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ENTERPRISE ERGONOMIC LIGHTING WITH THE USE OF LED TECHNOLOGIES

Purpose. To improve the energy efficiency of an enterprise by reducing electricity consumption of lighting devices and calculate the economic impact of the modern lighting technologies.

Methodology. Comparative analysis of the modern lighting technologies, their advantages and disadvantages in terms of the light flux power, efficiency, service life, ease of operation, and costs for implementation are shown. Development of software for calculating the economic effect of modern lighting devices for the enterprise.

Scientific novelty. Methods for improving the energy efficiency of enterprises by reducing the energy intensity of lighting devices are included. The comparative characteristics of the various lighting technologies, their advantages and disadvantages are presented. The types and systems of lighting are analyzed, the economic efficiency of replaced outdated lighting is determined**.**

Practical value. Up to 30% of the purchased energy resources is allocated to the production process. Lighting of industrial premises and workshops is one of the most energy-intensive areas. Payment for consumed energy of an enterprise is the main budget strain which increases yearly. The technology under study allows to save energy costs significantly. Moreover, replacing outdated lighting devices with LED lamps makes it possible to achieve almost tenfold energy savings in the enterprise.

Results. It has been established that the use of LED technologies and the replacement of outdated lighting devices with more modern ones is one of the most promising energy savings in the enterprise. The developed software for calculating the economic effect of modern lighting allows to calculate the investment, payback period and annual energy savings of an enterprise.

Keywords: energy efficiency, LED, lighting, energy saving.

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The problem and its connection with scientific and practical tasks. Energy saving at the enterprise is one of the most issues of the day faced by the industry. This is due to an increase in the cost of energy sources. Production spends plenty of finances for purchasing raw materials, maintenance work, but the most expensive is the payment for the energy components. Energy-saving activities that are conducted at enterprises can significantly reduce energy costs and accordingly will have a beneficial effect on the technical and economic performance of the enterprise. Increasing profitability and improving the potential competitiveness of products by reducing the cost of services will be forthcoming.

Analysis of research and publications. The poor state of energy efficiency is observed in both the public and the industrial sectors [1-14]. Indeed, payment for consumed energy at the moment is the main budget burden of any institution, and every year it increases significantly.

Formulating task. The operating modes of the lighting objects at the enterprises are oriented towards meeting the technological requirements of the objects, but in most cases, they are not optimal from the point of view of minimizing energy consumption. The level of energy consumption and reliability of these facilities, including their cost, reliability and power consumption modes does not meet the modern requirements of economy and reliability. In this regard, the urgent task is to study methods for improving the energy efficiency of enterprises by reducing the energy intensity of lighting devices.

Results and presentation materials. One of the most promising today is the technology of LED-lighting. LED (Light-emitting diode) is a technology that allows receiving light radiation at the point of contact between the cathode and the semiconductor connected to the anode (electrons interact with the emission of photons when passing through the semiconductor to the cathode). LED technology has several undeniable advantages in comparison with other light sources:

ability to withstand relatively harsh operating conditions (vibration, small shocks, water ingress, low temperatures, pressure);

low energy consumption (up to 10 times less than that of standard incandescent bulbs) and a high level of efficiency;

virtually don't contain compounds harmful to health and the environment (as opposed to fluorescent lamps and CCFL, which contain mercury);

durability (70-80 times higher than ordinary filament lamps, up to 80,000 hours and up to 2 times more durable than cold cathode lamps).

Cons of LED technology:

poor capability to resist high temperatures, which causes clouding of the light source and the surrounding material due to semiconductor decay;

narrow emission spectrum. However, quite successful work is currently underway to expand the spectrum for LCD monitors and TV.

Energy saving measures should be comprehensive. The effectiveness of the measures depends on the quality of energy audit conducted by the company and the scrupulous implementation of the requirements of energy auditors on the issues of saving electrical energy in production. To increase energy efficiency, use the following measures:

painting the indoor walls in light colors. This measure serves to increase the level of illumination of the room. Saving approximate 5-15% of electricity;

using windows with an increased area of double-glazed units, with a rational location relative to the course of the Sun. Savings - up to 20%;

prevent clipping and scattering of incoming light from windows by curtains or other objects. Savings - 1-5%;

maintaining cleanliness of light sources: windows, lights must be clean and light must pass well. Savings of 3%;

control of operating mode of lighting. Turn on the light only when needed, in the evening and avoid their work during off-hours. Savings - from 5%;

replacing outdated and energy consuming lamps with energy-saving lamps, the most economical lamps with LEDs. Savings in the segment of electricity consumption for lighting - from 50%.

Obviously, the last item is the most significant. Up to 30% of the purchased energy resources are spent on ensuring the production process and the maintenance of buildings [15]. Lighting is one of the most energy-intensive areas. Therefore, it is advisable to reduce the electricity consumption of lighting lamps. This is achieved by proper selection of specialized industrial lamps and the optimization of the working process of production equipment. Most buildings and premises do not meet modern requirements for energy saving; therefore, additional calculations are required to calculate the maximum level of energy efficiency. For clarity, a comparative table 1 of lighting devices is given, containing data on the parameters of heating, strength and radiated flux.

Also one of the most important issues is the illumination of workplaces in the enterprise. Due to workspace illumination creates a comfortable working environment and increases productivity. Insufficient illumination reflects badly on the vision of the worker. Incorrect workspace illumination can also lead to traumatic situations. Depending on the nature of the source of light energy, natural, artificial and combined categories of lighting exists, which is also divided into subcategories, therefore allowing to pick up correct type of illumination for each case which is shown in Fig.1.

Table 1

Calculation of energy efficiency when installing various light sources

Parameters \ Name of the lamp	Incandescent	Halogen	CFL	LED
Heat	Hot	Hot	Hottest	Cool
Durability	Glass and filament breaks easily	Glass can break easily	Glass can break easily. Mercury warning	Rugged. Special coat to prevent flying shards
Input power (W)	75	45	15	8
Light output (Lumens)	800			
Light quality	Bright and warm. Instant bright light	Look and perform like incandescent	Bright and warm. Takes time to warm up to full light	Bright and warm. Color options. Newer bulbs are multidirectional. Instant bright light
Life span (hours)	1000	2500	10000	30000
Cost (uah)	10	35	50	90

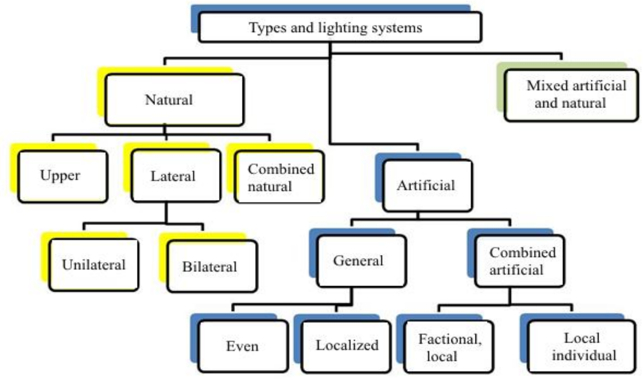

Fig 1. Types and lighting systems

Natural lighting subdivided into the side lighting (single or double sided) when light enters a room through light openings in external walls; upper, carried out through the lights and light openings in the roof; top and side combining top and side lighting.

Combined lighting used in rooms with insufficient natural light, which is complemented by electric light sources that work not only in the dark but also in the daytime.

Artificial (electric) lighting is divided by the nature of the tasks into working, emergency, evacuation, security, and duty. Working lighting arrange in all premises, as well as in open areas, intended for work, the passage of people and traffic.

We carry out economic calculations. If the lighting at the enterprise is operating in continuous mode, it is possible to calculate the hours of operation of one lamp per year using the formula

$$T = t \times d, \quad (1)$$

where t is the number of hours; d is the number of days in a calendar year.

Substituting the values in the formula we get

$$T = 24 \times 365 = 8760\ hrs.$$

Accordingly, the amount of electricity consumed during the year by one lamp can be calculated using the following formula

$$W = (T \times P) / 1000\ (kW \cdot h), \quad (2)$$

where P – the power of an individual lamp in watts; T – the number of hours of operation of one lamp per year, the division of the expression by 1000 in the formula is presented for translating the answer from watt-hours to kilowatt-hours.

Substituting the values in the formula we get corresponding values for each lamp:

incandescent lamp

$$W_i = (8760 \times 75) / 1000 = 657\ kW \cdot h;$$

halogen lamp

$$W_h = (8760 \times 45) / 1000 = 394.2\ kW \cdot h;$$

compact fluorescent lamp (CFL)

$$W_c = (8760 \times 15) / 1000 = 131.4\ kW \cdot h;$$

light-emitting diode (LED) lamp

$$W_l = (8760 \times 8) / 1000 = 70\ kW \cdot h.$$

In accordance with the data of the National Committee, the state of affairs of regulation in the fields of energy and public utilities (NKREKP) in the Dnipropetrovsk region the tariff for industrial consumers in the IV quarter of 2018 is 1.63754 uah / kW · h [16].

Calculate the prime cost of one lamp per year we can using the following formula

$$E = a \times W_x\ (uah), \quad (3)$$

where a and r the electricity tariff for enterprises in kWh and the power of an individual lamp in watts respectively. Substituting the values for each lamp in the formula we get for

incandescent lamp

$$E_i = a \times W_i = 1{,}63754 \times 657 = 1075{,}86\ (uah);$$

halogen lamp

$$E_h = a \times W_h = 1{,}63754 \times 394.2 = 645{,}51\ (uah);$$

CFL

$$E_c = a \times W_c = 1{,}63754 \times 131.4 = 215{,}17\ (uah);$$

LED lamp

$$E_l = a \times W_l = 1{,}63754 \times 70 = 114{,}62\ (uah).$$

As we can see, replacement of incandescent bulbs with LED bulbs allows us to achieve almost tenfold savings in electricity consumption.

In the course of the research, a computer program was developed that allows to calculate the economic effect of the introduction of modern lighting devices in enterprises, a screenshot of which is shown in Fig. 2.

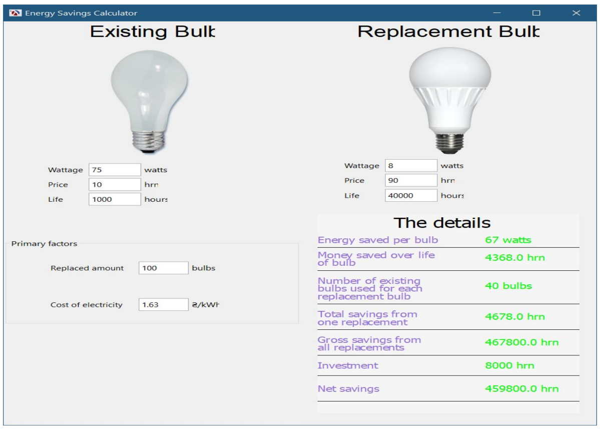

Fig. 2. The main program window for calculating the economic effect of modern lighting devices in enterprises

Conclusions and directions for further research. Studies have shown that the use of LED lamps is the most promising direction for energy saving in the enterprise. The developed software for calculating the economic effect of the introduction of modern lighting devices allows you to calculate the investment, payback period and annual energy savings. Regarding further research, it will focus on the efficiency assessments of light sensors on enterprises.

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