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EFFECTIVENESS ANALYSIS FOR RELAMPING REGARD TO AN OVERALL COSTS

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Abstract: Light and lighting, with this need we encounter in everyday life. During the day, it fills this need sunlight but there are cases when it is necessary to illuminate interior spaces during the day. In another situation we face at night when it is necessary to illuminate indoor or outdoor spaces artificially. This need for interior lighting fills the artificial lighting and discipline that deals with the lighting is called lighting technique. Well as other industries also lighting, respectively lighting technology goes through the development of new technologies. This paper deals with lighting, specifically analyzing the effectiveness of relamping in terms of investment costs. The first part of the article is devoted to the basic theoretical knowledge of the field of lighting technology. Subsequently are characterized further light sources. The last part of the article is the analysis and compares costs for different light sources and from the perspective of the average and useful life.
Keywords: lighting, lamps, operating costs, capital costs, total costs

1. INTRODUCTION

Light and lighting, with this need we encounter in everyday life. During the day, it fills this need sunlight but there are cases when it is necessary to illuminate interior spaces during the day. In another situation we face at night when it is necessary to illuminate indoor or outdoor spaces artificially. This need for interior lighting fills the artificial lighting and discipline that deals with the lighting is called lighting technique. Well as other industries also lighting, respectively lighting technology goes through the development of new technologies.

As in the past, also now this development is dependent on the level of progress and knowledge. Increasing demands on lighting technology are directly proportional to the increasing demands on quality, efficiency and quantity of work performed. Claims for the light level increasing requirements for working and living environment. Significantly increase the scope and duration of such areas with artificial lighting. In contrast to this trend are the high demands on reducing energy intensity. To meet these conditions, it is necessary to improve the basic parameters of light sources (luminous efficacy, lifetime, color rendering index). This development is, however, limited light-technical standardization, which is constantly changing. Impact of these changes has been to restrict the sale of certain light sources which power density does not meet current requirements and their use is equal to wasting.

2. BASIC LIGHT-TECHNICAL PARAMETERS

Light is electromagnetic radiation that is capable of initialing visual perception through the eye. The light radiation can be characterized by frequency or wavelength. Visible radiation is a part of the optical radiation that the shorter wavelength follows the ultraviolet radiation and the longer wavelength side extends to the infrared radiation [1] [2]. The current light sources there to give light to the following principles:

- Thermal excitation arising on heating the solids at high temperatures,
- Excite an atom in an electric discharge,
- Luminescence of solids,
- Issuance of a photon passing current semiconductor [1].

As well as in other scientific disciplines also in the description of light radiation are used physical quantities and units. Among the basic quantities are luminous flux Φ that defines how much light energy radiated light source into the environment. The unit of luminous flux is lumen (lm) [1] [3]. Light intensity are among the other photometric quantities. Indicates the value of the luminous flux incident on unit area (1 m^2). The unit of illuminance is lux (lx) [1]. Brightness is the determination of the area and spatial density of luminous flux. For these reasons it depends on the observer's location and the direction of his view. Indicates the L and is given in ($cd \cdot m^{-2}$) [1].

At the light sources, it is necessary to verify what is the level of conversion of electrical energy into light energy. Luminous efficacy is the proportion of the luminous flux Φ and electric power P. Luminous efficacy determines what the value of the luminous flux can be obtained from a single watt.

In the case of lamps with control gear such as light bulbs or discharge lamps must be added also power consumption of gear, which is about 20% lamp power consumption.

For lamps, without gear, power density is given for a lamp with ballast is necessary to identify it [1].

$$\eta_P = \frac{\Phi}{P} \qquad (1)$$

where: η_p is the luminous efficacy ($lm.W^{-1}$), Φ is luminous flux (lm), P is the electrical power consumption (W).

In the following table gives an overview of luminous efficacy a variety of light sources.

Table 1. Overview luminous efficacy [1]

Light source	Electrical power consumption [W]	Luminous efficiency [lm.W-1]
Light bulb	15-200	6-15
Halogen bulb	10-2000	14-26
Compact fluorescent lamp	5-60	56-88
Linear fluorescent lamp T8	10-58	65-90
Linear fluorescent lamp T5	14-80	70-104
Induction lamp	50-400	70-93
Mercury vapor lamp	50-1000	50-80
High pressure sodium lamp	50-1000	88-150
Metal halide bulb	35-3500	94-103
Low pressure sodium lamps	18-180	130-200
Light emitting diode	1-20	up to 140

The human eye is naturally adapted to the sunlight. At the sunlight is eye used to seeing color. If the same object we highlight the lamp having a different spectral composition, there may be a different color interpretation. To determine the influence of light sources with different spectral composition on color perception was the introduction of a general color rendering index Ra. It expressed the degree of plausibility of color perception of the illuminated object. Index is expressed in numerical form 0-100. A value of 100 represents the color rendering conformity with thermal sources and the value is 0, the color cannot be distinguished [1].

Table 2. Overview lifetime of light sources [1]

Light source	Average lifetime [h]	Useful lifetime [h]
Light bulb	1000	1000
Halogen bulb	2000-3000	2000-3000
Compact fluorescent lamp	15000	6000-15000
Linear fluorescent lamp	20000	10000-18000
High-pressure mercury lamp	16000-24000	10000-20000
High pressure sodium lamp	32000	20000
Low pressure sodium lamps	16000	16000
Metal halide bulb	10000	4000
Induction lamp	60000	20000
Power LED	50000-100000	25000-50000
Xenon discharge lamps	1000-3000	1000-3000

An important parameter that takes into account in light sources is lifetime. This parameter tells us how long the lamp can light up. In the case for light bulbs, the service life due to marginal status, by blowing fibers. For other sources, such as discharge or LED light sources leads to functional maintenance of lumen output. After some time, despite the fact that the lamp stays on, the luminous flux is low and operation of such a lamp is uneconomical [1].

Thus, there are two kinds of life:

≡ Average lifetime - this life is given to the time when the light source can emit light energy [1].
≡ Useful lifetime - For this type of lifetime, distinguish stability of lighting parameters of light sources during operation [1].

The table 2 shows the approximate lifetime of individual lamps.

2.1. Energy intensity of lighting system

Energy intensity of lighting systems and operational costs, whether it is for indoor or outdoor spaces depends on the choice of luminaires and light sources. Currently are available on the market various lamp from different manufacturers, where you can choose the type of light source.

Difficulty of investment depends on the choice of the luminaire and the light source. Currently, the market experienced a huge expansion of LED lights. These luminaries are among the most modern the luminaire with excellent lighting parameters. Compared to classic conventional lighting equipment and light sources have a significant disadvantage namely of the higher price.

The following sections of this paper we compare the energy consumption of individual lamps. In all cases, we calculate the time of use a 5 hours per day.

2.2. Heat and halogen bulbs

The advantages of these lamps are simple structure, small size and weight, easy power and low cost [3]. A major disadvantage is that the transition of electricity tungsten filament is converted to 95% of electric energy into thermal energy. The remaining 5% is converted into light radiation [3] [4].

The principle of the halogen bulb is similar to the principle of ordinary light bulbs. Improvement is filling with addition of halogens inside the bank. The benefits of halogen bulbs include better efficiency, longer lifetime, resistance to temperature changes, higher color temperature [3] [4].

2.3. Compact fluorescent bulbs

Fluorescent lamps are low-pressure mercury lamps that emit light energy primarily in the ultraviolet region. This radiation is converted into visible energy using a luminophore. The principle lies in the excitation of mercury vapor in the space between the electrode and results in a non-visible ultraviolet light emission. On the inside of the bulb is coated special fabric luminophore that converts ultraviolet radiation to visible light [3] [4]. The advantages of compact fluorescent light bulbs include higher power density, higher efficiency lamps [3] [4]. A considerable disadvantage is lifetime these light sources, which is influenced by the number of start-up. Therefore it is not appropriate to use in places where there is frequent switching on or off the luminaire [3] [4].

2.4. Light-emitting diodes - LED

LEDs are electronic device that generates light rays in the transition of current thought semiconductor junction. Therefore it uses a different physical principle, such as in light bulbs or fluorescent lamps. Semiconductor junction emits a very narrow spectrum. The primary radiation is monochromatic [3] [4] [5]. LEDs are now high-performance light sources that are enforced instead of conventional light sources [6]. The disadvantage may be halved average lifetime compared to the useful lifetime life.

2.5. Effectiveness analysis for relamping when considering average lifetime and useful lifetime

For the analysis of the total cost lamping when considering the average and useful lifetime we will build from table 2. For the study sample we select a heat bulb, halogen, compact fluorescent and LED light-emitting diodes. For our case we will consider the time of day use five hours throughout the year. Total costs are made up of the cost of buying the light source and the price of electricity.

In the calculation we will be based on the following equations.

$$A = \frac{P \cdot t \cdot d}{1000} \tag{2}$$

$$C_1 = A \cdot c \tag{3}$$

$$C = C_1 + C_2 \tag{4}$$

where: A - is a unit of energy consumed (kWh), P - is the lamp wattage (W), T - time running lights (h), d - is the number of days of operation the luminaire with a given light source (-), C_1 - operating costs (€), c - is the cost of electricity per kWh (€ / kWh), C_2 - the cost of replacing the light source (€), C - the total cost.

For the purposes of this article we choose lighting sources with the same luminous flux (lm 900-950). They were following light sources:

≡ Tungsten bulb (75W)
≡ Halogen bulb (52W)
≡ Compact fluorescent lamp (16W)
≡ LED light emitting diode (8W).

Analysis is performed for a period of one year, five years, ten years and twenty years. Firstly, we analyze the total cost for an average lamp life. In the calculation of operating costs, we will consider the price of electricity c = 0.12 € / kWh. Summary of total costs from period to period is in the following tables.

Table 3. Effectiveness analysis of relamping for operation within one year

Types of light source	Electrical power consumption [W]	Operating costs [€]	Cost of replacing [€]	Total costs [€]
Tungsten bulb	75	16,43	0,70	16,78
Halogen bulb	52	11,39	2,56	13,95
Compact fluorescent lamp	16	3,50	8,04	11,54
LED light emitting diode	8	1,75	25,99	27,74

Table 4. Effectiveness analysis of relamping for operation within five years

Types of light source	Electrical power consumption [W]	Operating costs [€]	Cost of replacing [€]	Total costs [€]
Tungsten bulb	75	82,13	3,15	85,28
Halogen bulb	52	56,94	12,8	69,74
Compact fluorescent lamp	16	17,52	8,04	25,56
LED light emitting diode	8	8,76	25,99	34,75

Table 5. Effectiveness analysis of relamping for operation within ten years

Types of light source	Electrical power consumption [W]	Operating costs [€]	Cost of replacing [€]	Total costs [€]
Tungsten bulb	75	164,25	6,65	170,90
Halogen bulb	52	113,88	25,6	139,45
Compact fluorescent lamp	16	35,04	16,08	51,12
LED light emitting diode	8	17,52	25,99	43,51

Table 6. Effectiveness analysis of relamping for operation within twenty years

Types of light source	Electrical power consumption [W]	Operating costs [€]	Cost of replacing [€]	Total costs [€]
Tungsten bulb	75	328,50	12,95	341,45
Halogen bulb	52	227,76	48,64	276,40
Compact fluorescent lamp	16	70,08	24,12	94,20
LED light emitting diode	8	35,04	25,99	61,03

To determine the effectiveness of relamping in the effective lifetime will follow the same calculation. It will be adjusted only lamp lifetime according to Table 2.

Summary of the results are in the following tables.

Table 7. Effectiveness analysis of relamping for operation within five years

Types of light source	Electrical power consumption [W]	Operating costs [€]	Cost of replacing [€]	Total costs [€]
Tungsten bulb	75	82,13	3,15	85,25
Halogen bulb	52	56,94	12,8	69,74
Compact fluorescent lamp	16	17,52	16,08	33,60
LED light emitting diode	8	8,76	25,99	34,75

Table 8. Effectiveness analysis of relamping for operation within ten years

Types of light source	Electrical power consumption [W]	Operating costs [€]	Cost of replacing [€]	Total costs [€]
Tungsten bulb	75	164,25	6,65	170,90
Halogen bulb	52	113,88	25,6	139,45
Compact fluorescent lamp	16	35,04	24,12	59,16
LED light emitting diode	8	17,52	25,99	43,51

Table 9. Effectiveness analysis of relamping for operation within twenty years

Types of light source	Electrical power consumption [W]	Operating costs [€]	Cost of replacing [€]	Total costs [€]
Tungsten bulb	75	328,50	12,95	341,45
Halogen bulb	52	227,76	48,64	276,40
Compact fluorescent lamp	16	70,08	56,28	126,36
LED light emitting diode	8	35,04	51,98	87,02

3. CONCLUSION

This post is dedicated to the issue of relamping. Currently the market offers different types of light sources operating on different principles and different electrical output. As mentioned in the previous part of the article, in the case of light sources, there are two kinds of lifetime average and useful life.

The decisive aspect for light sources replacement is the price. On the one hand, tungsten bulb characterized by low purchase price but on the other hand, this will be reflected in higher electricity costs.

In the case of LED light-emitting diodes, the situation is reversed. The cost is many times higher but compared to the consumption and hence price for electricity is significantly lower.

Taking into account the useful life over a longer time period, the total cost significantly changed in the case of compact fluorescent and LED light-emitting diodes.

Ultimately, when compared to the operation of the light sources in the long term, either when considering the average or useful life, the most economical operation is with LED.

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