

Chapter 7: Lifecycle analysis and lifecycle costs

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7 Lifecycle analysis and lifecycle costs

7.1 Lifecycle analysis

Lifecycle analysis (LCA) gives an overview of the cradle to grave. It considers also how much solid, generated in each stage of the product's life. (GDR

energy and raw materials use of a product from liquid and gaseous waste and emissions are (GDR C2009)

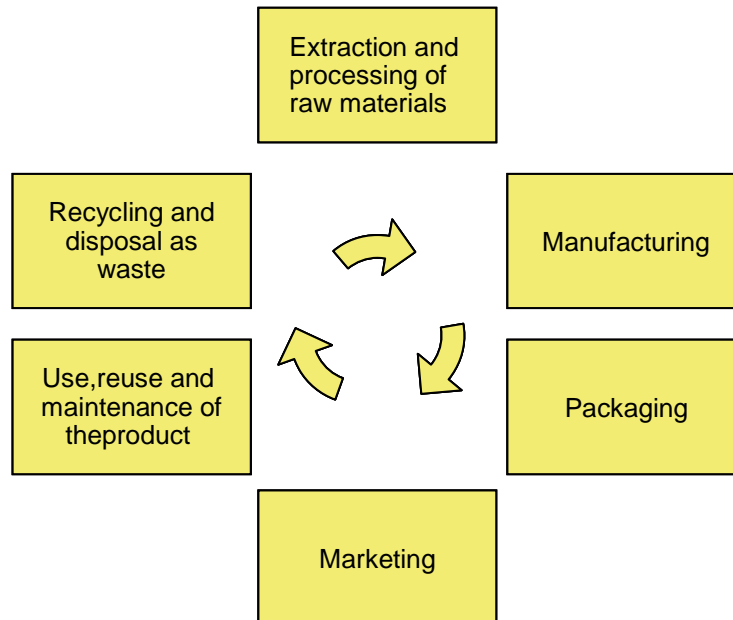


Figure 7-1. A principle schematic of a lifecycle analysis.

This scope definition is very crucial in LCA. It defines what is included in the analysis. For example, are transports or mining of the raw materials included, does the analysis concentrate on a specific lifecycle phase, or is the whole lifecycle considered. The energy resources used in the operation phase is very important to be defined. Usually, the energy use in operation phase causes the largest environmental impacts of the whole lifecycle, especially when it comes to energy-using products, such as lighting equipment.

The LCA is a useful tool in environmentally conscious product design. The results of the LCA can be used to compare products or technologies, and the results indicate on what to concentrate in ecodesign. The results of an LCA are often given as environmental impact categories or as the so-called single scale indices. Environmental impact categories are for example primary energy, toxicological impacts, global warming potential and acidification potential. These allow the comparison from the point of view of a single type of environmental impact. Single scale indices weigh different environmental impacts and calculate them into one score to describe the total environmental performance of a product. This makes the comparison of the total environmental impact of product easier. Single scale indices are for example Ecoindicator'99 and CML2001. The Ecoindicator'99 concentrates on respiratory effects and climate change, whereas the CML2001 emphasizes global warming and acidification. (Eco-I

In the following examples the environmental effects of different lamp types are compared on a general level. The comparison is made regarding the impact categories of single scale indices. This makes the analysis very simple and the comparison easy.

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In an early study by Gydesen and Maimann (1991), the energy consumption of a 15 W CFL and a 60 W incandescent lamp is compared for the production, operation and disposal phases. The lifetimes were 8000 h for CFL and 1000 h for incandescent lamp, respectively. The energy used was also calculated against the light service the lamps provide in lumen hours. The results showed that CFL consumes 17 kWh/Mlmh and incandescent lamp

consumes 82 kWh/Mlmh.

Table 7-1. Energy consumption and emissions during lifecycle of CFL and incandescent lamp. (Gydesen and Maimann 1991)

	15W CFL	60W GLS
Energy consumption & quantity of light		
Production	1.4 kWh	0.15 kWh
Use	120 kWh	60 kWh
Disposal	0 kWh	
Total	121 kWh	60 kWh
Energy consumption per Mlmh		
Production	0.19 kWh	0.21 kWh
Use	17 kWh	82 kWh
Disposal	0 kWh	
Total	17 kWh	82 kWh

	15W CFL	60W GLS
Production and use		
CO ₂	14.4 kg	70.0 kg
SO ₂	0.11 kg	0.53 kg
NO _x	0.07 kg	0.35 kg
CH ₄	0.05 g	0.25 g
flyash	0.82 kg	4.00 kg
mercury	1.00 mg	4.86 mg
gaseous/solids split	0.40/0.60	1.94/2.92
Disposal		
mercury	0.69 mg	
solid waste	0.015 kg	0.042 kg
Total mercury	1.69 mg	4.86 mg
Total solid waste	0.83 kg	4.04 kg

The mercury content in operation was achieved by asuming that the electricity is produced with coal power plant. The amount of mercury and other emissions from electricity generation depend on the electricity generation system that differs country by country.

The European Lamp Companies Federation has published environmental impact assessment of lamps on their webpage. According to that 90% of the energy is consumed during the operation phase. In other phases, energy is consumed as follows: resource 4%, production 5% and transport 3%, and disposal releases 2% (ELC 2009).

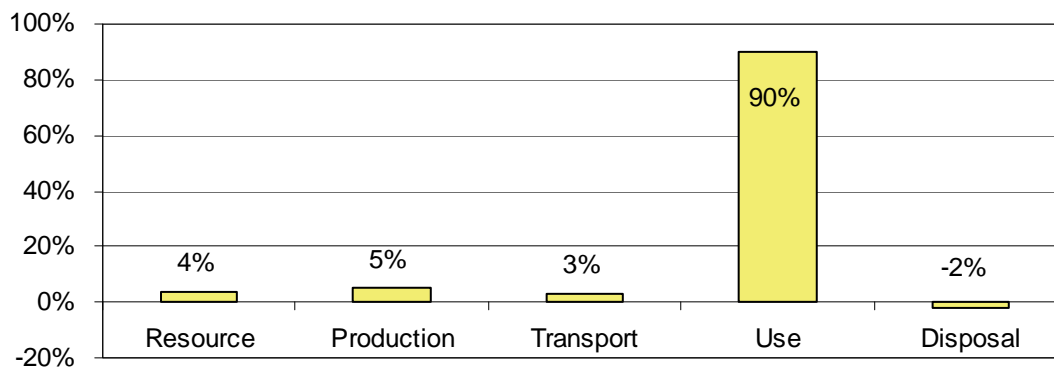


Figure 7-2. Lamp energy consumption during lifecycle according to European Lamp Companies Federation (ELC 2009).

Preliminary data of Osram on LEDs life cycle assessment show that only 2% of total energy consumed by LED based lamps is used in their production.

In the life cycle analysis of light sources the environmental impacts are assessed in raw material production, manufacturing, distribution, use / consumption and disposal through fifteen environmental indicators. One of the indicators is the Global Warming Potential (GWP), which is measured in kilograms of carbon dioxide (CO_2) equivalents. In the use phase the GWP indicator is measured by the power consumption. In the following the percentage is the GWP impact of these calculated over the total GWP impact for different light sources systems. (DEFRA 2009).

- integrally ballasted LED lamp, 93.3%
- dedicated LED luminaire system, 97.3%
- ceramic metal halide luminaire system, 98.7%
- T5 luminaire system, 97.7%
- integrally ballasted compact fluorescent lamp, 97.7 %
- general service incandescent lamp, 99.7%.

7.2 Calculation of lighting energy

The total lighting energy used by a lighting system (lamps, ballasts and luminaires), on the lighting design depends, in addition to the used equipment design and the room itself. The efficiency of the lamps can be defined as luminous efficacy (lm/W). The ballast losses define the efficiency of the ballast and luminaire output ratio (LOR) defines the efficiency of the luminaire. The lighting design has an effect on the position of the luminaires (related e.g. to working desk), the illuminance, illuminance distribution and maintenance. Also the room has an effect on the illuminance, since part of the light comes to the working desk through reflections. An extreme example of this is indirect lighting in which all the light is reflected through the ceiling and wall to horizontal surfaces. The shape of the room, height (luminaire distance from horizontal plane) and the surface reflectances (related to colors) together with the luminous distribution of the luminaire affect the illuminance and illuminance distribution in the room.

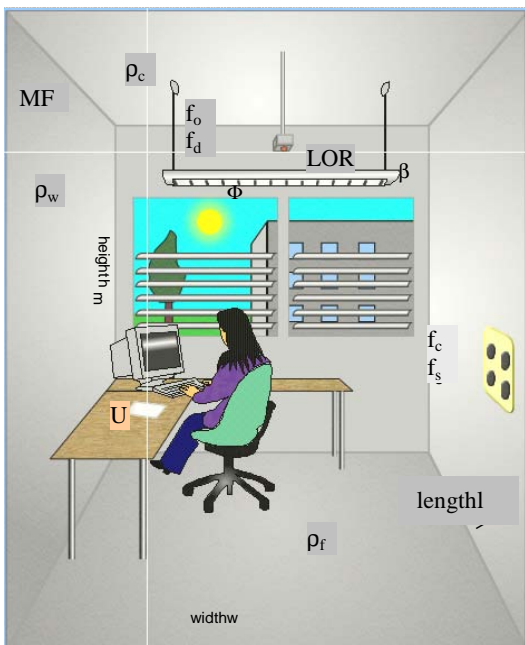


Figure 7-3 shows the factors affecting the total lighting energy consumption in a room. The efficiency of the luminaire (light output ratio) is represented by the symbol LOR . The utilance U describes the amount of luminous flux reaching the task area divided by the luminous flux of the luminaires. The utilance is affected by the luminous intensity distribution of the luminaire, reflectances of the room surfaces (ρ_c, ρ_w, ρ_f), width (w) and length (l) of the room and the distance between the workplane and the luminaires (h_m). The lumen maintenance factor (MF) includes the lumen depreciation of the lamps and the depreciation caused by contamination of luminaire and the room surfaces. The energy consumption can be reduced by dimming the lights according to daylight (f_d). Lights can be controlled also by an occupancy sensor (f_o), a switch (f_s) or a dimmer (f_c) in the room.

Figure 7-3. Factors affecting the total energy usage of lighting.

Reducing the installed power of a lighting system represents only one part of the lighting energy saving opportunity. Lighting energy consumption can also be decreased by reducing the use of power by using lighting controls systems. This can be done by the application of occupancy sensors,

and automatic switching and dimming according to the availability of daylight. The total energy consumption can be calculated, if the total installed power is known.

$$W = \sum P t f \quad (7-1)$$

where

W energy consumption, kWh
 P installed power, W
 t annual burning hours, h
 f control factor, which takes into account both the dimming and switch-off periods.

The average illuminance is luminous flux per illuminated area. Part of the luminous flux of the lamps is blocked by the luminaire while part of the luminous flux reaching the task area is reflected from the room surfaces.

The average illuminance of the room is

$$E = MF \cdot \eta \frac{N\Phi}{A} \quad (7-2)$$

where

E average illuminance, lx
 MF maintenance factor (product of lamp lumen depreciation and contamination of the luminaire and room surfaces)
 η utilization factor (product of luminaire light output ratio and utilization of the room).
 N number of the luminaires
 Φ luminous flux of the lamp in one luminaire, lm
 A area of the room, m²

The total luminous flux of the luminaires ($N\Phi$) is the product of system luminous efficacy (η_ϕ) and installed power (P) i.e. $N\Phi = \eta_\phi P$. Inserting this in Equation (7-2) leads to:

$$P_A = \frac{P}{A} = \frac{E}{MF \cdot \eta \eta_\phi} \quad (7-3)$$

where

P_A lighting power density in a room, W/m²
 η_ϕ system luminous efficacy (lamp luminous efficacy including ballast losses), lm/W

Equation (7-3) is used to calculate power densities as a function of light source luminous efficacy in Figure 7-4. With T5 lamps the luminous efficacy of the system is 90 lm/W and 500 lx can be reached with installed power density of 15 W/m². With CFLs the power density would be about 27 W/m².

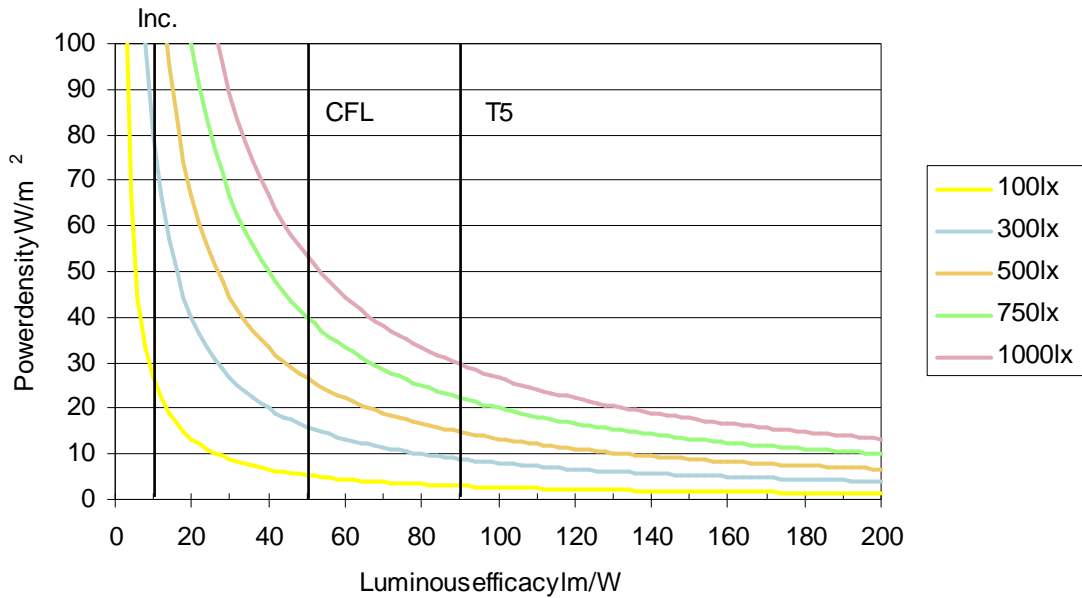


Figure 7-4. Power density (W/m^2) as a function of light source luminous efficacy (lm/W) at different illuminance levels (lx), maintenance factor $MF=0.75$ and utilization factor $\eta=0.5$.

Figure 7-5 shows the effects of maintenance factor MF and utilization factor η on power density. In the calculations illuminance has been 500lx and to achieve the desired illuminance level of 500lx with maintenance factor is higher than 0.90 and the utilization factor is higher than 0.80.

MF and utilization factor η on power density. In m pluminous efficacy 80lm/W. It is possible to h p power densities of less than $10W/m^2$, when the ization factor is higher than 0.80.

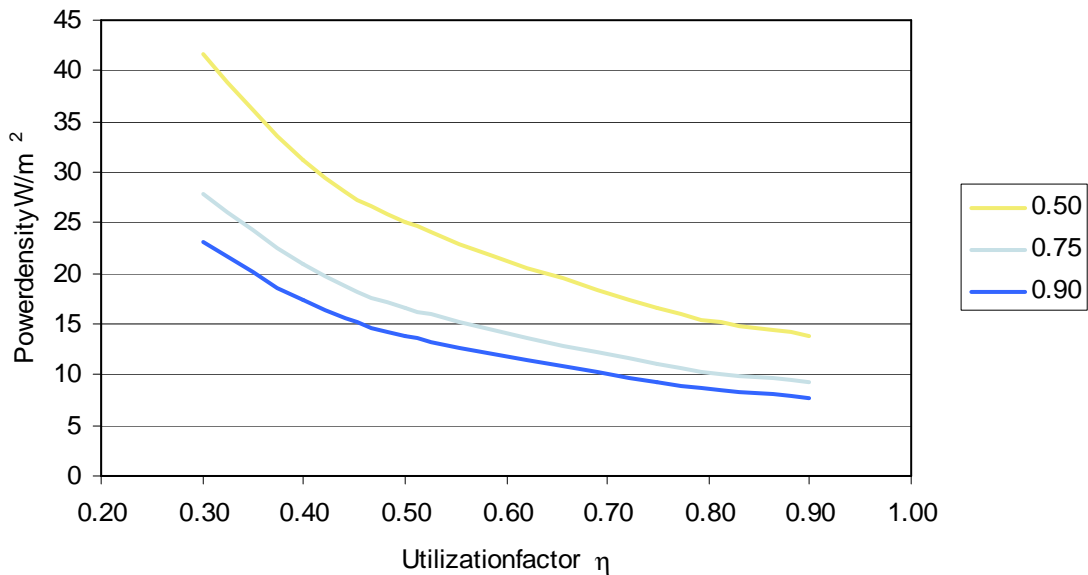


Figure 7-5. Power density (W/m^2) as a function of utilization factor at different maintenance factor values ($MF=0.50, 0.75, 0.90$), calculated for illuminance $E=500lx$ and system luminous efficacy $\eta_{\phi}=80lm/W$.

Normalized power density

Hanselaer *et al.* (2007) defined the normalized power density NPD by dividing the installed power by the maintained luminous flux on the task area (in units of 100lm or 100lx, m^2) as:

$$NPD = \frac{P_{sys}}{\Phi_{TA}^{fin}} [W / m^2 \cdot 100lx] = \frac{100}{MF \cdot U \cdot LOR \cdot \eta_{lamp} \cdot \eta_{gear}} \quad (7-4)$$

Where

NPD normalised power density, $W/(m^2 \cdot 100lx)$
 P_{sys} total system power, lamps, ballasts, etc., W
 Φ_{TA}^{fin} maintained luminous flux on the task area, lm
 MF maintenance factor, ratio of the average illuminance on the working plane after a certain period of use of lighting installation to the initial average illuminance
 U utilisation, relates the luminous flux from the luminaires to the luminous flux on the target area
 LOR Light Output Ratio or the efficiency of the luminaire
 η_{lamp} initial luminous efficacy of the lamp, lm/W
 η_{gear} efficiency of the control gear

According to Hanselaer *et al.* (2007) the target values for efficient lighting installations are $\eta_{gear} > 0.84$, $\eta_{lamp} > 70 lm/W$, $LOR > 0.75$, $MF > 0.75$, $U > 2 / (1 + 0.5(A_{nTA}/A_{TA}))$. A_{TA} is the task area and A_{nTA} the total non-task area. In defining the utilisation, it is supposed that the mean initial illuminance on the non-task area is lower than the initial illuminance on the task area.

7.3 Economic evaluation of lighting

For economic evaluation of different lighting solutions, a life cycle cost analysis has to be made. This means, that all cost categories including initial and variable costs must be considered over the lifetime of the whole lighting installation. Initial costs are e.g. costs for the lighting design, lighting equipment, wiring and control devices, and the labour for the installation of the system. Variable costs may include replacement of the burnt out lamps (relamping), cleaning, energy, replacement of other parts (reflectors, lenses, louvers, ballasts, etc.) or any other costs that will be incurred.

Usually, only the installation costs are taken into account. People are not aware of the variable costs. In commercial buildings the variable costs are often paid by others who rent the apartment, and the initial costs are usually paid by the investor who makes the system decisions. The energy costs of a lighting installation during the whole life cycle are often the largest part of the whole costs.

Costs

Initial costs

The initial costs are the investment costs, which can be converted to annual costs by multiplying them by the capital recovery factor.

$$C_I = I \times \frac{i(1+i)^n}{(1+i)^n - 1} \quad (7-5)$$

where

C_I annual costs of the initial investment, €
 I investment cost (initial costs of equipment, design, installation, etc.), €
 i interest rate ($i = p/100$, where p is interest rate in percentage)
 n number of years (service life of lighting installation).

Variable costs

The variable costs consist of maintenance costs and energy costs and lamp replacement costs. The service costs. The maintenance costs include cleaning and repair of luminaires. The service costs can include, for instance, the costs of

Energy costs C_e

Energy costs are calculated by multiplying the total power of the lighting installation by annual burning hours and the price of electricity.

$$C_e = n_{lu} c_e t P 10^{-5} \quad (7-6)$$

where

- C_e energy costs, €
- n_{lu} number of the luminaires
- c_e price of electricity/kWh
- t annual burning hours, h
- P power of the luminaire, lamp and ballast, W.

Lamp costs C_L

The annual lamp costs are calculated by multiplying the lamp price by the quotient of the annual burning hours and lamp life (t/t_{LL}). Instead of the quotient also the capital recovery factor can be used. This is reasonable if t/t_{LL} is small, i.e. either the burning hours are small or the lamp life is long.

$$C_L = n_L c_L (t/t_{LL})(1+k) \quad (7-7)$$

where

- C_L annual lamp costs including the lamps for spot relamping, €
- n_L number of the lamps
- c_L price of a lamp, €
- t burning hours, h
- t_{LL} lamp life, h
- k average mortality during lamp group replacement period, %.

Group replacement costs C_G

If lamps are changed by group replacement, the replacement period can be chosen based for example on 30% decrease of illuminance due to lumen depreciation and lamp mortality. Fluorescent lamps contain mercury and therefore the replacement costs have to include also the disposal of the old lamps.

$$C_G = n_L c_G / T \quad (7-8)$$

where

- C_G annual group replacement cost, €
- n_L number of the lamps
- c_G group replacement costs per lamping group replacement including lamp disposal, €
- T group replacement period in years, a.

Spot replacement costs C_S

$$C_S = n_L c_s k / T \quad (7-9)$$

where

C_S	annual spot replacement costs, €
n_L	number of the lamps
c_s	spot replacement costs per lamp in spot replacement including lamp disposal, €
k	average mortality during lamp group replacement period, %
T	group replacement period in years, a

Service cost

Service costs result from the cleaning and repair of luminaires and in dirty conditions also from the cleaning and/or painting of room surfaces. Service costs are very dependent on the circumstances. If the lamps and luminaires are cleaned on a regular basis, for instance combined with the group replacement, then the annual cleaning costs can be calculated by dividing the work and material costs by the cleaning period.

$$C_C = n_L (c_c + c_m) / t_c \quad (7-10)$$

where

C_C	annual cleaning costs, €
n_L	number of the lamps
c_c	work costs of cleaning per lamp, €
c_m	material costs of cleaning per lamp, €
t_c	cleaning period in years, a.

Example of the use of equations

In the following the energy costs C_e and lamp costs C_L using different lamps are calculated. The lamps are incandescent (Inc.), compact fluorescent (CFL) and LED lamps. Since the price of the lamps is quite different, the lamp costs have been calculated by using the capital recovery factor, Equation (7-5). The service life (number of years n) is one year for incandescent, three years for CFL1 and five years for CFL2, LED1 and LED2 lamps. The actual service life of, for example, LED2 is much longer than five years, taking the annual burning hours of 2000 h and lamp life of 50000 hours. The service life of LED2 would be 25 years and the initial costs only 3.55 €. However, due to service life of five years used in the calculations, the initial costs for LED2 are 11.55 €. Table 7-2 shows the initial values used for calculations. With incandescent lamp, another lamp costs of 1.05 € has been added after 1500 hours, 2500 hours and again after 3500 burning hours.

Table 7-2. Initial values for calculation of energy costs and lamp costs and the results of the calculations for different lamp types.

Initial Values	GLS	CFL1	CFL2	LED1	LED2
c_e price of the electricity, c/kWh	15	15	15	15	15
P power of the lamp, W	60	15	15	15	10
c_L price of the lamp, €	0.5	5	10	20	50
t_{LL} lamp life, h	1000	6000	12000	20000	50000
t annual burning hours	2000	2000	2000	2000	2000
k mortality, %	0	0	0	0	0
i interest rate	0.05	0.05	0.05	0.05	0.05
n service life (number of years)	1	3	5	5	5
Calculated values					
C_I Initial costs, €	0.53	1.84	2.31	4.62	11.55
C_e Energy costs, €	18.00	4.5	4.5	4.5	3.00
C_L Lamp costs, €	1.05	1.84	2.31	4.62	11.55

Figure 7-6 shows the effect of annual burning hours on the lamp and energy costs. When using the service lives of 3 years and 5 years, the total costs for CFL1 are 4 € and for CFL2 4.50 €, and for incandescent lamp 9.50 € with 1000 annual burning hours.

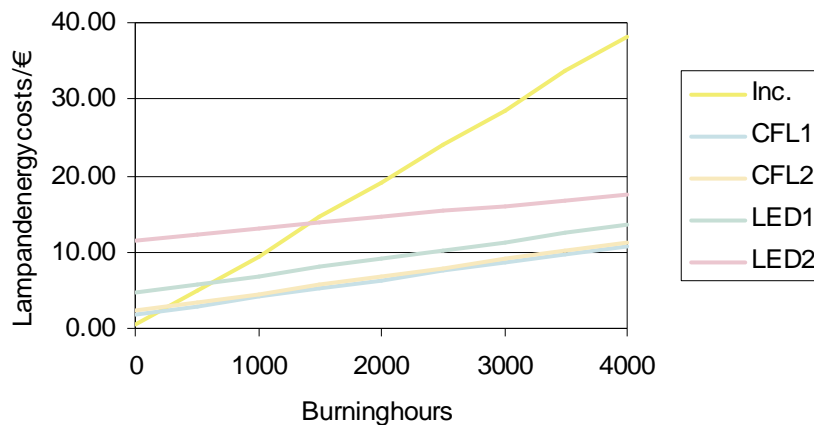


Figure 7-6. Combined lamp and energy costs as a function of annual burning hours for different lamp types.

Figure 7-7 shows the distribution of lamp costs and energy costs with 2000 burning hours. In case of the incandescent lamp, two lamps are used during this period. With LED1 annual energy costs and lamp costs are almost equal, 4.50 € and 4.62 €. The price of the LED1 lamp is 20 € and the service life is five years. The price of electricity is 15 c/kWh and the power of the lamp is 15 W. With CFL and Incandescent lamps the energy costs are dominating.

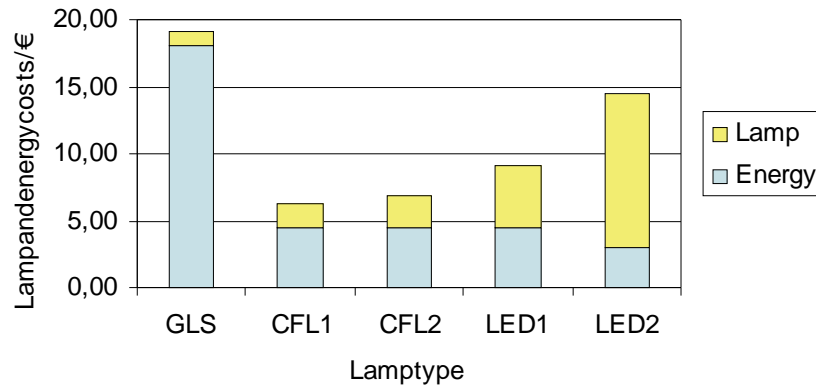


Figure 7-7. Lamp and energy costs of different lamp types with 2000 annual burning hours.

Other considerations

- The electric energy for lighting is an internal heat gain in a room. In winter peaking regions (cold areas) it can be utilized for heating, but in other regions and in summer time it will increase the need for cooling energy.
- If the lighting is dimmed, for instance according to daylight, this will decrease the energy consumption. With fluorescent lamps even if the luminous flux is on the minimum level (1% to 5%) the system energy consumption is still about 20%.
- Lighting control strategies can help to save energy. If fluorescent lamps are switched off regularly, this will save energy, but it will shorten the lamp life and thus increase the lamp and replacement costs. Calculations show that generally it is economical to switch off fluorescent lamps when the switch off time is 15 minutes or longer.

Maintenance

All system components age by time and must be replaced at certain periods (before dropping out). Lamp performance decreases over time before failure (Figure 7-8), and dirt accumulations on luminaires and room surfaces decrease the utilization factors. The lack of maintenance has a negative effect on visual perception, task performance, safety and security, and it wastes energy as well. Both aging and dirt accumulation can reduce the efficiency of a whole lighting installation by 50% or even more, depending on the application and equipment used. The following measures should be defined by a regular maintenance schedule:

- Cleaning of luminaires, daylighting devices and rooms (dirt depreciation)
- Replacement of burned out lamps
- Replacement of other parts (e.g. corroded reflectors)
- Renovation and retrofitting of antiquated systems and components.

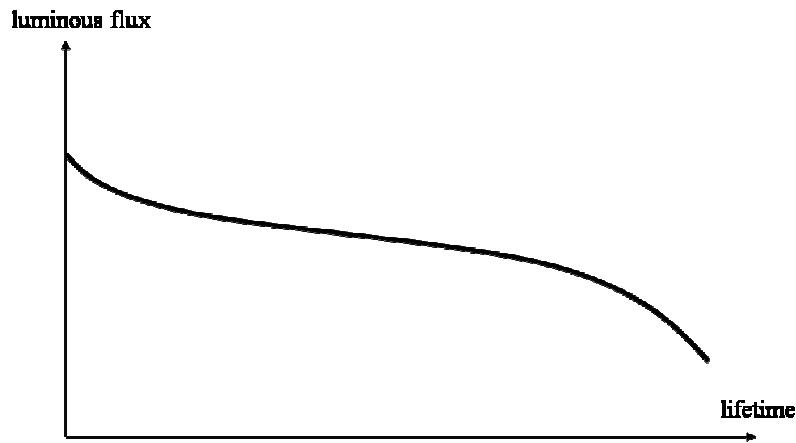


Figure 7-8. Lamp luminous flux depreciation during lifetime (principal sketch).

7.4 Examples of lifecycle costs

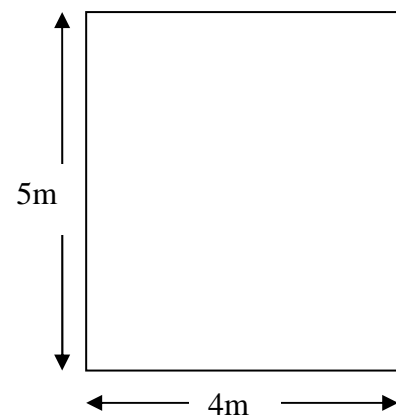
A simple appraisal with very common parameters (assumptions) for two lighting examples (shop lighting and office lighting) shows the LCC dimensions.

The following terminologies are used in the examples:

E	average illuminance, lx
MF	maintenance factor, including lamp lumen depreciation and dirt accumulation on luminaires and on room surfaces
η	utilization factor (product of luminaire light output ratio and utilization of the room)
Φ	luminous flux of the lamps in one luminaire, lm
A	area of the room, m^2
W	energy consumption, kWh
P	installed power, W
t	annual burning hours, h

Shop lighting

Required illuminance	$E=1000\text{lx}$
Dimensions	$A=4\text{m}\times 5\text{m}=20\text{m}^2$
η	0,6
MF	0.67(acc.to DIN12464)
t	3000h
lamptype	HCI-T35W \rightarrow 3500lm
power(perluminaire)	40W \rightarrow 87.5lm/W



Simple calculation without maintenance and relamping costs

$$\begin{aligned} \Phi &= E \cdot A / (\eta \cdot MF) = 49.8 \text{ klm} \\ \text{fort} &= 3000 \text{ h} \rightarrow 149 \text{ Mlmh} \\ P &= 49.8 \text{ klm} / 87.5 \text{ lm/W} = 569 \text{ W} \rightarrow 28 \text{ W/m}^2 \\ \text{fort} &= 3000 \text{ h} \rightarrow W = 1700 \text{ kWh} \rightarrow 85 \text{ kWh/m}^2, a \end{aligned}$$

Installation costs	100 €/m ²
Energy consumption	85 kWh/m ^{2, a}
Costs for electricity (0.15 €/kWh price)	12.75 €/m ^{2, a}
Costs for electricity for 10 years	127 €/m ²

Present value of a growing annuity

Present value of an annuity is a series of equal payments or receipts that occur at evenly spaced intervals that occur at the end of each period. In the present value of a growing annuity (PVGA) there is a rate of growth of the annuity. Annuity is the payment in the first period.

$$PV(a) = \frac{a}{i-g} \left[1 - \left(\frac{1+g}{1+i} \right)^{n_p} \right]$$

where

$PV(a)$	value of the annuity at time = 0
a	value of the individual payments in each compound period
i	interest rate that would be compounded for each period of time
n_p	number of payment periods
g	increase in payments, each payment grows by a factor of $(1+g)$.

We can consider the previous example of shop lighting with the following assumptions.

Total lifecycle	24 years
Maintenance interval (cleaning and relamping)	3 years ($n_p = 8$)
Maintenance costs	22 €/m ²
Interest rate	6%
Electricity cost	12.75 €/m ² year ($n_p = 24$)
Electricity price increase	1%/5%

Present values of the total lifecycle costs are	
Installation	100 €/m ²
Electricity	175 €/m ² (1% annual increase)
Electricity	259 €/m ² (5% annual increase)
Maintenance	137 €/m ² (no annual increase)

Figure 7-9 shows the share of energy costs in the lifecycle costs. The calculation is done over 24 years. Figure shows two examples of the increase of the prices one with 1% annual increase in the electricity price and the other with 5% annual increase in the electricity price.

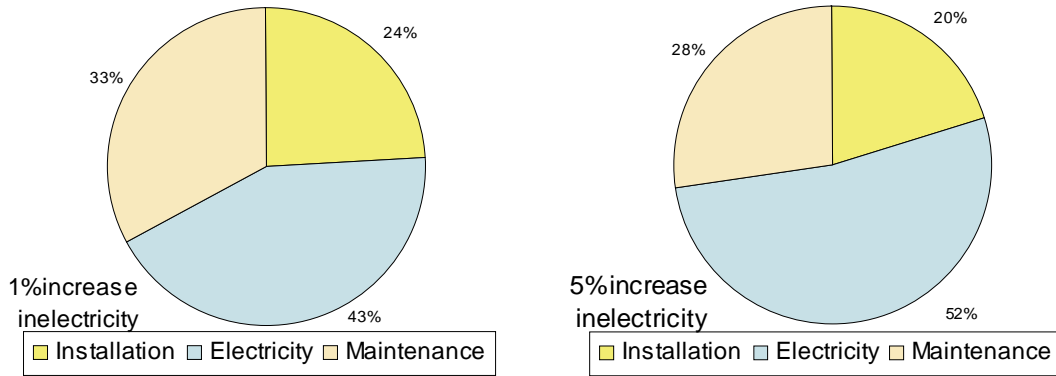
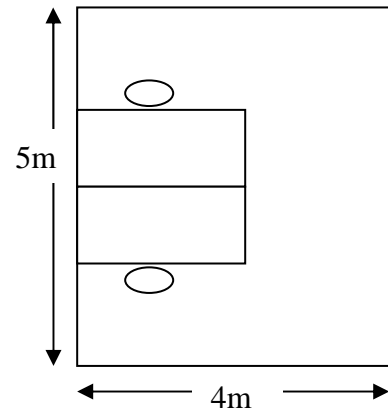


Figure 7-9. Distribution of costs [€/m²] for shop lighting during lifecycle of an installation (24 years). Increase of 1% (left) or 5% (right) of the price of electricity has been considered.

Office-lighting

Energy efficient office – low power density

Required luminance	500lx
Dimensions:	A=4m x 5m = 20m ²
η	0.7
MF	0.67 (acc. to DIN 12464)
t	2000h
lamp type	LFL 54W → 4450lm
power (per luminaire)	58W → 77lm/W



Simple calculation without maintenance and relampin g costs

$$\Phi = E \times A / (\eta \times MF) = 21 \text{klm}$$

$$\text{for } t = 2000 \text{h} \rightarrow 42 \text{Mlmh}$$

$$P = 21000 \text{lm} / 77 \text{lm/W} = 270 \text{W} \rightarrow 13.5 \text{W/m}^2$$

$$\text{for } t = 2000 \text{h} \rightarrow W = 540 \text{kWh} \rightarrow 27 \text{kWh/m}^2$$

Installation costs 31 €/m²

Energy consumption 27 kWh/m²,a
 Costs for electricity (0.15 €/kWh price) 4.05 €/m²,a
 Costs for electricity for 10 years 40 €/m²

Lifecycle costs with maintenance costs

Total lifecycle	24 years
Maintenance interval	6 years (n _p =4)
(cleaning and relamping)	
Maintenance costs	5 €/m ²
Interest rate	6%
Electricity cost	4.05 €/m ² ,a (n _p =24)
Electricity price increase	1%/5%

Present values of the total lifecycle costs are

Installation	31 €/m ²
Electricity	56 €/m ² (1% annual increase)
Electricity	82 €/m ² (5% annual increase)
Maintenance	20 €/m ² (no annual increase)

Figure 7-10 shows the share of energy costs in life cycle costs in office lighting. The calculation is done over 24 years. The figure shows two examples of the increase of the electricity prices; one with 1% annual increase in electricity, and the other with 5% annual increase in electricity price.

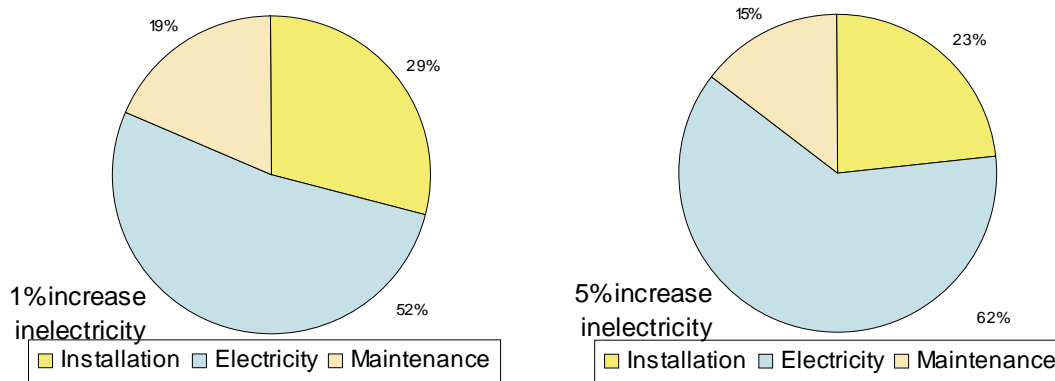


Figure 7-10. Distribution of costs [€/m²] for office lighting during life cycle of an installation (24 years). Increase of 1% (left) or 5% (right) of the price of electricity has been considered.

The standard EN 15193 defines limits for connected lighting power density. For office lighting the recommended power density is 15 - 25 W/m², ranging from basic requirements (15 W/m²) to comprehensive requirements (25 W/m²). In the following, costs for office lighting are calculated with power density of 25 W/m², and presented in Figure 7-11. The installation costs are 50 €/m².

Total life cycle	24 years
Maintenance interval (cleaning and relamping)	6 years (n _p =4)
Maintenance costs	5 €/m ²
maintenance costs increase	1%
Interest rate	6%
Energy consumption	25 W/m ² x 2000 h = 50 kWh/m ² year
Electricity cost	7.5 €/m ² year (n _p =24)
Electricity price increase	1%/5%

Present values of the total life cycle costs are	
Installation	50 €/m ²
Electricity	103 €/m ² (1% annual increase)
Electricity	153 €/m ² (5% annual increase)
Maintenance	20 €/m ² (no annual increase)

The increasing of the lighting power density up to 25 W/m² (maximum power density for office rooms according to EN 15193) increases the energy costs, Figure 7-11. When compared to Figure 7-10 an increased by about 85%.

25 W/m² (maximum power density for office-rooms) significantly compared to the installation related calculations, the electricity costs are

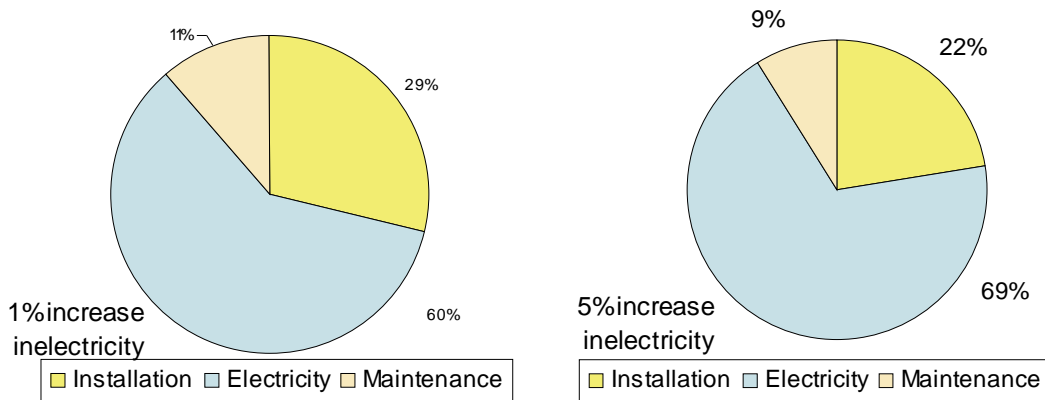


Figure 7-11. Distribution of costs [€/m²] for office lighting during lifecycle of an installation (24 years). Increase of 1% (left) or 5% (right) of the price of electricity has been considered. The lighting power density is 25 W/m².

Conclusions

There is lack of awareness of the fact that the variable costs (operation costs), especially the energy costs of a lighting installation during the whole life cycle, are mostly the largest part of the total costs, and that proper maintenance plans can save a lot of energy during the operating phase of the installation. Due to this lack of awareness in common practice, life cycle costs (LCC) and maintenance plans are very seldom put into practice. The calculations show that the management of LCC in the design phase can change the evaluation of different lighting solutions significantly. This adds weight to the energy aspects and thus influencing the final decision of the client to more energy efficient lighting solutions.

7.5 Long term assessment of costs associated with lighting and daylighting techniques

Fontoyne (2009) has studied financial data leading to the comparison of costs of various daylighting and lighting techniques over long time periods. The techniques are compared on the basis of illumination delivered on the work plane per year. The selected daylighting techniques were: roof monitors, façade windows, borrowed light windows, light wells, daylight guidance systems, as well as off-grid lighting based on LEDs powered by photovoltaics. These solutions were compared with electric lighting installations consisting of various sources: fluorescent lamps, tungsten halogen lamps and LEDs. Figure 7-12 shows the annual costs for various options (€/Mlmh).

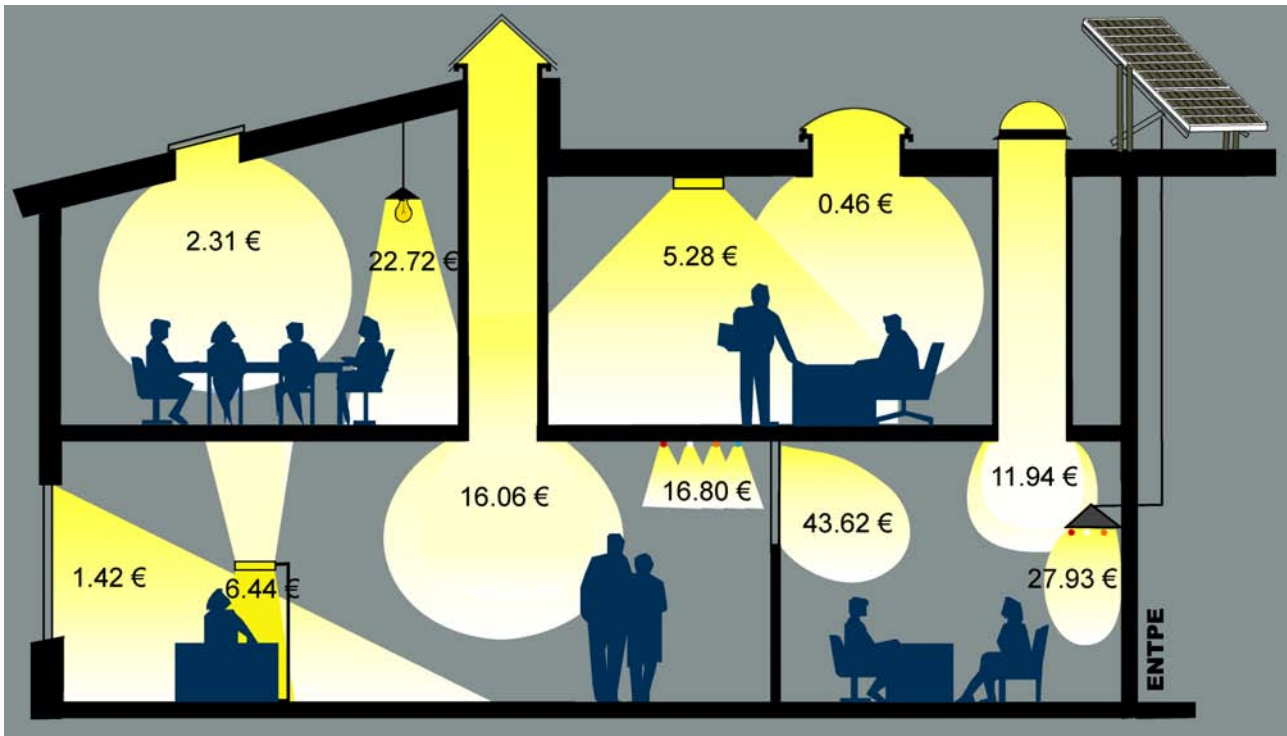


Figure 7-12. Annual costs for various lighting and daylighting techniques (Fontoynt 2009).

General results of the study were:

- Apertures in the envelope of the building are cost effective in directing light in the peripheral spaces of a building, mainly if they are durable and require little maintenance.
- Daylighting systems aimed at bringing daylight deep into a building are generally not cost effective, unless they use ready-made industrial products with high optical performance and low maintenance, and collect daylight directly from the building envelope.
- Tungsten halogen lamps, when used continuously for lighting, are very expensive and need to be replaced by fluorescent lamps or LEDs.
- Depending on the evolution of performance and costs of LEDs and photovoltaic panels, there could also be options to generalize lighting based on LEDs and possibly to supply them with electricity generated directly from photovoltaic panels.

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