ANALYSING CRITERIA FOR CHOOSING ENERGY EFFICIENT HIGH QUALITY LIGHT SOURCES AND LUMINAIRES

Gennady Ya. Vagin, Eugene B. Solntsev, and Oleg Yu.Malafeev[1]

The Nizhny Novgorod State Engineering University, N. Novgorod
[1]E-mail: omail1@mail.ru

ABSTRACT

The article analyses critera applying to the choice of energy efficient high quality light sources and luminaires, which are used in Russian domestic and international practice. It is found that national standards GOST P 54993–2012 and GOST P 54992–2012 contain outdated criteria for determining indices and classes of energy efficiency of light sources and luminaires. They are taken from the 1998 EU Directive #98/11/EU "Electric lamps", in which LED light sources and discharge lamps of high intensity were not included. A new Regulation of the European Union #874/2012/EU on energy labelling of electric lamps and luminaires, in which these light sources are taken into consideration, contains a new technique of determining classes of energy efficiency and new, higher classes are added. The article has carried out a comparison of calculations of the energy efficiency classes in accordance with GOST P 54993 and with Regulation #874/2012/EU, and it is found out that a calculation using GOST P 54993 gives underrated energy efficiency classes. This can lead to interdiction of export for certain light sources and luminaires, can discredit Russian domestic manufacturer light sources and does not correspond to the rules of the World Trade Organization (WTO)[1].

[1] At present, a draft of the Technical Regulations of the Customs Union "On informing consumers on energy efficiency of electric power-consuming devices", is in development, the basis of which is the Regulation of the European Union mentioned in this article (editor's note) .

Keywords: choice criteria of energy-effective and high-quality light sources, energy efficiency classes, engineering criteria, economic criteria

1. INTRODUCTION

There is a large number of LED light sources and luminaires of domestic and foreign production on the Russian market [1]. The technical specifications of many of these do not correspondent to the declared data and the requirements for energy efficiency and product quality. This means that sometimes uncertified products come to the market.

A wide choice of light sources and luminaires present a selection challenge for buyers. Various engineering and economic choice criteria for energy efficient and high-quality light sources and luminaires simplify the selection process.

2. A CHOICE CRITERION OF ENERGY EFFICIENT LIGHT SOURCES AND LUMINAIRES

The main selection criterion for energy efficiency of light sources and luminaires is their energy efficiency class (communicated via energy efficiency labelling).

Labelling energy efficiency is the main and most effective energy saving tool and a driving motive for decreasing the energy consumption capacity of the Gross National Product (GNP), as well as a stimulus for driving environmental improvements [2]. Energy efficiency equipment labelling is a method of classification and identification of product

Table 1. Energy efficiency classes of some LED light sources

Light source brand	Measured power, W	Actual luminous flux, lm	Energy efficiency class	
			According to GOST P 54993–2012	According to Regulation 874/2012/EU
IKEA	13.6	1121	A	*A*+
KOMTEX	9.34	912	A	*A*+
WOLTA	8.48	673	A	*A*+
Economica LED	11.12	815	A	*A*+
Elektromontazh	9.13	808	A	*A*+

within categories by power consumption their characteristics with the assignment of the corresponding label sign.

Power-consuming equipment is subject to energy efficiency labelling in more than 60 countries of the world [3]. The most complete penetration by this approach has occurred in the EU, where work on labelling began in 1992 after the adoption of Directive 92/75/EU.

The EU Electric lamps Directive 98/11/EU was published in 1998. It established seven classes of lamp energy efficiency (*A*, *B*, *C*, *D*, *E*, *F*, *G)*. Class A corresponds to maximum efficiency, and class G to minimum energy efficiency of lamps during operation. An energy efficiency class is determined by the energy efficiency index *EEI*, the calculating formulas for which are given in [4, 5].

Attempts to introduce energy efficiency labelling in Russia were made in the late 1990s. In 1999, three energy efficiency standards were issued. Unfortunately, these standards were not effective as implementation mechanisms for energy efficiency labelling were not developed and standard energy efficiency indicators of power-consuming equipment were not determined.

Work on energy efficiency labelling was started up again after the adoption of the Federal law #261-ФЗ [6]. Resolution of the Government of the Russian Federation #1221 of 12/31/2009 “On approval of the Rules of establishment of energy efficiency requirements of goods, works, services, which is commissioned to meet state and municipal needs” has confirmed a list of the goods, with reference to which requirements of energy efficiency are established. Light sources are included in this list.

Rules for determining the energy efficiency class of light sources by manufacturers and importers are stated in the Order of the Ministry of Industry and Trade of the Russian Federation #357 of 4/29/2010. These rules are taken entirely from Directive 98/11/EU. However, this Directive did not cover LED light sources and a number of high intensity discharge lamps.

Besides this Order, the mentioned rules are stated in the following standard documents: GOST P 54992–2012 and GOST P 54993–2012 [4, 5]. And GOST P 54993 establishes that it is also applicable to LED light sources.

Since 1998, there has been a rapid increase of light sources with a high luminous efficacy and especially of LED light sources. Therefore on 7/12/2012, the European Union adopted new Regulation #874/2012/EU on energy labelling of electric lamps and luminaires [7]. It covers requirements for incandescent lamps, fluorescent lamps, high intensity discharge lamps, LED lamps and LED modules. The scale of energy efficiency classes changed (*A* ++, *A*+, *A*, *B*, *C*, *D*, *E)*, and the formulae to determine energy efficiency indices also changed. Furthermore, an additional energy efficiency criterion – electric energy consumption by a light source – is introduced, measured in kW·h for 1000 h of its operation (W_c). Determination of energy efficiency indices is made according to the expressions given in [7].

Calculation of energy efficiency classes for the five best LED light sources with an E27 socle are given in Table 1 [1, Table 3]. The calculation is carried out in accordance with GOST P 54993 and according to EU Regulation #874/2012.

As can be seen from Table 1, calculation of an energy efficiency class according to the Russian standard documents gives underestimated results compared with Regulation 874/2012/EU. This can complicate export of Russian light sources and can discredit domestic manufacturers of the light sources.

3. ENGINEERING CRITERIA FOR CHOOSING HIGH-QUALITY LIGHT SOURCES AND LUMINAIRES

In work [1], an integral criterion to determine light source and luminaire quality is used:

$$K_0 = \frac{\Phi_v \cdot R_a \cdot \cos\varphi \cdot (100 - K_r)}{P \cdot T_{cc} \cdot C}, \quad (1)$$

where Φ_v is luminous flux of the illumination device, lm; R_a is general colour rendering index; $\cos\varphi$ is power factor; K_r is ripple factor of the luminous flux, %; P is power consumption of the illumination device, W; T_{cc} is correlated colour temperature, K; C is lamp cost, rbl.

The following notes are important to mention together with this criterion:

1. It is not possible to mix engineering and economic criteria in one expression, because this can generate unexpected results. For example, work [1] drows the conclusion that "an analysis has shown that lamps with the best parameters are cheaper than lamps of poor quality", although it is well-known that a high-quality product is always more expensive than a product of poor quality.

2. This criterion cannot be applied to compare light emitting diodes of cold-white and warm-white light (i.e. with different T_{cc}) as their fields of application are different.

In [8], the requirements for lighting product energy efficiency and quality are offered together and two types of standard to be developed:

1. Minimum energy efficiency standards (*MEPS*);

2. High energy efficiency standards (*HEPS*).

Minimum energy efficiency standards will establish threshold levels for the technical (engineering) characteristics of light sources and luminaires.

Maximum energy efficiency standards should establish higher levels of energy efficiency for the development of new ambitious light sources and luminaires.

According to the authors, these standards should contain:

1. Requirements for energy efficiency of lamps and luminaires;

2. Requirements for operational characteristics of lamps and luminaires.

The energy efficiency requirements should correspond to international practice admitted in the World Trade Organisation (WTO), that is requirements for labelling of light sources and luminaires, and Regulation #847/2012/EU should be the source of the limits.

At the same time, it is important to consider the legal status of these standards. The law "On Technical Regulation" transferred all standards to the voluntary application category. In order to transfer the standard into the mandatory application category, it should be referred to in the Technical Regulation. For the fourteen years that the law "On Technical Regulation" has been in existence, no Technical Regulations containing lighting characteristics have been developed.

In EU countries, voluntary standards are also used but there are mandatory documents as well, which specify what standards are to be guided for. These are:

1. Regulations, which are completely mandatory and directly applied in all EU member states;

2. Directives, which are mandatory for EU member states, establishing the thresholds, which should be reflected in national laws.

These documents are confirmed by the European Parliament and by the EU Council. This type of technical regulation has allowed EU countries to achieve great successes in the promotion of energy efficient equipment, including in illumination system. For instance, from 2008 to 2013 the number of installed incandescent lamps was reduced 2.85 times, CFL number increased 1.6 times, and the number of LED lamps increased 72 times [9].

Taking into consideration the creation of the Customs Union and the complexity of standard documents and their agreement process between members of this Union, it is prudent to look to the experience of the EU. The practice of establishing energy efficiency requirements using Resolutions of the Russian Federation Government under the conditions of the Customs Union does not work as these Resolutions do not extend to other members of the Union.

Studies [10–12] show that all gas-discharge and LED light sources create higher current harmonics when operating. The greatest harmonics are created by compact fluorescent and LED light sources, which have no power factor correctors (PFC) in their control devices. An analysis of these tables [1] shows that most light sources present on the Russian market do not have PFC, i.e. they generate significantly high harmonics levels and have low power factors.

According to the Technical Regulation of the Customs Union TR CU020/2011 "Electromagnetic compatibility of technical facilities", all technical facilities generating electromagnetic noise should correspond to the electromagnetic compatibility standards. An evaluation of this correspondence is given in GOST P 56029–2014 [13].

The requirements for permissible level of higher current harmonics generated by light sources are stated in GOST 30804.3.2–2013 [14]. Operational characteristics of lamps and luminaires (along with Φ_v, R_a, $\cos\varphi$, K_p, P, T_{ct}, U_{rt} and energy efficiency class) need to be added, with information on how they meet the requirements of GOST 30804.3.2. In the EU, correspondence of light sources to the electromagnetic compatibility requirements is indicated by the sign. This sign is placed both on the packing of light sources and luminaires, and on light sources and luminaires themselves.

4. EVALUATION OF ECONOMIC EFFICIENCY OF INTRODUCING ENERGY EFFICIENT LIGHT SOURCES

When replacing light sources and luminaires with energy efficient devices, as well as evaluating their technical criteria, the analysis of economic efficiency of the replacement is important. When evaluating economic efficiency of introducing a new product, where there is a considerable difference in service life, the product service life cost (PSLC) technique is widely used in the international practice [15–18]. This approach allows selecting the most economic products with long service lifetimes.

According to GOST P 27.202–2012 [15], the PSLC evaluation is an economic analysis which determines the total cost of acquisition, possession and utilisation of a product.

Twenty years is the recommended life period used to determine PSLC value for illumination devices (ID) [16]. The service life includes the following stages:

– Acquisition;
– Installation and adjustment;
– Operation and maintenance;
– Charge-off and utilisation.

The cost of service life for the interval equal to an ID life time, can be determined by the formula [17, 18]:

$$PSLC = C_{acq} + \sum_{t=1}^{T} \left(O_t + \Delta K_t + U_t \right) \cdot \alpha_t, \qquad (2)$$

where C_{acq} is ID cost connected with acquisition, installation and adjustment; O_t is annual operational expenses connected with cost of electricity, ΔK_t is the accompanying cost connected with replacement of the failed lamps; U_t is disposal value, i.e. utilisation cost of the failed lamps containing mercury; α_t is discount factor; T is life time period.

The discount factor is determined by the formula:

$$\alpha_t = \frac{1}{(1+r)^T}, \qquad (3)$$

where r is a real interest profit rate, relative units:

$$r = \frac{E_{rt} - b}{1+b}, \qquad (4)$$

E_{rt} is a rated discount rate, relative units; b – inflation level, relative units.

Annual operational expenses connected with the electricity cost are determined by the formula:

$$C_t = C_{\text{ee}} \cdot W_{ee}, \qquad (5)$$

where C_{ee} *is* electricity cost during the initial stage, *rbl/kW·h*; W_{ee} is value of the consumed electricity per year, kW · h.

Accompanying annual expenses connected with the replacement of the failed lamps:

$$\Delta K_t = C_l \cdot N_l \cdot \frac{T_y}{T_{sl}}, \qquad (6)$$

where C_{l} is cost of a lamp, rbl; N_{l} is number of lamps, pieces.; T_y is operating time of the illumination system per year, h; T_{sl} is standardised lifetime of a lamp, *h*.

Annual expenses for recycling and disposal of lamps containing mercury:

Table 2. Specific indicators of office IDs

Illumination device and lamp	Lamp		Luminaire		ID power (accounting for ballast losses), W	ID luminous flux, lm	ID life time, T_l, h
	Power, W	C_l Cost, roubles	Efficiency, %	C_{lu} Cost, roubles			
ЛВО10–4x18–021 *Rastr* and *T8 L 18/640 G13*	4x18	42.44	66	1968	86	3168	13000
ЛВО10–4x18–031 *Rastr* and *T8 L 18/840 G13 LUMILUX*	4x18	58.59	66	2094	79.2	3564	20000
ЛВО10–4x14–031 *Rastr HF* and *T5 FH 14/840 G5*	4x14	122.31	71	2405	61.6	3834	24000
ДВО11–42–001 *Frost* 840	–	–	–	6996	38	3712	50000

Note. LED luminaire is a non-demountable luminaire. When calculating, C_1 is accepted to be equal to C_{lu}

$$C_t = C_{\text{util}} \cdot N_1 \cdot \frac{T_{\text{y}}}{T_{\text{sl}}}, \quad (7)$$

where C_{util} is cost of recycling and disposing of a lamp, rbl.

ID service life cost comparison criterion is the value of specific cost for one year of operation [19]:

$$\frac{PSLC}{T} = \frac{C_{acq} + \sum_{\text{t=1}}^{\text{T}} \left(O_{\text{t}} + \Delta K_{\text{t}} + U_{\text{t}}\right) \cdot \alpha_{\text{t}}}{T} \quad (8)$$

As an example, a calculation of service life costs for the following IDs was carried out:

1) ЛВО10–4x18–021 luminaire manufactured by *Rastr* Company АСТЗ OJSC with electromagnetic ballast and with fluorescent lamps *OSRAM T8 L 18/640 G13*;

2) ЛВО10–4x18–031 luminaire manufactured by *Rastr HF* Company АСТЗ OJSC with electromagnetic ballast and with fluorescent lamps *OSRAM T8 L 18/840 G13 LUMILUX*;

3) ЛВО10–4x14–031 luminaire manufactured by *Rastr HF* Company АСТЗ OJSC with electromagnetic ballast and with fluorescent lamps *OSRAM T5 FH 14/840 G5*;

4) ДВО11–42–001LED luminaire manufactured by *Frost* 840 Company АСТЗ OJSC.

Characteristics of these IDs are given in Table 2. The data was sourced from the price-list and information from the АСТЗ JSC official website as well as data from the Elektrik online store [21].

Using expressions (2) – (8) and characteristics given in Table 2, as well as varying number of operation hours of the illumination system per year, dependences of ID life service cost reduced to a year were obtained (Fig. 1). The cost of electricity is taken to be 5.04 rbl/kW·h (Nizhny Novgorod region), rated discount rate is equal to 15 %, inflation level is 5 % and 10 %. Cost of recycling and disposal for lamps containing mercury is taken to be 17 rbl/piece according to the price list of the company providing these services in N. Novgorod [22].

5. CONCLUSIONS

1. When choosing energy efficient and high-quality light sources, both technical and economic criteria should be considered.

2. To choose energy efficient light sources and luminaires according in line with international practice, it is necessary to use energy efficiency classes which meet international standards.

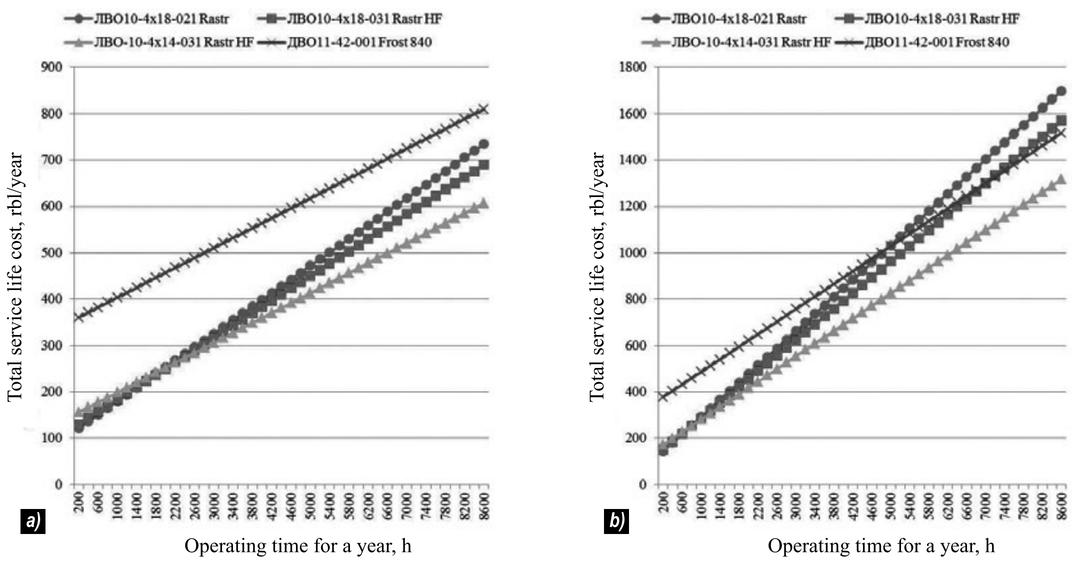


Fig. 1. ID service life cost: a) for inflation rate of 5 %, b) for inflation rate of 10 %

3. GOST P 54992–2012 and GOST P 54993–2012 should be revised as the use an outdated technique for the determination of light source and luminaire energy efficiency classes.

4. When selecting high-quality luminaires, apart from the main technical criteria given in GOST P 54350–2011, it is necessary to consider whether they meet the requirements for electromagnetic compatibility in the documentation submitted to the consumers.

5. As an economic criterion for energy efficient and high-quality light sources and luminaires selection, the *cost of service life* criterion is appropriate.

REFERENCES

1. Report on implementation of the project “Independent quality check of lighting products”// Svetotekhnika. 2016, #1, pp. 69–86.

2. Naumov A.L. Labelling of energy efficiency of engineering equipment as the basic tool of energy saving // Energy saving. 2008, #3, pp. 4–21.

3. Use of labelling engineering equipment of buildings when developing measures to increase energy efficiency during energy auditing objects of different purpose: educational handbook / G. Ya. Vagin, N.N. Golovkin, A.M. Mamonov, etc.; under the editorship of E.A. Zenyutich. N. Novgorod: Rastr-NN LLC, 2014, 256 p.

4. GOST P 54993–2012. “Household lamps Factors of energy efficiency” Moscow: Standartinform, 2013, 7 p.

5. GOST P 54992–2012. “Household lamps Methods of determining energy efficiency” Moscow: Standartinform, 2013, 6 p.

6. Federal law of November 23, 2009 #261- ФЗ “On energy saving and increase of energy efficiency and on introduction of amendments to some legal acts of the Russian Federation”.

7. Commission delegated regulation (EU) No 874/2012 of 12 July 2012 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of electrical lamps and luminaires.

8. Shevchenko A.S. A promotion program of energy-effective illumination in Russia // Svetotekhnika, 2014, #1–2, pp. 112–117.

9. Analysis of the lighting product market state and perspectives in the member countries of the Eurasian Economic Union (EEU) / Program of Development of the United Nations (UNDP), 2015, 78 p.

10. Study of current higher harmonics generated by energy saving light sources / G. Ya. Vagin, A.A. Sevostyanov, E.B. Solntsev, etc.// Industrial power engineering, 2014, #6, pp. 51–55.

11. Mantorski Z. Harmonic Problems Caused by Light Sources Controlled// Light & Engineering, 2008, #3, pp. 46–51.

12. Aniruddha Mukherjee, Rajat S. Mandal, Asit Kumar Sur, and Saswati Mazumdar

Power Factor and Harmonic Analysis of Self Ballasted Compact Fluorescent Lamps// Light & Engineering, 2010, #2, pp. 101–107.

13. GOST P 56029–2014. Correspondence evaluation. Order of necessary confirmation of a product correspondence to the requirements of the Technical regulation of the Customs Union “Electromagnetic compatibility of technical facilities”. Moscow: Standartinform, 2015, 58 p.

14. GOST 30804.3.2–2013 (IEC61000–3–2:2009). Electromagnetic compatibility of technical facilities. Emission of current harmonious components by technical facilities with the consumed current no more than 16A (in one phase). Test standards and methods.

15. GOST P 27.202–2012 (IEC60300–3–3). Reliability of the facilities. Reliability control. Cost of service life. – Moscow: Standartinform, 2014, 16 p.

16. Vagin G. Ya. Energy saving in the budgetary sphere: a manual for power managers // N. Novgorod: NSTU, 2010, 145 p.

17. Perera, O., Morton, B., Perfrement, T. Life Cycle Costing. A Question of Value / International Institute for Sustainable Development (IISD). URL: ec.europa.eu/environment/gpp/pdf/WP-LifeCycleCosting.qx.pdf (дата обращения: 20.05.2017).

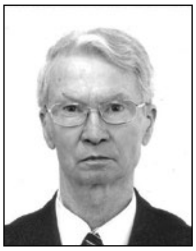
18. Benuzh A., Kazeykin V., Podshivalenko D. Methodical recommendations on calculation of life cycle cost. URL: naiz.org/news/Podshivalenko.pdf (addressing date: 5/20/2017).

19. Vagin G. Ya., Solntsev E.B., Terentyev P.V., Malafeev O. Yu. Techniques of economic choice of illumination devices based on service life cost // Engineering bulletin of Don, #2, p. 2 (2015). URL: ivdon.ru/ru/magazine/archive/n2p2y2015/3040 (addressing date: 5/20/2017).

20. Illumination of public rooms. Product catalogue // Ardatosvky Lighting Factory JSC. URL: http://www.astz.ru/ru-production/public/(addressing date: 5/20/2017).

21. Fluorescent lamps. Internet shop // Elektrik Internet shop. URL: https://svetelektro.net/section-lamp/energy-saving-fluorescent-lamps.

22. Utilisation of mercury-containing waste and fluorescent lamps // Ekologika LLC. URL: ecologika-nn.ru/lampy (addressing date: 5/20/2017).



Gennady Ya. Vagin,
Doctor of Technical Science, honoured scientist of the Russian Federation, Professor of the Chair "Electrical energy industry, electric power supply and power electronics" of the Nizhny Novgorod State Technical University, expert of the Russian Government Analytical Centre, graduated from the Gorky Polytechnic Institute in 1965

Eugene B. Solntsev,
Ph.D., an Associate Professor of the Chair "Electrical energy industry, electric power supply and power electronics" of the Nizhny Novgorod State Technical University, graduated from the Gorky Polytechnic Institute in 1977

Oleg Yu. Malafeev,
an assistant of the Chair "Electrical energy industry, electric power supply and power electronics" of the Nizhny Novgorod State Technical University, graduated from the Gorky Polytechnic Institute in 2010