing Showing Daylighting in Thin Vs. Thick Floor Plate

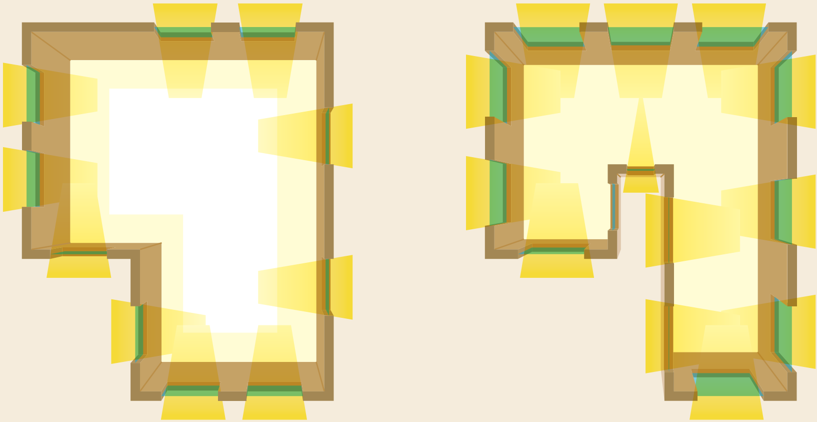
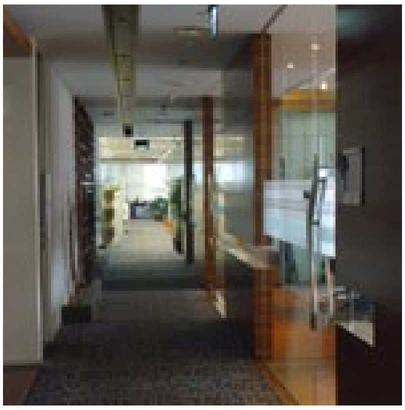


FIGURE. 17

Transparent Internal Partitions[13]



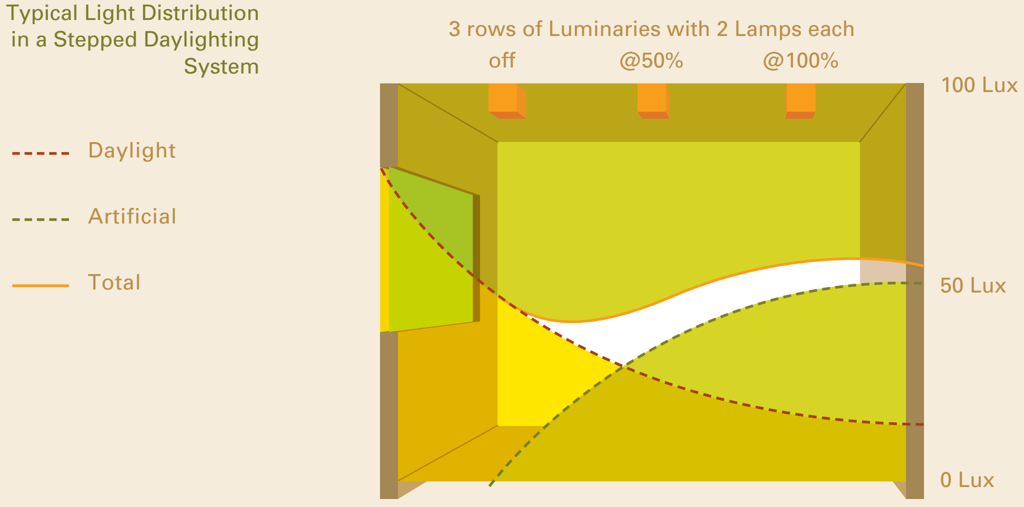
DAYLIGHTING CONTROL

Designing a building with good daylight access is an important step, but does not guarantee energy savings. Even if the space gets ample natural light, some occupants may not proactively switch off lights, thus not reducing energy costs. Energy savings are only available if the lights are switched off or dimmed. While this could be done manually, higher energy saving is possible by using strategically placed photosensors in the space. These sensors dim down or turn off lamps to maintain the desired light level. The continuous dimming approach provides more savings as compared to the stepped approach, but is also more expensive to implement.

[13] Jatmika Adi Suryabrata.

FIGURE. 18

Typical Light Distribution in a Stepped Daylighting System



A potential issue with most stepped daylighting controls is that the user suddenly sees lights going off and is disturbed. With the continuous dimming system, as the electric lights are gradually dimmed the overall light level (electric light + daylight) is maintained. So the change is transparent and usually not noticeable to the user. However such a system requires dimming ballasts for the lamps, which cost more than regular ballasts.

TABLE. 02

Impact of Daylight Link Lighting System on Total Energy Saving

Impact of Daylight Link Lighting System on Total Energy Saving

	Office	School
No Daylight	0.0%	0.0%
With Daylight	4.9%	3.5%

In a well daylit typical office building, continuous dimming control can reduce lighting energy by up to 50%, whereas stepped control can reduce it by up to 36%.

More guidance on daylighting design and control is available from these sources:

- Energy Design Resources. Your Guide to Energy Efficient Design Practices. Daylighting Design *(http://energydesignresources.com/technology/daylighting-design.aspx)*
- Daylighting Collaborative. Light Every Building Using the Sky *(http://www.daylighting.org)*

REDUCTION OF INSTALLED LIGHTING

The primary aim of lighting design is to provide sufficient amount of light for the task in that space. Minimum acceptable light levels (illuminance) are defined by standards such as in **Table 1 of SNI 03 6197**. Lighting design can meet these minimum levels, but not exceed them by too much, as it may result in increased energy use.

These illuminance requirements can be achieved with varying levels of efficiency. With a good lighting design, it is possible to get desired light levels with relatively low lighting power, thus saving operational energy without compromising visual comfort.

TABLE. 03

Impact of LPD (W/m²) on Total Energy Saving[14]

Impact of LPD (W/m2) on total energy saving

LPD (W/m²)	Office	Retail	Hotel	Hospital	Apartment	School
20		-10.0%				
17			0.0%			
15	0.0%	0.0%		0.0%		-5.0%
13				4.6%		0.0%
10.8	7.3%	8.3%	7.0%	9.5%	0.0%	5.3%
8	12.9%		10.0%	15.9%	5.6%	12.2%
6					9.6%	

FIGURE. 19

Energy Savings through Lighting Design Options with Same Light Levels

[14] IFC Energy Analysis.

In **Figure 19** above, computer rendering images shows an office setting with similar light levels but significantly different LPDs. One system uses 2x36 W fluorescent producing 14.54 W/m^2 (top), while the other uses 1x27W LED lighting consuming only 6.54W/m^2 (bottom).

Various low cost and free design tools such as the ones listed below are available to easily calculate light levels and lighting power density.

- Lightswitch Wizard NRC (www.buildwiz.com)
- Daysim NRC (www.daysim.com)
- COMcheck-EZ PNW National Laboratory (www.energycodes.gov)
- SPOT Architectural Energy Co. (www.archenergy.com/SPOT)

The light level requirements are usually determined for the work surface, where the critical task is being performed (e.g. office desk, industrial assembly line). Ambient light levels outside the critical work surface could be lower. A typical application of this approach is to have the office ambient lighting designed for 100-150 lux, and task lighting provided at each desk to provide focused light at 350 lux. This approach is sometimes referred to as a "task-ambient lighting system".

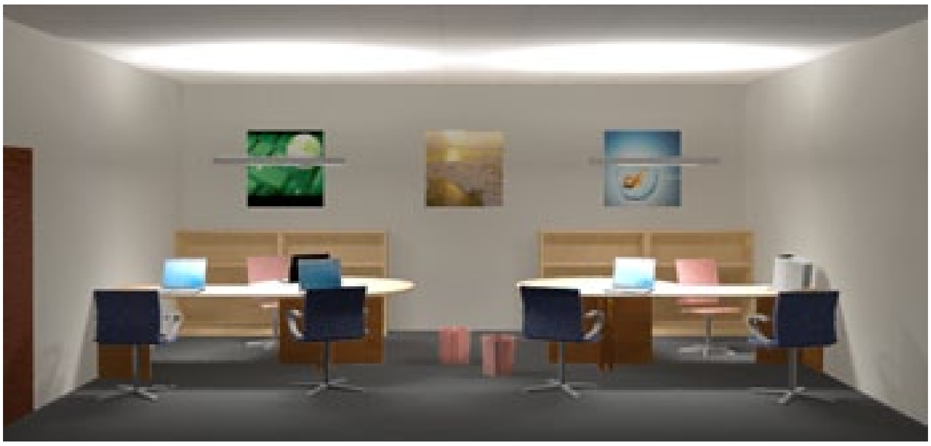


FIGURE. 20

Suspended 2x25W T5 fluorescent system with up lighting to create noticeably brighter interior and sufficient light levels on the desktop (300 lux) with only 3.3 W/m^2 LPD

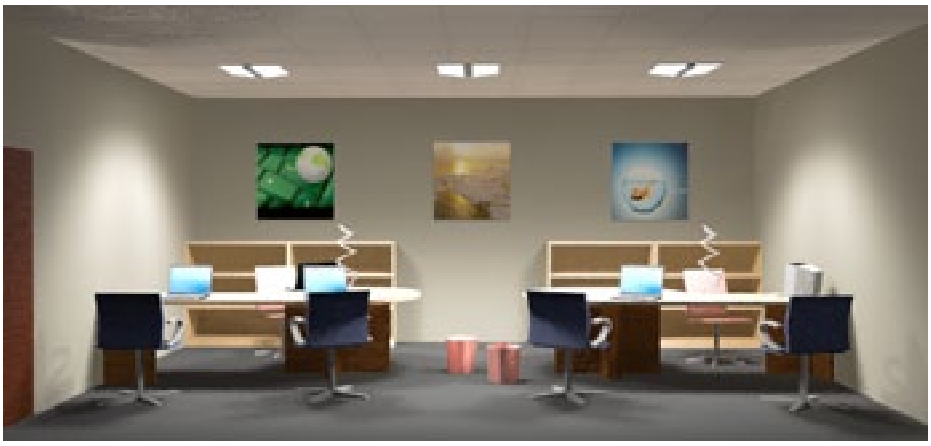


FIGURE. 21

Desktop lighting LED: light output 282 lm; power = 8.7W desktop illuminance 350 lux. General lighting 2 x 14 W T5 wide. Power = 32W. Luminous flux = 2400 lm. LPD = 2.5 W/m^2

Figure 22 below shows a lighting scheme that integrates daylighting and furniture layout creating an energy efficient lighting system with a comfortable luminous environment. Sidelight from windows is integrated into furniture layout. The uplighting from suspended luminaires improve significantly the luminous environment of the space by creating brighter and more spacious interior. Window size is optimized for providing sufficient illuminance without the accompanying glare.

FIGURE. 22

Office at Austrian Embassy Jakarta[15]

Light level requirements are also related to visual comfort of the occupants. **Table 1 of SNI 03-6197** shows minimum light levels for different space types. The mandated illuminance level has been determined as the minimum that is needed *at the work surface* to perform the task well. Any extra illuminance provided is essentially wastage, and may cause visual discomfort through glare.

It should be noted that the desired light level can be achieved with varying levels of energy consumption. A well designed light layout, along with efficient lamps and fixtures uses less electricity to provide the desired light level.

USE OF EFFICIENT LAMPS AND FIXTURES

Another important step in optimizing lighting energy use is selecting appropriate lamps and fixtures.

[15] Jatmika Adi Suryabrata.

LAMP EFFICIENCY

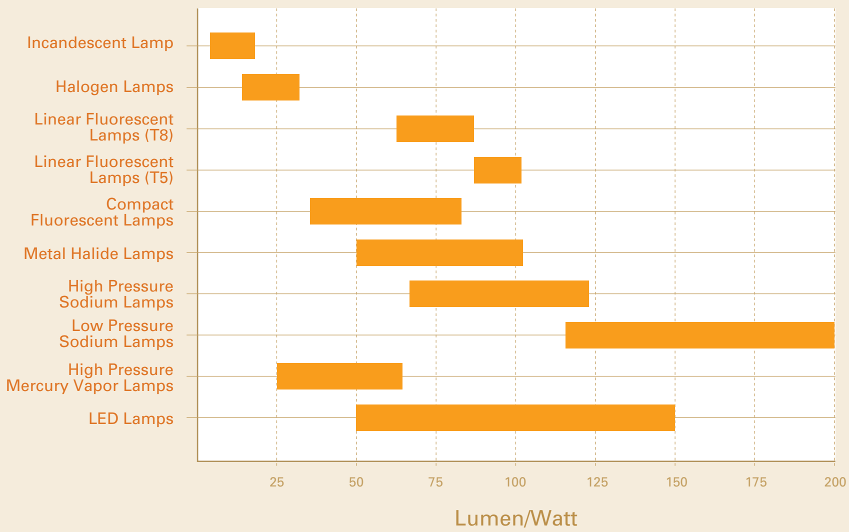
Appropriate selections of light sources are important in lighting design to both create pleasant luminous environment and save energy. There are a number of light source characteristics that should be considered during lighting design:

- **Luminous efficacy:** efficiency of the lamp in converting electricity to visible light. (Lumens/watt)
- **Lamp life:** number of hours of operation it takes for the emitted light to depreciate to a specific level.
- **Color rendering index:** ability of a light source to reproduce the colors of various objects faithfully in comparison with an ideal or natural light source.
- **Correlated color temperature:** the color appearance of light sources. It is often designated as warm, warm white and cool daylight.

For energy conservation, luminous efficacy is the primary criterion, whereas the other 3 characteristics have an impact on project budget, replacement cost and ambience. Lamps with higher luminous efficacy use less energy. However, lamp selection should involve all the criteria mentioned above these requirements influence lamp selection, but do not have a direct energy impact. For example, high pressure and low pressure sodium lamps have very high luminous efficacy but poor color rendering index, so are not suitable for most interior applications. Most fluorescent lamps have very good efficacy as well as color rendering index.

FIGURE. 23

Luminous Efficacy (lm/W) of Various Light Sources[16]



[16] Energy Efficiency Best Practice Guide Lighting. *(http://www.sustainability.vic.gov.au)* And various sources.

Some of the available high efficiency lamps are listed below:

- **High Intensity Discharge (HID) lamps**
  One of the most efficient lamp types in use currently, they have specialized applications due to their extreme brightness. They are best suited for high ceiling spaces and exterior applications.
- **T8 fluorescent lamps**
  Various versions available ranging from 58W to 10W, including the high performance variety that provides higher initial lumens in comparison to the standard T8. Some of the low wattage systems may not be dimmable.
- **T5 fluorescent lamps**
  T5 and T5 high output (HO) lamps offer similar or higher lumens watt as compared to T8 lamps. Because of smaller diameter, these lamps appear brighter and therefore need proper glare control.
- **Compact fluorescent lamps (CFL)**
  Offer about 30% lower efficiency (lumens/w) as compared to linear fluorescent, but are well suited as replacement for incandescent lamps in can lights and recessed fixtures.
- **Light Emitting Diodes (LED) lamps**
  Because of their long life and directional nature, LED lamps are becoming popular and feasible for some specialized applications, such as refrigerator lights, exit signs, under cabinet lights and task lights. If the directional nature of the light is utilized properly, the LED fixtures can perform significantly better than linear fluorescent fixtures.

Another criterion for lamp selection is its potential to harm the environment after its life is over. Most fluorescent lamps, except some low-mercury variations have high levels of mercury that can pollute waterways and marine life. While LED lamps do not contain mercury, they do contain semiconductors which can cause environmental pollution. The higher lifespan of LED lamps means that less number of LED lamps will end up in landfill as compared to fluorescents.

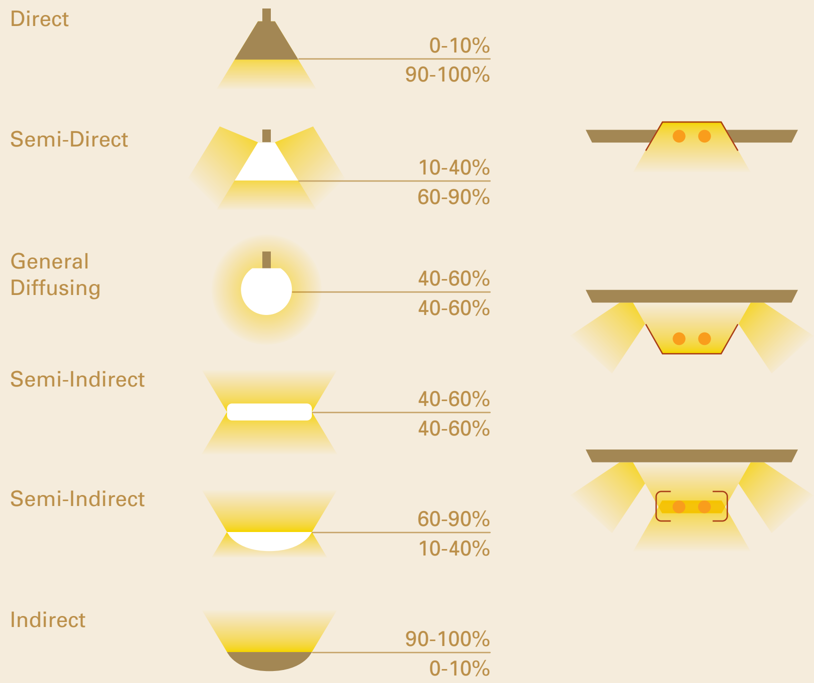
FIXTURE EFFICIENCY

Effectiveness of a lighting system is also determined by how well the light being produced by the lamps is distributed by the fixtures. This efficiency is measured by Light Output Ratio (LOR), which is a ratio between the lumen outputs from the lamp to the total lumen distributed out of the fixtures. SNI 6197 recommends a minimum LOR of 60%. LOR for the fixtures can sometimes be found on its packaging or on the manufacturer’s website.

The common fixture configurations are direct, indirect and direct-indirect. Most indirect and direct-indirect fixtures are suspended from the ceiling. A variation of the indirect lighting fixture is a “recessed indirect” fixture which can replace a typical ceiling troffer panel.

FIGURE. 24

Lighting Fixture Configurations



Direct fixtures are usually the most efficient in lighting up the work surfaces, as they guide most of the light directly at the work surface without bouncing it around the room. However, such fixtures can cause glare if not designed properly. The indirect and direct-indirect fixtures throw some light on the ceiling as well, creating a well-lit feel in the space. Often spaces with brightly lit ceilings are perceived to have higher light levels than they actually do. In such situations, it may even be possible to design the space to lower light levels and yet be acceptable to the occupants. Recessed indirect fixtures do a good job at diffusing the light, but are not as efficient in lighting up the ceiling.

FIGURE. 25

Highly directional downlight may create gloomy visual environment although light levels at the desktop are very high

SURFACE REFLECTANCE

Some of the light that reaches the work surface from the lamps comes after reflection from surrounding surfaces like walls and ceilings. In a way, these surfaces act as an extension of the fixture. Higher reflectivity of these surfaces would results in more light reaching the work surface. The recommended reflectances of the interior surfaces are shown in **Figure 26**, while **Figure 27** shows the typical impact of surface reflectances on light levels.

FIGURE. 26

Recommended Interior Surface Reflectances per IESNA Lighting Handbook

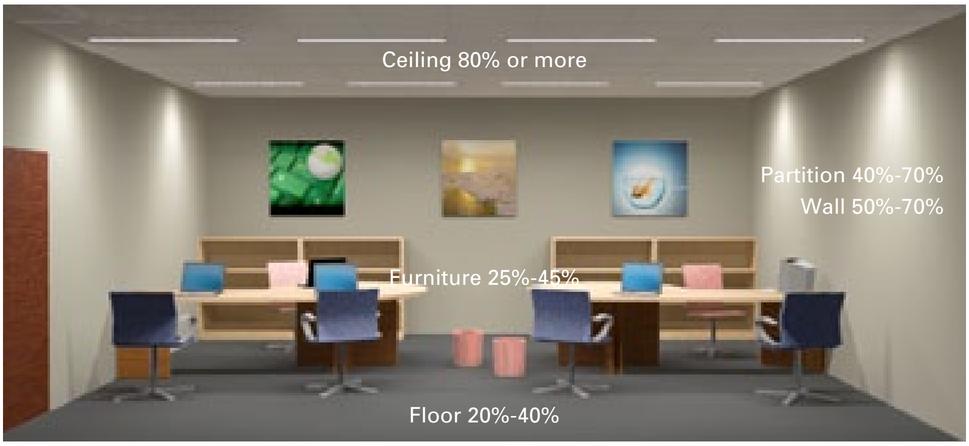
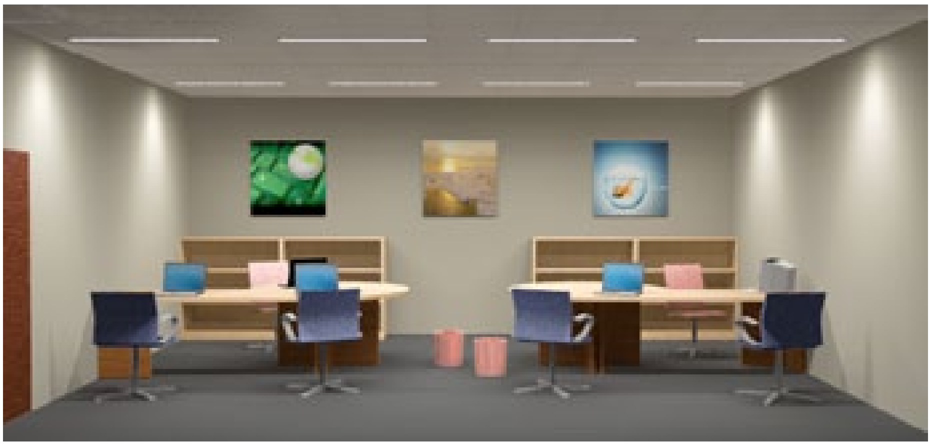
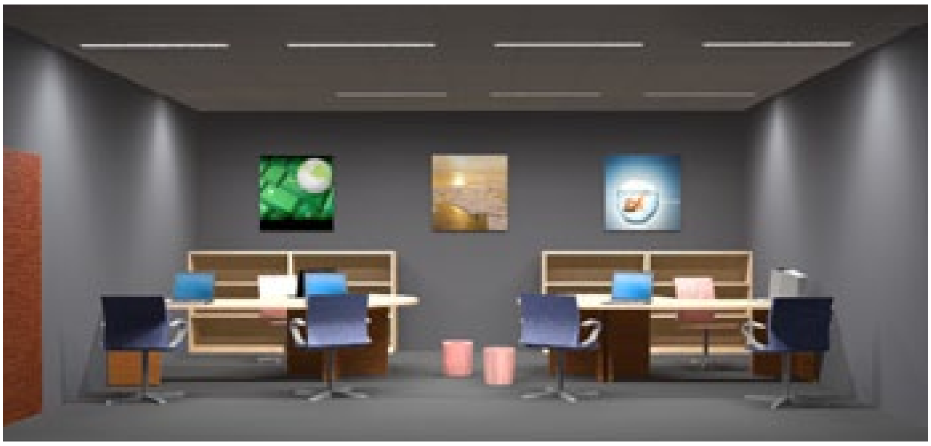


FIGURE. 27

Darker interior surfaces causes gloomy interior (bottom) although the lighting systems are exactly the same



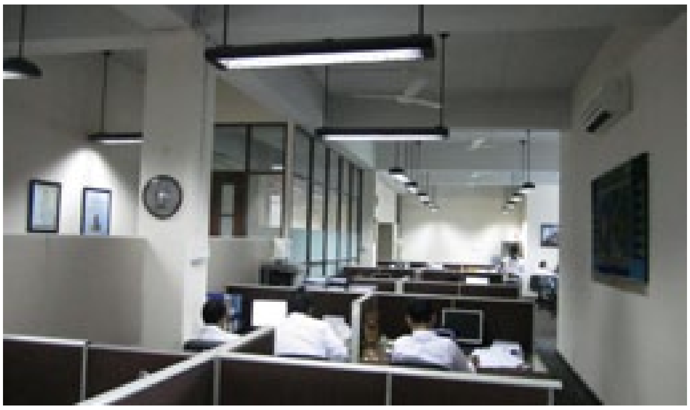


DISTANCE TO SOURCE

Intensity of light at a surface has a strong relationship with its distance from the light source. According to the "inverse square law", light intensity is inversely proportional to the square of distance from source. This means that a light fixture that is designed to provide 300 lux at the work surface when mounted on a 3 meter high ceiling, will provide approximately 44% higher light level (432 lux) if the fixture is suspended by 0.5 meter. Similarly a direct suspended fixture at 3 meters height will provide almost 3 times the illuminance as compared to a similar 5 meter high fixture. Consequently, the suspended fixture can be used with lamps having lower light output and less energy use. This principle can also be observed in task lights, as they provide relatively high illuminance even with low powered lamps.

FIGURE. 28

Suspended Lighting System in a Typical Open Office[17]



[17] Jatmika Adi Suryabrata.

On the other hand, inappropriate selections of luminaire combined with high ceiling may lead to a waste of light and energy. **Figure 31** shows a lighting system that employs exactly the same luminaire and spacing for the low ceiling lounge and the high ceiling lobby spaces. While the average light level in the lounge is around 100 lux, the lobby only has an average of 11 lux due to inverse square law.

FIGURE. 29

Demonstration of Inverse Square Law in a Split Height Space[18]

In addition to lamp and fixture efficiency, ballast efficiency should also be considered. For fluorescent lamps, program rapid start ballasts are usually the most energy efficient, as they cause the least reduction in lamp life. Instant start ballasts may be used when lights are kept on continuously for long periods. Dimming ballasts may be used where manual dimming or continuous daylighting dimming is desired.

USE OF LIGHTING CONTROLS

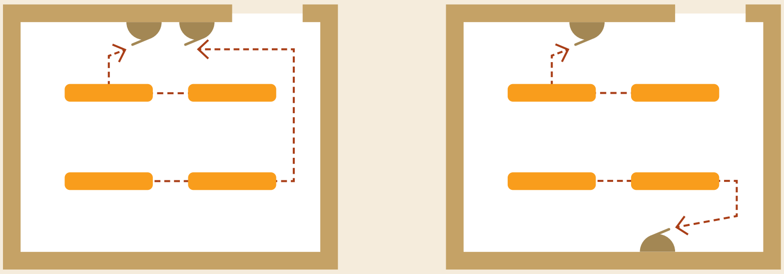
Lighting controls are ways of switching off or dimming lamps when they are not needed. The simplest controls comprise of multiple light switches to control some of the lamps in fixture or some of fixtures in a space. This level of manual control is fairly simple and inexpensive to install. However, energy saving is totally dependent on user behavior. If the users of the space do not switch off some of the lamps or fixtures when not needed, energy savings will not be utilized.

A slight variation of this strategy is to place the multiple switches in different locations, so that the user is not allowed to switch all the lights on at once. An example of this "strategic switching" approach is in classrooms where one of the switches controlling 1/3rd of the lights is placed near the blackboard, where the teacher can control it.

[18] Jatmika Adi Suryabrata.

FIGURE. 30

Multiple Switching (left) and Strategic Switching (right)



In situations where the occupancy pattern of the space is consistent, automated timer controls maybe used to switch off the lights at a specific time. This control can be implemented in individual spaces or as a building wide sweep through the building management system. Typically such systems have a way of warning the occupants before the shutoff, usually through blinking of lights. The user is allowed to manually override the switch-off. Since this system is less dependent on user behavior, energy savings from it are more reliable.

Frequent switching may shorten the life of fluorescent lamps and HID lamps but not significantly affect the life of incandescent and LED lamps.

If there are several periods during the day when the space is left unoccupied, occupancy sensors could be used to turn the lights on and off. Infrared (which sense motion) or dual technology (which includes body heat sensing ultrasound) occupancy sensors could be wired to control all or some of the lights in a space. This technique works best if the sensor has a clear view of all the occupants in the space. Typical applications include restrooms, storage rooms and private offices.

"Dual level" occupancy sensor controls is another variation used in small spaces like private offices. It incorporates the dual level switching and occupancy sensor technologies into a wall mounted panel and allows multiple levels of control.

More information on this system can be found at various manufacturers' websites.[19]

More information on high efficiency lamps is available at Whole Building Design Guide's website.[20]

[19] Dual-Circuit Switch with Occupancy/Partial-On Sensor. (*http://www.lutron.com/TechnicalDocumentLibrary/369758a.pdf*)

[20] Whole Building Design Guide, A Program of the National Institute of building Sciences. Energy Efficient Lighting. (*http://www.wbdg.org/resources/efficientlighting.php*)

More information and guidance on lighting design and control is available at:

- ASHRAE/IESNA Standard User's Manual 2004
- Daylighting and Window Design - CIBSE Lighting Guide 1999
- CIBSE Code for Lighting, CIBSE 2002
- Advanced Lighting Guidelines, National Buildings Institute (NBI) 2001 *(www.newbuildings.org/lighting.htm)*
- Daylighting Design Guidelines, Daylighting Collaborative *(http://www.daylighting.org/designguidelines.php)*
- Sensors and Controls - Tips for Daylighting with Windows, LBL, 1997 *(http://windows.lbl.gov/daylighting/designguide/section8.pdf)*

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