Light & Engineering
Vol. 27, No. 6, pp. 41–48, 2019
https://doi.org/10.33383/2018-031

THE EVALUATION OF AN OFFICE BUILDING ACCORDING TO LEED CERTIFICATE LIGHTING CRITERIA

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ABSTRACT

The progress in industrial and technological areas, which started with the Industrial Revolution, has deteriorated the ecological balance and depleted the natural resources. Sustainability, which initially seemed as a solution within this concept, became an important part of Interior Architecture as in disciplines related to design. The lighting systems of the offices that are the secondary living areas should be evaluated in terms of sustainability as well.

In this paper, the energy savings and loss of the artificial office lighting systems has been calculated according to the ASHRAE/IES standard 90.1–20078 [1] which are included in the Leadership in Energy and Environmental Design (LEED) certificate's lighting criteria [1]. The wattage of the artificial lighting systems has been calculated while the systems were in use. The results of these measurements have been compared with lighting wattage and thus the lighting energy savings and loss have been configured. The office has been comparatively analyzed according to LEED criteria.

Keywords: office, lighting, sustainability, energy efficiency, LEED criteria

1. INTRODUCTION

Natural Lighting is the lighting system designed to meet the visual comfort requirements of the daylight whose main source is the sun.

Some of the light sources produce light on their own. These are called natural light sources. Sun, stars, fireflies, lightning, streak and some species of fish living deep in the sea are natural light sources [2].

A principal characteristic of daylight is its variability. The colour of daylight changes with the time of day, the cleanliness of the atmosphere, and the inter reflection of surrounding objects. The intensity of the sun changes with the time of day, the time of year, and the latitude of the site. The luminance of the sky depends on whether the light is coming from an overcast sky, from a clear sky only, or from a clear sky and direct sunlight [3].

Direct sunlight is usually an impractical source for interiors unless it is shielded. Just as electric luminaires are designed to reduce glare, direct sunlight entering interior spaces requires careful control [3].

For centuries, daylight has played an important role regarding the design of the buildings. As a result of technological developments, the electric power started to be used for lighting and it became widespread. This situation enabled the architects to become free in their designs; however, the necessity of the careful consumption of the energy resources became a fact which has to be accepted

[1] At present time, there is a new version of this standard *ANSI/ASHRAE/IES* Standard 90.1–2016 (editor remark)

by everyone. That's why the effective use of sunlight and the creation of the solutions regarding the decrease in the consumption of electric power have become the most important topics of today's architecture [4].

Light emitting diodes (LED) is also an important solution for sustainability as an artificial lighting system. It is uses for energy efficiency at the spaces.

LEDs are light sources based on electro luminescence and are very similar to conventional semiconductor diodes. The light is generated in the depletion layer by the recombination of electrons and hole, the emitting spectra is depending on the composition of the semiconductor material. Beside the typical coloured LED also white LEDs are available since several years. The white radiation is not the direct result of the LED emission but is generated by fluorescence conversion in blue LEDs covered with a phosphor layer [5].

Sustainability has arrived in the field of interior architecture pretty late from the design-based disciplines. Lighting is one of the most important subjects designed within the framework of interior architecture. When the daylight usage is increased, used properly and supported by the least artificial lighting, the energy consumption and CO_2 emission can be decreased, the greenhouse gas emission related to energy can be prevented, and also light pollution can be decreased. In this paper, it can be seen that when the sustainable lighting criteria are applied properly, all the above-mentioned economic, social and environmental factors can be managed.

Sustainable design is an exciting area of architecture and building which has been moving into the mainstream. And there's a good reason that 'green' or sustainable buildings are also known as 'high performance buildings': they not only tend to save on running costs, there is also growing evidence that they can increase productivity and well-being for occupants through improved lighting and air quality. Where office buildings have been designed or refurbished to be more sustainable, productivity gains in terms of better quality of work and reduced absenteeism can often dwarf the reductions in energy bills [6].

In this paper, the evaluation of the artificial lighting usage of office buildings according to the LEED certificate lighting criteria is done. This is based on a DENGE Company Office, which is designed by MATT Architectural Company in Izmir. The energy savings and loss of the artificial office lighting systems are calculated and then are divided into office sections and types in accordance with the ASHRAE/IES standard 90.1–2007 which are included in the LEED certificate's lighting criteria.

1.1. LEED and Lighting

Due to the environmental problems arising from global warming, ways to decrease carbon dioxide emissions is become ever more important. According to various studies, buildings are responsible for approximately 40 % of overall CO_2 emissions in the world. Due to this fact, green building certification systems that aim to reduce the carbon emissions of the buildings and the negative impact of building construction on the environment are being developed worldwide [7].

LEED (Leadership in Energy and Environmental Design) is a product of the US Green Building Council, and is the most well-known rating system for commercial buildings. The LEED framework consists of several rating categories, applicable to different points in a building's lifecycle [8].

Within this system, in order to meet the requirements of the designed artificial environments, the building is classified according to its typologies, and 9 different options – new buildings, present buildings, commercial buildings, shell – core, schools, places for sales, health buildings, residences, urban development centres- were suggested for the planned certification. All the points needed for the certification of the building are different from each other within the framework of the each evaluation system created for each typology, and a certain value is present for each of the measurements [9].

In LEED version 4 [10] the lighting categories are:

- Light pollution reduction,
- Optimize energy performance,
- Advanced Energy Metering,
- Interior lighting.

1.1.1. Light pollution reduction

The lighting design must avoid light trespass from exterior luminaires onto neighbouring property. As well as preventing sky glow from both interior and exterior luminaires [11].

Fig.1. DENGE open office and cell office spaces (Idil Bakır Küçükkaya Photo Archive, 2015)

In LEED2009, the light trespass criteria included both a horizontal and vertical foot-candle maximum, which varied by Lighting Zone, without a lot of specificity in how the criteria should be documented. In addition, the horizontal foot candle requirement was <0.1 fc (1.08 lx), which meant that if you had a high-density design with lighting anywhere near the LEED boundary, this credit was nearly impossible to attain even if your exterior lighting was very sensible and dark-sky friendly. In LEED V4, there is only a vertical foot-candle requirement, with clear guidance on how the calculation grids should be built, or you can comply by using fixtures with an appropriate bug rating [12].

1.1.2. Optimize energy performance

This credit intends to achieve increasing levels of energy performance beyond the perquisite standard to reduce environmental and economic harms associated with excessive energy use [10].

In requirements there is an option for small to medium office building. This option is ASRAE50 % advanced energy design guide for small to medium office building.

This credit includes:

- Building envelope, opaque: roofs, walls, floors, slabs, doors, and continuous air barriers (1 point);
- Building envelope, glazing: vertical fenestration (1 point);
- Interior lighting, including daylight and interior finishes (1 point);
- Exterior lighting (1 point);
- Plug loads, including equipment and controls (1 point).

1.1.3. Interior lighting

This credit incorporates the former Controllability of Systems – Lighting credit (IEQ 6.1), with the further requirement spaces have bi-level switching [12].

1.1.4. Advanced energy metering

This credit intends to support energy management and identify opportunities for additional energy savings by tracking building-level and system-level energy use. The requirements are to install advanced energy metering for the following:

- All whole-building energy sources used by the building;
- Any individual energy end uses that represents 10 % or more of the total annual consumption of the building [10].

2. THE EVALUATION OF AN OFFICE BUILDING: DENGE OFFICE IN IZMIR

DENGE is a certified consultant company in Izmir. DENGE Office situated at thirteenth floor in Punta Residence. The settlement of the working areas is done according to 35 people's comfort and suitable working conditions.

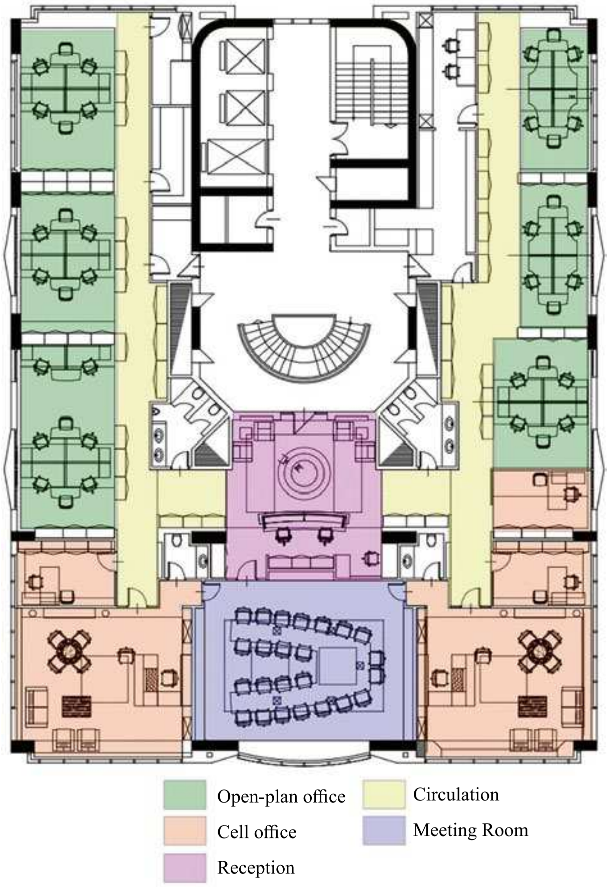

Fig.2. DENGE office layout

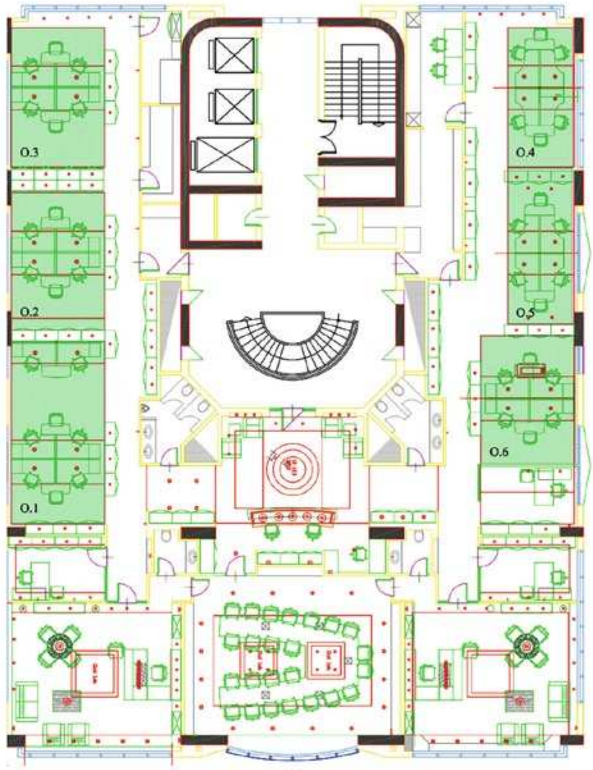

Fig.3. DENGE office lighting layout

This office includes both, cell and open-plan offices, a conference room, kitchen, bathrooms, reception, corridors, storage and a technical room. The lighting systems are designed according to this office models.

In the DENGE Office, the natural and artificial lightings are designed together. The location of the building is situated very convenient for fluent usage of daylight as seen in Fig.1. The spotlight systems are used to provide aesthetic view. The spotlights are chosen as LED lighting spots for reducing the energy demand for lighting. Above every worker spotlights are located providing working conditions very comfortable without glare. In the corridors, reception and the cell offices, wall fixtures are used to illuminate the paintings by creating an aesthetic view and also illuminating corridors [13].

The Layout diagram illustrates a typical space, identifying the specific locations where lighting and energy performance have been calculated, Fig.2.

The DENGE office lighting layout is shown in the Fig.3. At the top of each table in open office space there is a drop ceiling and the spotlights are fixed in them. Tiny LED spotlights are also located at the top of the closets. In cell offices, it has six types of lighting fixtures. There are round and square spotlights, wall (painting) fixtures, two types of ceiling lightings, and also LED band lightings. At the top of the working table spotlights and ceiling light is located. The drop ceiling has concealed lightings, which is LED band lighting. The other ceiling light is the top of the meeting table and visitor's coffee tables. In the meeting room, a lot of spotlights are used. It has drop ceilings which has concealed lightings. The lightings are located according to chairs and tables places. In the entrance of the DENGE office there is a drop ceiling with the 18 pieces power LED (1 watt) and concealed lighting. Top of the reception tables, there is ceiling fixtures and wall fixtures. At the side of the door, there are two niches with the spotlights. LED lighting was used through the corridors. And there is also wall lighting and drop ceiling with the concealed lighting. And top of the cabinets, there is spotlights, Table 1.

The calculations of the lighting power presented in Table 2 are added to the number showing the power of the lighting written on the "watt" section, and were divided with square meter. Presented in Table 2 lighting energy saving are as follows: open office 1–68 %, open office 2–31 %, open office

Table 1. DENGE Office Lighting Systems Analyses

	Luminaire	Nominal Size	Light Source	Power, W	Luminous flux, lm	Voltage	Rated life, h
Open Office Lighting Systems	NASSA LED Spotlight	Radius 19.5	LED	18	2000	85–265	50000
	NASSA LED Spotlight	Radius 15.5	LED	20	2000	86–265	50000
Cell Office Lighting Systems	NASSA LED Spotlight	13×13×8 cm	LED	20	2000	85–265	50000
	NASSA LED Spotlight	Radius 15.5	LED	20	2000	86–265	50000
	NASSA Jupiter Ceiling lighting	35×35×37 cm	Energy Smart Bulb	40	475	220–240	8000
	PHILIPS	206×117×5 cm	Fluorescent	28	2900	230	24000
	NASSA Wall Fixture	53×52×29 cm	4xE4	2×20	2000	230	24000
	NASSA Band LED Lighting	16 m	3x300 LED	14,4 (1 m)	475	12	24000
DENGE Meet-ing Room Lighting Systems	NASSA LED Spotlight	Radius 19.5	LED	18	2000	85–265	50000
	NASSA LED Spotlight	Radius 15.5	LED	20	2000	86–265	50000
	NASSA Band LED Lighting	16 m	3x300 LED	14,4 (1 m)	475	12	24000
DENGE Reception Lighting Systems	NASSA POWER LED	Radius 5	LED	1	130–150	3–4	10000
	NASSA LED SPOTLIGHT	Radius 15.5	LED	20	2000	86–265	50000
	NASSA Jupiter Ceiling lighting	35×35×37 cm	Energy Smart Bulb	40	475	220–240	8000
	NASSA Wall Lighting	10×10×18 cm	Halogen	20	320	12	2000
	NASSA Spotlight	6×6×8 cm	LED	20	2000	86–265	50000
	NASSA Band LED Lighting	16 m	3x300 LED	14,4 (1 m)	475	12	24000
DENGE Corridors Lighting Systems	NASSA Wall Fixture	53×52×29 cm	4xE4	2x20	2000	230	24000
	NASSA LED Spotlight	Radius 15.5	LED	20	2000	86–265	50000
	NASSA Wall Fixture	10×10×18 cm	Halogen	20	320	12	2000

3–41 %, open office 4–56 %, open office 5–12 %, open office 6–53 %. At the office's cabinets: 1 shows 59 % loss, 2 shows 59 % loss, office cabinet 3 shows 18 %, cabinet 4 shows 18 %, and office's cabinet 5 shows 18 % lighting power loss. According the results of meeting room 21 % loss of energy is obtained, 9 % energy loss in lighting power is obtained at the reception, and 100 % loss of lighting power at the corridors.

As shown in Table 3, appropriate watt according to ASHRAE and the current watt at the office are compared and then the amount of power savings are calculated. The lighting power saving of the DENGE office is 3 % in total, which is a low rate in comparison to the desired 10 % according to LEED certificate.

DENGE office building which is without a certificate is presented with lighting projects, analyzed regarding lighting in terms of sustainability, and measured in terms of their lighting power. According to the results seen in Table3 DENGE Office only shows 3 % energy saving. Even though DENGE Office is not sustainable, energy saving is provided only by using the efficient types of light.

According to the LEED certificate, in the criteria of optimize energy performance, the saving must be 10 % in general office buildings. DENGE Office can't provide this rate. DENGE Office consumes more than enough lighting power. According to the results, in the meeting rooms and corridors, DENGE Office consumes more than enough energy. Especially in the corridors section, the wall

Table 2. DENGE Open Office and Cell Office Lighting Energy Analyses

Lighting Space	Area, m²	% of total	Standard 90.1 Allowance		Connected power, W	Savings, %
			W/m²	Power, W		
Cell Office 1	49	6	12	588	933	–59
Cell Office 2	49	6	12	588	933	–59
Cell Office 3	12	2	12	144	170	–18
Cell Office 4	12	2	12	144	80	18
Cell Office 5	12	2	12	144	170	–18
Open Office 1	34	4	12	408	132	–68
Open Office 2	28	4	12	336	232	31
Open Office 3	30	4	12	360	212	41
Open Office 4	25	3	12	300	132	56
Open Office 5	20	3	12	240	212	12
Open Office 6	20	3	12	240	112	53

lightings and spotlights indicate a 100 % over-used lighting.

Table 4 shows the interior lighting criteria of LEED certificate's implementation and evaluation on the DENGE Office project. While the sustainable Office Buildings include all of the lighting criteria such as controllability of lighting systems, interior lighting quality, optimized energy performance, daylight and view, DENGE Office does not. In the DENGE office, the Artificial Lighting Systems aren't controlled. As a result, DENGE Office Building doesn't provide the LEED sustainable lighting criteria [13].

3. CONCLUSION

In this paper, the energy savings and loss of the office artificial lighting systems is calculated according to the ASHRAE/IES standard 90.1–2007 which is included in the LEED certificate's lighting criteria. The wattage of the artificial lighting systems of DENGE Office is calculated while the systems were in use.

As a result of this evaluation, for DENGE Office the lighting energy savings or loss for open offices is the 45 % savings, for cell offices – 0,3 % loss. Energy saving through individually controlled artificial lighting with sensor of daylight for meeting rooms that has been made by DENGE office, the percentage could decrease drastically about 21 % loss. For reception areas are 9 % of losses and for circulation areas are 100 % losses in lighting energy saving. This percentage is considerably high. These are significant losses both, economically and environmentally. The lighting energy saving is not sufficient regarding circulation areas. Luminaires choices were not selected adequately and further studies must be done about this subject.

DENGE Office only fulfils suitable fenestration and interior configuration criteria. The most important for lighting energy saving is suitable and efficient luminaire specification. Because of the unsuited luminaire choices; DENGE office has a large loss of lighting energy in circulation areas, meeting room and reception areas. The lighting systems should be controllable and supported by daylight-connected sensors. The lamps of the lighting systems should be changed into LED lights. In the circulation areas which consume the energy the most, the spotlights should be changed and the wall lightings should be replaced by lighting systems with led lights which consume less energy. In the reception areas fewer spotlights should be used, their lamps should be replaced by LED lights. In the cell

Table3. The Lighting Energy Savings or Loss Calculation of DENGE Office

Space	Area m²	% of Total	Standard 90.1 Allowance		Connected, W	Savings (–)/loss, %
			W/m²	W		
Open Offices	157	20	12	1884	1032	–45
Cell Offices	134	17	12	2278	2286	0.3
Meeting Room	65	8	11	715	872	21
Corridors	102	13	5	510	1025	100
Reception	45	6	14	630	691	9
Other	297	37	10	2970	2820	–5
Total	800	%100	–	8987	8726	–3

Table4. The Assessment of DENGE Office with the LEED Sustainable Lighting Criteria

Credit	Description	
SS Credit 8	Light Pollution Reduction	Not in Scope
EA Prerequisite 2	Minimum Energy Performance	Achieved 3 % reduction in lighting power
EA Credit 1	Optimize Energy Performance	Achieved 3 % reduction in lighting power
IEQ Credit 6.1	Controllability of Systems -Lighting	The Artificial Lighting Systems aren’t controlled.
IEQ Credit 8.1	Daylight and Views – Daylight	Insufficient
IEQ Credit 8.2	Daylight and Views – Views	Insufficient
Pilot Credit 22	Interior Lighting – Quality	Insufficient

offices, fewer spotlights should be used and when it comes to individual lightings, less-energy using lightings should be preferred. By these ways the energy performance in the office can be optimized. The eye exhaustion and screen glare of the employees will disappear and the work efficiency will increase.

As mentioned in the LEED criteria, providing the requirements carries great importance for the lighting control. Controllable systems should be designed for the building and automatic lighting systems connected to a general system should be implemented. LED lights, which have great effect on energy savings in artificial lighting systems, should be used. Implementation of these criteria can increase the productivity of the employees.

The issues studied, analyzed and presented in this paper can serve as a guideline for a designer. The design of the lighting systems should be managed in order to provide visual comfort conditions in the office and also to reduce the energy consumption; and within this subject it should be improved by using technological methods.

Finally, all of the studies about sustainability aim to leave a sustainable world in which the future generations can live, the resources are efficient, and there is no light pollution. Lighting covers a great part of this cycle. In all of the studies that are being or will be done, the understanding of a sustainable design is required. All around the world including Turkey, interior architecture and the other disciplines related to design should accept the subject of sustainability as a priority, embrace the sustainable lighting criteria and feed it with modern methods. In the offices in which people spend most of their time, lighting systems that provide comfortable study areas without any glare effect on our eyes, efficient daylight angle support the artificial lighting and spend less energy in an appropriate way.

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