

ENERGY EFFICIENCY IN BUILDINGS

6. LIGHTING

6.1. ARTIFICIAL LIGHT

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DEFINITIONS

Luminaire efficiency

Ratio of light output emitted by the luminaire to the light output emitted by its lamps.

Percentage of light output produced by the lamps that are in turn emitted by the luminaire.

It is measured by the luminaire output ratio (LOR)

Lamp efficacy

Measure of how well a lamp produces visible light, measured in lumens per watt.





DEFINITIONS

Circuit-watt

The power consumed in lighting circuits by lamps, and where applicable, their associated control gear (including transformers and drivers) and power factor correction equipment

Luminaire (or light fitting)

A complete lighting unit

Lamp

A device to give light. The lamp emits light within the luminaire

Bulb

A lamp

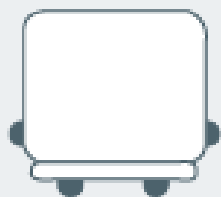




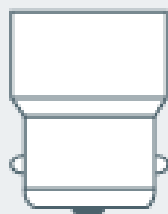
CHARACTERISTICS TO CONSIDER WITH LAMPS

Bulb fittings

Bayonet

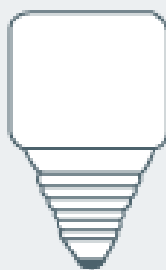


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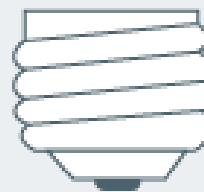


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Screw

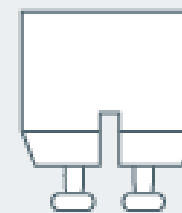


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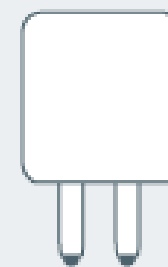


E27

Other



GU10



MR16



CHARACTERISTICS TO CONSIDER WITH LAMPS

How Many Lumens Do You Need? More Lumens = More Light

If you used to buy this in incandescent	Look for this much light in lumens	LED (most efficient)	CFL (more efficient)	Halogen (more efficient incandescent)
100 W	1600	up to 22 W	up to 26 W	up to 72 W
75 W	1100	up to 20 W	up to 23 W	up to 53 W
60 W	800	up to 12 W	up to 15 W	up to 43 W
40 W	450	up to 9 W	up to 11 W	up to 29 W

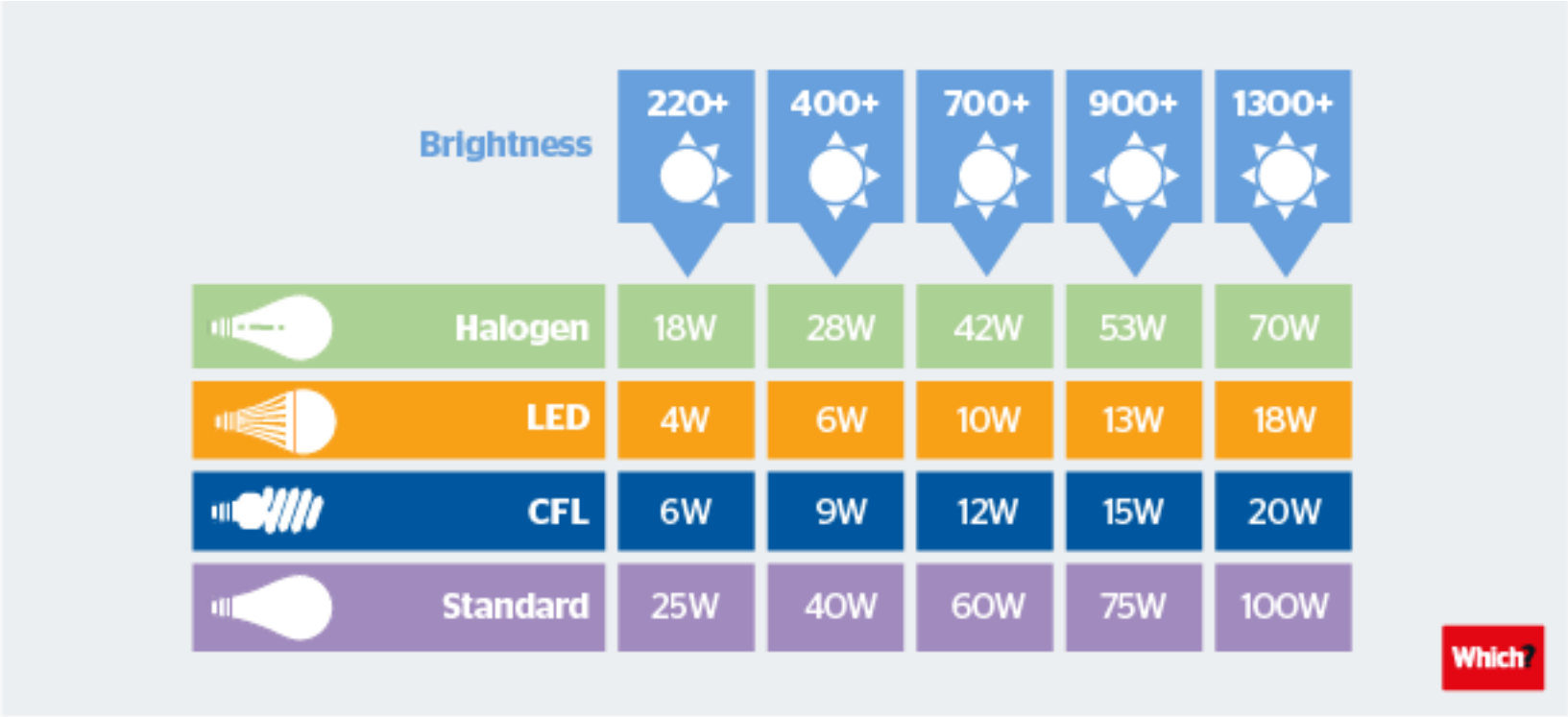
Lumens vs Watts: Output and wattages based on most common products available for each medium screw-based light bulb. Actual light output may vary by product.



CHARACTERISTICS TO CONSIDER WITH LAMPS

Lumens vs Wattage

Lumens is a measure of brightness
Wattage is a measure of energy





CHARACTERISTICS TO CONSIDER WITH LAMPS

Colour of light (Kelvin scale)

Kelvin scale is a measure of temperature

Midday sunlight: 5,500k

Sunset or sunrise lighting: around 2,500k

Candle: 1,600k

Atmosphere	Candlelight	Traditional Incandescent light bulb	Midday sun	Overcast sky	Blue sky
Kelvin	1,500K	2,700K	5,000K	7,000K	10,000K



CHARACTERISTICS TO CONSIDER WITH LAMPS

Colour rendering index (CRI)

Measure of the ability of a light source to accurately represent different colours

Midday sunlight: 5,500k

Sunset or sunrise lighting: around 2,500k

Candle: 1,600k

Traditional incandescent and halogen bulbs have a near perfect CRI and score in the high 90s. LEDs and CFLs are a little behind this and are more likely to have a CRI value in the mid 80s. 80 is considered an acceptable level.





Building Regulations. Part L1

At least 75% of fittings must be low energy, defined as

- Efficiency greater than 45 lamp lumens/circuitW
- Delivering at least 400lm

Fittings less than 5W are exempt from the total count

Fittings in infrequently accessed areas (such as cupboards) are exempt

Halogen and GLS lamps are highlighted in the guidelines as non compliant

A single light switch should normally operate no more than six light fittings with a maximum load of 100 circuit Watts.



LIGHTING DESIGN CALCULATION

The Lumen Method

$$N = \frac{E \times Area (m^2)}{L \times UF \times MF}$$

N: Number of luminaires

E: Illuminance (luxes) required

L: Lumens of each luminaire (Sumation of all lamps lumens in the luminaire)

UF: Utilization factor

MF: Maintenance factor



Illuminance required

CIBSE Code for Lighting

Activity	Typical locations/types of work	Average illuminance (lux) 1x	Minimum measured illuminance (lux) 1x
Movement of people, machines and vehicles	Çlorry park, corridors, circulation routes	20	5
Movement of people, machines and vehicles in hazardous areas; rough work not requiring any perception of detail	Construction site clearance, excavation and soil work, loading bays, bottling and canning plant	50	20
Work requiring limited perception of detail	Kitchens, factories assembling large components, potteries	100	50
Work requiring perception of detail	Offices, sheet metal work, bookbinding	200	100
Work requiring perception of fine detail	Drawing offices, factories assembling electronic components, textile production	500	200



LIGHTING DESIGN CALCULATION

Utilization factor

Ratio of effective luminous flux to the total luminous flux of light sources.

It depends on:

- Efficiency of luminaire
- Luminaire distribution
- Geometry of the space
- Room reflectances
- Polar curve



LIGHTING DESIGN CALCULATION

Utilization factor

The method of calculating the utilization factor (UF) is detailed in lighting design books

Lighting manufacturers' catalogues give factors for standard conditions.

The UF is expressed as a number which is always less than unity

A typical value might be 0.9 for a modern office building.



LIGHTING DESIGN CALCULATION

Utilization factor

Calculation of Room Index (RI)

$$\text{Room Index (RI)} = \frac{l \times b}{h_{wc}(l + b)}$$

l :length of the room

b :width of the room

h_{wc} :height between work plane to ceiling



LIGHTING DESIGN CALCULATION

Utilization factor

Example of table given by the luminaire manufacturer to calculate UF

Room reflectance			Room index								
Ceiling	Wall	Floor	0.75	1.00	1.25	1.50	2.00	2.50	3.00	4.00	5.00
0.70	0.50	0.20	0.43	0.49	0.55	0.60	0.66	0.71	0.75	0.80	0.83
	0.30		0.35	0.41	0.47	0.52	0.59	0.65	0.69	0.75	0.78
	0.10		0.29	0.35	0.41	0.46	0.53	0.59	0.63	0.70	0.74
0.50	0.50	0.20	0.38	0.44	0.49	0.53	0.59	0.63	0.66	0.70	0.73
	0.30		0.31	0.37	0.42	0.46	0.53	0.58	0.61	0.66	0.70
	0.10		0.27	0.32	0.37	0.41	0.48	0.53	0.57	0.62	0.66
0.30	0.50	0.20	0.30	0.37	0.41	0.45	0.52	0.57	0.60	0.65	0.69
	0.30		0.28	0.33	0.38	0.41	0.47	0.51	0.54	0.59	0.62
	0.10		0.24	0.29	0.34	0.37	0.43	0.48	0.51	0.56	0.59
0.00	0.00	0.00	0.19	0.23	0.27	0.30	0.35	0.39	0.42	0.46	0.48



LIGHTING DESIGN CALCULATION

Maintenance factor

This factor depends on the maintenance staff of the building. In general it is taken as 0.8 -0.9.

$$MF = \frac{\text{lumens of lamp after some time}}{\text{lumens of lamp when new}}$$

Room classification	Lamp maintenance factor	Maintenance factor for dirty lamp	Total maintenance factor
Very clean	0.9	0.85	0.85-0.9
Clean	0.9	0.9	0.8
Average	0.9	0.8	0.7
dirty	0.9	0.7	0.6



LIGHTING DESIGN CALCULATION

Example

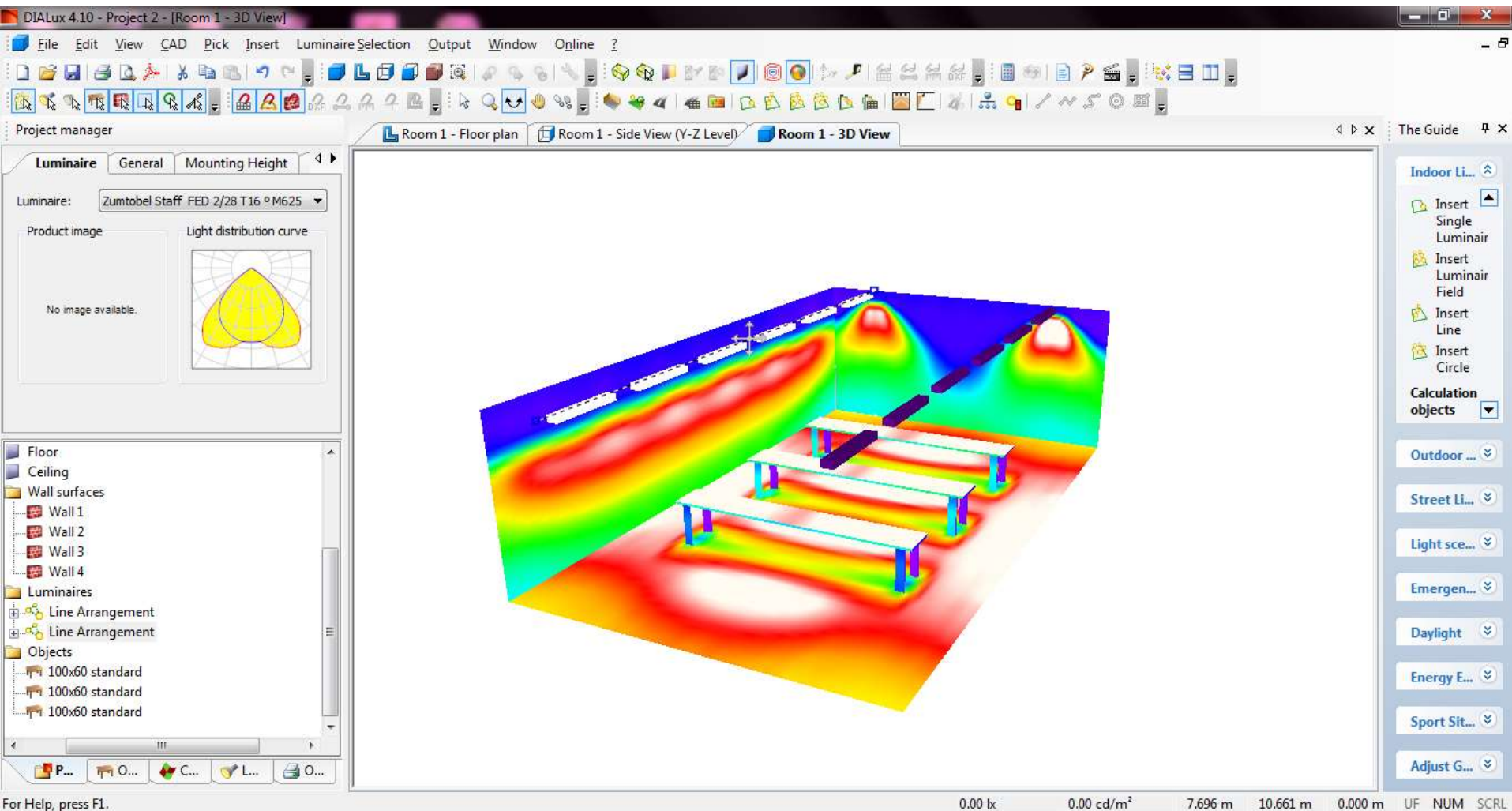
It is proposed to illuminate an office of dimensions 9 x 8 x 3m to an illuminance of 250 lx at the desk level. The specification calls for luminaires having one 1200mm 58W fluorescent natural tube with an initial output of 4100 lumens. You can consider the room is clean. The UF given by the manufacturer is 0.9.

$$N = \frac{250 \text{ lx} \times 9 \times 8}{4,100 \times 0.8 \times 0.9} = 6.1$$

7 luminaires are needed



ARTIFICIAL LIGHT



For Help, press F1.



NATURAL LIGHT CALCULATION

Natural Light Sources

- All natural light emanates from the sun, either being direct light or diffuse light.
- The illuminance provided by a bright sunny sky may be as much as 100,000 lux, though light of this intensity often causes glare and overheating.
- In the UK much of the light entering buildings is diffuse.
- The nature and brightness of the sky affects the quality of light inside a building. It is necessary to have a mathematical model to describe the sky.
- In general the standard sky model used in lighting design represents an overcast sky. The model is the uniform standard sky. Considered 5,000 lux as a design value in the UK.



NATURAL LIGHT CALCULATION

Daylight Factors

The quantity of daylight inside a room varies with the brightness distribution of the sky

Daylight factor (DF) is defined as the ratio of the actual illuminance at a point in a room (lux) and the illuminance available from an identical unobstructed sky

$$DF = \frac{E_i}{E_0} \times 100$$

E_i: Interior Illuminance

E₀: Exterior illuminance

for example, if the daylight factor inside a room is 2% and the illuminance of the sky is 8000 lux then the illuminance at the point inside the room is: 0.02 x 8000= 160 lux.



NATURAL LIGHT CALCULATION

The Daylight Factor and the light inside a room is made up of three separate components:

- The sky component – light arriving at a point in a room coming directly from the sky
- The externally reflected component – light arriving at a point in a room reflecting into it from an external obstruction
- The internally reflected component – light arriving at a point in a room having been reflected from an internal surface.

These three components can be recorded and added to give the overall daylight factor.



NATURAL LIGHT CALCULATION

Recommended Daylight Factors

Location	Average Daylight Factor (%)	Minimum Daylight Factor (%)	Working Plane
General Office	5	2	Desks
Classroom	5	2	Desks
Entrance Hall	2	0.6	Working plane
Library	5	1.5	Tables
Drawing Office	5	2.5	Boards
Sports Halls	5	3.5	floor



NATURAL LIGHT CALCULATION

Assessment of Daylight Factors

Inside an existing building daylight factors can be measured directly using a photometer which gives a direct reading of the daylight factor.

In the design stage, daylight factors can be predicted using:

- Design tables
- Waldram diagram
- Computer programs
- Scale models
- Daylight factor protractors.



Combined natural and artificial light (PSALI)

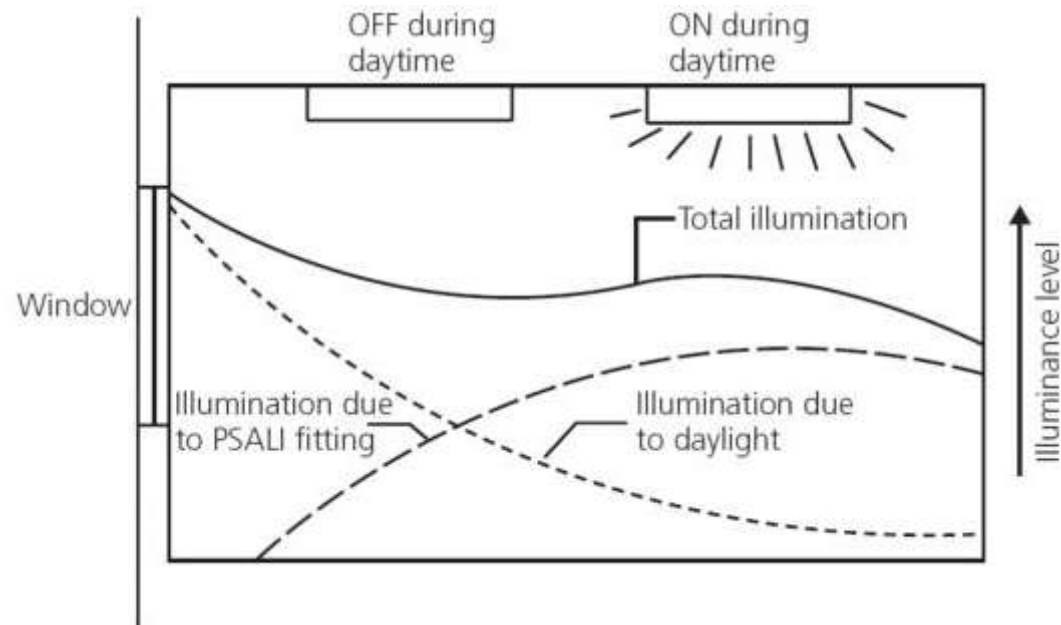
PSALI – Permanent Supplementary Artificial Lighting of Interiors

Provide an even illumination. That appears to be of good daylight character

Daylight illumination increases gradually towards the windows.
Supplementary illumination is provided by choosing a design lighting level and subtracting the contribution of daylight

The lamps used should match natural light in colour appearance

Lights are switched on and off as daylight levels go up and down (phot-electric switching)





A summary of Part L2

Area of Application	Minimum Requirement
General lighting in office, industrial and storage areas	60 luminaire lumens per circuit Watt
General lighting in other types of space	60 lamp lumens per circuit Watt
Display lighting	22 lamp lumens per circuit Watt

It is not necessary for individual luminaires to meet 60 luminaire lumens per circuit Watt, giving the designer flexibility to use a mix of technologies that average 60 lm/cW



CONTROL FACTORS

Proposed for two different situations:

- daylit spaces with daylight linked lighting control, either photoelectric or local manual
- infrequently occupied spaces with absence detection. Here a sensor switches off the lighting after it detects the absence of occupants, but switching on is done manually.

The purpose is to improve flexibility of designer and encourage energy savings



CONTROL FACTORS

$$\phi_{lum} = \frac{1}{P} \sum \frac{LOR \times \lambda_{lamp}}{CF}$$

ϕ_{lum} = the luminaire efficacy (luminaire lumens/circuit Watt)

L.O.R = the light output ratio of the luminaire

λ_{lamp} = the sum of the average initial (100hour) lumen output of all the lamp(s) in the luminaire

P = the total circuit watts for all the luminaires

CF = the lighting control factor.



Building Regulations Part L2. Control Factors

Light output control	Control factor	Result of applying control factor
(A) Daylit space with daylight sensors with or without override	0.90	54 luminaire lumens per circuit Watt
(B) Daylit space with daylight sensors and dimming with or without override	0.85	51 luminaire lumens per circuit Watt
(C) Unoccupied space with auto on and off	0.90	54 luminaire lumens per circuit Watt
(D) Unoccupied space with manual on and auto off	0.85	51 luminaire lumens per circuit Watt
(E) Space not daylit, dimmed for constant illuminance	0.90	54 luminaire lumens per circuit Watt
A+C	0.80	48 luminaire lumens per circuit Watt
A+D	0.75	45 luminaire lumens per circuit Watt
B+C	0.75	45 luminaire lumens per circuit Watt
B+D	0.70	42 luminaire lumens per circuit Watt
E+C	0.80	48 luminaire lumens per circuit Watt
E+D	0.75	45 luminaire lumens per circuit Watt