Energy Efficient Lighting In Retail Spaces - Case Study Evaluations

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ABSTRACT

Energy efficient design gains in importance for reducing of both CO_2 emissions and high energy costs. The electricity used for lighting needs have a large percentage of the buildings' total energy consumption; therefore lighting systems should be designed carefully.

There are several certification methods to assess the sustainability of the buildings which differ according to the lighting related categories and the percentages of these categories in the overall building assessment. In this context, Lighting and Energy Consumption requirements of BREEAM Retail 2009 and LEED Commercial Interiors 2009 are investigated for retail spaces. Retail buildings are important energy users because of their long-period and common usage. As a case study the parameters determined by the methods are evaluated on a retail centre in Turkey.

This study aims to emphasize the parameters of sustainable lighting design for retail spaces, which should provide the visual comfort conditions while minimizing the energy consumption.

Keywords: Sustainable lighting, Energy performance, Building assessment methods, Retail lighting

1. INTRODUCTION

The subsystems like heating, cooling and lighting constitute a considerable portion of the total energy consumption of buildings. Energy efficient design strategies gain in importance in order to reduce of both CO_2 emissions and high energy costs. Lighting systems in buildings should be designed precisely since the electricity used for lighting needs have a large percentage of the buildings' total energy consumption. The environmental assessment of buildings aims to reduce the energy consumption of the fossil fuels and the negative environmental impact.

The parameters of energy efficiency and sustainability have to preserve life conditions of future generations and environmental values while meeting contemporary needs [1].

Sustainable lighting is determined as, "Lighting that meets the qualitative needs of the visual environment with the least impact on the physical environment" [2]. Sustainability also requires an adequate and efficient use of natural light, efficient lighting design providing visual comfort in the built environment.

Although many lighting systems exist that meet energy-efficiency requirements, it is seemed that more energy-efficient lighting design will result in poorer quality of lighting. The absence of a common definition of lighting quality has been one impediment to progress on this issue and definition of lighting quality. According to this definition, lighting quality exists when the luminous conditions are suitable for the needs of the people who will use the space. These needs are grouped in six categories [3]:

- Visual performance;
- Post-visual performance (e.g., reading, eating, sewing, walking);
- Social activities, communication;
- Physiological requirements
- Health and safety;
- Aesthetic requirements

Several methods were developed to assess the sustainability of buildings in the design and post-construction cases. LEED and BREEAM are introduced in this study and discussed in terms of assessing the lighting systems.

Today, it is agreed that retail centre buildings should be designed with sustainable considerations because of the increasing numbers of these large buildings that are used throughout the day. This study covers principles to reduce lighting energy consumption of retails basing on the investigated methods.

Retail centers have become popular in most of the metropolises in Turkey since the last quarter of the past millennium. On the other hand, shopping action is traditional structure of our culture.

Shopping brings people together and allows them to make joint activities since the ancient times. Forums of ancient Greek, open trade areas of Rome, Inns and caravanserais of Ottomans and bazaars of the East are all places which were constructed to combine trade and social activities. Over time these spaces have been changed to closed passages and market buildings so with the changes going on the single-storied buildings have lasted until the industrial revolution. The industrial revolution gave the possibility of constructing large closed places with the usage of iron and reinforced concrete, so this had enabled constructing total spaced buildings like Crystal Palace in the building of which was taken advantage of these new possibilities. Large indoor spaces with advanced HVAC systems and escalators that simplified the vertical circulations, created continuous total inner spaces instead of the floor based systems.

Retail centers determine a lifestyle with lots of units embodied in them and these types of buildings are mostly designed as a complex that contains open-closed car parks, hypermarkets, shops, food courts, which contain fast-food units, cafeterias and also special restaurants, cinema and entertainment units. These shopping buildings have become living spaces with various functions, so the daily usage time of retail centers was increased. Although, retail centers are active from 10.00 to 22.00 they could be used until midnight because of the entertainment units.

The study comprises the evaluation of common places as entrance-lobby, circulation areas, food court and cafes, atrium spaces of retails in accordance with the green building assessment programs and related lighting standards. The evaluation of the shops is not included in this study, because of the various functions and specific design of the areas. "LEED for Commercial Interiors" and "BREEAM Retail" and "BREEAM EUROPE" models are introduced and the criteria which are used to evaluate the lighting systems of retail centers are examined.

2. ASSESMENT METHODS

Various models of assessments have been developed to reduce the environmental impact of building and energy consumption during/ after design and construction phases of the building. These methods are in accordance with legal regulations and general conditions of the relevant countries.

The methods, investigated in this study are LEED and BREEAM which are widely used as certification systems in USA and Europe.

BREEAM is set out by the Building Research Establishment. This method is used to determine the environmental impact of the single buildings or settlements during the design or construction stages. New buildings, renovated buildings and additional buildings can be assessed by BREEAM. Assessed building types can be listed as; office, education, industry, health, sales, prisons and courts. Assessments are performed in the below given subjects.

'Site management', 'health and comfort', 'energy', 'transportation', 'water', 'construction materials', 'waste management', 'land use and ecology', 'pollution' [4]. Building receives BREEAM certificates according to the assessment scores listed as;

Unclassified : <30 scores
Pass : 30-44 scores
Good : 45-54 scores
Very Good : 55-69 scores
Excellent : 70-84 scores
Outstanding : ≥85 scores

The LEED model which was prepared in 1998, based on the concept which is related on the principle of sustainability in building human and environmental awareness like settlement design, water efficiency, energy efficiency, with nature-friendly materials selection and interior air quality criteria. Certification grades according to the score are listed below [5].

LEED : 40-49 scores
Silver : 50-59 scores
Gold : 60-79 scores
Platinum : 80- 110 scores

According to the developing requirements of design parameters, 9 options as; new buildings, existing buildings, commercial interiors, core & shell, schools, retail, healthcare, homes, neighborhood development were presented. Evaluation system was created for each typology of the structure required for the certificate according to a specific value for each of the criteria. The subjects are listed as, 'Sustainable settlement Design', 'Water consumption', 'Energy Efficiency', 'Materials', 'Indoor air quality', 'Design-Innovation.

In this study, energy consumption and lighting requirements of both systems are summarized and experienced in a case study building.

3. EVALUTION OF LIGHTING SYSTEMS

Lighting and Energy Consumption requirements of both methods are discussed in this section. BREEAM UK Retail and BREEAM Europe, LEED Commercial Interiors 2014 are investigated and the categories are listed below.

Daylighting and View out

Daylighting is the practice of bringing natural light into a building and distributing it to provide illumination. It reduces the reliance on artificial lighting and thus reduces energy consumption and energy costs, but can also increase undesired solar gain and undesired glare.

LEED evaluates the daylight availability to provide occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the tenant space. Daylight illuminance levels are evaluated by 4 methods which are simulation method, prescriptive method which uses visible light transmittance and window to floor area ratio, measurement method or combination of other 3 methods. At least 75% of regularly occupied spaces should achieve daylight illuminance levels of a minimum 250 lx and maximum 5000 lx in clear sky conditions on September 21^{st} at 09.00 and 15.00. LEED recommends to design the tenant space to maximize interior daylighting with strategies such as lower partition heights, interior shading devices, interior glazing and high ceiling reflectance values and automatic photocell-based controls.

BREEAM determines daylight requirements to give building users sufficient access to daylight. For retail developments, at least 35% of the common areas (where applicable) the point daylight factors given in Table 1 according to the building location are required.

For view out criteria, it is aimed to allow occupants to refocus their eyes from close work and enjoy an external view, thus reducing the risk of eyestrain and breaking the monotony of the indoor environment. It is determined to provide an adequate view out, window opening area must be at least 20% of wall area, and the relevant building will have 7 m distance of a wall with a window or permanent opening.

Table1: Minimum point daylight factors for latitude ranges defined in BREEAM Europe 2009

Latitude (º)	Minimum point daylight factors (%)
≤40	1.5
40-45	1.7
45-50	1.8
50-55	2.0
55-60	2.1

The view out should ideally be through an external window providing a view of a landscape or buildings (rather than just the sky) at seated eye level (1.2 – 1.3m) in the relevant building areas. A view into an internal courtyard or atrium will comply the provided distance from the opening to the back wall of the courtyard/atrium is at least 10m. The view cannot be an internal view across the room, as this is likely to become obstructed by partitions, filing cabinets etc. Roof lights and high level windows do not provide an adequate view out.

Glare Control

Glare Control criteria is aimed to reduce problems with glare in occupied areas through the provision of adequate controls.

According to 'daylight' criteria of LEED, it is suggested to provide daylight redirection and/or glare control devices to avoid high contrast situations that could impede visual tasks. On the other hand automated shades for glare control are acceptable for only the minimum 250 lx illuminance level.

According to BREEAM's glare control section, an occupant-controlled shading system on all windows, glazed doors and roof lights in all relevant building areas is required for glare control. This requirement is specified for office spaces; but common places, circulation and sales areas are not included. Glare control is required specifically for daylighting systems.

Internal and External Lighting Levels

This issue is contained in BREEAM to ensure lighting has been designed in line with best practice for visual performance and comfort. Internal and external illuminance levels are specified in accordance with national best practice lighting guides. Where the lighting strategy of the building design is based on a localized or local lighting system, the task illuminance should be compliant with those levels and the average 'ambient' level at least one-third of this value or at the requirement of the non-task areas.

The uniformity of illuminance over any task area is equal to or greater than 0.7 and the uniformity of the surrounding area should be at least 0.5.In EU countries and in Turkey the standard EN 12464-1 should be applied for the maintained illumination, UGR values and Ra index, which are summarized in Table 2 [6].

Table 2: EN 12464 requirements for spaces related to retail centers

Space Type
Corridors (dimmed)
Entrance Hall –Lobby
Showroom
WC
Food Court-Café
Sales Area
Waiting Lounges
Stairs
Exhibition Halls

Lighting Controls and Lighting Zones

BREEAM evaluates that occupants have easy and accessible control over lighting within each relevant building area in Lighting zones and Controls section.

According to "Lighting Control" criteria, lighting control is required in office areas belonging retail. But it is not noted any recommendations about common and sales spaces are determined.

External light fittings are controlled through a time switch, or daylight sensor, to prevent operation during daylight hours. Daylight sensor override on a manually switched lighting circuit is acceptable.

LEED evaluates lighting control to maximize energy performance of lighting systems. For this purpose it gives points if the building contains daylight responsive controls in all regularly occupied daylit spaces within 4.5m of windows and under skylights, or if the building contains daylight responsive controls for 50% of the connected lighting load, or if occupancy sensors are installed for 75% of the connected lighting load.

Light Pollution Reduction

To ensure that external lighting is concentrated in the appropriate areas and that upward lighting is minimized, reducing the light pollution, energy consumption and nuisance to neighboring properties is aimed in this section.

According to Light Pollution criteria of BREEAM, all external lighting (except for safety and security lighting as well as illuminated advertisements) can be automatically switched off between 23.00-07.00. This can be achieved by providing a timer for all external lighting set to the appropriate hours. If safety or security lighting is provided and will be used between 23.00-07.00 this part of the lighting system complies with the lower levels of lighting recommended during the hours according to different countries, for example by using an automatic switch to reduce the lighting levels at 23.00 or earlier. LEED gives 1 point if the building whose nonemergency interior luminaries with a direct line of sight to any openings in the envelope, have their input power reduced (by automatic device) by at least 50% between 23.00 and 05.00.

Energy consumption

Energy Consumption criteria determines to recognize and encourage the specification of energy-efficient light fittings for external areas of the development.

LEED necessitates complying with ASHRAE Standard 90.1-2007 for lighting energy issue. Standard 90.1-2007 contains reference lighting power density (LPD) values for building interior and exterior lighting systems and it is suggested to prove the compliance of building LPDs by lighting simulation models [7]. Lighting power allowance for all exterior and interior building applications that is defined in Standard 90.1-2007 is shown in Table 3. The standard requires the usage of lamps having a minimum efficacy of 60 lm/W in all exterior building grounds luminaries that operate at greater than 100 W.

Table 3: LPD allowances for sample areas of retail buildings

	Evaluated area	LPD allowances
Exterior	Entrances and Exits	200-300W/linear meter of door width
	Canopies and Overhangs	12,5W/m^2
	Building facades	2W/m^2 for each illuminated wall
Interior	Retail (whole building)	15W/m^2
	Atrium	6W/m^2
	Sales Area	17W/m^2
	Mall concourse	17W/m^2

LEED compares building LPDs with the allowed values by the referenced standard and some extra point could be earned for reducing LPD below the standard 90.1-2007. In addition LEED requires using efficient EnergyStar® labeled lighting equipment in retail buildings.

For the 'high frequency lighting', EnergyStar® labeled equipment usage is a prerequisite to achieve for LEED and EnergyStar® label is given only to lamps or luminaries which use electronic ballasts [8].

BREEAM requires for energy consumption criteria that all external light fittings for the building, access ways and pathways have a luminous efficacy of at least 50 lamp lumens / circuit Watt when the lamp has a color rendering index (Ra) greater than or equal to 60 or 60 lamp lumens / circuit Watt when the lamp has a color rendering index (Ra) less than 60.

And also it is recommended for all external light fittings to car parking areas, associated roads and floodlighting has a luminous efficacy of at least 70 lamp lumens / circuit Watt when the lamp has a color rendering index (Ra) greater than or equal to 60 or 80 lamp lumens / circuit Watts when the lamp has a color rendering index (Ra) less than 60.
External light fittings are required to be controlled through a time switch, or daylight sensor to prevent operation during daylight hours. Daylight sensor override on a manually switched lighting circuit is acceptable.

For the 'high frequency lighting', all fluorescent and compact fluorescent lamps require fitting with high frequency ballasts.

Sub-metering of Energy Uses

To recognize and encourage the installation of energy sub-metering that facilitates the monitoring of in-use energy consumption is determined in the section.

LEED suggests to install sub-metering equipment to measure and record energy use within the tenant space, although it suggests to negotiate a lease whereby energy costs are paid by the tenant and not included in the base rent for the retail building with an area that constitutes less than 75% of the total building area. If total area is 75% or more of the total building area, it is suggested to install continuous metering equipment for the each sub-system of the building.

BREEAM recommends to separate accessible energy-sub meters to provide energy efficiency. Lighting is one of the sub-meter energy parameters. Recommended separation is determined below:

- Space Heating
- Domestic Hot Water
- Humidification
- Cooling
- Fans (major)
- Lighting
- Small Power (lighting and small power can be on the same sub-meter where supplies are taken at each floor / department).
- Other major energy-consuming items where appropriate
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4. CASE STUDY

The retail centre is in Turkey, at 38º38' latitude on North hemisphere. It was designed with 4 shopping malls and 2 entrances each of which has glazed facade and roof. Plan scheme and evaluated areas by Dialux simulations are shown in Image1. Common areas such as entrance, atrium, food court and shopping malls were evaluated in terms of the principles mentioned in BREEAM, LEED and the standards referenced by these two models.

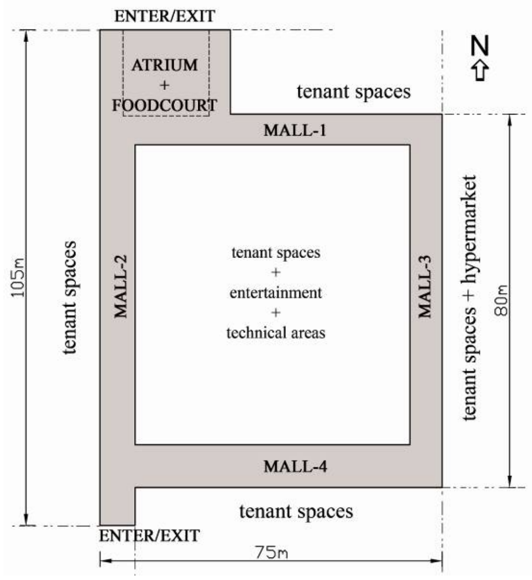

Image1: Plan scheme of the simulated common areas with Dialux

Daylighting evaluations were made in two steps; the first one is the daylight factor, and the second one is the daylight illuminance levels at 09:00 and 15:00 on 21st September. BREEAM Europe looks for 1,5% daylight factor in 35% of common areas for the retail buildings which are exist at 38º38' latitude and LEED allows daylight illuminance levels in range of 250-5000 lux. Daylihting results for each simulated area are given in Table 4.

Table4: Daylighting results in simulated areas

Area	BREEAM (1,5% DF)	LEED (250-5000lx) (E_m)	
		21Sep09:00	21Sep15:00
Atrium(entrance)	23%	1850	2330
Food court	3%	380	390
Mall-1	2%	180	200
Mall-2:1	19%	1400	1375
Mall-2:2	7,5%	1425	570
Mall-2:3	27%	1670	2900
Mall-3	0,0%	0	0
Mall-4	4,4%	460	570

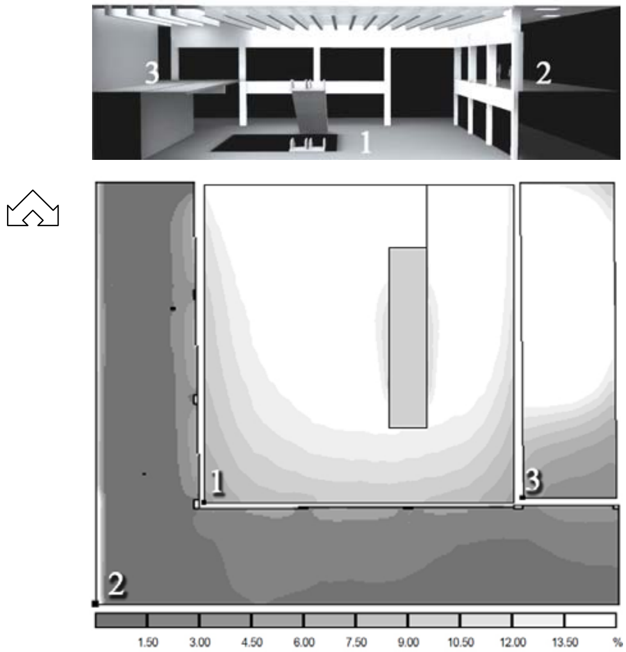

Image2: Model view and 1,5% Daylight factor isolux contours in plan view of atrium (1) and foodcourt (2-3)

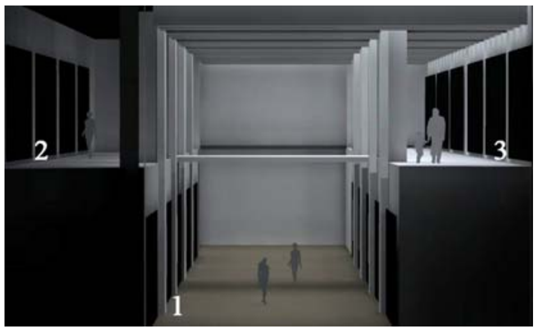

Image3: Model view of Mall-2

Automatic controlled shading system is used only at the glazed roof of Mall-2 for preventing glare. LEED suggests solar control devices unless daylight illuminance level is more than 250 lx, therefore it is reasonable to use control devices for this mall according to daylighting simulation results.

For internal illumination levels BREEAM refers EN 12464:1 for European countries. Artificial lighting simulation results of the investigated areas are compared in Table 5.

Table 5: Artificial lighting results in simulated areas

Area	EN12464	Simulated E_m (lx)
Atrium (entrance)	300	200
Foodcourt	200 (for self service areas)	195
Mall-1	200	200

Mall-2:1	200	245
Mall-2:2	200	200
Mall-2:3	200	300
Mall-3	200	225
Mall-4	200	150

LEED refers ASHRAE Standard 90.1-2007 for lighting power densities in energy consumption criteria, so the lighting power densities of the simulated areas were compared with the standard in Table 6.

Table 6: Lighting power densities in studied areas

Area	ASHRAE 90.1-2007	Installed (W/m^2)
Atrium (entrance)	6W/m^2	5,9W/m^2
Foodcourt	14W/m^2 (leisure dining)	9,1W/m^2
Mall-1	17W/m^2	14,1W/m^2
Mall-2	17W/m^2	10,25W/m^2
Mall-3	17W/m^2	10W/m^2
Mall-4	17W/m^2	4,2W/m^2

Both LEED and BREEAM suggest using energy efficient lamps and luminaries in external areas and they define efficacy values for lamps. Comparison of the installed lamps in case study and values of LEED and BREEAM are given in Table 7.

Both LEED and BREEAM pay attention to high frequency lighting. In the investigated retail building metal halide and fluorescent lamps were used with electronic ballasts in internal and external areas.

Table 7: Efficacy of lamps installed in external areas

	Lamp Type	lm	W	lm/W	LEED lm/W	BREEAM lm/W
Facade	HCI-TC	6600	70	94	60	50
	HCI-PAR	5500cd	35	-		
	LED	800	32	25		
	T5 FL.	3700	49	75		
Access ways	HQI-T	13k	150	80	60	60
	HQI-T	5300	70	75		
	HIT-CRI	x	70			
	TC-D	1100	18	61		

5. CONCLUSION

In this paper, 2 well known building environmental assessment tools, LEED and BREEAM, were examined in terms of the criteria on lighting systems for retail buildings. The assembled criteria were experienced on a case study by computer simulation.

In the examined environmental assessment tools the criteria have been prepared with regard to energy consumption issue. Daylight usage, lamp efficiency, energy metering, lighting control systems and lighting power density criteria are related to energy consumption of building lighting systems. On the other hand, it was detected that adequate determinations related to visual comfort to assist the energy-related issues cannot be found.

Although daylighting criteria of methods can be easily assessed on the case study building, it is found out that the discomfort and safety glare limits are not determined for the common used spaces as circulation areas, food court and atrium.

However solar control devices to prevent glare are recommended for the spaces which have high lighting levels, this alone can not be accepted as an effective method.

In conclusion, the assessment methods assess buildings with various numeric criteria and by computer simulation method, however criteria which are related to psychological needs and comfort needs should also be considered for lighting quality. If lighting quality issue is ruled out from the assessment tools, it cannot be possible to assess lighting systems of buildings properly even if the building comply with the all criteria of the assessment tools.

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