

FRI-K1-1-QHE-16

CULTURE OF QUALITY OF THE EDUCATION. BORDERS OF LIGHTING DESIGN. BEYOND BORDERS

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Abstract

Lighting design is a multi-factorial and interdisciplinary area that includes a number of well-developed fields. The architectural lighting, the interior lighting, the advertising and information lighting, the street and road lighting and the transport lighting are leading the development of the contemporary lighting. Regardless of the group to which they belong, lighting systems follow a common frame, with varying domination of functionality and aesthetics, according to the light organization levels: light – lighting – lighting environment. These levels follow a logical hierarchical sequence.

Light is a “herald” of beauty. Lighting design realizes this human striving for beauty. The education process in the field of lighting design is aimed at harmonizing the lighting environment, where light pollution determines the borders of the lighting design. Light pollution management outlines the range of these borders. Creativity allows a closer view to the “beyond borders” aspect searching for useful innovative solutions.

The culture of the quality of education in lighting design is based on a synchronized behavior of lighting systems, where light pollution management signifies for the level of the lighting environment evolution. The methodology of the lighting design education process includes the following aspects: light systems as a pollutant; structure of artificial outdoor lighting in the context of light pollution; quality assessment of light pollution in Bulgaria; a classification system of measures to reduce light pollution; compensation of large light load; limitations of light pollution as part of the good lighting practices.

Keywords: *Lighting Design, Culture of Quality of the Education (CQoE), Methodology (GMmQ), Borders, Beyond borders, High Border, Low Border, Education, Light pollution; Classification system; Creativity, Innovations, Intelligent lighting, Elegant metacommunication, Automotive Lighting Metasculpture, Metamob, Light-based Semantic Field, Intelligent Urbanized Regions (Smart Cities).*

JEL Codes: *I20*

INTRODUCTION

The Strategy for the Development of Higher Education in the Republic of Bulgaria for the period 2014-2020 [1] provides adapted teaching methods to the students' necessities and updating of the educational curricula and programs (including updating of the educational disciplines's content according to the professions and the professional realization of the students; realization of the labor market). The National Accreditation System provides for assessment of the academic knowledge and skills represented to the students contributing to their educational growth and future career [2,3].

Lighting design education at national and international level is in a state of a dynamic development. Artificial light is the civilization choice of modern society. This motivates its common accessibility and use. In the year of 2018 Pope Francis draws attention to the presence of the so-called "Culture of Waste" in his Easter Message “Urbi et orbi (“Towards the City and the World”, April 1, 2018). Such an example in the contemporary lighting is the scattering of the artificial light.

EXPOSITION

CULTURE OF QUALITY OF LIGHTING DESIGN EDUCATION

Light culture in the educational system of lighting engineering and design leads to two interconnected directions: (a) the quality of the lighting design education; (b) the quality of lighting design product solutions. Regardless of the group to which they belong, modern lighting systems follow a common frame with a variety of the functional and aesthetic influence (and dominance), and in accordance to the light organization scheme: *light – lighting – lighting environment – light-based semantic field – smart cities*. These levels follow a logical sequence and hierarchy.

The quality culture of lighting design education is based on an *achieved balance* between functionality and aesthetics defining the purpose of each lighting system. Functional lighting rely on light-based technical norms, according to which quantitative and qualitative indicators of lighting systems should be realized satisfying the type of the visual tasks. The functional requirements are unconditional – the artificial light should be provided only "*where necessary, as much as necessary*". This implies minimal investments, minimum operating (including energy) costs, guaranteed quantity, quality and work safety.

Decorative lighting systems are devoted to the emotional impact and aesthetics, revealing the beauty of the lighting environment, as a result of the creative and intellectual potential of lighting designers. The creative freedom follows its own rules associated with the level of information expressiveness and light comfort, which in few cases puts the observer under test. History, especially the recent, shows that every human activity is in a state of progress, but at a certain point it begins to *move out of the socially acceptable norms*. Particularly, the development process of the contemporary lighting technologies often leads to a significant violation of the reasonable limits. As a result, the megalomania in contemporary lighting goes further by the presence of several overlit areas. Hence, the scattering of the artificial light leads to the formation of the well-known light pollution, **TABLE 1**.

TABLE 1

BORDER LEVELS OF THE LIGHT-BASED SEMANTIC MODELING. BEYOND BORDERS

LIGHT-BASED SEMANTIC MODELING

BORDERS OF LIGHTING DESIGN	ALFA LEVEL	HARMONIOUS LIGHTING ENVIRONMENT (LIGHT COMFORT)
	BETA LEVEL	LIGHT SPOT (LIGHT BURNOUT). HIGH BORDER LIGHT CLOUD. LOW BORDER
	GAMMA LEVEL	CHAOS OF RAYS. (LIGHT POLLUTION, VISUAL GLARE)
BEYOND BORDERS	DELTA LEVEL	ENGAGED LIGHT INTELLIGENT (ELEGANT) LIGHTING METACOMMUNICATION [11,30] METAMOB [11,30] LIGHT-BASED SEMANTIC FIELD INTELLIGENT URBANIZED AREAS (SMART CITIES)

Light is a herald of beauty and harmony. Contrary to this philosophy and the expectations of majority, modern picture turns the night into a day. Moreover, the light "improvements" of the urban night vision often happens to harm the natural rhythm - the starry sky and the night silhouettes disappear, the 24-hour circadian rhythm is disturbed. The quality culture of the light design education aims to draw the attention of lighting designers to the *Measure* of the artificial light impact - the *borders of lighting design* should be clearly defined and applied, as well as the conceptual "over-space" recognized as "*beyond the borders*" where designers often tend to find irrational solutions, **TABLE 1**.

LIGHT SCATTER - IN THE CONTEXT OF THE QUALITY CULTURE OF THE LIGHTING DESIGN EDUCATION

Exterior lighting systems (i.e. architecture lighting, interior lighting, advertising-information lighting, street and road lighting, and automotive lighting) are still experiencing their teenage period (**FIGURE 1**), showing an inclination for light scattering that in many cases goes beyond the acceptable limits. The free distribution of the artificial light in space create light pollution of the environment (nature), light pollution of the public environment (the urbanized areas), incl. systemic visual glare that society *still tends to perceive as normal* and acceptable.

The quality culture of the lighting design education implies the necessary limitation (even non-admission) of the artificial light scattering. In general, light scattering leads to the following negative consequences: **(a)** light pollution (including physiological and psychological glare); **(b)** forced and practically unnecessary consumption of electrical power; **(c)** pollution of the natural environment, **(d)** global warming, which is objectively proven and evaluated. The other extreme is the lack of illumination (the so-called "light poverty"), usually associated with energy poverty or a lack of light-based technical master plan. The methodology that examines the scattering of the artificial light (addressing the quality culture of lighting design) covers a logical sequence of the following issues/activities, **TABLE 2**:

TABLE 2
LIGHT SCATTERING METHODOLOGY

LIGHT SCATTERING	
POLLUTANT	Sources of light pollution - lighting systems as a pollutant.
STRUCTURE	Structure of external lighting in the context of light pollution. Structural model of the luminous flux emitted in space.
REDUCTION	Standardized reduction of light pollution.
ECONOMY	Saving measures of electrical consumption by limiting light pollution.
MEASURES	Classification system of light pollution reduction measures. Limiting light pollution as a part of lighting design.
QUANTITY EVALUATION	Quantitative assessment of light pollution (national in Bulgaria, international, global).
RANKING ASSESSMENT	Quantitative ranking system for the influence of light pollution.
MANAGEMENT	Light pollution management
MAINTENANCE FACTOR	The maintenance factor (MF) in light pollution.
EACH STREET ...	Achieving the "ES-D-IA" principle "EACH STREET DESERVES INDIVIDUAL APPROACH"
CIVIL TWILIGHT	Civil twilight - an opportunity to reduce outdoor artificial lighting.
COMPENSATION	Compensation of high light load.
LIGHT COMPOSITION	Light pollution - an element of light composition: light proportioning, harmonized lighting environment;

The light scattering forms the *borders of lighting design*, where the unreasonable waste of artificial light is taken into account. In this sense, this is the **high border** of the lighting design. Light "poverty" creates the alternative - the **low border** of the lighting design, **TABLE 1**. In the present work, some of the more important elements for limiting of the artificial light scattering are outlined addressing the systemic lighting design.

LIGHT POLLUTION SOURCES. CLASSIFICATION SYSTEM

Light pollution of the artificial light sources has multiple manifestations and variations, represented by a classification system in **TABLE 3**, [4].

TABLE 3
CLASSIFICATION OF LIGHT POLLUTION SOURCES

LIGHT POLLUTION SOURCES	
NATURAL LIGHT SOURCES	volcanic activity; natural sources of combustion; other natural external light sources
OUTDOOR FUNCTIONAL LIGHTING	street and road lighting (especially from luminaires emitting scattering luminous flux); outdoor lighting (squares, pedestrian zones, yards, parks, etc.); sports facilities lighting (stadiums, courts, playgrounds, ski runs, etc.); airport lighting (airplane runways, platforms, other open serving airport sites); railway and bus stations lighting, transport hubs, etc.; architectural lighting; audio-visual performances ("Sound and Light" performances); advertising and information lighting (including lit panels, billboards, etc.); vehicles exterior lighting (road, rail, water, air), serving for lighting, signaling, identification, decoration, and other types of functionality); other outdoor artificial lighting
OUTDOOR DECORATIVE LIGHTING	fireworks and other similar light effects with a single action; decorative lighting systems dedicated to national celebrations and holidays; light projectors - spotlights and remote action effects; lasers; other types of outdoor decorative lighting.
INDOOR ARTIFICIAL LIGHTING	different types of premises, i.e. industrial, commercial, public, residential and other buildings lighting; illumination of premises with atriums and other large glazed surfaces; greenhouses and farms lighting; other internal lighting devices emitting light through illuminating and other type of openings.

NEGATIVE IMPACT OF LIGHT POLLUTION

Outdoor lighting, serving the dark period of the 24-hour cycle, often leads to a negative harmful or even dangerous effect of disturbed functions, conditions and activities, especially if it is overdosed, improperly managed and directed, with inadequate light color, **TABLE 4**.

TABLE 4

NEGATIVE IMPACT

BIOLOGICAL RHYTHM OF PEOPLE	Change in people's behavior, self-esteem and causing illness Conducted medical researches have shown that neighborhoods with bright night artificial light during night causes hormonal disturbances of the melatonin and cancer risk, particularly in women, [16]. Sleep best restores energy; when external light enters inside premises, the 24-hour balance is disturbed leading to stress, depressive states, poor mood, headache, premature fatigue, anxiety [17,18,19,20]. Overlit zones disturbs the sense of privacy and causes worsening of the vigilance and mood [21]. The bright night artificial light activates the sense of self-preservation and provokes aggression, systemically disturbed sleep and rest, tension, headache, irritability, general physical and spiritual discomfort.
BIOLOGICAL RHYTHM OF ANIMALS	Change in behavior, causing disease in animals Birds, under the influence of bright light at night, run to exhaustion, lose orientation, twitter in unusual hours, and become more cautious when searching for food during the day [22,23,24]. Night insects lose orientation. Turtles, instinctively, instead of turning to the true bright horizon, move toward the distracted artificial light [25]. Nightlife becomes more cautious when searching for food during bright nights.
BIOLOGICAL RHYTHM OF PLANTS	Deformation of plant growth Incorrect development and plant hypertrophy under the influence of artificial light.
ASTRONOMICAL OBSERVATIONS	Visibility disturbance of astronomical objects Light emitted above the horizontal, which after distraction violates the natural appearance of the stars and interferes with astronomical observations;
ROADS AND STREET CONDITIONS	Distraction and visual glare in drivers It is a prerequisite for road accidents. In addition, bright advertising billboards near streets can cause diminishing vision, which often leads to accidents [26].
AIR-FLIGHT CONDITIONS	Distractions and visual glare in pilots It is a prerequisite for accidents in aviation. Especially dangerous is the action of projector lighting, laser effects and more.
TERMS OF WORK, OTHER ACTIVITIES AND REST OF PEOPLE	Violation of the normal and environmentally friendly working and resting conditions Including, the action of light reaching private property – e.g. entering the windows of buildings.
COMFORT OF EXTERNAL ENVIRONMENT	Discomfort action Light with high brightness and intensive colour causes harmful effect especially with its dynamics over time. Harmful effects caused by outdoor street lighting: when looking outside towards open areas.
TOURIST ACTIVITY	Discomfort action Light with high brightness, intensive colour and dynamics causes harmful effects. This may also result in deterioration of the aesthetic values.

LIGHT POLLUTION AS AN ENVIRONMENTAL FACTOR

Light pollution has a complex impact on the environment, examined and evaluated multifactorily, TABLE 5, [5,6].

TABLE 5
COMPLEX IMPACT OF LIGHT POLLUTION

COMPLEX IMPACT	
ANTHROPOGENIC FACTOR	Light pollution is involved in all human activities that cause environmental change.
ABIOTIC FACTOR	Light is a component of inanimate nature.
PARAMETRIC FACTOR	The impact of light pollution is assessed with the following parameters: brightness, color, dynamics, direction; duration of impact; scope of impact (zone, territory, population, etc.); others.

STRUCTURAL MODEL OF THE LUMINOUS FLUX DISTRIBUTION EMITTED IN THE SPACE FROM A WHITE SPHERICAL UNSHIELDED LUMINAIRE FOR OUTDOOR LIGHTING

The structure of the outdoor light in the context of light pollution is represented by a structural model showing the external light distribution intended to assess the effect of light pollution management measures, FIGURE 1. The model represents the general case of spherical unshielded luminaires for outdoor artificial lighting which practically have been widely used. They have a uniform light distribution emitting light into the two hemispheres of space. These luminaires are relatively cheap, and create uncontrolled light pollution with its several peculiar harmful effects. They also do "scatter" electrical power.

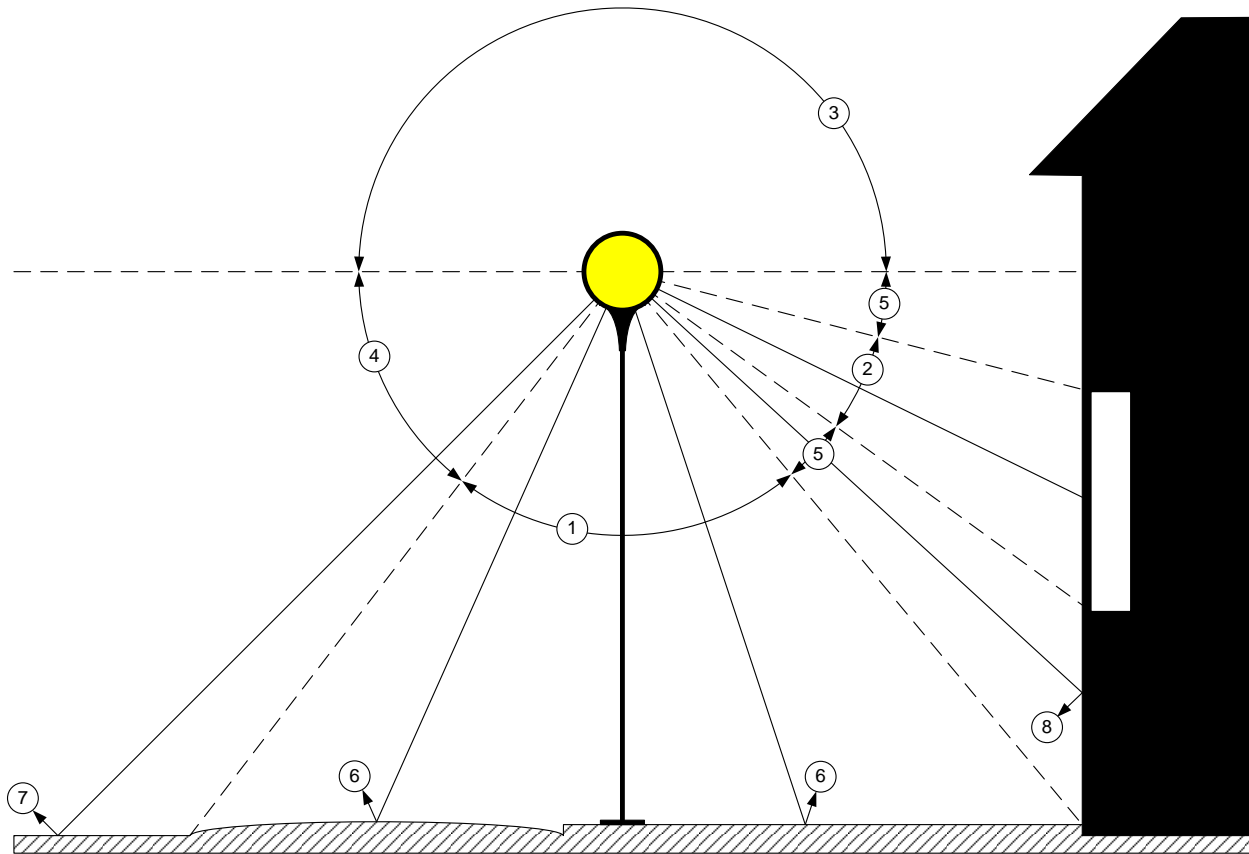


FIGURE 1. STRUCTURAL MODEL OF THE LUMINOUS FLUX DISTRIBUTION EMITTED IN THE SPACE FROM A WHITE SPHERICAL UNSHIELDED LUMINAIRE FOR OUTDOOR LIGHTING. **MARKINGS:** 1. LIGHT FOCUSED ON THE FUNCTIONALLY ILLUMINATED SURFACE; 2. SCATTERED LIGHT ENTERING THE PREMISES THROUGH THE ILLUMINATING OPENINGS; 3. SCATTERED LIGHT DIRECTED TOWARDS THE DARK SKY; 4. SCATTERED LIGHT EMITTED TO SURROUNDING OPEN SPACES; 5. LIGHT DIRECTED TO THE WALLS OF THE BUILDINGS; 6. REFLECTED LIGHT FROM A FUNCTIONALLY ILLUMINATED SURFACE; 7. REFLECTED LIGHT FROM SURROUNDING OPEN SPACES; 8. REFLECTED LIGHT FROM THE WALLS OF THE BUILDINGS.

IMPACTS OF LIGHT POLLUTION. A SYSTEM OF CRITERIA

The light pollution’s effects are of various types and have specific consequences. They are classified into three groups of impacts according to *14 classification criteria*:

1. Impacts specification; 2. Impacts progress in time; 3. Structure of impacts [7]. This systemization allows to assess the nature and severity of the light pollution effects.

TABLE 6
A SYSTEM OF LIGHT POLLUTION IMPACT CRITERIA

IMPACTS OF LIGHT POLLUTION

IMPACTS SPECIFICATION	Type of impacts
	Nature of impacts
	Sequence of impacts
	Extent of impacts
	Consequences of impacts
	Interaction with other impacts
	Impact requirements
	IMPACTS PROGRESS IN TIME
IMPACTS PROGRESS IN TIME	Frequency of occurrence of impacts
	Trends in development of impacts
	Accumulation of consequences of impacts
STRUCTURE OF IMPACTS	Scope of impacts
	Objects of impacts
	Conditions of Impact

METHODOLOGY OF LIGHT POLLUTION MANAGEMENT

There has been proposed a methodical approach to light pollution management [8]. It contains a sequence of operations following a closed cycle scheme. It implies the continuous improvement of

the lighting environment conditions through objective assessment, compliance with the regulatory framework, control of the light pollution development and, last but not least, the development of public awareness and influence. The main operations are specified in the block diagram of **FIGURE 2**.

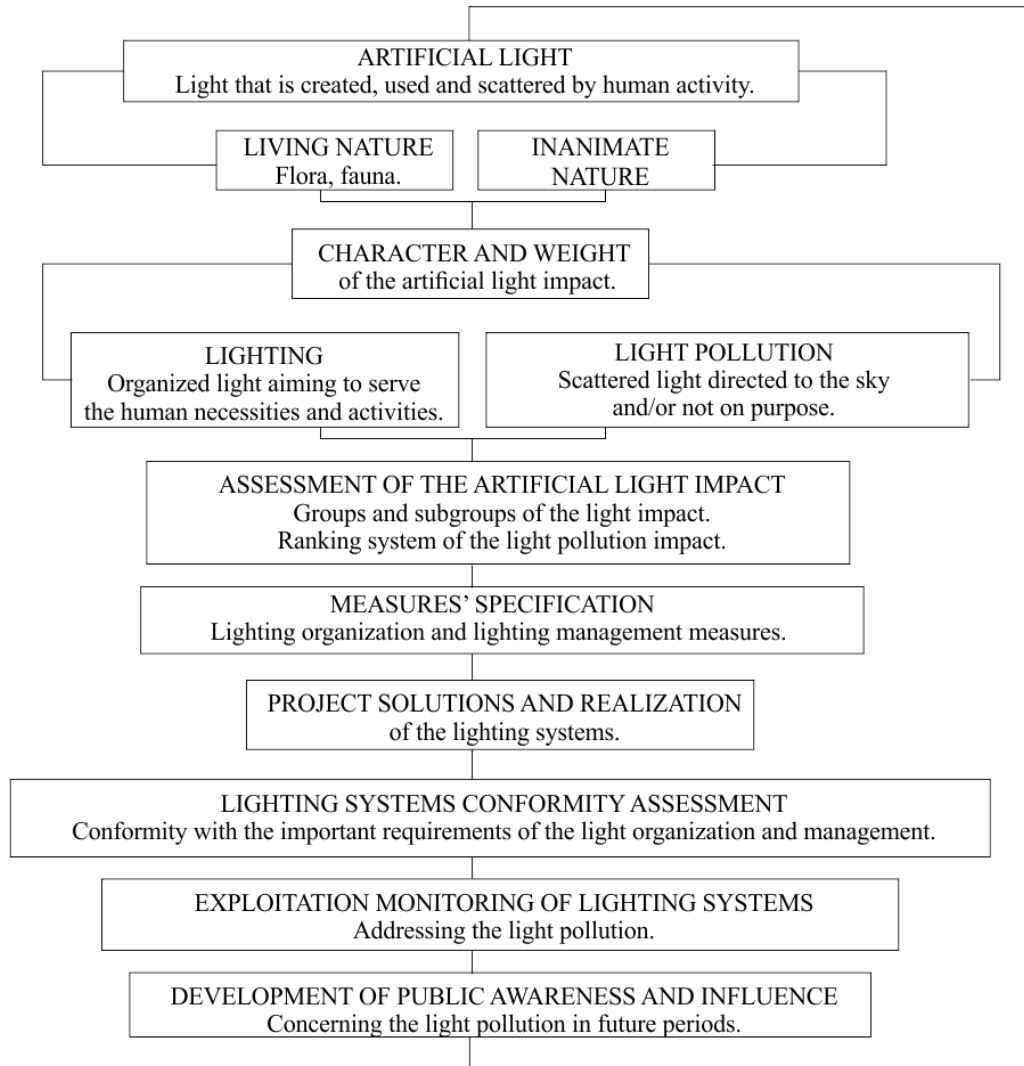


FIGURE 2. METHODOLOGICAL APPROACH TO LIGHT POLLUTION MANAGEMENT

**LIGHT POLLUTION LIMITATION MEASURES,
IN THE CONTEXT OF THE QUALITY OF EDUCATION**

TABLE 8 represents exemplary measures for limiting light pollution, according to the realization, as follows:

TABLE 8
LIMITATION MEASURES OF LIGHT POLLUTION

LIMITATION MEASURES	
NATIONAL STANDARDIZATION	Legal and regulatory acts; national standardization
DIRECTIVES AND REGULATIONS	Implementation of European directives and regulations;
PRACTICES	Specification and application of good practices;
STUDIES	Specialized surveys, measurements, studies;
DESIGN	Quality investment design;
TECHNICAL EQUIPMENT	Application of an adequate lighting technical equipment;
CONSTRUCTION ACTIVITIES	Implementation of the construction and assembly works strictly following the requirements of the project solutions;
MONITORING	Presence of systemic monitoring;
ENERGY CULTURE	Enhancing the ecological and energy culture of the population;
INDICATORS	Maintaining the indicators according to the project decisions throughout the whole operational period.

LIGHTING POVERTY - SYSTEMIC DEFECT

Lighting poverty represents the *low border* in lighting design where there is no light scattering or in case of presence it further deteriorates the light conditions. Lighting poverty can occur in: **(a)** forced lighting poverty conditions where normal activities are performed in the dark in order to save energy; **(b)** performing normal activities in the dark because there are no basic functional lighting devices; **(c)** unsatisfactory light conditions (such as the quantity and quality of functional lighting); **(d)** unsatisfactory decorative lighting performance as a concept and realization; **(e)** ethnic and religious limitations; others.

Lighting poverty can be rooted in the economic poverty (i.e. low income reflecting on the purchasing power, including the payment of energy costs, etc.) as well as in the lack of knowledge (incl. insufficient energy and lighting technical culture) of the average consumer. The unsatisfactory general and specific lighting technical competence of the lighting designers is also a prerequisite for the presence of poor lighting solutions which in most cases leads to a reaction in the consumers of lighting design products.

CONCLUSION

The question that still arises at present is when the average citizen and the representatives of lighting industry will identify the existence of light pollution as harm rather than a benefit. Visual culture is educated through the realization of adequate lighting environment, and this in turn reflects the way national, international and global challenges are shaping the present day. Globe at Night [28] and Earth Hour [29] campaigns, and many others, are important because they wake up and focus public attention and awareness on the light pollution issue and its impact. The benefit of those campaigns does not relate to their demonstrational manner (because the candles are also energy), but to the lack of adequate energy and environmental culture that should corresponds to the present high-technological progress. The lack of awareness in business representatives creates those conditions, but also dictates the behaviour of direct energy users, of the society as a whole. Because the effect of modern lighting still repeats the behaviour of the unshielded street luminaire, the artificial light is still experiencing its teenage period, spreading uncontrollably, even in the presence of technological advances. It is necessary to rethink the artificial light, the understanding of the hygiene of lighting, especially if it is overdosed, unsatisfactorily managed. Aren't we on the verge of a new lighting technical age? The truth is that light is life. Darkness, too.

Резултатите от научната статия са представени с подкрепата на „ПРОЕКТ 2018 – РУ – 04. Изследване на възможностите за проследяване на професионалната реализация на завършилиите студенти на Русенски университет.“

The results of the scientific paper are presented with the support of "PROJECT 2018 - RU - 04. Study of the possibilities for tracking the professional realization of the graduates of the University of Ruse".

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