

UDK 628.979:159.93

ASSESSMENT OF LIGHT POLLUTION ACCORDING TO PROPOSED METHOD „OPEN HOUSE”¹

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Abstract: The Construction Cluster „DUNDJER“, together with a number of its members, is participating, as a leading partner, in a national project co-financed by the National Agency for Regional Development, which deals with innovative implementation of LED lamps in the system of public enlightening by introducing distance control. Although outdoor lighting is imperative to illuminate sidewalks, parking lots and driveways for safety and convenience reasons, it can alter a site's nocturnal ecosystem and limit sky observations. Therefore, in order to avoid light pollution, the design of external lighting should be in accordance with the following:

- To design only the strict necessary external lighting and to ensure that external lighting is concentrated in the appropriate areas;
- To avoid disturbance on animal and human health and psychology;
- To avoid disruption of ecosystems;
- To reduce sky glow and glare;
- To improve nocturnal sky observations (effects on astronomy).

According to LEED and BREEAM norms, the method for assessment of light pollution is developed. This method will be used in design and calculation of enlightening in frame of noted project. The key study is realized in the Municipalities Knjaževac, Bela Palanka, and Preševo. The assessment methodology is presented in this paper.

Keywords: Light pollution, external lighting, LED lighting, distance control of lighting, assessment of light pollution.

OCENA SVETLOSNOG ZAGAĐENJA PREMA PREDLOŽENOM „OPEN HOUSE” METODU

Rezime: Gradjevinski klaster „DUNDJER“, zajedno sa nekoliko svojih članova, učestvuje kao vodeći partner u nacionalnom projektu koji je delimično finansiran od strane Nacionalne agencije za regionalni razvoj i koji se bavi inovativnom primenom LED svetiljki u sistemu javnog osvetljenja sa primenom daljinskog upravljanja. Iako je spoljašnje osvetljenje neophodno za osvetljavanje pešačkih prolaza, parkirališta i pristupnih puteva radi sigurnosti i komfora, ono može narušiti noćni ekosistem i ograničiti osmatranja neba. Stoga, da bi se izbeglo svetlosno zagađenje, projekat osvetljenja bi trebalo da bude u saglasnosti sa sledećim ograničenjima:

¹ This work is in part supported by National Agency for Regional Development of R. Serbia ;

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- Projektovati strogo neophodno spoljašnje osvetljenje uz osiguranje da je spoljnje osvetljenje strogo orijentisano na ciljane površine;
- Izbegavati uticaj na ljudsko i životinjsko zdravlje i psihologiju (mentalno zdravlje);
- Izbegavati narušavanje eko-sistema;
- Ograničiti sjaj i odblesak neba;
- Poboljšati uslove za noćno osmatranje neba (uticaj na astronomiju).

U skladu sa LEED i BREEAM normama, razvijen je metod za ocenu svetlosnog zagađenja. Ovaj metod će biti korišćen za projektovanje i proračun osvetljenja u okviru ovog i drugih projekata. Ocena je primenjena pri projektovanju osvetljenja u opštinama Knjaževac, Bela Palanka i Preševo. Metodologija procene je prezentovana u ovom radu.

Ključne reči: Svetlosno zagađenje, spoljno osvetljenje, LED osvetljenje, daljinsko upravljanje osvetljenjem, ocena svetlosnog zagađenja

1. INTRODUCTION

The evaluation framework defines the hierarchical structure of the assessment methodology. It is composed of 6 main categories:

- Environmental Quality,
- Social/Functional Quality,
- Economic Quality,
- Technical Characteristics,
- Process Quality,
- The Location).



Environmental quality contains the following criteria:

- 1.1 Global Warming Potential (GWP)
- 1.2 Ozone Depletion Potential (ODP)
- 1.3 Acidification Potential (AP)
- 1.4 Eutrophication Potential (EP)
- 1.5 Photochemical Ozone Creation Potential (POCP)
- 1.6 Risks from materials
- 1.7 Biodiversity and Depletion of Habitants

1.8 Light Pollution

1.9 Non-Renewable Primary Energy Demand (PEnr)

1.10 Total Primary Energy Demand and Percentage of Renewable Primary Energy

1.11 Water and Waste Water

1.12 Land use

1.13 Waste

1.14 Energy efficiency of building equipment (lifts, escalators and moving walkways)

2. OBJECTIVES OF LIGHT POLLUTION PROTECTION

Although outdoor lighting is imperative to illuminate sidewalks, parking lots and driveways for safety and convenience reasons, it can alter a site's nocturnal ecosystem and limit sky observations. In order to avoid it, the following limitations are recommended.

- To design only the strict necessary external lighting and to ensure that external lighting is concentrated in the appropriate areas,
- To avoid disturbance on animal and human health and psychology,
- To avoid disruption of ecosystems,
- To reduce sky glow and glare.

To improve nocturnal sky observations (effects on astronomy).

3. ASSESSMENT METHODOLOGY

Projects should illuminate areas only as required for safety and comfort, provide only the light levels necessary to meet the design intent, and select efficient fixtures using efficient sources to meet the lighting requirements of the site while minimizing light pollution (LEED, SSc8). Therefore, the installed lighting power densities including emergency lighting is compared to maximal acceptable values.

High illuminance at a site boundary can affect neighbouring areas and buildings and impact surrounding ecosystems or neighbourhoods. The goal is to retain the emitted light within the site boundaries and the horizontal and vertical illuminance values at the site boundary are thus assessed.

Light sources pointing directly towards the sky cover have a critical impact in terms of night-time sky glow and glare, thus limiting the potential for night sky observations. The goal is to limit the amount of light pointing directly towards the sky cover and this is assessed with the percentage of luminaries with lumens emitted at 90° or higher from **nadir** (**nadir** is the direction pointing directly below a particular point, i.e. normal angle direction).

The following sub-indicators will be assessed:

- Lighting power densities (LEED)
- Illuminance at the site boundary (LEED & BREEAM)
- Angle of light emission (LEED)

4. CALCULATION AND RATING

4.1. Lighting power densities (LEED)

Lighting power densities must not exceed the requirements given below, ASHRAE 90.1-2007, Section 9, Table 9-4-5., Lighting for External Areas for the classified zone (Tradable surfaces or

non-tradable surfaces).

Tradable Surfaces (LPDs for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs, and outdoor sales areas may be traded):

Uncovered parking areas (Parking lots and drives) – 1.6 W/m²;

Building grounds (Walkways less than 3 m wide) – 3.3 W/linear meter; (Walkways 3 m wide or greater, Plaza areas, Special feature areas) – 2.2 W/m²; Stairways 10.8 W/m²;

Building entrances and exits (Main entries) – 98 W/ linear meter of door width; (Other doors) – 66 W/linear meter of door with;

Canopies and overhangs (Canopies – free standing and attached and overhangs) – 13.3 W/m²;

Outdoor sales (Open area – including vehicle sales lots) – 5.4 W/m²; (Street frontage for vehicle sales lots in addition to “open area” allowance) – 66 W/linear meter.

Nontradable Surfaces (LPDs for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the “Tradable Surfaces” section above):

Building facades – 2.2 W/m² for each illuminated wall or surface or 16.4 W/linear meter for each illuminated wall or surface length;

ATM and night depositories – 270 W per location plus 90 W per additional ATM per location;

Entrances and gatehouse inspection stations at guarded facilities – 13.5 W/m² of uncovered area

(covered areas are included in the “Canopies and Overhangs” section of “Tradable surfaces”);

Loading areas for law enforcement, fire, ambulance, and other emergency service vehicles – 5.4 W/m² of uncovered area (covered areas are included in the “Canopies and Overhangs” section of “Tradable surfaces”);

Drive-through windows at fast food restaurants – 400 W per drive through;

Parking near 24-hour retail entrances – 800 W per main entry.

This sub-indicator is based in the table 4.1 Lighting Power Densities for Building Exteriors.

4.1. Lighting power densities	Points
Lighting power densities lower than the ANSI/ASHRAE/IESNA Standards 90.1-2007 for the classified zone	100
Lighting power densities higher than the ANSI/ASHRAE/IESNA Standards 90.1-2007 for the classified zone	0

4.2. Illuminance at the site boundary (LEED & BREEAM)

The requirements for maximal illuminance depend on the classification of the project. The project must be categorized under one of the following zones defined in IESNA RP-33 and must follow all the requirements for that zone:

Zone: LZ1

Lighting environment: Intrinsically dark;
Characterization: Developed areas within national parks, state parks forest land and rural areas;
Maximum initial illuminance value: 0.1 horizontal and vertical lux at the site boundary and beyond.

Zone: LZ2

Lighting environment: Low district brightness;
Characterization: Primarily residential zones, neighbourhood business districts, light industrial with limited nighttime use and residential mixed use areas);
Maximum initial illuminance value: 1.0 horizontal and vertical lux at the the site boundary 0.1 horizontal lux 3m beyond the site boundary.

Zone: LZ3

Lighting environment: Medium district brightness;
Characterization: All other areas not included in LZ1, LZ2 or LZ4, such as commercial/industrial, and high-density residential);

Maximum initial illuminance value: 2.0 horizontal and vertical lux at the site boundary 0.1 horizontal lux 5m beyond the site boundary.

Zone: LZ4

Lighting environment: High district brightness;

Characterization: High activity commercial districts in major metropolitan areas;

Maximum initial illuminance value: 6.0 horizontal and vertical lux at the site boundary 0.1 horizontal lux 5m beyond the site boundary.

To measure compliance with the light trespass requirements, use lighting design software and develop a site illumination model. The model should show the full extent of the site and all installed fixtures. Figure 1 shows the photometric site plan generated by an illumination model. The example is in

compliance with the credit requirements for a project located in LZ2: the light level at the property line does not exceed 1 lux, and the light level 3m beyond the property line does not exceed 0.1 lux.

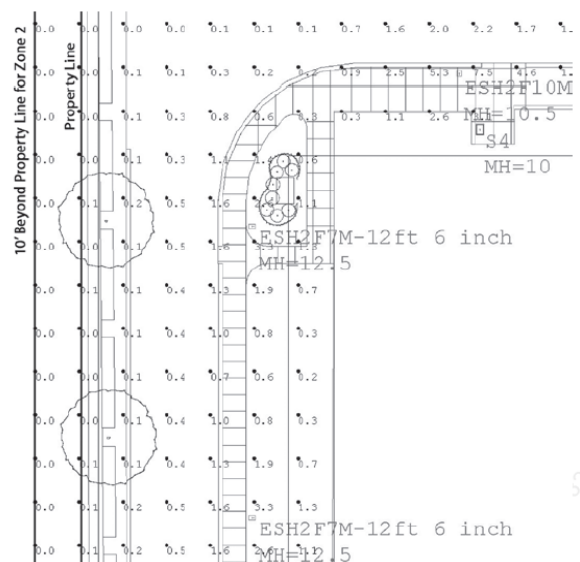


Figure 1 Sample Illumination Model

Attenuation measure

All external lighting (except for safety and security lighting as well as illuminated advertisements) can be automatically switched off between 23h and 7h. This can be achieved by providing a timer for all external lighting set to the appropriate hours (BREEAM, Pol 7). External light fittings can also be controlled through a daylight sensor, to prevent operation during daylight hours (BREEAM, Ene 4). This sub-indicator is based on the maximum initial illuminance as defined above.

4.2. Illuminance at the site boundary	Points
Fulfilment of the requirement depending of the zone (Initial illuminance value < maximum)	100
Non-fulfilment of the requirement depending of the zone (Initial illuminance value > maximum) but fulfilment of the attenuation Measure.	50
Non-fulfilment of the requirement depending of the zone (Initial illuminance value > maximum) nor of the attenuation measure.	0

4.3. Angle of light emission (LEED)

The requirements for the angle of light emission depend of the classification of the project. The project must be classified under one of the following zones, defined in IESNA RP-33 and must follow all the requirements for that zone:

Zone: LZ1

Lighting environment: Intrinsically dark;
Characterization: Developed areas within national parks, state parks forest land and rural areas;
Requirements are: 0 % of the total initial designed fixture luminous flux (in lumens) is emitted at an angle of 90 degrees or higher from **nadir** (**nadir** is the direction pointing directly below a particular point). Practically, this means that the entire luminous flux must be directed below the horizontal direction.

Zone: LZ2

Lighting environment: Low district brightness;
Characterization: Primarily residential zones,

neighbourhood business districts, light industrial with limited nighttime use and residential mixed use areas);

Requirements are: No more than 2 % of the total initial designed fixture lumens are emitted at an angle of 90 degrees or higher from **nadir** (**nadir** is the direction pointing directly below a particular point).

Zone: LZ3

Lighting environment: Medium district brightness;
Characterization: All other areas not included in LZ1, LZ2 or LZ4, such as commercial/industrial, and highdensity residential);

Requirements are: No more than 5 % of the total initial designed fixture lumens are emitted at an angle of 90 degrees or higher from **nadir** (**nadir** is the direction pointing directly below a particular point).

Zone: LZ4

Lighting environment: High district brightness;
Characterization: High activity commercial districts in major metropolitan areas;

Requirements are: No more than 10 % of the total initial designed fixture lumens are emitted at an angle of 90 degrees or higher from **nadir** (**nadir** is the direction pointing directly below a particular point).

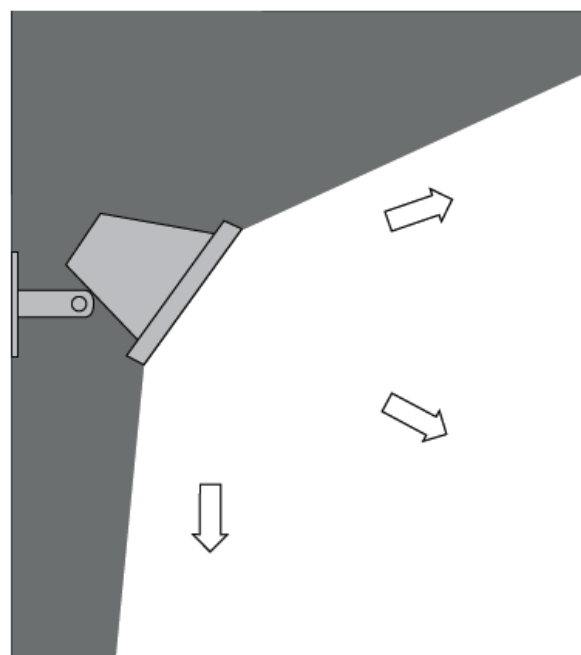


Figure 2 Unshielded Floodlight Angle of light emission > 90°

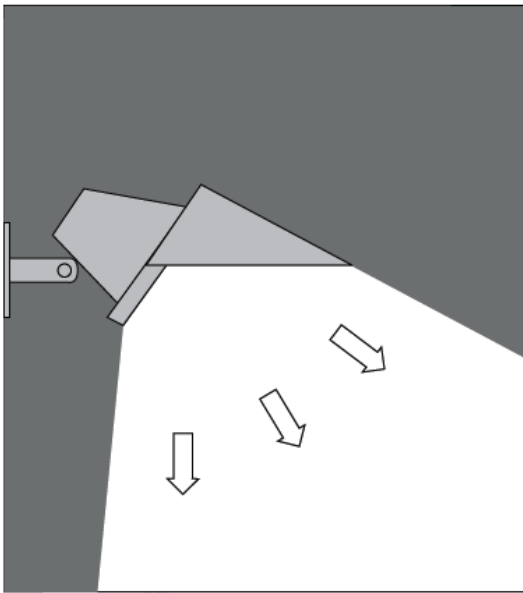


Figure 3 Shielded Floodlight Angle of light emission < 90°

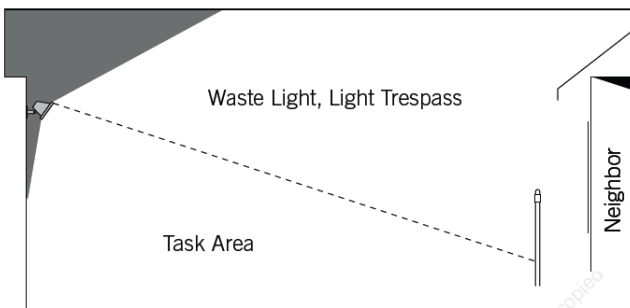


Figure 4 Task Area from Unshielded Floodlight

This sub-indicator is based on the requirements for angle of light emission as defined above.

More than 40 % of the total initial designed lumens fixture are emitted at an angle of 90 degrees or higher from nadir	0
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5. DOCUMENTATION GUIDELINES

The following documents are required to assess the building:

Basic & Quick Assessment

Letter of commitment or **easily and quickly** accessible documentation for the required evidence (see Complete Assessment), e.g. reasonable estimations for intended/expected values.

Complete Assessment

4.1 Lighting Power densities

- Technical data sheet of lighting fixtures,
- Manufacturer’s data for lamps used on a project site.

4.2 Illuminance at the site boundary

- Classification for a project site,
- Description of the light trespass analysis procedure conducted to determine compliance with Photometric site plan
- Specification confirming external lighting control strategy

4.3 Angle of light emission

- Pictures of installed fixtures showing angles <90° from **nadir**.

6. RELATION TO OTHER INDICATORS

Indicator 1: Visual comfort (Indicator 2.7, Open House Manual);

Indicator 2: Non-Renewable Primary Energy Demand (PE_{nr}) (Indicator 1.9, Open House manual);

Indicator 3: Total Primary Energy demand and Share of renewable Primary Energy (Indicator 1.10, Open House manual).

4.3. Angle of light emission	Points
All designed lumens fixture are emitted at an angle lower than 90 degrees from nadir	100
Fulfilment of the requirement depending on the zone	90
Percentage (of the total initial designed lumens fixture are emitted at an angle of 90 degrees or higher from nadir) close to the requirement (up to 1,5% higher)	75
Percentage higher than the requirement, up to 40 %	30

LITERATURA

[1] BREEAM Europe Commercial 2009 Assessor Manual

[2] LEED Reference Guide for Green Building Design and Construction 2009 Edition

[3] ANSI/ASHRAE/IESNA Standard 90.1-2007, Energy Standard for Buildings Except Low-Rise Residential Lighting, Section 9 (without amendments)

[4] Lighting for Exterior Environments RP-33-99, by the Outdoor Environment Lighting Committee of

Illuminating Engineering Society of North America (www.iesna.org) (IESNA, 1999)

[5] International Dark-Sky Association (www.darksky.org).