Green Building Handbook for South Africa
Chapter: Lighting

Luke Osburn
CSIR Built Environment

Lighting consumes between about 29-35% of the energy used within commercial office space while lighting only consumes about 11% of the energy used in a residential environment. Through conscientious design of the lighting systems, the lighting load can be reduced by more than half within both environments. These estimates can vary significantly as a consequence that buildings vary significantly in shape and size as well as functions. Additionally, the more inefficient a building is, the greater the potential to accrue savings.

While the absolute energy required to light a space, whether in an office or residential environment, is the same, the percentile difference in energy loads occur as a result of different energy demands between office and residential environments.

Office environments operate very differently to residential environments. Offices have a very high level of occupancy during office hours and are then largely unoccupied, while residential buildings have highly sporadic occupancy levels throughout the year. Consequently, the same intervention will have different results depending in which environment it operates.

Fluorescent Tubes

Fluorescent tubes should always be used where possible as they use roughly a quarter of the power that incandescent bulbs require to produce the same amount of light. Because the fluorescent tubes are more energy efficient than the incandescent bulbs, they also produce significantly less heat which means that a smaller HVAC system is required and less energy is required from the HVAC systems to maintain a comfortable temperature and working environment.

A variety of fluorescent tubes are available and care should be taken that the most appropriate fluorescent tubes are installed for the given application. High performance T8s (Super T8) are appropriate for most office environments and are able to produce up to 100 lumens per watt. T5s offer similar efficiency performance when compared to T8s, but because they are smaller they offer better optical control. T5s are a more appropriate choice if they are to operate in a warm or enclosed space as they offer a higher level of performance than T8s at higher temperatures. T5s can also operate more efficiently; however, they are significantly more expensive than T8s.

Electronic High Frequency Ballast

Care should also be taken to select the appropriate ballast. Electronic high-frequency ballasts are about 12% more efficient than conventional magnetic ballasts as well as eliminating flicker and hum.

Programmed Start Ballast
Programmed start ballasts increase the lamp life of the fluorescent tubes but with a penalty to the operating efficiency. They are appropriately used when the tubes are frequently turned on and off, as is the case when motion detection switching is used.

Mercury Content
A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapour. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to fluoresce, producing visible light.

The use of higher quality phosphors or using a triphospor mixture within fluorescent tubes will produce a light of a higher quality that is more soothing. Additionally, use of such phosphors allows the manufacturer to use less mercury within the construction of the tube.

Care should be taken within regard to the phosphor use and mercury content when selecting a fluorescent tube. Care should also be taken in regard to the proper and correct disposal of fluorescent tubes.

Light Emitting Diodes

Light-emitting diodes (LEDs) are capable of producing 100 lumens per watt and offer some advantages for making them well suited for niche applications. LEDs have very long life, are vibration resistant, produce a highly directional light and are very small; however, they need to become more cost effective before their use becomes widespread. Despite their high capital cost, they are, however, the most efficient and cost effective lighting solution within certain niche applications.

Filtered Light
In order to produce light of a specific colour, incandescent bulbs can be used, which already have a low efficiency of 17 lumens per watt and a filter is then used to block light and to only allow the light of the desired colour to pass through. Consequently the overall efficiency falls to 5 lumens per watt. Coloured LEDs can produce the coloured light at a higher efficiency as the light does not need to be filtered and their small size allows them to be used in most applications in which coloured light is required.

Display Lighting
LEDs are well suited to be used in display lighting as they are able to vary colour, create sparkle and the light produced is highly directional. Other light sources produce omnidirectional lighting and only a fraction of the light produced falls on the object which needs to be lit. All the light that the LED produces can fall on the desired object and consequently higher overall efficiencies can be achieved.

Area Lighting
LEDs can be used for area lighting and can achieve lighting efficiencies in excess of 100 lumens per watt. However, such installations, while currently technically possible, are very rare due to the very high capital costs associated with the installation of the LEDs required. Additionally, the energy savings when compared to a fluorescent tube fit out are very meagre.

LEDs are an advancing technology and it is expected that future developments will improve the efficiencies of LEDs as well as reducing their cost.

Controlling Lighting Levels

Care should be taken to ensure that an interior space is not lit beyond what is required, so that only as much light as is required is produced and therefore no light is wasted. The Green Star SA rating tool recommends that lighting levels within office spaces is kept below 400 lux, while SANS 204 recommends a lighting level of 300 lux for low risk commercial space. Operating in the range between 300-400 lux will provide sufficient lighting for conventional office tasks while not wasting energy.

The CH_2 building in Melbourne was the first Australian building to achieve a rating of 6 Stars on the Australian Green Star system and has a lighting level of 150 lux, which is quite low; however, the building does have task lighting so that higher lighting levels can be achieved in limited spaces as required.

Task Lighting

Particular tasks, such as reading, writing or drawing, require higher than normal lighting levels to be performed comfortably. Such lighting levels need not be supplied to the whole area but task lighting can be supplied in those areas where such tasks are performed. Consequently, a lower overall lighting level can be maintained with dedicated task lighting that should only be used as it is needed.

Task lighting can be used in offices, homes, kitchens and studies, and is particularly effective in an open-office plan structure wherein each employee has dedicated lighting and it needs only be on while that employee is at his work station.

Energy savings are accrued from having a lower than normal lighting level and through task lighting only being used as required. Also, task lighting helps to define a person’s individual space within the work environment.

Light Switching

The light switching within a used space should be such that only the areas that are being used are lit. Each private office should have its own light switch that is controllable by the office occupant. Within an open-office plan, the area should be divided into zones, which are each controlled by an individual switch so that, if work is only being done in one zone, then the other zones need not be lit and thus energy is saved. Green Star recommends that an individual light switch should not control an area greater than 100m^2.

Conventional offices within South Africa have large window façades, which is capable of adequately lighting the area near the window, the space in which the work station is often placed. Depending on the size of the office, normally 2 or 3 luminaries are used and are typically linked to a single switch near the entrance to the office.

The office worker may often find that the luminary above him is not necessary as the daylight is sufficient to allow him to work comfortably. Additionally, he may find the other luminaries in his office unnecessary as he is not working in the area that those luminaries are lighting. Allowing the energy conscious office worker to individually control the individual luminaries could result in significant energy saving. Such manual control can be used in conjunction with automatic dimming controls with the office worker's control taking priority. To be effective the office worker should have a remote with which to control the lighting.

Motion Detection Switching

The lights (and indeed the air-conditioning system) can be linked to motion detection sensors, so that only areas that are occupied are lit and areas that are not occupied will have their lights automatically turned off. The gains to be made from the installation of motion detection sensors is highly variable with some suppliers claiming a saving of as much as 80% on electricity used on lighting.

In a building with highly energy responsible individuals, who always turn the lights off when an area is not being used, the gain to be made from installing motion detection switching would be nil. Alternatively, the same sensors, in the same building but with different employees could potentially save a large percentage of electricity used on lighting as well as being cost effective.

Motion detection switching has the greatest potential for energy saving within public spaces that have a low or inconsistent level of occupancy, such as board rooms, restrooms or basement parking. Simple payback for the installation of such sensors can be as low as 2 years. Care should be taken to correctly adjust the timing of the sensors so that they do not prematurely turn off and disturb the people who are working in the area.

Motion detection switching is not recommended for use within a residential environment. The households that would consider such an option would be

ones that are energy conscious and would be better served by saving their money and manually turning lights on and off as required.

Automatic Dimmable Lighting Controls

The light within a building will consist of both natural and artificial light; however, the buildings lighting system needs to be able to provide the minimum specified lighting level independent of the natural lighting component.

Spaces in the building that have a lot of natural light can accrue an energy saving by installing dimmable fluorescent lights that are linked to a daylight sensor. The sensors will measure the light level and will adjust the output of the fluorescent tubes accordingly to maintain a preset lighting level. Such control systems are expensive and would only be appropriate in areas which have access to high levels of natural light.

Areas with installed dimmable lighting controls can reduce the energy required for lighting by about 33%. The amount of energy saved will depend on the weather, fenestration and the lighting level required in the office space. The energy saving occurs mainly between 11:00 and 16:00 when the space would receive large amounts of daylight.

This intervention is more appropriate to be used within office spaces as typically these spaces have high levels of fenestration and are often occupied during the daylight hours. Such instances do not typically occur within a residential environment and consequently the potential energy gains would be meagre and the installation of a system is unlikely to be cost effective.

Day Lighting

Day lighting is the method of maximising daylight within the occupied space of buildings to improve the quality of the light and to create a more comfortable and productive environment. Effective implementation of daylighting strategies can also reduce the energy required by artificial lighting by as much as 80%; however, this energy saving can only be effectively accrued if dimmable lights with sensors are installed.

Additionally, minimising the need for artificial lighting will significantly reduce the heat generated within the building and thus less air-conditioning will be required and it may even be possible to down size the air-conditioning plants and thus accrue a capital cost as well as an operational cost saving.

Light Shelves
Light shelves are reflective surfaces placed at windows which reflect additional light through the window and into the work space, typically installed at two thirds of the windows height. Light shelves can be placed internally or externally and will help to create a more comfortable working environment by

importing natural light into the area, improving the daylight factor, increasing the light levels as well as enhancing the light quality.

Light shelves serve to distribute the available daylight more evenly throughout the office and reduce the glare that occurs near the window, thereby creating a more comfortable and lighting effective workspace. A shading device can also be attached to the light shelf to reduce the glare from the sun near the window. Blinds will thus be needed less frequently due to the reduction of glare and will consequently allow light to travel throughout the office space more easily.

The implementation of light shelves will significantly improve the cost effectiveness of automatic dimmable lights, especially near the back of the room. The walls and ceiling should be a light reflective colour in order to maximise the benefit that can be gained by using light shelves.

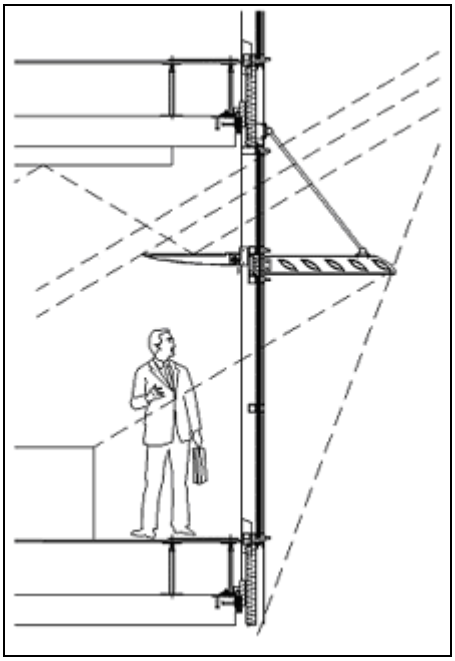


Figure 1: HunterDouglas, http://www1.hunterdouglascontract.com/HDWeb/Cultures/en-US/Products/SolarControl/LightShelves/SystemDescription.htm#top.

Light Tubes

Light tubes (pipes) capture sunlight on the façade of the building within a reflecting chamber in which the light gets reflected and transported horizontally along the length of the room. The light then enters the diffusing chamber, which has a highly reflective upper surface, but the bottom surface contains glass to allow light to leave the diffusing chamber and to enter the work space. The effective result is that daylight is distributed evenly throughout the work space.

In comparison to the normal case without light tubes, there would be high levels of illumination near the window and very low levels of illumination near the back of the room.

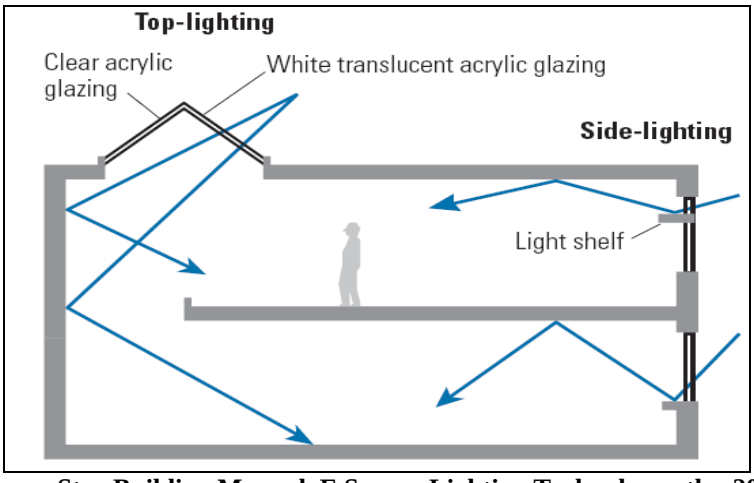
Normally office workers have their workstation near the window, in the area that can reach uncomfortably high levels of illumination and thus blinds are often used. The use of blinds blocks out natural light as well as the view and can significantly diminish the value added by having windows installed.

The implementation of a light tube will significantly improve the cost effectiveness of installing automatic dimmable lights, especially near the back of the room and can increase the amount of energy saved in the order of 25%. The walls and ceiling should be a light reflective colour in order to maximise the benefit that can be gained by using light tubes.

Top Lighting

Daylight can also be brought into the building space through the roof by means of sky lights or any form of glazing on the upper surface of the building. Care should be taken to reduce glare and areas that could become uncomfortably bright for office work. Also, the introduction of highly thermally conductive glass could increase the HVAC load through the conduction of heat either into or out of the building. Significant energy savings can be accrued by using top lighting; however, its use is effectively limited to low-rise buildings.

Positioning top-lighting glazing to face in a southerly direction such that light will penetrate but direct sunlight will never occur is recommended. Shading and blinds may then be unnecessary for those windows.



Energy Star Building Manual, E Source Lighting Technology atlas 2005.

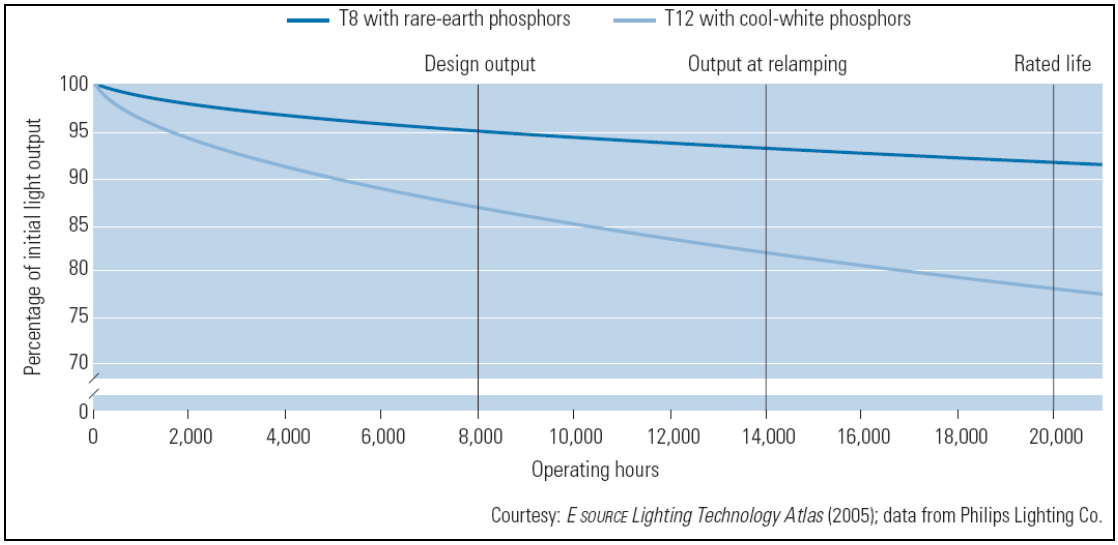
Luminary Housings

Luminaries are usually fitted in a housing that contains the luminary, prevents direct glare and adds aesthetic value to the space. Depending on the luminary housing, a large amount of the light produced can be trapped within the housing and not be used to light the space and thus energy is wasted. This is a particularly important consideration for fluorescent tubes as they produce light in all directions and, if inappropriate fittings are used, a lot of energy can be wasted.

Care should be taken in the selection of luminary housings to ensure that as much light as possible is being used to light the space and not trapped within the housing, while controlling the glare from the luminaries. Highly reflective surfaces on the top side of the light housings are an effective means of reducing the amount of light that is wasted within the fitting.

Operation and Maintenance

Lighting systems experience different rates at which lumen depreciation occurs. As the lamps age, the amount of light they produce depreciates. To account for this depreciation, lighting systems are typically over designed to provide 35% more light than the minimum requirements so that for the life of the building the lighting level never drops below the specified minimum.



Energy Star Building Manual

Proper design and maintenance, specifying high quality lamps, ballasts and fittings, can allow the designer to specify the lighting system to be over designed by as little as 15%, which will allow the building to save electricity over its entire life.

Group Relamping

Once the lighting system has been designed, a maintenance interval should be specified for when all the lamps within the building will be replaced. This

time interval should coincide with the ability of the lighting system to just meet the minimum lighting demand.

Typically lamps are usually replaced as they burnout at the end of their life; such a methodology has a high cost of maintenance associated with it. Replacing the lamps collectively has much lower labour costs and allows for easier and proper disposal of the fluorescent tubes, which contain hazardous materials, including mercury.

Controlled Purchasing and Inventory

Spare parts for the lighting system should always be kept on site so that when a failure occurs the failed part can be replaced with the correct part. If the correct parts are not kept on site then the wrong equipment will be installed and the efficacy of the building's lighting system will be compromised.

References

Energy Information Administration, 1995, Commercial Buildings Energy Consumption Survey.

Buildings Energy Data Book, 2005.

United States Department of Energy, Energy Efficiency and Renewable Energy, Energy Savers, Tips on Saving Energy and Money at Home.

Green Building Council of South Africa, Green Star, South Africa, Office Rating Tool.

Li D.H.W, Lam T.N.T and Wong S.L., 2006, Lighting and energy performance for an office using high frequency dimming controls, Energy Conversion and Management 47, 1133–1145.

Reffat. R.M., 2004, Sustainable Development of Buildings and Environment, Proceedings of Second International Conference on Development and Environment.

Canziani.R, Peron.F and Rossi.G., 2004, Daylight and energy performances of a new type of light pipe, Energy and Buildings 36 1163–1176.

Energy Star Building Manual, revised November, 2006.