# ENERGY EFFICIENCY IN LIGHTING -THE LESS CONSIDERED CRITERIA

S. Ranasinghe AMIIlumES (Lond) MIES (N.A)

**Abstract**

Energy efficiency in lighting had in most instances been simply considered in terms of energy consumption by lamps and controlgear. So, the search for more efficient equipment continues; no doubt contributing to greater technological advancements in this field.

The role played by most lighting designers , though employing such efficient lamps and control gear in their exercises, signifies greater emphasis on aesthetics of the visual environment rather than functionality and energy efficiency.

It is disheartening to observe that either least or no attention is paid by many a lighting designer, to factors such as Interior Surface Reflectance's, Luminaire Photometrics, Effective Design Systems, Appropriate Lighting Levels, Brightness Balances etc., the many criteria that contribute strongly to energy efficiency. It is also little understood by many, that these criteria could collectively contribute to more energy efficiency than efficient lamps and efficient control gear.

It is in this context that the writer attempts to explain that designing for energy efficiency in lighting is a multi-disciplinary exercise applicable to all situations.

## Introduction

The continuing growth of world population and the commitment of every nation to improve the quality of life of its people , are factors that are causing a grave concern amongst every right thinking person.

Good lighting is one of the very important contributions to good living. When one refers to good lighting, it means both quantity and quality of light, in the work place, in the domestic environment, in the place of worship , in the place provided for recreation etc.

During the day, in most countries where there is good sunshine throughout the year, a good proportion of the lighting requirement is met with natural light and the balance supplemented with artificial light. However, in situations where natural light is either not freely available or cannot be provided due to many other unavoidable reasons, such as design limitations, external obstructions etc., and during night time, total dependence on artificial lighting would be inevitable.

Energy to produce artificial light is derived from many sources such as fossil fuels, nuclear power, solar radiation, wind power etc., at a tremendous cost in terms of material and equipment, that is continually escalating.

It is also important to consider the fact that energy generation from some of these sources and its conversion to light contribute strongly to the pollution of the environment, which is a much valued and protected element essential to the sustenance of life on this planet.

Being aware of this situation , lamp and luminaire technology is constantly receiving attention at laboratory level to produce more efficient equipment and approaches to the art of lighting. We see today more and more efficient lamps being produced for every type of application and these being used all over the world .How best these technological products and recommendations could be adopted to suit specific national economic situations and developmental policies of different countries, specially the developing ones need careful considerations.

In addition to the efficacy factor of lamps , which no doubt is one of the most important considerations, there are many other criteria that contribute to lighting efficiency, every lighting designer, technologist or architect is quite aware of. However, it is regretting to note that these criteria , which involve no extra monetary involvement but only a right understanding and a commitment to the cause, are receiving least or sometimes no attention at all in the implementation of many a lighting exercise. It is surprising , when looking at them closely, that these other criteria could prove to be more efficient and environment friendly than the efficient lamp it self.

It is in this context that this paper attempts to enlighten the reader of the importance of paying attention to

the following criteria, when creating an efficient, effective , and an economical lighting system.

The light source , be it the artificial lamp or the sun, are the fundamental considerations in the choice of an approach to designing a lighting system. This paper however will not consider the artificial lamp , but other factors such as Natural light, Luminaire design, Interior surface reflectance's , Brightness balance , Design systems, Control methods etc.; to achieve a cost effective, environment friendly lighting approach.

## Natural Lighting

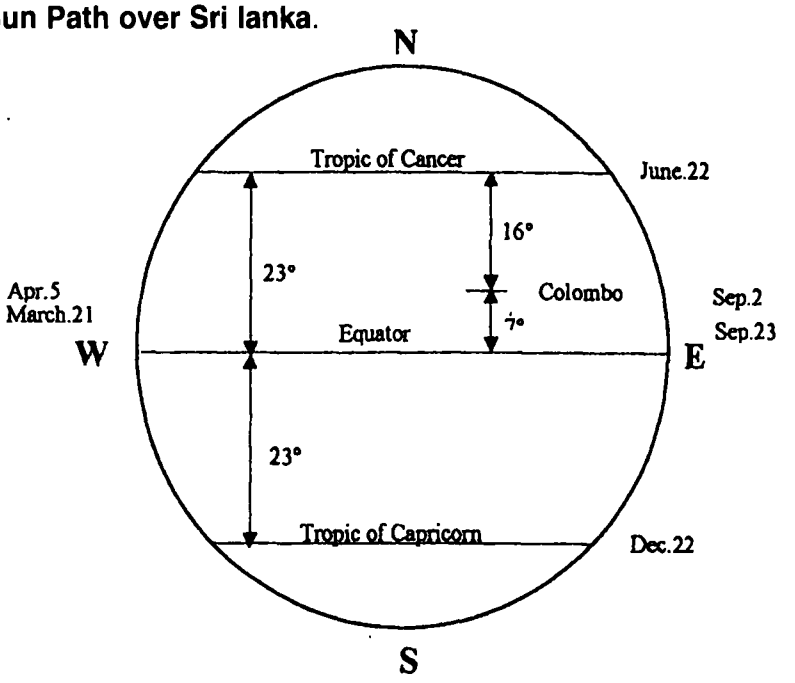
Natural light which is the visible radiation of the sun reaching the earth's surface in different ways, is a freely available light source that should be intelligently harnessed to make use of its beneficial constituents for interior lighting, for it also contains the element of radiation that produces heat, which in certain situations could be undesirable.

In countries blessed with an abundance of sunshine during a greater part of the year, natural lighting is the most economical approach to lighting of most interiors by day. Tropical countries should therefore look at this aspect positively, when designing buildings, to optimise the intake of natural light , whilst minimising on the intake of radiation that would produce undesirable heat.

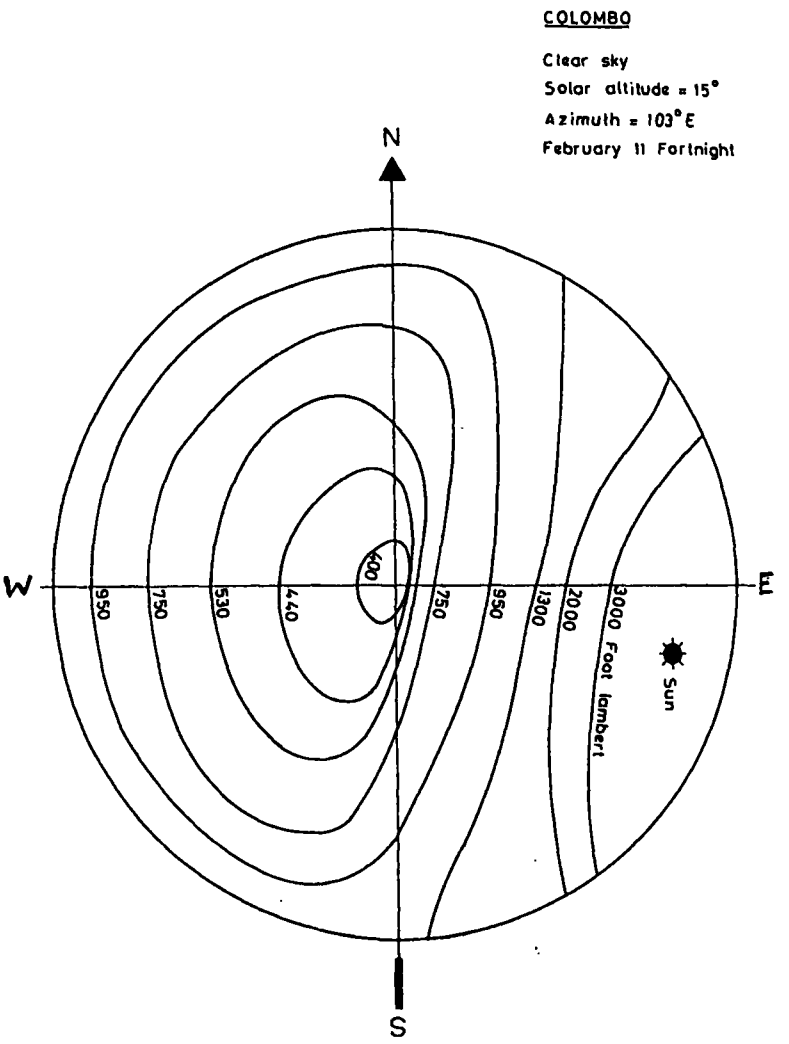
Even countries in the temperate zone of the world, experiencing overcast sky conditions during a greater part of the year have appreciated the economic advantage of natural lighting, both in terms of freely available light and the solar radiation that provides them with the much needed heat during certain parts of the year.

In this context, the architecture of buildings could incorporate many positive features, such as proper

**Sun Path over Sri lanka.**




**Sky brightness relative to location.**



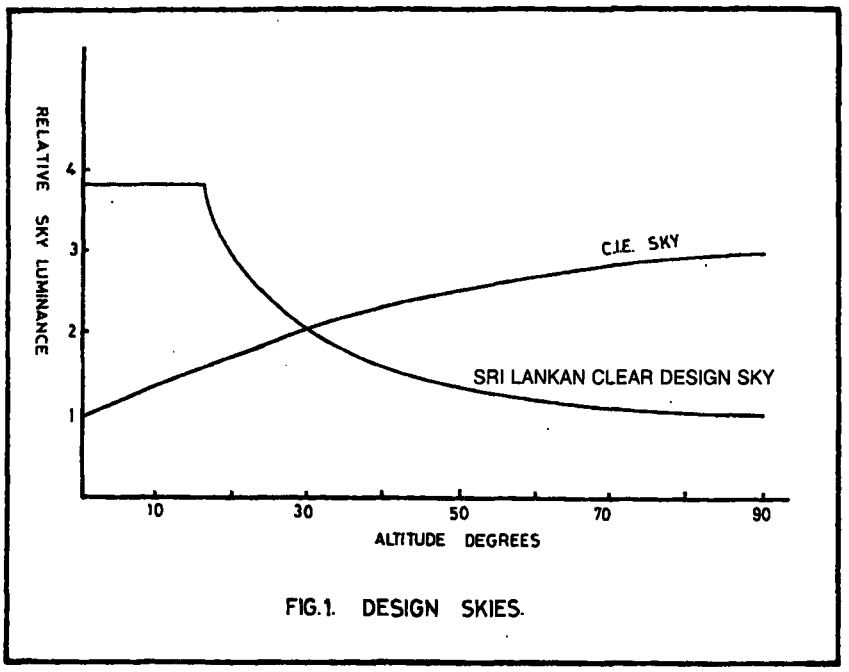
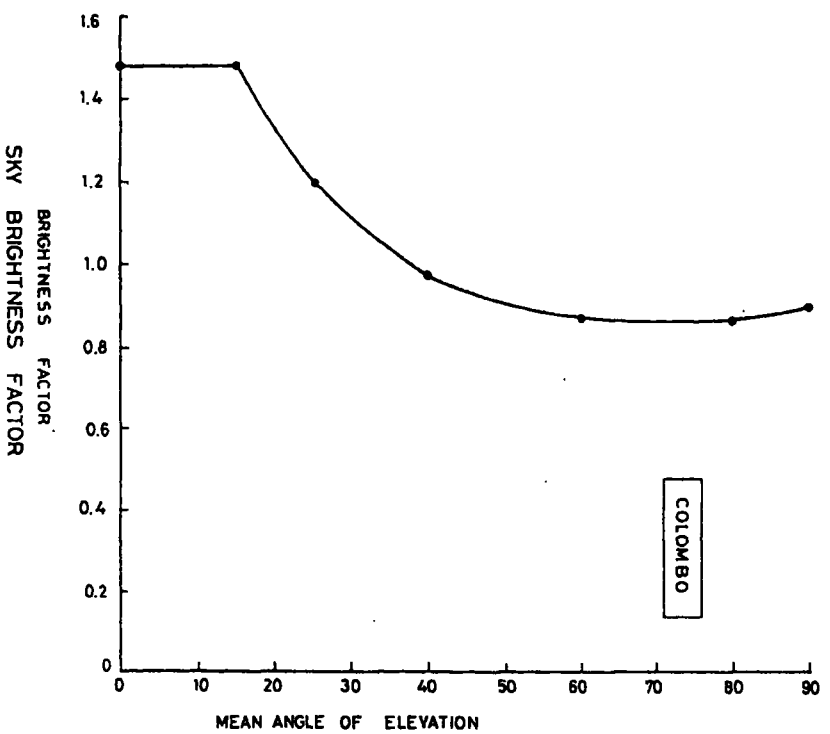



FIG.1. DESIGN SKIES.




orientation of windows, appropriate shapes and sizes of windows, less intricate interiors, good surface reflectance's, incorporation of court yards and atriums etc.; in order to make them daylight conscious buildings. Such attention would also lead to an appreciable reduction in the energy needed for the supplementary artificial lighting during the day.

A very brief clarification of each of the above stated aspects would be considered useful. Maximum benefit from windows would be derived by orientating them towards specific directions which would be specific to the country and the particular location, where the sky brightness would be maximum throughout the working period during the day. In certain parts of the world , orientation towards both Northern and Southern hemispheres , with correctly designed sun shading devices have proved to provide best results.

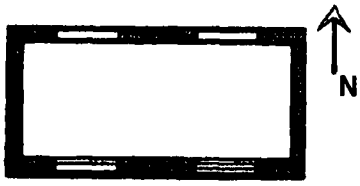
Shapes and sizes of windows are very important considerations in a good daylighting exercise. Excessively large windows and glazed wall cladding produce a totally negative effect in the tropical regions of the world. They contribute to excessive glare and immense heat build up within the interior, completely negating the requirement. Surprisingly, extensively glazed multi-storey buildings are gaining popularity in tropical regions of the world, specially in the developing countries, to satisfy meaningless aesthetic and prestige considerations. These buildings consume more energy to neutralise the heat build up than to provide artificial lighting.

An important consideration in the design of buildings for optimum daylighting , is that free flow of light in to the interior, through openings in horizontal or vertical surfaces should not be obstructed but assisted . In this regard the spaces should firstly be least intricate and secondly the surfaces should be made adequately and effectively reflective to permit interplay of light for deeper penetration. These are two simple considerations generally over looked by most designers who are more concerned with aesthetics rather than functionality.

Sunlight, as opposed to daylight, is an extremely effective component of natural light, with an efficiency of about 100 lm/w, which can be intelligently harnessed to provide very effective lighting to interiors. This is specially so , in certain parts of the world where sun light is plentifully available during most parts of the year . In certain regions of the world, that come within the 46 degree sun paths, when shifting from the Northern-hemisphere to the Southern-

hemisphere the sun light reflected off the external surfaces , specially the ground, could be made to effectively enter interior space through properly designed windows.

Effective window orientation relative to location.




Large factory buildings with diffusing roof lights and multi -storey buildings with atriums could be designed to receive sunlight extremely effectively without contributing to undesirable heat build up . It is difficult to deal with this aspect in greater detail within the scope of this paper; yet the fact remains that natural lighting is virtually cost free lighting , except for cost of installation of openings and maintaining them in good order.

## Surface Characteristics and Luminaire Photometrics

Colours and other physical surface properties of interior surfaces, such as walls, ceilings and floors are looked at by many a designer mainly from a point of view of aesthetics. Sometimes even some of the lighting designers too take a similar view of these characteristics. It is generally not realised by many involved with such decision making that low colour saturation and improved surface reflectance's could appreciably contribute to energy efficiency in lighting.

In this regard, the compatibility of the spectral characteristics of light with the surface colours, the Luminaire photometrics and the reflective properties of surfaces are the important considerations. The factors, spectral characteristic of light, surface colour and the degree of reflectivity of the surface would decide as to how much of light falling on a surface would be returned by reflection as useful lightly. The photometrics of the luminaire would decide the amount of light that would fall on the surface referred to, to be returned as useful light.

A look at how the coefficient of utilisation for a given room index and for a given luminaire combination would vary with variations in the reflectance of the principal surfaces, would provide interesting information.

For a specific room index and for a system that uses recessed louvered luminaires an increase of 6% in the coefficient of utilisation was observed when the wall reflectance was increased by 40%. [ from 0.1- 0.5] whilst reflectance's of other surfaces remained unchanged.

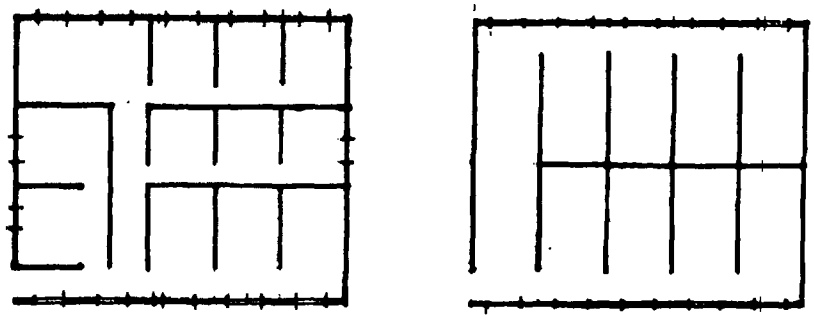
For the same room index, but a system that used surface mounted general diffusing type luminairs, an increase of 10% in the coefficient of utilisation was observed for the same 40% increase in wall reflectance, whilst reflectance's of other surfaces remained unchanged.

With surface mounted fluorescent luminaire with clear prismatic diffusers, for a given room index , the coefficient of utilisation increased from 27% to 60% [33%] when ceiling, wall and floor reflectance's were raised by 30% , 50% , and 20% respectively.

These figures clearly prove the fact that improved reflectance's of interior surfaces together with luminaires of appropriate photometric characteristics , would contribute to an appreciable saving in energy for lighting.

Appropriate shapes and sizes of windows relative to location.

Less intricate interiors and good surface reflectances.



**Factors related to Efficient artificial Lighting**

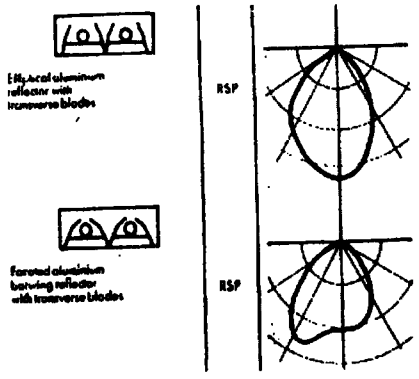
**A.**luminaire photometrics relative to the specific application.

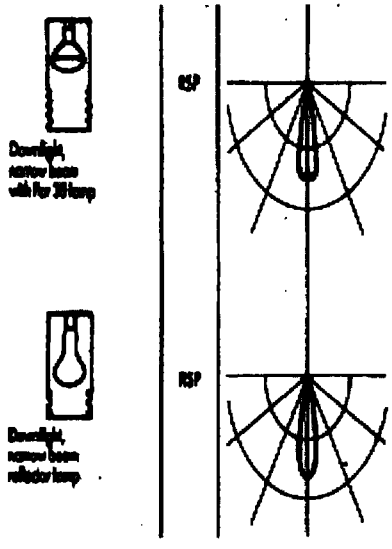
**B.**Reflective properties of the interior surfaces.

**C.**The design system.

**A. Luminaire photometrics**

the light out put pattern of luminaires.





**B.Reflective properties of the interior surfaces.**

Ceiling :80%-70% 50%-30%
walls :50%-30%-10%
Floor :30%-10%

**C.The design system.**

The distance from the luminaire to the work surface,referred to as mounting height,(Hm) is The effective factor in a design system.

Room index-$R_I$
Lenght of space-L
width of space-W
Mounting height of luminaire-Hm

$$R_I = \frac{L \times W}{Hm\,(L + W)}$$

**Brightness Balance**

In the case of daylit interiors , which are reasonably large and deep , there is generally a problem of brightness imbalance between the areas near windows and the deepest point, which contribute to a high degree of visual discomfort. This is the result of there being very much more light and brightness at the area near windows and comparatively less light and less brightness at the deep end.

This is conventionally rectified by providing a high level of supplementary artificial lighting to the deep end. This no doubt would be a satisfactory solution to the problem, but at a considerable waste of energy for excessive lighting.

It must be realised that the visual discomfort created in such a situation is the result of brightness of surfaces within the field of view, rather than the level of lighting. Therefore attention should first be drawn to this factor rather than the lighting level . The major surfaces in the field of view are primarily the walls, ceiling and the furniture. Controlling the reflectivities of these surfaces in a manner not to appreciably reduce the flow of day light into the deeper end of the interior would help reduce the brightness to tolerable limits.

It would be an interesting exercise to provide a smoothly increasing reflectivity gradient, say from 50% to 80% on wall surfaces that extend from window end to the deeper end of the interior; an approach that would also be aesthetically appealing.Such an arrangement would considerably reduce the need to provide high supplementary artificial lighting levels to bring about a brightness balance. The problem of brightness balance could be totally avoided and the need for supplementary artificial lighting totally eliminated by reducing the depth of the interior space to be daylit to an optimum amount. In order to create such a situation; the need to design a building exclusively for day lighting and to avoid the use of artificial lighting by day should be taken into account as a design concept at the planning stage.

Such buildings, whether single or multi-storey, would have courtyards or atriums that would help to take in daylight from outer and inner windows into comparatively shallow spaces. Such a system, in addition to providing adequate daylight throughout the day, ensures less or no glare from inner windows. This could be considered a very efficient approach to providing extremely economical lighting.

**Design Systems.**

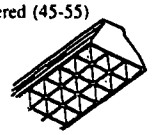
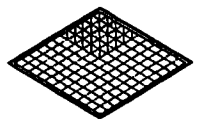
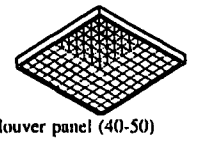
Very often it is observed that the method of providing lighting to a particular situation is decided generally by the building designer, firstly to satisfy the aesthetic compatibility with the architecture of the building or the interior and to achieve the desired effect to be created by light, and secondly to satisfy the visual requirements of the task. It would not be incorrect to say that very often the energy efficiency aspect is either least or not considered at all.

These are many energy efficient design systems that can be adapted in providing either artificial lighting or combined natural and artificial lighting to any interior.

A few of the criteria relevant to such design systems would be briefly explained as follows.

a. Distance of source to task.
b. Flexibility of the system.
c. Control systems.

**Coefficient of utilization of the light produced by a luminaire, related to the selected design system.**

| Description of Luminaire,and Typical Typical outline Downward Light Output Ratio% | Basic DLOR | Reflectance % Ceiling | 70 | | | 50 | | | 30 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (F) Enamel slotted trough, louvered (45-55)  | | Walls | 50 | 30 | 10 | 50 | 30 | 10 | 50 | 30 | 10 |
| | % | Room Index | | | | | | | | | |
| | 50 | 0·6 | 0·27 | 0·24 | 0·22 | 0·26 | 0·24 | 0·22 | 0·26 | 0·23 | 0·22 |
| | | 0·8 | 0·32 | 0·3 | 0·27 | 0·32 | 0·29 | 0·27 | 0·31 | 0·29 | 0·27 |
| | | 1 | 0·35 | 0·32 | 0·3 | 0·35 | 0·32 | 0·3 | 0·34 | 0·31 | 0·3 |
| | | 1·25 | 0·38 | 0·35 | 0·32 | 0·38 | 0·35 | 0·33 | 0·38 | 0·34 | 0·33 |
| (F)  | | 1·5 | 0·41 | 0·38 | 0·36 | 0·4 | 0·38 | 0·35 | 0·4 | 0·37 | 0·35 |
| | | 2 | 0·45 | 0·42 | 0·4 | 0·43 | 0·41 | 0·39 | 0·43 | 0·4 | 0·39 |
| Louvered recessed(module) luminaire (40-50) | | 2·5 | 0·47 | 0·44 | 0·42 | 0·45 | 0·43 | 0·41 | 0·45 | 0·42 | 0·41 |
| | | 3 | 0·48 | 0·45 | 0·44 | 0·46 | 0·45 | 0·43 | 0·46 | 0·44 | 0·42 |
| (F)  | | 4 | 0·49 | 0·47 | 0·46 | 0·48 | 0·47 | 0·45 | 0·47 | 0·45 | 0·44 |
| | | 5 | 0·5 | 0·49 | 0·48 | 0·49 | 0·48 | 0·47 | 0·48 | 0·47 | 0·46 |
| Shallow ceiling – mounted louver panel (40-50) | | | | | | | | | | | |

## Distance Factor.

In artificial lighting the distance between the light source and the task is one of the critical factors that determine the efficiency of the system. The closer the source to the task the more efficient would be the system. Since illuminance would vary as the inverse of the square of the distance. This would provide the opportunity to use a very low wattage lamp to produce the required design illuminance. Secondly, lesser the distance between the luminaire and the task, the higher would be the Room Index, indicating a high coefficient of utilisation.

Therefore reducing the distance between the source and the task, within practical limits and design and functional constraints, would mean a considerable saving in energy.

## Flexibility Factor.

The term flexibility as applied to lighting design would mean the possibility to change the positions of luminaires, as and when necessary, with the least inconvenience and expenditure.Flexibility is an essentialquality in office lighting to permit frequent changes in the interior arrangements associated with changes in systems & methods of administration.

Without flexibility, certain areas would have less light, needing extra lighting and certain other areas would have excessive or redundant lighting.

Local lighting of individual work stations , using movable luminaires, is an effective way of fulfilling the flexibility and the distance factor requirements in one exercise.

## Control Systems Factor

In the practice of artificial lighting the arrangement of circuitry and switching systems to provide a variety of choices of lighting levels and positions is yet another approach to energy efficient lighting.

Such an approach becomes extremely advantageous when combining natural lighting with supplementary artificial lighting, as artificial lighting could be precisely regulated to meet any short fall in natural lighting.

Local and localised lighting design systems are provided with individual user control switches, contributing to much saving in energy.Time switches and photo cells introduced correctly to the circuits, would control the lighting extremely beneficially in terms of energy usage.

Dimming is yet another method of efficiently controlling lighting, specially in domestic, hotel and hospital situations.

Few of the methods of lighting control described here in addition to providing energy efficiency could also contribute to visual efficiency, visual comfort and aesthetics of the visual environment.

## Lighting Levels

The quantitative aspect of lighting, refers to the recommended Design Service Illuminance for any particular task. If one looks at the Design Service Illuminances of different countries it would be quite obvious that there is some disparity. Research carried out recently in Sri Lanka, by the Sri Lanka Energy Managers Association (SLEMA) has clearly shown that design service illuminance levels could be reduced by nearly 50% of the values recommended by developed countries.It is therefore in the interest of every developing country to reconsider this criterion, specially from a point of view of conserving energy.

## Conclusion

It would be clear from what is stated in the foregoing paragraphs, that there are many other criteria, other than efficient lamps and control-gear, that could extremely effectively contribute to energy efficiency in lighting.

The sole responsibility of recognising and applying these criteria to energy efficient lighting lies in the hands of the dedicated team comprising of the Architect, Illuminating Engineer, Electrical Engineer, and the Interior Designer and should receive attention from the very beginning of the planning stage of a building.It should be emphasised that frugal use of energy is in the long term interest of the survival and the well being of the human race.