

# Combined Electric Lighting and Day Lighting

## Introduction

Energy can be saved if the use of electric lighting is reduced. This can be achieved by ensuring that the maximum use is made of daylight. However, daylight enters buildings through windows and these have a high U-value compared to the walls. Thus there is a balance to be made between the heat that is lost from windows and the reduction in the energy consumed by the electric lighting.

The following is a simplified study of this interaction. Because it is simplified, caution should be exercised in directly applying the results. However, the principles hold true and provide a methodology for investigating this type of problem – that of optimising a design in order to minimise energy consumption. Often in real situations there is a need to include many more factors that have been included in this analysis. Under these more complex circumstances then it may well be that simulation techniques would be more likely to provide a reliable answer. Unfortunately, simulation techniques are only able to check the results of a design, and without an appreciation of the underlying factors the initial design proposal becomes a matter of guesswork.

## Variations in daylight

Figure 10.1 shows a chart taken from IES Technical Report 4 on Daylighting. It shows average iso-lux contours for different times of the year. A simplified chart is shown in Figure 10.2 that may be more easily understood.

Note in Figure 10.1 that all the data is plotted for GMT and therefore a correction to the time scale is needed in order to allow for the clocks being put forward during British Summer Time.

The data was produced by averaging averages over a seven year period and this has relevance to energy usage as the results will be applicable to the average expectation of daylight over a period of time.

More recent data has been produced by DRG Hunt with the publication of 'Availability of daylight' by BRE 1979.

Differences between data are apparent, but Hunt's use of a statistic on the cumulative data rather than averaging averages over the years means that peak values are more prominent in Hunt's data.

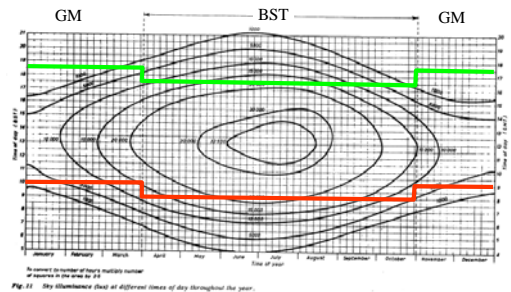


Figure 10.1 – Average Daylight levels

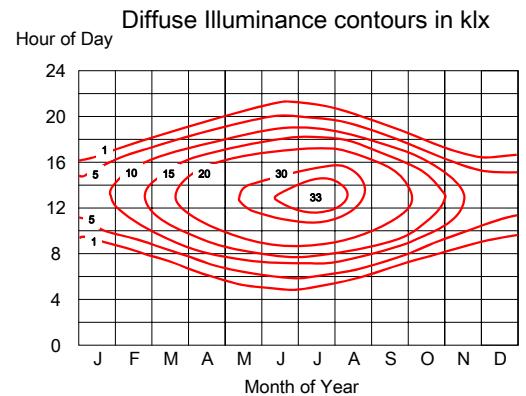


Figure 10.2 – Simplified daylight chart

The hatched areas in Figure 10.3 shows the periods for which the diffuse daylight illuminance is less than, 10000 lx, 5000 lx and 20000 lx.

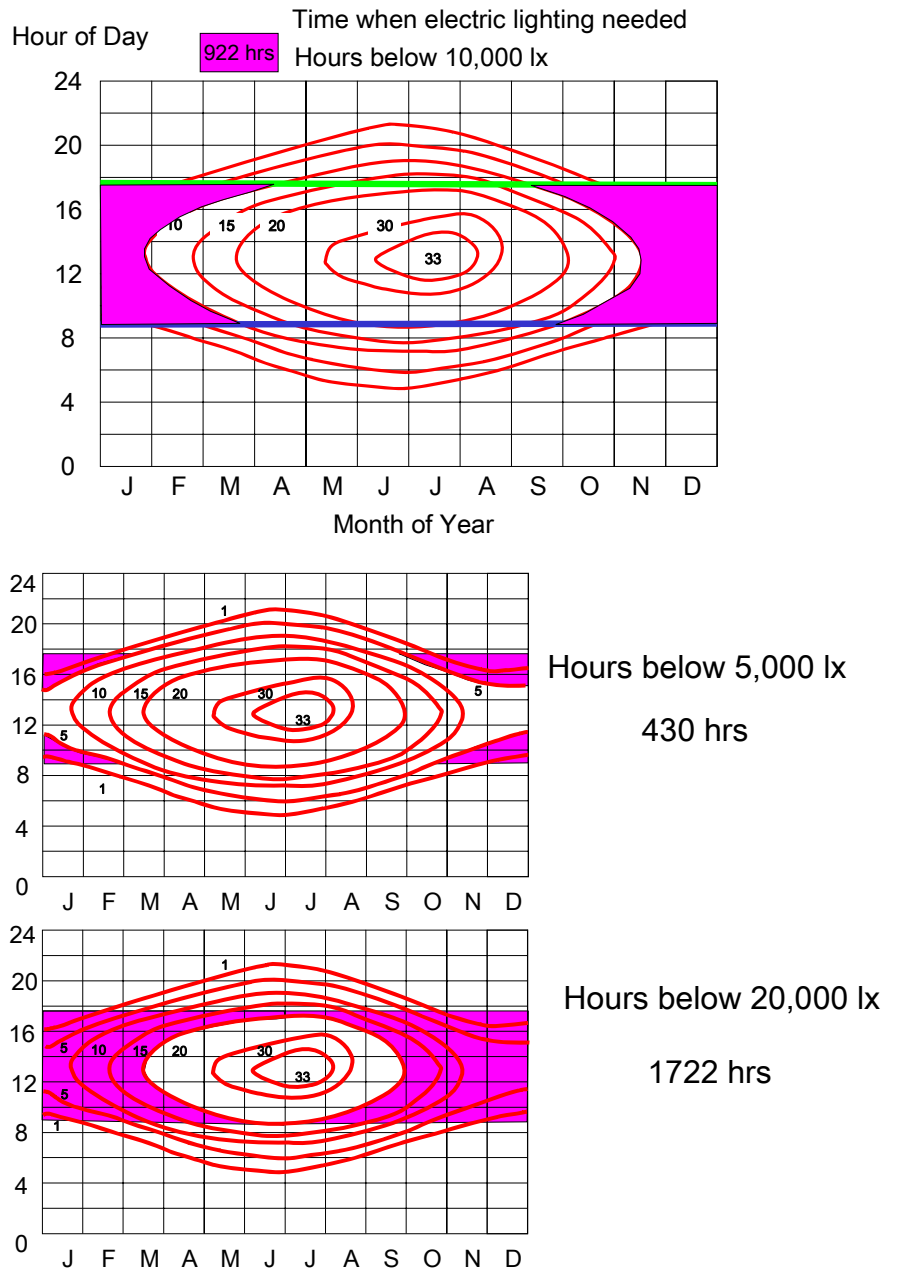


Figure 10.3 – Analysis of the Daylight Chart

Working day from 9-00am to 5-30pm with an hours lunch. Including holidays and weekends, working hours 2625 hrs

Sky illuminance In lx	Working hours below this sky illuminance	% of working hours below this illuminance	% of working hours above this illuminance
5,000	430 hrs	16%	84%
10,000	922 hrs	35%	65%
20,000	1722 hrs	66%	34%

Figure 10.4 – Result of chart analysis

The results from this analysis are summarised in the chart shown in Figure 10.4. The number of hours when the illuminance is below the given level during the working day is in the first column.

A working day between 9-00am and 5-30pm has been chosen, and from the initial data, the percentage of the working year above and below a given illuminance is calculated.

These results can be plotted on a graph as shown in Figure 10.5.

One interesting aspect of the result is that the probability curve is almost linear and this makes the analysis somewhat simpler.

### Switching electric lighting

The average illuminance within a room from daylight will vary as the sky illuminance changes. The average illuminance  $E_{AV}$  will depend upon the sky illuminance and average Daylight Factor as shown in Figure 10.6.

$$E_{AV} = \frac{DF_{AV} \%}{100} \times E_{SKY} \text{ lx.} \quad \dots 10.1$$

If  $E_{AV}$  exceeds  $E_s$ , - the service illuminance required in the room in order to achieve a given level of visual performance, then no additional light from the electric lighting installation will be required. If however, there is insufficient daylight then the electric lighting will need to be switched on in order to ensure the service illuminance is provided as shown in Figure 10.7.

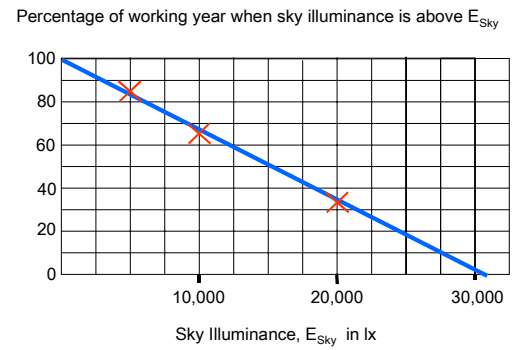


Figure 10.5 – Probability of  $E_{SKY}$

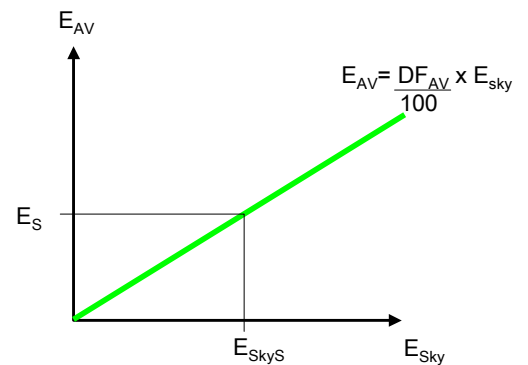


Figure 10.6 – Variation of DF

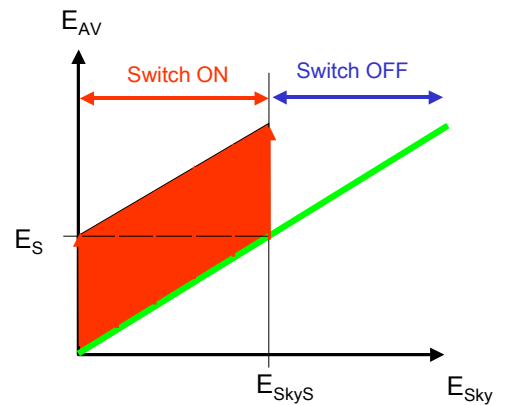
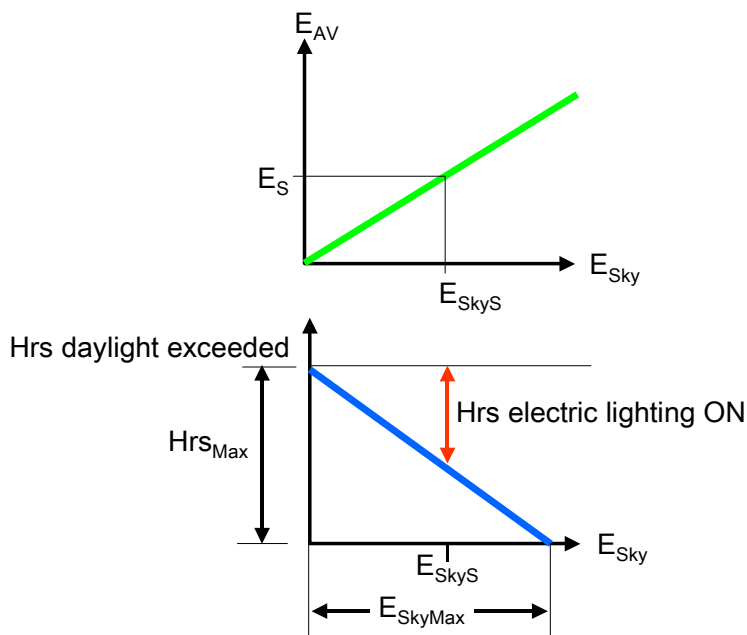


Figure 10.7 – Switching electric lighting

Arranging Figure 10.5 below Figure 10.6 as above, shows how the two are linked. By similar triangles in Figure 10.5,

$$\frac{Hrs_{MAX}}{E_{SKY_{MAX}}} = \frac{Hrs_{ON}}{E_{SKY_S}}$$

and on re-arrangement

$$Hrs_{ON} = \frac{Hrs_{MAX}}{E_{SKY_{MAX}}} \times E_{SKY_S} \text{ hrs} \quad \dots 10.2$$

From equation 10.1, the sky illuminance that provides the service illuminance is given by:

$$E_S = \frac{DF_{AV} \%}{100} \times E_{SKY_S} \text{ lx}$$

and with re-arrangement this gives,

$$E_{SKY_S} = \frac{100 \times E_S}{DF_{AV} \%} \text{ lx.}$$

If this is used in equation 10.2, then the hours the electric lighting is on is given by:

$$Hrs_{ON} = \frac{Hrs_{MAX}}{E_{SKY_{MAX}}} \times \frac{100 \times E_S}{DF_{AV} \%} \text{ hrs} \quad \dots 10.3$$

### Energy consumed

The energy used by the electric lighting is given by,

$$J_{Lighting} = \text{Power} \times \text{Time Joules}$$

The power used by the electric lighting will be proportional to the service illuminance provided and therefore,

$$J_{Lighting} \propto E_S \times E_S \times \frac{Hrs_{MAX}}{E_{SKY_{MAX}}} \times \frac{100}{DF_{AV} \%} \text{ J}$$

Daylight Factor is proportional to the window area and so this can be simplified to:

$$J_{Lighting} \propto \frac{E_S^2}{A_{Window}} \text{ J}$$

Heat loss in Winter is also approximately related to the window area,

$$J_{Heating} \propto A_{Window} \text{ J}$$

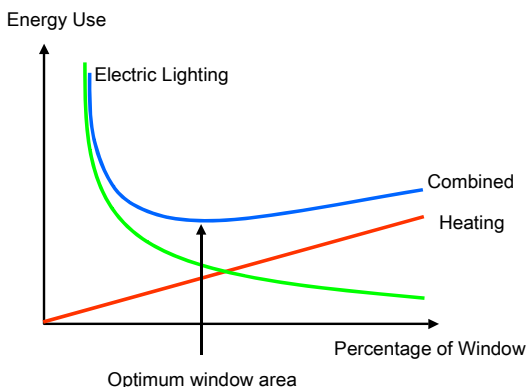


Figure 10.8 – Energy consumed

If these are plotted as in Figure 10.8 then it is apparent that there is an optimum percentage of window area that leads to a minimum use of energy.