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LED lamps – are they inexpensive and effective?

Abstract: This article presents some results of work on the selection of the most promising types of lamps for various objects in industry, in commercial and residential buildings. It is shown that the use of a particular type of lamp depends on the conditions of a particular country (the cost of credit resources, the availability of different types of lamps on the market, and government incentives or restrictions), as well as on the conditions of the specific object (cost of lamps, duration of operation during the day, tariffs for energy resources, the cost of equipment and its installation (dismantling, utilization), the cost of replacing the equipment after leaving it, the term of service of various types of lamps). It is also necessary to consider the possible risks of changes in tariffs and the cost of money.

Keywords: lamp, LED, energy-efficient, incandescent, feasibility study

Introduction

It is sometimes proposed to not take into account the economic indicators of projects in the field of energy and energy saving. This is probably appropriate for those who have enough money to implement all the newest and most modern technologies. However, not a single country

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nor a single enterprise has such opportunities. Therefore, it is necessary to apply what pays off as quickly as possible, and of the two energy-efficient solutions, use the one that has the best technical and economic indicators.

More than thirty years ago, a real alternative to incandescent lamps appeared on the markets of different countries – halogen and energy efficient. Purely emotionally, their use was more attractive. It was very prestigious to use such lamps ("Eurofashion") in the offices of companies. Most importantly, they were more economical, although they cost more. Manufacturers and dealers of lighting-system equipment began an active marketing campaign to promote them on the market. The same policy continues today. At the same time, the technical characteristics of the lamps are usually described, but they do not give unambiguous recommendations for their choice. For example, the site (Levison 2020) describes the technical and hygienic aspects of choosing the type of lamp, but there are no economic indicators. This is well known to experts. But there are no real guidelines. Only the technical characteristics of different types of lamps are given, but there are no recommendations for analysis. And the most common recommendation is "Contact us – we will help you!" This is one more example of the approach to choosing the type of lamps (Lamp Selection Guide), where only the description and technical specifications are presented, without recommendations regarding the choice of a specific type for a particular case. In conclusion, a typical equipment manufacturer or dealer recommendation is: "Choosing the correct LED lighting and lamps can help you save valuable time on ongoing maintenance and drastically reduce your energy costs. This handy guide will help you to select the right lighting for the job, whatever industry you are working in…".

An interesting approach to evaluating lamp prospects is presented in the literature (How to Select... 2015). The comparison of light sources based on life, price and light output is recommended. The more lumen-hours per dollar, the better. Here they are not trying to count money, but have invented some very controversial criterion (lumen-hours per dollar). Incidentally, LED lamps are not the most efficient here. This approach does not take into account the cost of money and electricity tariffs.

In the literature (Energieetikette für Leuchtmittel 2022), another approach to evaluating the efficiency of lamps was proposed. The evaluation of lamps by efficiency: 1 Lumen per 1 watt of lamp power. However, this does not take into account the tariff for electricity, the cost of lamps, their service life and the cost of money.

The traditional approach to evaluating lamp efficiency has been presented in a tutorial (Prokopenko et al. 2009). Thus, in example 7.1, to calculate the savings from the use of energy-efficient lamps, the difference between the energy costs of different types of lamps is determined. At the same time, they do not take into account the risks of a possible change in tariffs, the value of service life, the cost of money, the duration of work during the day, etc.

In another tutorial (Homyshyn et al. 2017), example 7 for calculating a simple, undiscounted payback period from the use of more energy efficient lamps is presented. Savings are defined as the difference in the cost of electricity for the operation of different types of lamps for one year in the case of ten hours of operation per day. To determine the payback period, the expected savings are divided by the difference in the cost of more expensive energy efficient lamps compared to the cost of cheaper non-energy efficient lamps. In this case, as in the previous case (see Prokopenko et al. 2009) the risks of possible changes in tariffs, the value of service life, the cost of money, etc. are not taken into account.

An example of carrying out calculations on the feasibility of using energy-efficient lamps in comparison with incandescent lamps is presented in the literature (Mamalyga 2017, 2002; Roosa 2017).

One of the most common recommendations during the audit is to use energy-efficient lamps and LED lamps instead of incandescent lamps. The countries of the European Union, North America, Japan and other developed countries have banned the use of incandescent lamps. Manufacturers of energy-efficient lamps and LED lamps carry out an active marketing policy with the aim of selling these particular lamps, and in many cases, they work like pushy sales managers. However, the use of economical types of lamps is not always economically justified. The priority of energy efficiency is not an area of compromise. At the same time, the comparison of LED lamps and energy-efficient lamps should also be economically justified.

In December 2018, at one of the conferences, I talked about the myths of energy conservation, specifically that if there is no political decision to use only energy-efficient equipment, this is not always economically and technically feasible. As an example, I gave information about the use of lamps in Ukraine. When it was shown that LED lamps should be used for cases when long-term work is required for a day, and electricity tariffs are quite high, one businessman from Saudi Arabia said that the LED lamp it is so cheap and effective. I replied that I did not have information about the market in Saudi Arabia (the level of electricity tariffs and the price of lamps). I promised that I would definitely do the appropriate calculations. The results of the calculations are presented below.

The objective of this work is to develop approaches to the selection of equipment (in particular, energy efficiency), which is presented in works (Mamalyga 2011, 2014a, b; Mamalyga and Malay 2021; Mamalyga and Gorb 2017).

1. Methodology

Taking into account the approach developed in the literature (Mamalyga 2014a) on the feasibility study for energy and energy conservation projects, the feasibility study should be carried out in two phases: Phase 1 – preliminary (technical and technological) justification; Phase 2 – detailed (complete) justification.

Let us examine this in more detail. At the first stage, there is no need to determine the technical and economic indicators of the project. The following should be taken into account here:

1. The presence/absence of technical and technological constraints. For example, certain types of infrared heating systems can be used in rooms with a height of not less than 6–12 m. Certain types of lamps can only be used for outdoor lighting – streets, parking areas, etc.

2. Environmental aspects such as the impact of different types of equipment on human health and the human psyche (for example, a different spectrum of light); safety issues; the specifics of exploitation and utilization.

3. The location of equipment, the environment – the presence/absence of explosive substances and chemically aggressive compounds. For example, at the objects of the oil and gas industry and coal mines, it is not possible to use all types of lighting devices; necessary in this case is also the use of a special protective lamp case, etc.

4. Subjective factors – the presence of personnel of appropriate qualifications for maintenance and design.

5. The availability of equipment of desired quality with certain technical characteristics in the domestic (regional) market.

6. The question of the unification of equipment at a particular enterprise – for example, if certain types of lamps are used in the enterprise, and other types of lamps may be economically feasible for the project being developed, it is necessary to analyze the appropriateness of purchasing new equipment, as well as the feasibility of establishing a proper repair fund etc.

7. "Healthy conservatism" of the investor (buyer) – if before certain types of equipment (lighting systems) were not used by the consumer (at the enterprise), they should be convinced that the new one really is better, and therefore it is necessary to give specific, detailed justifications and the recommendations of trusted experts (for enterprises – recommendations of professionals, profile associations, energy auditors etc.).

At the second stage, when developing a detailed (full) justification, the economic indicators of the project should be taken into account:

1. The cost of money (interest on a loan for the implementation of the project, and in case of its implementation at its own expense – the internal rate of return of the enterprise).

2. The duration of functioning during the day (week, month, year).

3. Exchange rates (if it is possible to use equipment of domestic or foreign producers).

4. Tariffs for energy resources (should be indexed automatically with changes in exchange rates in the case of imported energy resources, but for Ukraine, this may occur with a delay of several months). Different tariff plans (different values of tariffs during the day, week, month) may take place. Electricity tariffs for private individuals and for industry in Ukraine differ several times (unlike the vast majority of countries in the world, tariffs for individuals are lower, which cannot be explained either technically or economically, since this is a purely a political decision of the authorities).

5. The cost of equipment and its installation (dismantling, utilization). The cost of replacing the equipment after leaving it (incandescent lamps, for example, have a lifetime of 1,000 hours, and energy efficient lamps – 8,000 to 10,000 hours, which requires an appropriate increase in the cost of replacing incandescent lamps compared to more durable energy-efficient lamps).

6. Passport or actual (if such information is available for each particular object), the term of service (expiration date) of various types of equipment.

7. The presence or absence of special lighting networks (enterprises usually provide for the creation of special lighting networks, where the voltage is stabilized, for example, the lifetime of

the incandescent lamps decreases by more than ten times in the case of an increase in the voltage in the power supply by 10% (OST 12.25.011 1984).

Figure 1 of article (Mamalyga 2002) gives an example on the cost of purchasing and operating one energy-efficient lamp and ten incandescent lamps, depending on the value of money. In this case, the formulas presented in Appendix E E.1 of (Mamalyga 2017) were used.

The costs of B_1 for the operation and purchase of one energy efficient lamp are:

$$B_1 = \frac{Cost_{elf}}{(1+i)^0} + \frac{P_{elf} \cdot T \cdot t_{el}}{(1+i)^1} + \ldots + \frac{P_{elf} \cdot T \cdot t_{el}}{(1+i)^{10}} \qquad \text{B1}$$

The costs of B_2 for the operation and sequential purchase of 10 incandescent lamps are:

$$B_2 = \frac{Cost_{inl}}{(1+i)^0} + \frac{Cost_{inl} + P_{inl} \cdot T \cdot t_{el}}{(1+i)^1} + \ldots + \frac{Cost_{inl} + P_{inl} \cdot T \cdot t_{el}}{(1+i)^{10}} \qquad \text{B2}$$

In this case, the following notation is used.

$Cost_{inl}$ – the price of an incandescent lamp

$Cost_{elf}$ – the price of an energy efficient lamp

P_{inl} – incandescent lamp power

P_{elf} – energy efficient lamp power

t_{el} – electricity tariff.

The lamps operate 24 hours a day.

T – the service life of an incandescent lamp (T = 1,000 hours)

service life of an energy-efficient lamp – 10,000 hours.

The value of i is determined by both the cost of money and the duration of operation during the year for an incandescent lamp T (T = 1,000 h).

Unfortunately, this example considers the case for using energy-efficient and incandescent lamps when operating only for 24 hours a day. It is interesting that an analysis was also made of the feasibility of using energy-efficient lamps at different tariff levels. However, at the same time, options for the different duration of operation during the day were not considered. The feasibility of using only energy-efficient lamps that were common on the market at that time was also analyzed. It should be noted that LED lamps are currently the most widely used in the market of many countries. Therefore, it is interesting to develop a methodology for analyzing the efficiency of using lamps of different types, which takes into account the cost of different types of lamps, their service life, and the duration of work during the day.

It is also necessary to take into account possible changes in electricity tariffs for different groups of consumers (residential and industrial) and for different countries. It should be noted that in the further presentation, for each specific case, calculation formulas similar to those presented above are used, which take into account all the necessary factors.

Thus, it is necessary to answer the question about the advisability of using energy-efficient equipment – is it always justified and economically feasible?

The use of such a methodology is shown on practical examples for different countries. This is the subject of this article.

2. Results and discussion

The order of application of the above approaches will be considered on concrete examples for Ukraine (Mamalyga and Gorb 2017) in the case of the placement of lamps in private residences and in industry for the implementation based on incandescent lamps with a power of 40 W (service life – 1,000 hours), as well as energy-efficient lamps similar to it under the light flow (power 7 W, service life – 8,000 hours), halogen (power 35 W, lifetime – 2,000 hours) and LED (power 3.5 W, lifetime – 48,000 hours).

The calculations were made (*First option* – Fig. 1) for lamp prices and electricity tariffs for electricity as of August-September 2014 amounted to 0.4194 UAH per 1 kWh (for private residences and apartment buildings) and (*Second option* – Fig. 2) 1.6646 UAH/kWh (for industrial consumers of class 2 voltage). The calculations were made for different operating hours of the lighting system during the day – 4, 12 and 20 hours per day.

The analysis shows that in spite of the advertising campaign on the expediency of using economical types of lighting devices (halogen, energy efficient, LED) at the level of electricity tariffs for the residentials, it is economically expedient to use:

- incandescent lamps - for rooms with a short duration of operation of the lighting system (up to 4–8 hours per day), i.e. practically all private residences;
- energy efficient (compact luminescent) lamps – in case of working more than 16–20 hours per day and with the possibility of attracting relatively cheap credit resources (up to 17–20% per year), i.e. in one or two places of a private residence – at the desk of the schoolboy/schoolgirl (student), in the kitchen, where they prepare/eat food, etc.; otherwise, it is advisable to use cheap incandescent lamps.

It is interesting that at the level of electricity tariffs in the third quarter of 2014, the use of the most economical LED lamps in the residences is fundamentally inappropriate. The same applies to halogen lamps, which at one time were actively installed in the offices of commercial firms (the so-called "Eurofashion"). However, since electricity tariffs for households are several times lower than for industry, the feasibility of using different types of lamps for industry should be analyzed. Moreover, the tariffs for residential buildings will be brought to the level typical of industrial enterprises. It should be noted that in developed countries, tariffs for households are higher than for industry, which is explained by purely technical considerations (see Electricity prices – Fig. 0–1 Comparison of EU27 weighted average with G20 (trade) weighted average (Study on energy prices... 2020)).

After all, the operation and construction of low-voltage electrical networks and the supply to residential buildings is much more expensive than industrial plants, which are usually powered by high-voltage electric networks.

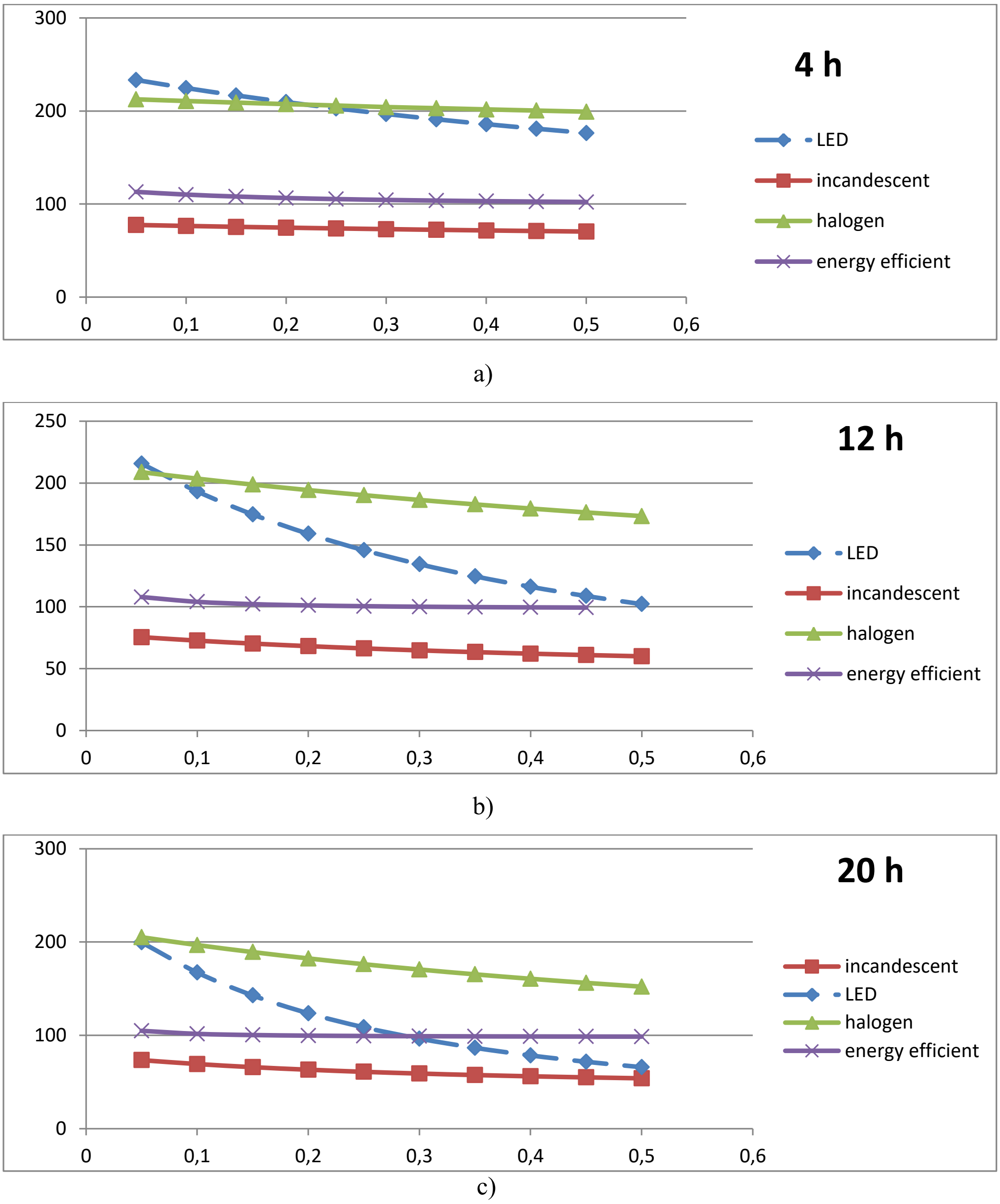
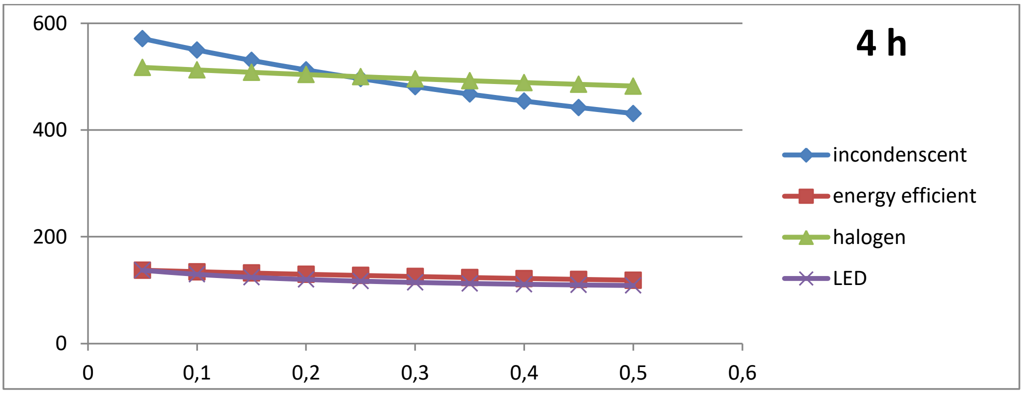
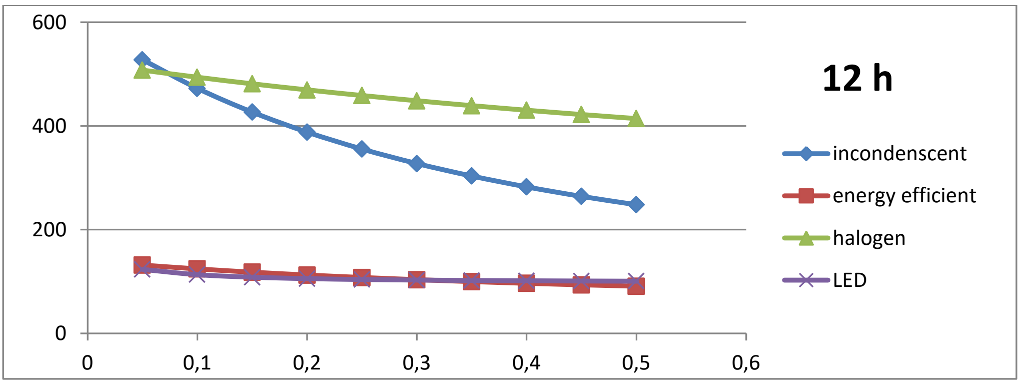


Fig. 1. Purchase and operation costs in the case of a tariff of 0.4194 UAH per 1 kW · h depending on the interest rate a) functioning time per day – 4 hours; b) functioning time per day – 12 hours; c) functioning time per day – 20 hours

Rys. 1. Koszty zakupu i eksploatacji obudowy dla taryfy 0,4194 UAH za 1 kW · h w zależności od oprocentowania a) czas funkcjonowania na dobę – 4 godziny; b) czas funkcjonowania na dobę – 12 godzin; c) czas funkcjonowania na dobę – 20 godzin



a)



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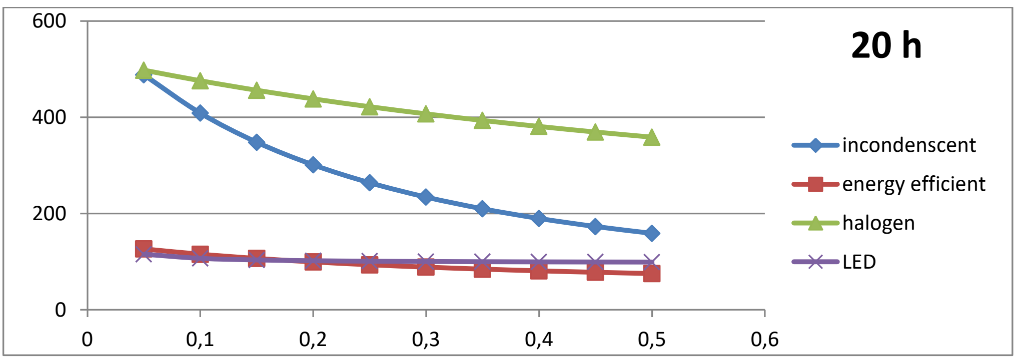


c)

Fig. 2. Purchase and operation costs in the case of a tariff of 1.6646 UAH per 1 kW · h depending on the interest rate a) functioning time per day – 4 hours; b) functioning time per day – 12 hours; c) functioning time per day – 20 hours

Rys. 2. Koszty zakupu i eksploatacji obudowy dla taryfy 1,6646 UAH za 1 kW · h w zależności od oprocentowania a) czas funkcjonowania na dobę – 4 godziny; b) czas funkcjonowania na dobę – 12 godzin; c) czas funkcjonowania na dobę – 20 godzin

Different types of local and foreign lamps are available in the markets of different countries; there are different tariff levels, cost of credit resources and different tax incentives. Therefore, the Saudi Arabian market is interesting as it has the world's cheapest electricity tariffs and enterprises that produce some types of lamps.

In 2019, calculations were made for Saudi Arabia. At the same time, the market of lamps available for use in Saudi Arabia was analyzed.

A comparison was made between 40W incandescent lamps manufactured in the USA, 20W energy-efficient lamps manufactured in Saudi Arabia, and 5W LED lamps manufactured in Saudi Arabia.

The lamps had approximately the same luminous flux (± 5%). The comparison was made for different electricity tariffs of $ 0.024 / kWh and $ 0.013 / kWh. We have compared the costs of the lighting system when operating for 4, 8, 12 and 20 hours a day for different costs of money (from 5% to 30% per year).

The calculation results are shown in Figure 3 for an electricity tariff of $ 0.024 / kWh and in Fig. 4 – for electricity tariff $ 0.013 / kWh.

For the conditions of Saudi Arabia, as a result of the analysis of the dependencies shown in Fig. 3 and Fig. 4, the following conclusions can be drawn.

A) *At the level of tariff $ 0.013 / kWh* (Fig. 4):

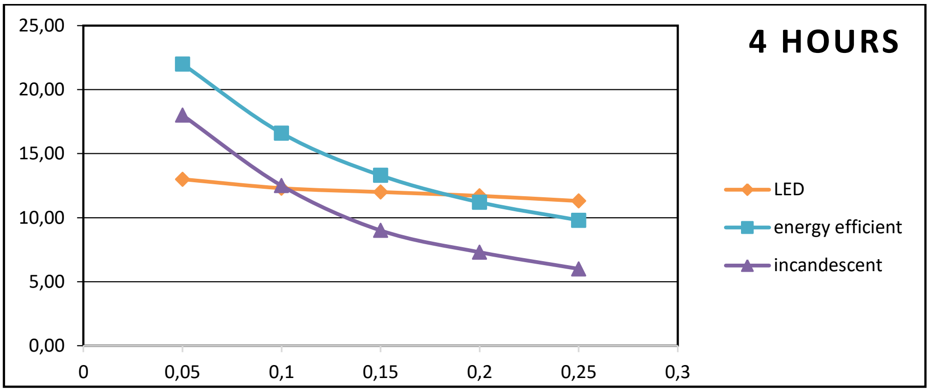
- With a short operating time during the day (4 and 8 hours), it is more expedient to use the cheapest incandescent lamps.
- When the lighting system is operating for 12 hours a day, incandescent lamps have an advantage if the cost of money exceeds 12% per annum; if there is cheaper money (less than 12% per annum), it is more advisable to use LED lamps.
- When the lighting system is operating for 20 hours a day, incandescent lamps have an advantage if the cost of money exceeds 20% per annum; if there is cheaper money (less than 20% per annum), it is more advisable to use LED lamps.
- In comparison with LED lamps, energy-efficient lamps are advisable to use only when working for 4 hours a day and the cost of money is more than 18% per annum.

Thus, at a tariff of $ 0.013 / kWh, it is more promising to use incandescent lamps, especially in the case of short work during the day. The use of LED lamps becomes expedient for the case of long-term operation during the day and the availability of cheap money for their purchase.

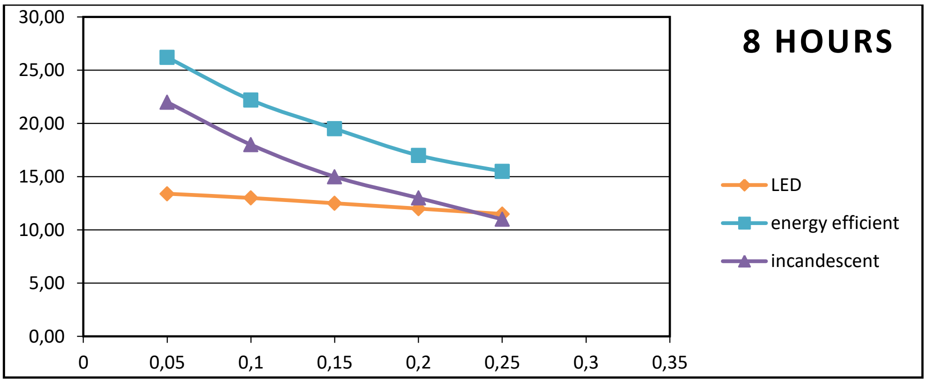
B) *At the level of tariff $ 0.024 / kWh* (Fig. 3):

- Incandescent lamps have an advantage only in the case of credit resources more expensive than 10% per annum when working for 4 hours a day and in the case of more expensive money (more than 22% per annum) when working for 8 hours a day.
- When working for a long time during the day, it is most advisable to use LED lamps.
- In comparison with LED lamps, energy-efficient lamps are advisable to use only when working for 4 hours a day and the cost of money is more than 15% per annum.

Thus, at a tariff of $ 0.024 / kWh, they are more promising for using LED lamps, especially in the case of long-term operation during the day. The use of incandescent lamps becomes advisable in the case of short work during the day and the presence of expensive money for their purchase.



a)



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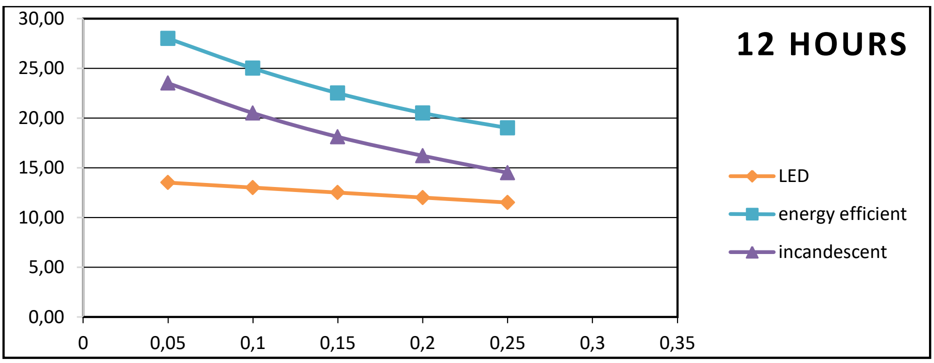
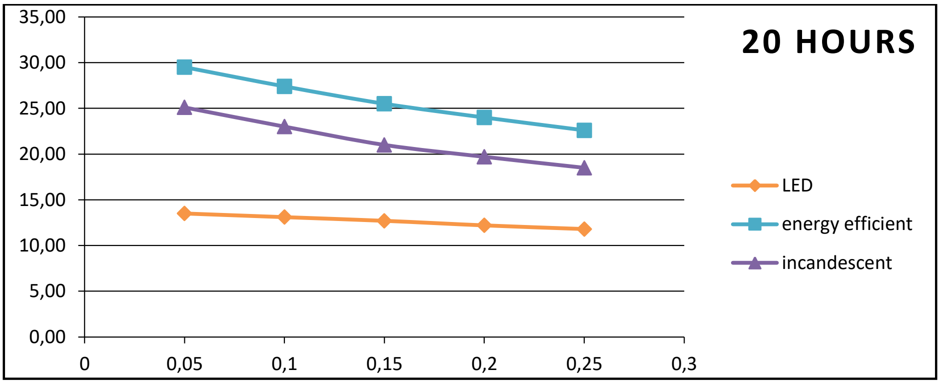


c)

Fig. 3. Purchase and operating costs in the case of a tariff of $ 0.024 / kWh depending on the interest rate
a) functioning time per day – 4 hours; b) functioning time per day – 8 hours; c) functioning time per day – 12 hours

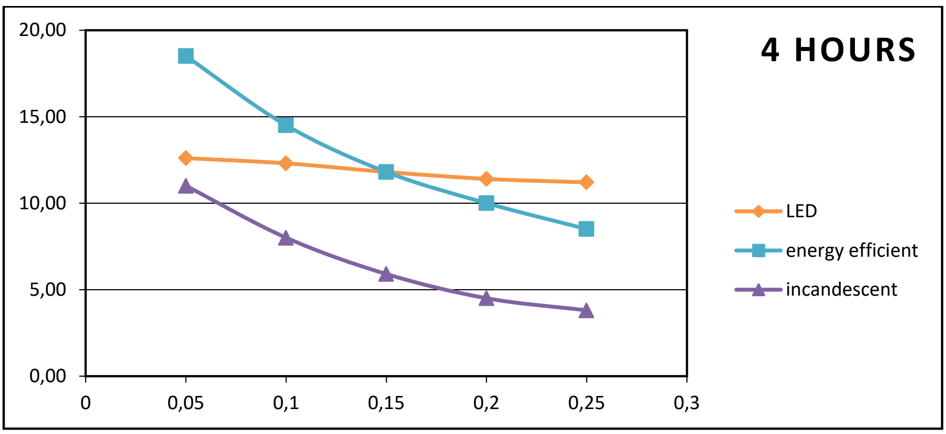
Rys. 3. Koszty zakupu i eksploatacji w przypadku taryfy 0,024 USD/kWh w zależności od oprocentowania
a) czas funkcjonowania na dobę – 4 godziny; b) czas funkcjonowania na dobę – 8 godzin; c) czas funkcjonowania na dobę – 12 godzin



d)

Fig. 3 cont. Purchase and operating costs in the case of a tariff of $ 0.024 / kWh depending on the interest rate d) functioning time per day – 20 hours

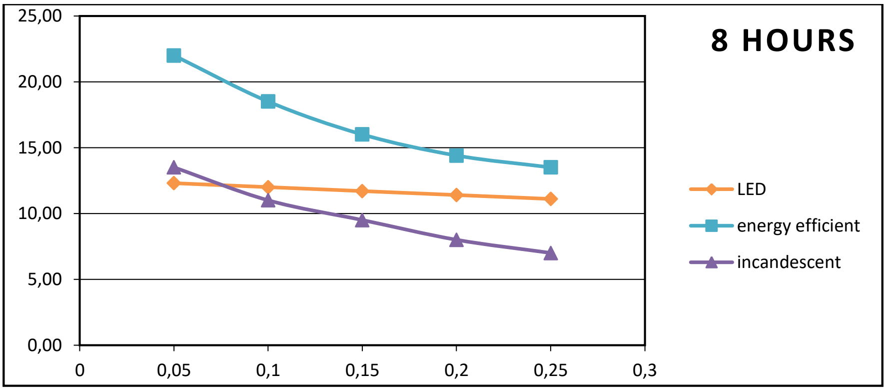
Rys. 3 cd. Koszty zakupu i eksploatacji w przypadku taryfy 0,024 USD/kWh w zależności od oprocentowania d) czas funkcjonowania na dobę – 20 godzin



a)

Fig. 4. Purchase and operating costs in the case of a tariff of $ 0.013 / kWh depending on the interest rate a) functioning time per day – 4 hours

Rys. 4. Koszty zakupu i eksploatacji w przypadku taryfy 0,013 USD/kWh w zależności od oprocentowania a) czas funkcjonowania na dobę – 4 godziny



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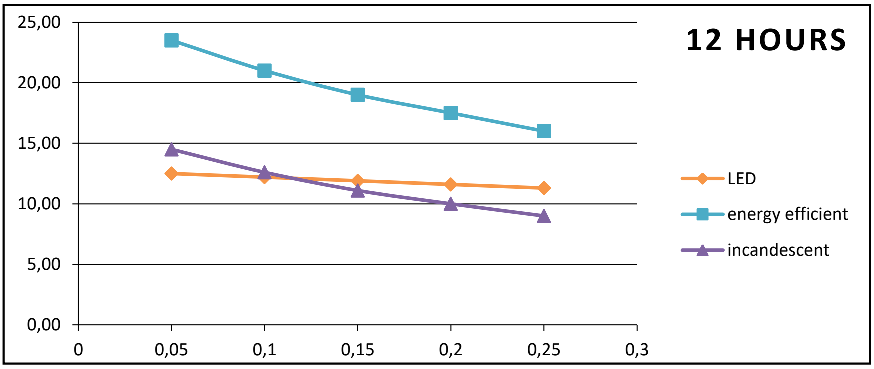

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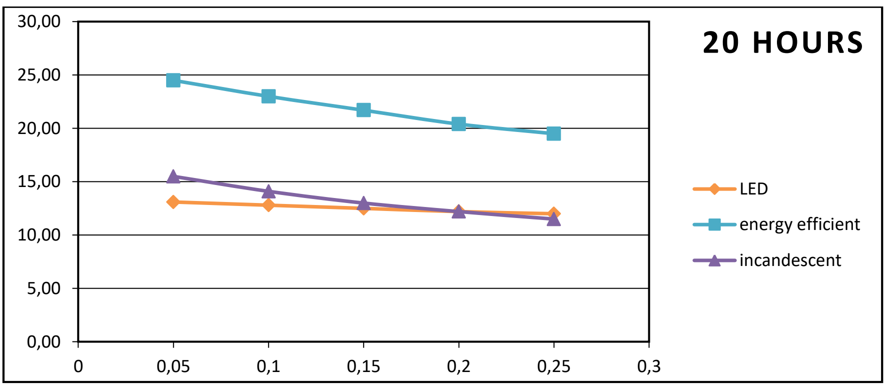


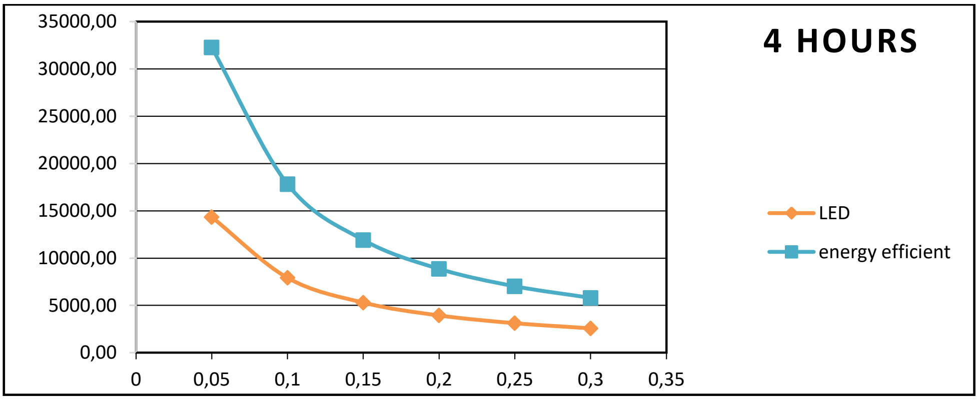
d)

Fig. 4 cont. Purchase and operating costs in the case of a tariff of $ 0.013 / kWh depending on the interest rate b) functioning time per day – 8 hours; c) functioning time per day – 12 hours; d) functioning time per day – 20 hours

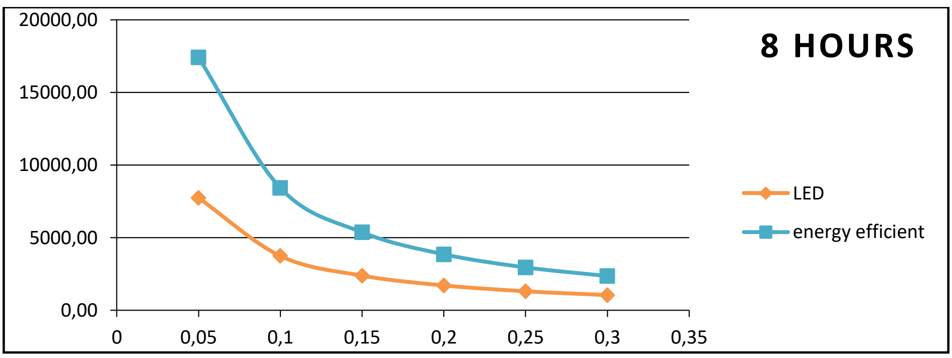
Rys. 4 cd. Koszty zakupu i eksploatacji w przypadku taryfy 0,013 USD/kWh w zależności od oprocentowania b) czas funkcjonowania na dobę – 8 godzin; c) czas funkcjonowania na dobę – 12 godzin; d) czas funkcjonowania na dobę – 20 godzin

Next, we consider a situation analysis using different types of lamps in the European Union (Germany, Denmark and Poland) (Prokopenko et al. 2009). As using lamps has the greatest impact on the bill for electricity tariffs, there is a need to replace energy-intensive incandescent lamps with modern, more energy-efficient lamps.

Incandescent lamps, due to their inefficiency and related ban on use in the EU, require alternatives, the most common of which are energy efficient and LED lamps. You can use either three energy-efficient lamps (service life of 10,000 hours), or thirty conventional incandescent lamps (1,000 hours), or two (15,000 hours) to illuminate the premises. The lamps operate 4, 8, 12 and 20 hours a day. Various sources of funding can be used to purchase lamps (from i = 5% to i = 30% interest per year). The results of the calculations are shown in Figure 5.



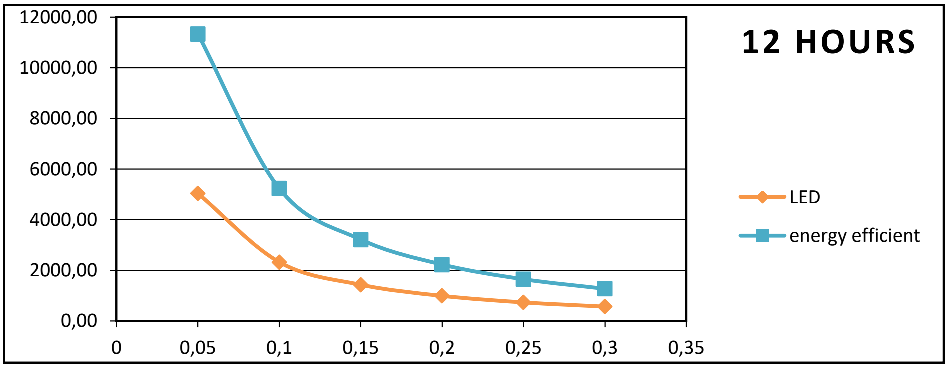
a)



b)

Fig. 5. Purchase and operating costs in the case of a tariff of $ 0.30 / kWh depending on the interest rate
a) functioning time per day – 4 hours; b) functioning time per day – 8 hours

Rys. 5. Koszty zakupu i eksploatacji w przypadku taryfy 0,30 USD/kWh w zależności od oprocentowania
a) czas funkcjonowania na dobę – 4 godziny; b) czas funkcjonowania dziennie – 8 godzin



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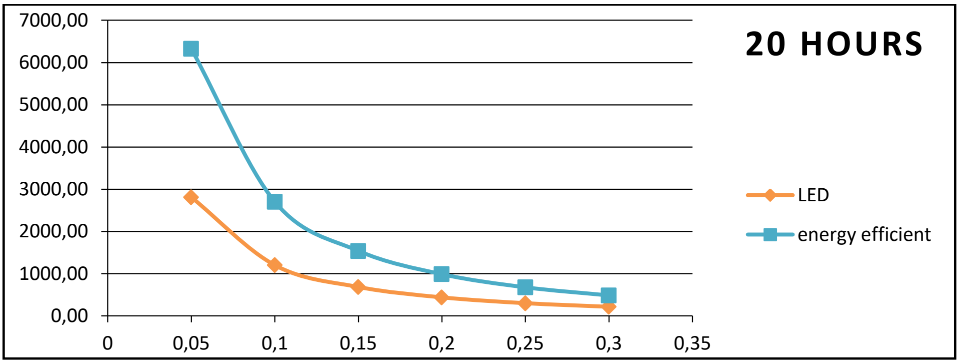

d)

Fig. 5 cont. Purchase and operating costs in the case of a tariff of $ 0.30 / kWh depending on the interest rate c) functioning time per day – 12 hours; d) functioning time per day – 20 hours

Rys. 5 cd. Koszty zakupu i eksploatacji w przypadku taryfy 0,30 USD/kWh w zależności od oprocentowania c) czas funkcjonowania na dobę – 12 godzin; d) czas funkcjonowania na dobę – 20 godzin

There is a tendency that with an increase in the interest rate, costs decrease. At rates of 30% per year, the cost is the lowest for any duration of the operation of lamps during the day. However, at 12 hours, the level of consumption is twice as low as it is at 8 hours of operation, both for LED and energy-efficient lamps. At the same time, the cost of operating LED lamps is two times less than when using energy-efficient lamps.

Thus, the calculations indicate that LED lamps are the most cost-effective, because the cost of their operation is the lowest for EU countries (Germany, Denmark, and Poland) compared to other types of lamps. In addition, with regard to the characteristic pulsation, which gives the impression of uniform light and leads to nausea, eye fatigue and impaired vision, LED lamps are the lowest. Cold and blue tones of LED lamps dull the production of melatonin, which affects the quality of sleep and the speed of falling asleep, but in the conditions of production shops and offices, the use of such light is justified. In addition, both energy-efficient and incandescent lamps have a glass body, so when dropped they can break and cause various injuries and damage. LED lamps use polycarbonate, which makes them more impact resistant. LED lamps do not contain harmful substances and can be completely recyclable. Therefore, LED lamps can be considered safe and environmentally friendly.

Similar approaches to the development of feasibility studies are used in the teaching of courses "Computer Eco-Energy-Economic Monitoring", "Energy Management", "Business Planning", etc.

Conclusions

The article shows that the decision to use different types of lamps depends on the political and economic situation in each particular country.

At the same time, statements that it is advisable to use only LED lamps are unfounded. The article shows that the use of more expensive and durable LED lamps is advisable for cases of long-term operation during the day and in cases where they are cheap to purchase.

For any country in the world, it is advisable to consider the following when choosing the type of lamp:

- the cost of money, taking into account possible risks;
- the duration of functioning during the day (week, month, year);
- exchange rates (if it is possible to use equipment of domestic or foreign producers);
- tariffs for energy resources;
- the cost of equipment and its installation (dismantling, utilization) and the cost of replacing the equipment after leaving it;
- the term of service of various types of lamps;
- the presence or absence of restrictions associated with the use of certain types of lamps, including the unification of equipment.

Moreover, we also need to consider the possible risks of changes in tariffs and the cost of money. Therefore, it is advisable to calculate the dependence of the cost of project implementation depending on the cost of money for different tariff levels, which will simplify the decision-making on the choice.

Thus, innovation and energy saving can only be achieved by taking a pragmatic approach when making decisions about the choice of lamp type for each specific country and in each specific case. We should not follow the logic of energy-efficient equipment sellers. We must always count money with regard to economic and political risks.

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References

Energieetikette für Leuchtmittel 2022. [Online] https://www.toplicht.ch/compendium/energieetikette-fur-leuchtmittel/ [Accessed: 2022-02-15].

Homyshyn et al. 2017 – Homyshyn, V.G., Tarasenko, M.G., Kozak, K.M. and Ivasechko, R.R. 2017. Guidelines for the implementation of the course project with course „Energy Audit" (*Metodychni vkazivky do vykonannya kursovogo proektu z kursu "Energetychny Audit"*). Ternopil: Publishing House I. Pulyuya TNTU, 59 p. (*in Ukraininan*).

How to Select Bulbs and Fixtures 2015. [Online] https://www.lrc.rpi.edu/patternbook/techniques/select.asp [Accessed: 2022-02-15].

Lamp Selection Guide. [Online] https://docs.rs-online.com/7b7f/0900766b81602daa.pdf [Accessed: 2022-02-15].

Levison, S. 2020. How To Find The Right Light Bulb: A Step-By-Step Guide. [Online] https://www.thelightbulb.co.uk/resources/how-to-find-the-right-light-bulb-step-by-step-guide/ [Accessed: 2022-02-15].

Mamalyga, V. 2002. National Standard of Ukraine DSTU 4065-2001 "Energy saving. Energy audit. General requirements" (*Natctionalniy standart Ukrayiny DSTU 4065-2001 "Energozberegennya. Energetychny Audit. Zagalny tehnichni vymogy"*). Kyiv: Derzhspozhyvstandart of Ukraine, 34 p. (*in Ukraininan*).

Mamalyga, V.M. 2011. Feasibility study of choosing the type of lighting devices at ceramic production enterprises (*Tehniko-ekonomicheskoe obosnovaniye vybora osvetitelnyh ustroystv na predptiyatiyah keramicheskogo proizvodstva*). Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine: *Keramika: Nauka i Zhizn* 3(13), pp. 64–69 (*in Ukrainian*).

Mamalyga, V.M. 2014a. Designing the feasibility study of projects in the sphere of energy and resource saving. *Eastern-European Journal of Advanced Technologies* 3(1(69)), pp. 51–56, DOI: 10.15587/1729-4061.2014.24896.

Mamalyga, V.M. 2014b. Justification of the use of energy efficient equipment for the coal industry. (*Obosnovanie ispolzovaniya energoeffektivnogo oborudovaniya dlya ugolnoy promyshlennosty*). *Ugol Ukrainy* 5(689), pp. 23–28 (*in Ukrainian*).

Mamalyga, V. 2017. Saving Energy – Politics or Business? Strategic Planning for Energy and the Environment 37(2), pp. 58–67. [In] *Roosa S.A. 2017. International Solutions to Sustainable Energy, Policies and Applications.* Part 11, pp. 211–220. [Online] https://www.crcpress.com/International-Solutions-to-Sustainable-Energy-Policies-and Applications/Roosa/p/book/9780815381020 [Accessed: 2022-02-15].

Mamalyga, V.M. and Gorb, I.Y. 2017. Paradoxes of technical and economic substantiation of choice of energy efficient equipment (on the example of lighting devices) (*Paradoxy Tehniko-ekonomichnogo obgruntuvannya (na prykladi osvitlyuvalnyh prystroyiv)*). State Research Economic Institute of Informatization and Modeling of Economy: *Formuvannya rynkovyh vidnosyn v Ukrayini* 5(192), pp. 79–87 (*in Ukrainian*).

Mamalyga, V.M. and Malay, T.V. 2021. Feasibility study for the choice of street and indoor lighting systems using lamps of different types for the European Union (Germany, Denmark, Poland) and Ukraine (*Tehniko-ekonomichne obgruntuvannya vyboru system ocvitlennya vulytci ta prymischennya z vykorystannyam lamp riznyh typiv dlya krayin Evrosoyuzu (Nimechchyna, Daniya, Polshcha) ta Ukrayiny*). Formuvannya rynkovyh vidnosyn v Ukrayini 3(238), pp. 62–69 (*in Ukrainian*).

OST12.25.011 1984. Saving electrical energy in coal mines. Basic activities and calculation methods. M.: Ministry of Coal Industry of the USSR, 136 p. (*OST 12.25.011 1984. Ekonomiya elektricheskoy energii na ugolnyh shahtah. Osnovnye meropriyatiya i metody pascheta. – M: Minugleprom SSSR*) (*in Russian*).

Prokopenko et al. 2009 – Prokopenko, V.V., Zakladniy, O.M. and Kulbachniy, P.V. 2009. Energy audit with examples and illustrations: Textbook (*Energetychniy audit z prykladamy ta ilustraciyamy: Navchalniy posibnyk*). Kyiv: Education of Ukraine, 438 p. (*in Ukraininan*).
Study on energy prices... 2020. Study on energy prices, costs and their impact on industry and households 2020. [Online] https://op.europa.eu/o/opportal-service/download-handler?identifier=16e7f212-0dc-5-11eb-bc07-01aa75ed71a1&format=pdf&language=en&productionSystem=cellar&part [Accessed: 2022-02-15].

Volodymyr Mamalyga

Lampa ledowa – czy jest tak tania i efektywna?

Streszczenie

W artykule przedstawiono niektóre wyniki prac nad doborem najbardziej obiecujących typów lamp dla różnych obiektów w przemyśle, w budynkach komercyjnych i mieszkalnych. Wykazano, że zastosowanie określonego rodzaju lampy zależy od warunków danego kraju (koszt środków kredytowych, dostępność różnych rodzajów lamp na rynku, zachęty lub ograniczenia rządowe), a także od warunków konkretnego obiektu (koszt lamp, czas pracy w ciągu doby, taryfy za surowce energetyczne, koszt sprzętu i jego instalacji (demontażu i utylizacji), koszt wymiany sprzętu po zaprzestaniu jego eksploatacji, okres eksploatacji różnych rodzajów lamp). Konieczne jest również rozważenie możliwego ryzyka zmian taryf i kosztu pieniądza.

Słowa kluczowe: lampa, lampa ledowa, lampa energooszczędna, lampa żarowa, studium wykonalności