(MASTER THESIS)

THE EVALUATION OF THE OFFICE BUILDINGS ACCORDING TO LEED CERTIFICATE LIGHTING CRITERIA

İdil BAKIR

Thesis Advisor : Yrd. Doc. Dr. Ebru ALAKAVUK

Department of Interior Architecture

Bornova – İZMİR 2015

YASAR UNIVERSITY GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

THE EVALUATION OF THE OFFICE BUILDINGS ACCORDING TO LEED CERTIFICATE LIGHTING CRITERIA

İdil BAKIR

Thesis Advisor : Yrd. Doc. Dr. Ebru ALAKAVUK

Department of Interior Architecture

Bornova – İZMİR 2015

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Ebru ALAKAVUK (Supervisor)

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Ecehan ÖZMEHMET

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Eray BOZURT

Prof. Dr. Behzat GÜRKAN

Director of the Graduate School

TEXT OF OATH

I declare and honestly confirm that my study, titled "The Evaluation of the Office Buildings According to LEED Certificate Lighting Criteria" and presented as a Master's Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions, that all sources from which I have benefited are listed in the bibliography, and that I have benefited from these sources by means of making references.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

Page

TABLE OF CONTENTS (cont.)

Page

TABLE OF CONTENTS (cont.)

ACKNOWLEDGEMENTS

In this study in which office buildings were evaluated and analyzed according to LEED certificate lighting criteria, first of all, I would like to express my deepest appreciation to my most dear teacher, Asst. Prof. Dr. Ebru ALAKAVUK for her great contributions in this study, for her patience, tolerance, support and help throughout my thesis.

I would like to thank (MSc) Architect Müge YORGANCIĞLU who shared her knowledge and projects with me, stayed with me whenever I needed, approached me with patience and tolerance during my thesis study; to MATT Architecture and all of its employees; to employees of ERKE Design and its founding partner Özlem Dilda YAMAN who made great contributions during my thesis and shared their projects with me; to Denge certified public accountancy company for their tremendous help; to my mother Prof. Dr. Aykut YAFE who was always there for me and supported me, my aunts Aydan Seyhan and (MSc) Architect Serap YÜKSEL, my grandmother Fevziye DİKMEN, my fiancé Eren KÜÇÜKKAYA who supported me throughout this process, a friend Seda TOPUZ and my best friend Mina Şakrak for all the support she gave me.

I would like to dedicate my thesis study to my father (MSc) Architect M. Turgay BAKIR who was always there for me at all the moments of my life, encouraged me for my education and gave me all the moral and material support; and to my uncle civil engineer I. Önder YÜKSEL.

Idil BAKIR

İzmir, 2015

ABSTRACT

THE EVALUATION OF THE OFFICE BUILDINGS ACCORDING TO LEED CERTIFICATE LIGHTING CRITERIA

BAKIR, İdil

MSc in Interior Architecture
Supervisor: Yrd. Doc. Dr. Ebru ALAKAVUK
July 2015, Pages 156

The progress in Industrial & technological areas, whıch has started with the Industrial Revolutıon, has deteriorated the ecological balance and depleted the natural resources. Sustaınability, whıch initially seemed as a solution wıthin this concept, became an important part of Interior Architecture as in disciplines related to design. The placement and design of the lighting system and the sufficient usage of daylight encompasses a major part of the sustainability criteria. The lighting systems of the offices that are the secondary living areas should be evaluated in terms of sustainability as well.

In this research, the energy savings and loss of the artificial office lighting systems has been calculated and then divided into office sections and types, according to the ASHRAE/IES standard 90.1-2007 which are included in the LEED certificate’s lighting criterıa. The offıces sampled here in have been analyzed and compared ın accordance wıth thıs crıteria. In the case study, first of all, the definition, progress, types and sections of offices are discussed later on, the subjects of light and lighting have been mentioned. The term of sustainability has been defined. There is a variety of certificates originated ın different countries. In Turkey, the most prevalent and detailed certificate that analyzes lighting criteria is LEED. Other sections of the certificate are not dıscussed in this case study, only the lighting systems have been studied. This is based on a hypothetical Optima Project that is created by a lighting company.

The comparison in this case study is between the three offices, ERKE, with the LEED certificate, DENGE, without it and the hypothetical optima project. The main criteria for the evaluation of these three offices are that they both have all the office types and sections of the ASHRAE/IES standard 90.1-2007. The wattage of the artificial lighting systems of these three offices have been calculated while the systems were in use. In the sections of the LEED certificate, the ASHRAE/IES standards 90.1-2007 of lighting power density proportions have been used. According to these proportions, the square meter configuration of these office types and sections has been taken into account. The results of these measurements have been multiplied wıth lighting wattage and thus the lighting energy savings and loss have been configured. In order to consider adequate savings of lighting energy in accordance with lighting power density, the said savings has to be 10 % or more. The three offices have been comparatively analyzed according to these criteria.

Keywords: Office, Artificial Lighting, Sustainability, Energy efficiency, LEED

INDEX OF FIGURES

INDEX OF FIGURES (cont.)

INDEX OF FIGURES (cont.)

INDEX OF FIGURES (cont.)

INDEX OF FIGURES (cont.)

INDEX OF TABLES

INDEX OF TABLES

INDEX OF SYMBOLS AND ABBREVIATIONS

LEED	: Leadership in Energy and Environmental Design
LEED NC	: Rates New Construction
BREEAM	: Building Research Establishment's Environmental Assessment Method
CASBEE	: The Comprehensive Assessment System for Built Environment Efficiency
CO_2	: Carbon Dioxide
LED	: Light Emitting Diodes
Fc	: Foot Candle
sDA	: Spatial Daylight Autonomy
ASE	: Annual Sunlight Exposure
HID	: High-intensity Discharge
K	: Kelvin
CRI	: Color Rendering Index
NM	: Nanometers
VCP	: Visual Comfort Probability
VDT	: Video Display Terminals
Lm	: Lumen
W	: Watt
V	: Voltage
JSBC	:Japan Sustainable Building Consortium
GBCA	: Green Building Council of Australia
EPA	:Environmental Protection Agency
M^2	: Square Meters
GHG	: The Greenhouse Gas Emissions
IEQ	: Indoor Environment Quality
IDA	: The International Dark Sky Association
PVC	: Polyvinyl Chloride
HVAC	: Heating, Ventilating and Air Conditioning
LPS	: Low Pressure Sodium

1. INTRODUCTION

“Sustainability” means the skill of being permanent. Sustainability is not only a term connected to architecture but also a word of many different fields. In Turkey, there is a limited number of subject and structure which can be analyzed under “sustainable architecture”. Sustainable architecture is a title also covering the previous architectural approached, and a way of total, strategic and planned structuring supported as a solution for global environmental problems and developmental issues.

With the increase in technological developments after the Industrial Revolution, the number of buildings increased, the resources started to be consumed more, the energy crises occurred and the excessive usage of resources gravely endangered the lives of the future generations and the way nature worked. As a result of the awareness of the above-mentioned issues, sustainable development occurred. Sustainability should not be evaluated only by environmental factors but also by social, economic and cultural dimensions. Architectural sustainability is the evaluation of the structures from different angles such as air quality, energy performance, material and lighting.

The offices in which we spend most of our time during the day are the places that have to be designed in the most careful and efficient way in terms of lighting. In the second chapter of the study, the office was defined and the history was told. The reasons why we still have offices today, the types and sections of the offices were mentioned. The aim of the chapter is to understand the separation between the office types, examine the office types and sections while designing the lighting systems and lighting systems design them separately.

In the third chapter of the study, light, eye, sight, lighting and types of lighting which are the issues that you have to know in order to understand the lighting criteria, design the lighting systems and the use them were explained with details and examples. In terms of sustainability the most important issue regarding lighting is the sufficient usage of daylight. What has to be done is to support the daylight with the artificial lighting. For this reason in this chapter daylight and artificial lighting were highly mentioned. And the types of lighting systems and luminaires were also mentioned.

In order to evaluate the sustainability of the buildings, certain certificates were created in some parts of the world. The most common ones are LEED, BREEAM, CASBEE and Green Star. These certificates explain sustainability with grading and rating systems by separating them into criteria and sections. Lighting is the one of the most important issues that criteria have to deal with. The continuous of the third chapter of the study handles these certificates and lighting criteria.

The fourth chapter is all about the aim of this study: the evaluation of the office buildings according to the LEED certificate lighting criteria. This is based on a hypothetical Optima Project, which is created by a lighting company. The comparison in this case study is between the two offices, ERKE, with the LEED certificate, and DENGE, wıthout it. The main criterıa for the evaluation of these two offices are that they both have all the office types and sections of the ASHRAE/IES standard 90.1-2007. The energy savings and loss of the artificial office lighting systems has been calculated and then divided into office sections and types, according to the ASHRAE/IES standard 90.1-2007 which are included in the LEED certificate’s lighting criteria. The offices sampled here in have been analyzed and compared in accordance with these criteria.

There are a lot factors in terms of determining the aim of the study. Sustainability which was late-coming subject to Turkey arrived the field of interior architecture pretty late from the design-based disciplines. Lighting is one of the most important subject designed within the framework of interior architecture. People should be aware of the issue of lighting. If people know that lighting is a really important factor in terms of sustainability, it can create many positive effects on the environment. The daylight usage is increased, used properly and supported by the least artificial lighting, the energy consumption decreases, the greenhouse gas emission related to energy is prevented, CO_2 emission decreases and light pollution decreases. If the office owners can provide the necessary budget financially, they can actually make profit while saving lighting energy in the long term. In this study, it can be seen that when the sustainable lighting criteria are applied properly, all the above-mentioned economic, social and environmental factors are managed.

Within the framework of the aim and coverage of the above-mentioned study, firstly the subject of sustainability, its way of working in the field of interior architecture discipline, scanning and evaluation of the current sources about the office structures and lighting issues were mentioned. Later the subject came out and the main titles were specified. As a result of this analysis, a point of view through which the general titles are integrated into details, supported by examples and tables, based on seeing the connections between the issues was internalized. Within this subject, the research for sustainable lighting criteria was made based on the certificates and the standards applied in USA and Europe. While making the lighting analysis, these studies were taken into consideration.

There are former studies which were done in Turkey and other countries related with office, sustainability and lighting criteria are given.

Kaçel (2007) stated that, basing on the principles of office lighting and energy efficient lighting system design, a case study office buildings is investigated in order to determine the effect of different facade alternatives and lighting control systems on the lighting energy consumption. The office building taken as a case study first of all is investigated in the facade design issue. Different facade layouts are simulated by using DAYSIM software in order to choose the layout that would supply glare-free enhanced daylight.

Apaydın (2012) stated that, aspire the use of artificial energy with the efficient illumination systems by benefitting from the daylight of the illumination designs in offices most effectively at indoors where the effect of daylight diminishes. Taking aim at the principle of sustainability has been emphasized by contributing to the architecture of office buildings and sustainability of methods which are used and spreading the use of contemporary systems which are about to develop.

Alkan (2010) stated that, In the first part of the research, concepts of space, light and color are discussed with their definitions and explanations. Following this, color and light issue is considered from the spatial design point of view. In the second part, natural and artificial light sources and the fundamental principles of lighting with artificial lights, are discussed. In the last part, the effects of light and color – elements of visual comfort – on the spaces are investigated through visual examples and different types of colors and lighting needed for creating efficient working atmospheres, are discussed.

Uyan (2010) stated that, visual comfort needs which are the role of todays lighting systems in buildings. by researching the lighting criteria of building certification program models which are assessing sustainability of buildings like LEED, BREEAM, CASBEE and Green Star, their lighting viewpoints have been analyzed. Visual comfort needs, the energy consumption of building systems, energy consumption of lighting systems and lighting devices, and lamp classification in the regulations and standards of USA, EU countries and Turkey have been studied and the issues discussed in this documentations have been gathered.

Saka (2011) stated that, evaluates the significance of the notion of sustainability in our lives and review earlier studies on sustainability through discussing the inseparability of sustainability and energy and considering the influence of the building and energy sector over sustainability. Istanbul Technical University ARI Teknokent Incubation Center is analyzed with regard to the criteria set forth by LEED, the energy simulation of the building is studied and advices are given to the project team in order to earn more credits for the building towards LEED certification system. The credit earnings through the current state of the project and the situation in which the given advices are applied are analyzed.

In Karslı (2008) stated that, it’s aimed to form an environmental performance analysis model by examining the certificate programs in use abroad in order to expand sustainable architectural applications and to encourage the sustainable design and construction of office buildings which has high environmental impact. Establishments rewarding the sustainable buildings with a certificate in developed countries such as Great Britain, United States of America and Switzerland and environmental performance analysis models of these establishments are examined before the model is formed. In the research, primarily the sustainability subject and the principles of sustainable architecture are defined, in the framework of these definitions, office buildings are assessed and in accordance with the determined design criteria, an environmental performance analysis model for office buildings in Turkey is proposed.

In Binol (2008) stated that, A field study was performed to collect illuminance data for four months in the subject building of the Faculty of Architecture in Ġzmir Institute of technology. The study then involved the weather data obtained from the local Weather Station and building parameters from the architectural drawings. A three-layer ANNs model of feed-forward type was constructed by utilizing these parameters. Input variables were date, hour, outdoor temperature, solar radiation, humidity, UV Index, UV dose, distance to windows, number of windows, orientation of rooms, floor identification, room dimensions and point identification. Illuminance was used as the output variable. The first 80 of the data sets were used for training and the remaining 20 for testing the model. Microsoft Excel Solver used simplex optimization method for the optimal weights.

In this study, firstly, previous studies were examined, as stated above, and in this regard, literature studies were done and content was created through observations. For the case studies mentioned, area studies were conducted. Distinctively than previous study results, all the lighting systems were examined, lighting powers were calculated in terms of watts, depending on the office sections and lighting systems were evaluated, based on the lighting criteria on the LEED certificate. 3 offices mentioned in the study (optima office, ERKE office and Denge office) were compared and a proposal was made based on these results.

2. THE ANALYSIS OF THE OFFICES

Office building is a term previously used for “bureau”. In time, the term has gained a new definition in terms of subject and meaning and it has embraced a new identity. Office buildings have gone through various changes and developments till today. Accordingly, it has been classified and new definitions have been made considering the office buildings.

According to Scognamillo, office is everywhere in which a deed is done and endeavor is made. According to Architect Gassan, office is a place where various business people called chief, officer, clerk, accountant work at a desk suitable for their line of work. (Dökmeci, Dülgeroğlu and Akkal, 1991)

The term office (bureau), as we use today, was derived from “burro” which means “coarse fabric” in Latin. In time “bure” (writing table cloth) in French has gone through some changes and become “bureau” (writing table). In the 19th century, the word “office” which came out as a need for different buildings and also is used today, became a term used for a physical building where editorial based occupations took place. (Yıldız, 2003)

Today, on the other hand, the increase in technological developments and the importance of communication have led to some differences regarding the understanding of the term “office”. Especially with the time subject gaining importance as a result of Industrial Revolution, offices settled in houses and working environments were increased. We can see the most obvious differentiation caused by this particular situation in the working hours between 9a.m- 5p.m. Flexible time movement was recommended by a female economist named Christel Kammerer in Germany in 1965 in order to bring more industrial workers into the market. At that time, firstly, the workers were given the opportunity to go to work whenever they wanted. In time it was realized that this practice had a more beneficial effect on both the psychology of the worker, and the productivity and the production. Since people embraced different working hours, the time subject expanded into different time periods rather than 9a.m-5p.m. This situation created a new identity for the office buildings. (Toffler,1996)

2.1 The Development process of the Offices

Office buildings have gone through different changes and developments from the first time they emerged till today. Especially after the Industrial Revolution, with the technological developments, various needs emerged. Various lines of work were formed; more workers and employees were required; and all of these brought different types of offices. Architects and designers developed new environments regarding the social needs.

Offices firstly emerged in the 15th century and by going through some changes in the second half of the 19th century, they gained a new understanding suitable for today's information technologies and the age of communication. Jerusalem is known as the oldest place where pecuniary affairs were held by the Jews 2000 years ago. This place was also used as an assembly. Although this particular place was not defined as a bureau based structure, it was used as one for years. (Duffy and Worthington, 1976)

While the trade networks were the private households of the merchants and taverns from 16th century till the end of 18th century, later the term “office” became a word used for a type of a physical building. In the common sense, office buildings emerged in the 19th century thanks to the communication revolutions which radically changed the business methods. With the inventions of Morse Code in 1844, typewriter in 1866 and telephone in 1874, people who used to live and work in the same neighborhood gained the opportunity to work in the different buildings, towns and cities separate from their homes. (Dökmeci, Dülgeroğlu and Akkal,1993).

In the 16th century, on the other hand, during monarchical periods in Europe, ministries used royal palaces as working places. Even though these were just eye-pleasing, sumptuous places far from any functionality, in principle they were pretty close to today's offices. The most important one among these buildings is Uffizi Palace which was considered as the first office. This palace was designed by Giorgi Vassari in Folorance between 1560- 1581 is showed figure 2.1.Even if this building, in principle, looks like an office building, 19th century is thought as the period when the office types throughly similar to today's office buildings emerged. Till the 19th century people worked in buildings similar to the above-mentioned structure. (Dökmeci, Dülgeroğlu and Akkal,1993).

Figure 2.1 : Uffizi Palace External View

(http://www.uffizi.com)

First commercial offices started to be built in the industrial cities located in the north of the United States of America in the 19th century. The fact that steel frame system started to be effectively used in Chicago, which was the railway center of America's west side, led to the construction of much higher office buildings. (Karslı, 2008)

Along with the rapid growth in the business sector and the increasing job potential as a result of technological developments, more people who could work in different fields were required, various needs emerged related to these people and the designers started to create their designs considering these needs.

The office building designed by Frank Lloyd Wright in 1904 for Larkin Mail Order in New York Buffalo became en example for other office buildings thanks to its different environments is displayed in figure 2.2.

Figure 2.2 : Frank Llyod Wright’s Johnson Wax Building Internal View

(http://all-that-is-interesting.com/famous-designs-frank-lloyd-wright/2)

In the 20th century the number of people who worked in the offices increased. Especially the percentage of women employees considerably increased compared to the past. As a result of these developments, some changes were made in the office buildings. The building designed by Frank Lloyd Wright can be considered as the best example to these changes in figure 2.2. This building is the first example of the new office type and considered as a pioneer. Spatial arrangements combined with furniture settlements and designs. Social requirements were also considered. Separate toilets for men and women, showers, locker rooms, restrooms, infirmary, and libraries were the great examples of these requirements.

The privatization of the concept “bureau” with functional sufficiency occurred at the beginning of the 20th century. This situation created a change in both appearance and working pattern of the bureau environment. For example, in the 19th century, white collar workers used to work at accordion covered writing desks. The feeling of specialness this provided to the personality of the user disappeared as a result of bureau environments and new working methods. Easily cleaned and less equipped desks were designed according to different jobs in advance and this prevented the user from wasting any time and also provided high productivity. Besides, by decreasing the possibility of losing or replacing documents, the functional sufficiency in the bureaus were increased. (Office, 1991)

With the situation in the bureau getting more and more coordinated, scientific rules were made for maximum efficiency. The pace of communication made the workers treat more information more quickly. In order for more officers to be evaluated in different duties, new administrative structures were formed (Office, 1991).

With a delay of almost over half a century, our country started to get used to the contemporary bureau phenomenon emerging around the world. Especially the economic life having starting to improve since 1923 revealed the bureau phenomenon and followed a development reaching to our time. The institutions firstly working in the bureaus consisting of apartments with a staff of 8-10 people began to go beyond 8-10-storey buildings when they developed and experienced growth in parallel with economic and commercial activities in the 1970's and 1980's and started to be managed from a single center as conglomerates (Office, 1991).

Owing to the still ongoing technological developments, the development and change of the office buildings are still underway. With the increase in the number of offices, many factors in the design of the buildings emerged. The comfort of the employees, the lighting system in the building, spatial settlement patterns and ventilation can be considered among those factors. The fact that computers and other additional technological devices have come into our lives have led to new arrangement patterns in the offices. With the use of natural and artificial lightings, the location of the computers, the reflection of the light on the computer screen, the amount of glare, and spatial patterns have turned into factors which have to be taken into consideration; and lighting design has become pretty important for the offices (Office, 1991).

2.2 The Types of Offices

The period of time that we spend in the offices throughout the day nowadays shows us that they are our actual living environments. However, the thorough and efficient evaluation and design of the offices provide various opportunities to the employees. One of the most important parts which has to be evaluated while designing the office is the lighting. The creation and application of the proper lighting criteria depend on the type of the office.

When the office buildings are examined from the beginning, the emergence of these criteria is related to the economic, social, cultural and technological developments. Regarding these developments, the office functions directly affect the number of employees and the office regulations. Considering all of the above, various office plan approaches occurring with the different regulation of the planning elements have been formed. These are:

- Cell (traditional) office plan type
- Team office plan type
- Open-plan office type
- Flex-office plan type
- Combination-office plan type

2.2.1 Cell office

Cell office plan type consists of rooms with various sizes and its space depth is limited to 5.50-6.00 meters since it mostly depends on natural lighting. That's why the rooms have the ability to enlarge in one way. The size of the rooms changes according to the number of the employees, the hierarchical structure of the management and the working pattern. This is a planning approach suitable for individual work and respectful to the privacy of the employee. (Naghavi,1995)

Cell offices generally have a small volume of 1-3 people; its depth is maximum 6, minimum 2.40-2.60 meters starting from the windows. Even though the depth changes at will within these values, mostly applied depth is 3-4 meters.

Cell offices are mostly used by only one person such as the manager and senior officer since it provides privacy and prestige to the user. The cell offices used as shared areas for 2-3 employees are arranged in order to strengthen the relationship among the staff.

In this planning approach, the two sides of the main are transport axis are walled. The cells are separated from the corridors with stable walls. That's why their working areas are limited between the corridor and façade. The main transport axis, that is the corridor, can be arranged as one-sided, two-sided or three-sided. The core containing vertical transport elements and service units is generally located at the two ends of the corridor. (Bostancı, 1996)

Cell offices are applied all around the world; however, the increase in communication, the need for evaluating the employees, the search for flexibility in the buildings and the technological developments have caused new planning approaches to be analyzed as shown as Figure 2.3. (Bostancı, 1996)

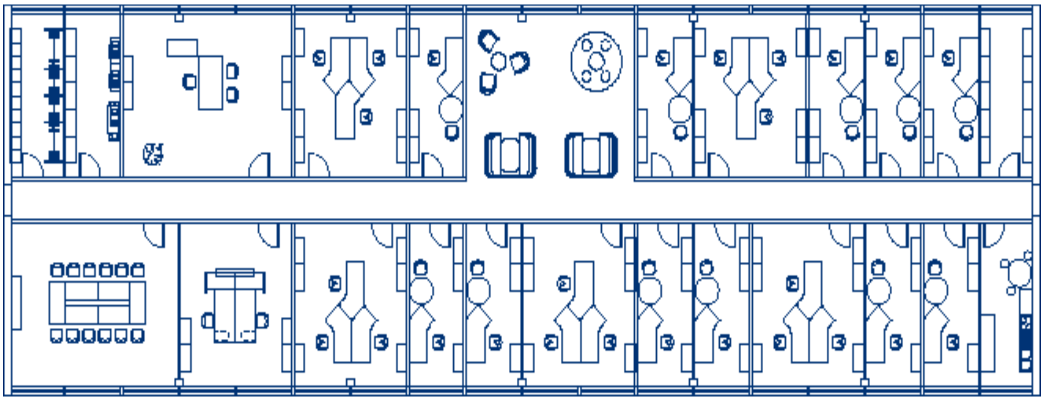


Figure 2.3 : Cell Office Model

http://bene.com/pics/planning-design/cellular-office.gif

2.2.2 Team office

Team office plan generally applies to middle-sized places designed for working groups of 5-10 people. This approach is counted as a transition from cell office plan to open-plan office in terms of sizes and arrangement. The working environments vary between 40-150 m2, and the depth is measured 6-10 meters from the window platform. Team office plan is designed by removing the dividing walls and including the cell offices to the corridors. In this type of offices, there are 2 or 3 groups of 5-10 people on one floor as shown as figure 2.4. Since the depth of the place is measured according to the position of the sunlight, it can only go up to 12-14 meters; since the corridor is included to the environment, direct access is possible from the core to the working environment. Rather than solid walls, the groups are divided from each other by using movable separators such as storage tools or window boxes. Since the communication among the employees are easy and comfortable, a middle-sized volume may be enough to apply this plan type. (Çete, 2004),

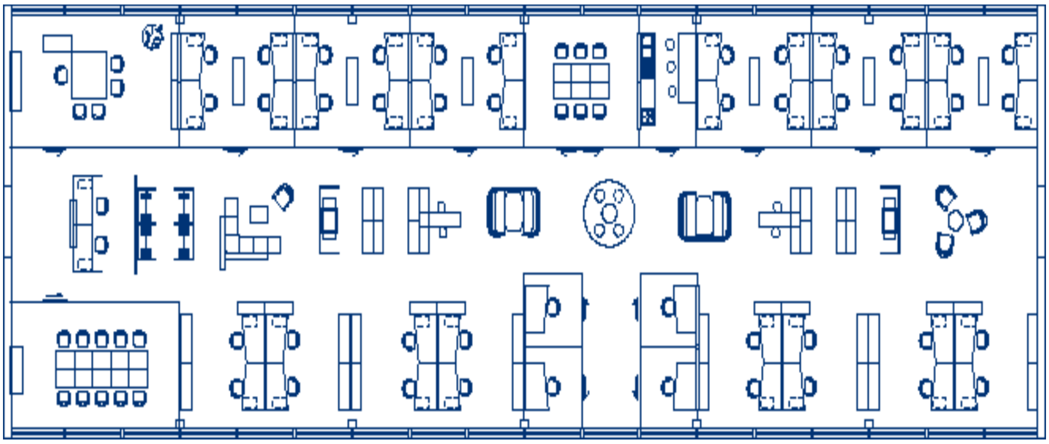


Figure 2.4 : Team Office Plan Model

(http://bene.com/pics/planning-design/team-office.gif)

2.2.3 Open-Plan Office

This office type Brings together the advantages of several office forms in open-plan application scenarios as shown as figure 2.5. Communication and the quality of interaction become the focus without mitigating privacy and the opportunity to concentrate. Employees choose the zones and areas that are best suited to their activities. Space efficiency is achieved with compacted, non-territorial workplace areas. (Bene,2015)

This office type advantages are; efficient use of space, flexibility in open-plan application scenarios, Mix of open-plan, group and combination offices, Openness and exchange of knowledge, concentration, communications. (Bene, 2015)

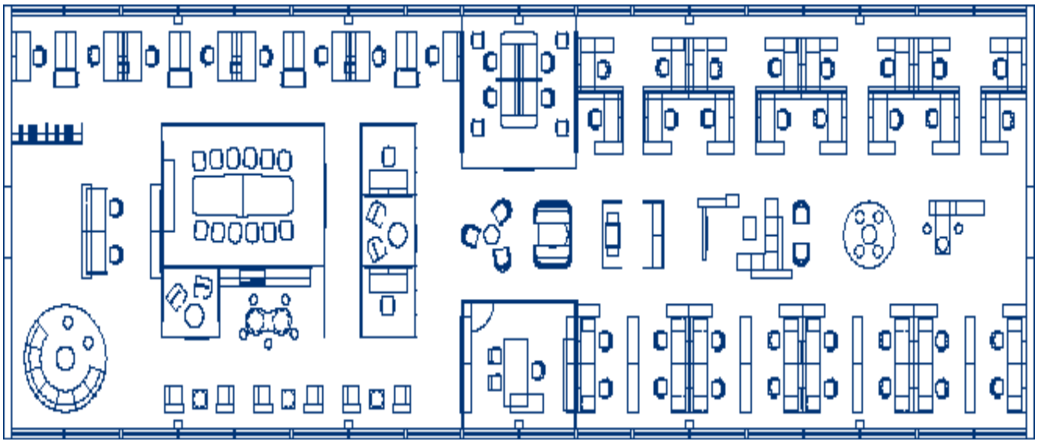


Figure 2.5: Open-Plan Office Model

(http://bene.com/pics/planning-design/open-office.gif)

2.2.4 Flex Office

Flex office is the most flexible office type with no personal workstations and good access to back-up spaces. (Figure 2.6) Free-plan office buildings is an arrangement which came out when in Germany a group called "Quickborn" brought some innovations to the office structure in the early 1960's. The main purpose of this arrangement is to turn the deep and wide office environments into places where people can use them in the most ergonomic way. These places should have the flexibility to meet the changing needs of the users in time. The workplaces should be taken into consideration as a whole. They should keep up with the changing technological developments. The distribution of the groups through the building and the floors should be arranged according to the communication among the staff. Free-plan office buildings provide a nice physical environment among the groups and therefore lead to high work efficiency. They are flexible, and they enable certain changes in time after the whole place is throughly used.

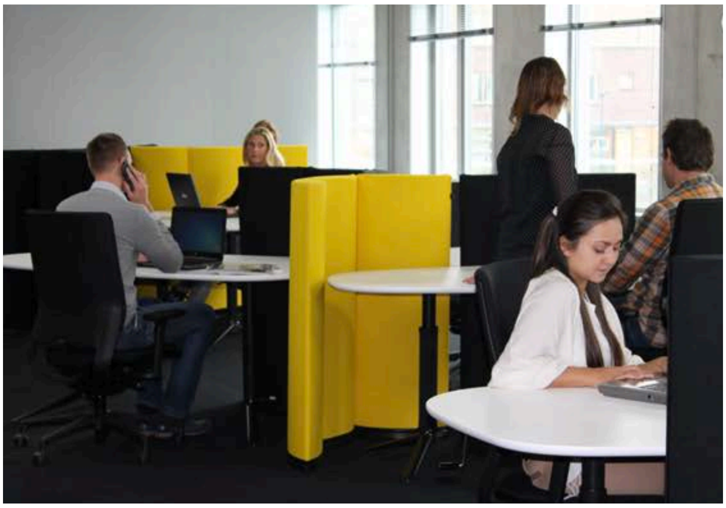


Figure 2.6 : Flex office Example

(http://www.zappoffice.nl/fotos-en-video/)

2.2.5 Combination Office

In combination office, combination of standardised one and multi-person offices for focused work, with significantly reduced floorspace. Communication occurs in the interior multi-functional shared area (central area) as shown as figure 2.7. Hallway walls are transparent in order to provide the central area with natural light. The central zone also serves as the central meeting point for exchange, interaction and support areas. The advantages of combination office are; focused work, communication in the central zone, Transparency (Visual contact possible thanks to central break-out area), Standardised configuration and For frequent shifts between focused individual work and more communicative project or team work.

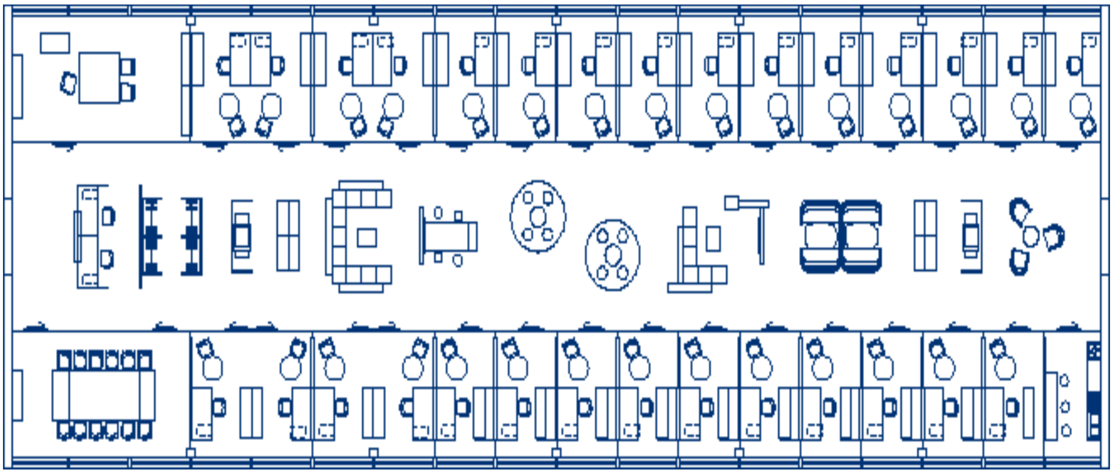


Figure 2.7 : Combination Office Model

(http://bene.com/pics/planning-design/combination-office.gif)

2.3 Common Areas in Office buildings

In office buildings, there are the other places except the office models. These are, the reception, circulation areas, meeting rooms and seminar rooms.

2.3.1 The reception

The Reception is the entrance of the office building. The Entrance, more than any other space, gives the office building its character and is the public face of both the building and the company. In addition to an inviting light setting, both the luminaire design and the lighting scheme form the first impression of the visitor.

Entrance lighting needs to provide guidance to the reception and other parts of the building. Since the foyer is an important adaptation zone for people coming in from bright sunlight, the light levels should be a little higher than the minimum requirement of 100 lux. Proper horizontal and vertical lighting in the reception area is important to aid the receptionist's work and to help see people's faces. Vertical lighting requirements should also be considered in social zones and sitting groups.(http://glamox.com/uk/solutions/entrance-areas-and-foyers)

Receptions are also a place of work for the receptionists. an individually adjustable task light for each work station is as natural as adjustable chairs. (Figure 2.8)

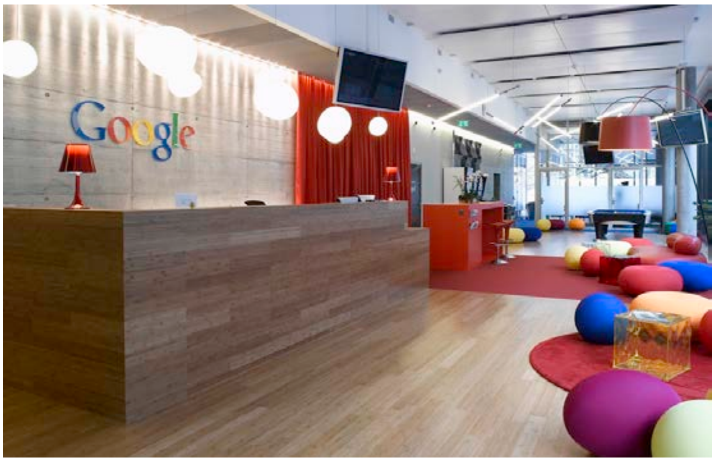


Figure 2.8 : The reception of Google office in Tel Aviv

(http://www.mydesignweek.eu/inside-the-google-office-in-tel-aviv/#.VZFNKutYCfQ)

2.3.2 Meeting and seminar rooms

Meeting rooms need careful attention because the range of activities spans from one-to-one talks via presentation to big conferences. At the same time, the interior and lighting design communicate the company culture internally and externally.

A flexible lighting scheme with efficient control systems supports the various uses of the meeting room. Ceiling luminaires provide efficient background lighting and lighting for more demanding tasks. (Figure 2.9)

Spotlighting and wall washers light up details or walls and create variation. An easy to operate control panel should contain various light settings to support activities such as e.g. note-taking, presentations or conversations. A good presentation light is needed to see the presenter’s face well. This light would need to be synchronized with screen-based presentations or videos. (http://glamox.com/uk/solutions/meeting-rooms)

Figure 2.9 : The Meeting Room Example Hayden Place in USA

(http://www.homedit.com/10-amazing-offices-design-around-the-world/)

2.3.3 Office corridors and circulation areas

Modern office workers spend more and more time away from their desks in formal or informal meeting spaces. Open plan offices have communication zones where workers move around and talk to each other. The lighting of these areas should support the conditions for visual communication.

As shown as figure 2.10, an office corridor is not only a traffic zone, it is the space where people relax, exchange ideas, work in teams or even meet with clients. Light may be used to emphasize different zones in the circulation area, but must not dazzle those working inside adjacent rooms. Corner-mounted luminaires provide glare-free, asymmetric light to the walls and ceiling. Indirect light makes corridors seem bigger and more inviting.

By casting more light onto walls, ceilings and people’s faces, the conditions for visual communication are improved. Wall illuminances in circulation areas should be minimum 50 lux and the ceiling should have at least 30 lux. In sitting groups and communication zones, higher illumination levels should be considered, as well as cylindrical illuminance and the light’s modelling effect.

Narrow and long corridors may be divided into sections by accent lighting on details such as artwork or information boards. (http://glamox.com/uk/solutions/meeting rooms)

Figure 2.10 : Media Turgul. Office Corridors

(http://www.homedit.com/10-amazing-offices-design-around-the-world/)

2.4 The Assesment of the Chapter

While designing an office and its lighting system, one has to know what office is, what its types are, and which sections it has. This chapter is related to the above-mentioned issues. When it comes to the office lighting design, every section in the office or every office type has to be individually evaluated. The types of office have to be taken into consideration. In this chapter first of all, the definition of the office was made; and the history of the first office buildings were mentioned. The development process of office buildings were analyzed through case studies. Later, five different office types (open-plan office, cell office, combination office, flex office, team office) and common areas in the offices were analyzed along with their features and definitions in detail through pictures and examples.

3. LIGHTING AND LIGHTING CRITERIA OF EXISTING SUSTAINABLE CERTIFICATE SYSTEMS FOR OFFICES

The Perception, what we perceive as light is a narrow band of electromagnetic energy, ranging from approximately 380 nanometers (nm) to 760 nm. Only wavelengths in this range stimulate receptors in the eye that permit vision. These wavelengths are called visible energy even though we cannot directly see them. In a perfect vacuum, light travels at approximately 186,000 miles per second. When light travels through glass or water or another transparent substance, it is slowed down to a velocity that depends on the density of the medium through which it is transmitted. This slowing down of light is what causes prisms to bend light and lenses to form images. When light is bent by a prism, each wavelength is refracted at a different angle so the emergent beam emanates from the prism as a fan of light, yielding all of the spectral colors. All electromagnetic radiation is similar. The physical difference between radio waves, infrared, visible light, ultraviolet, and x-rays is their wavelength. A spectral color is light of a specific wavelength; it exhibits deep chromatic saturation. Hue is the attribute of color perception denoted by what we call red, orange, yellow, green, blue, and violet. (Gordon, 2003)

The Eye , A parallel is often drawn between the human eye and a camera. Yet visual perception involves much more than an optical image projected on the retina of the eye and interpreted “photographically” by the brain. The human eye is primarily a device that gathers information about the outside world. Its focusing lens throws a minute inverted image onto a dense mosaic of light-sensitive receptors, which convert the patterns of light energy into chains of electrical impulses that the brain will interpret (figure 3.1). The simplest way to form an image is not with a lens, however, but with a pinhole. A ray from each point of the object reaches only a single point on the screen, the two parts being connected by a straight line passing through the pinhole. Each part of the object illuminates a corresponding part of the screen, so an upside down image of the object is formed. The pinhole image is dim, however, because the hole must be small (allowing little light to pass through) if the image is to be sharp. (Gordon, 2003)

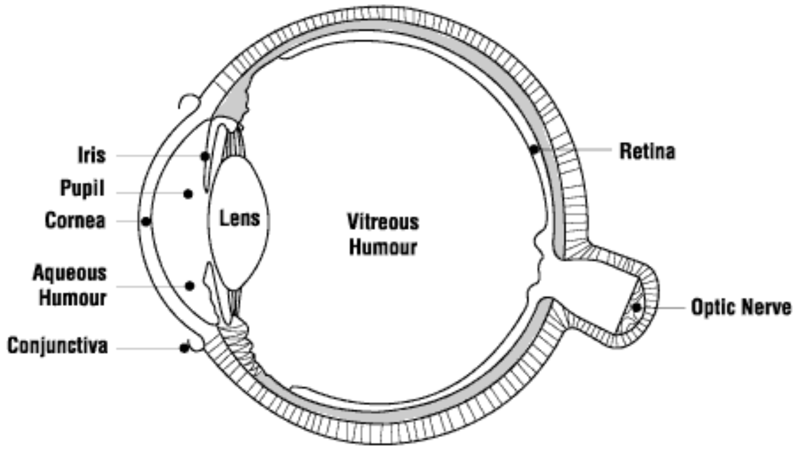


Figure 3.1 : The Human Eye

(https://aviator-sunglasses.net/uv-protection/protect-your-eyes-from-solar-radiation-part-ii/attachment/eye_structure/)

Light is the form of visible energy, getting from sunlight, or from a candle flame, or from an electric lamp. Light, either directly from a light source or reflected off an object, is perceived by human eyes and analyzed into images in the brain. “Normal” light is white, but it consists of different colors, the colors of the spectrum which are seen in the rainbow or in the science laboratory when light is passed through a triangular glass prism. (Sezgin, 2011)

In physics, ”light” includes every known radiation field, also called the “electromagnetic spectrum”. The light we can see with our eyes is called “visible light”. The visible light speed is calculated at vacuum as exact and finite 299,792,458 meters per second (that is approximately 983.5 million feet per second). According to the theory of relativity Einstein no substance or information can travel faster than this speed. Light interacts with matter and gravity, and therefore can be reflected, diffracted, scattered, adsorbed or transmitted depending on the conditions of interaction. Although light needs no medium to propagate, its speed may decrease when light passes through any media and even change its direction as shown as Figure 3.2.

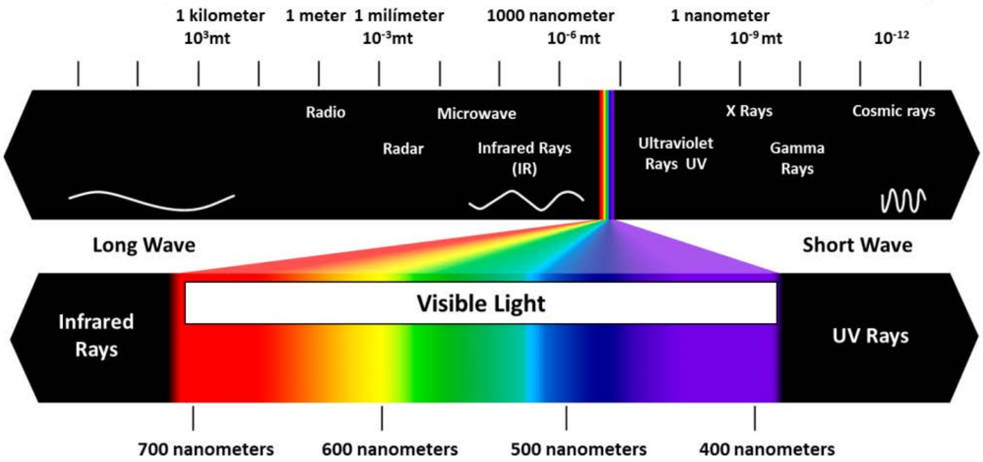


Figure 3.2 : Visible Light Speed

(http://www.artinaid.com/2013/04/what-is-light-or-electromagnetism/)

The color of the architectural environment most often begins with the color selection of its surfacing materials, but once in place the appearance of those surfaces is altered by the color of the illumination that makes them visible. For this reason it is essential that special attention be given to the color of light itself. (Michel, 1995)

Mixing Color Light, combining two or more hues of light does not produce the same results that happen when pigments are blended by a painter. Red light mixed with green light will appear yellow, far different from mixing red and green paint. blue light mixed with green will look cyan , and red light plus blue will appear magenta. Physicist refer to mixing colored light as additive, which increases the luminance on a surface. When a green light is mixed with red, the additive nature of the combination increases the brightness in the area of overlap. (Michel, 1995)

Color Rendering Index – CRI, The color rendering index (CRI) is a measurement of how well a light source represents color compared to an ideal source. Color rendering index (CRI) is measured on a scale of 0 to 100. A score of 100 indicates perfect agreement. Incandescent and tungsten halogen lamps have a CRI of 100, because their chromaticity coordinate lies on the black body curve, whereas the CRI of fluorescent lamps usually vary between 50 and 95.

The higher the CRI of a light source, the more “natural” colors will appear under it. -Natural, means as seen in daylight or sunlight. If an object looks different according to the color in the light illuminating it, because of this, it cannot be named true color-. Light sources with a low CRI will distort colors. For instance; Boyce’s experiments (2003) show that a light source with a CRI above 80 creates visual clarity and greater brightness perception; and a light source with a CRI below 60 produces an unattractive rendering of skin tones and a non-white color appearance of the lighting in Table 2.1.

As a result of researches, it is understood that CRI is the most important characteristic to perceive color correctly. For this reason, CRI of the light sources should be selected carefully to present products to the customers effectively. (Sezgin, 2011)

Table 3.1 : CRI of Selected Lamps (Michel ,1996)

Lamp Sources	CRI		Color Temperature (K)
Incandescent	99	at	2700
Deluxe cool white fluorescent	89	at	4100
Natural white fluorescent	86	at	3600
Daylight fluorescent	76	at	6300
Deluxe warm white fluorescent	74	at	2950
Metal-halide high-intensity discharge (HID)	70	at	3200
Cool-white fluorescent	62	at	4200
Warm-white fluorescent	52	at	3450
Mercury, warmtone, HID	52	at	3300
Mercury, clear, HID	22	at	5900
High-pressure sodium HID	20	at	1800

Color temperature describes how a lamp appears when lighted. Color temperature is measured in kelvin (K), a scale that starts at absolute zero (–273°C). Color temperature is not a measure of the surface temperature of an actual lamp or any of its components. Color temperature refers to the absolute temperature of the laboratory blackbody radiator when its visible radiation matches the color of the light source.

Glare is a condition in which vision is uncomfortable or visual recognition is reduced. It is caused by the relatively great luminance of a surface in the field of view. In artificial lighting, the greatest luminance in the room is the luminance of the luminaire, so glare is caused directly or indirectly by the luminaires. Glare may be direct or indirect. In direct glare, discomfort is caused by the visible luminaire, while in indirect glare, discomfort results from the image of the luminaire reflected on a shiny surface in the field of view. In some possible but rare cases, glare results if a mat surface is illuminated by very strong light. Glare may vary greatly. In extreme cases, visual recognition of the field of view may cease partly or completely for a time. A relatively great luminance may cause various degrees of glare depending on

- the area of the bright surface causing glare. The larger the surface, the greater the glare.

- the luminance of background surfaces surrounding the bright surface, i.e. the luminance of the rest of the field of view. The greater the luminance of the background, the smaller the effect of glare.

- the position of the surface causing glare in the field of view. The nearer the surface of high luminance to the axis of view, the greater the glare effect. (Majoros, 2011)

Usually, the uncontrolled luminance of an exposed light source produces glare. For this reason, bare lamps (the technical word for light bulb) are rarely used in architectural applications When direct glare occurs in the normal field of view, three main control techniques are available. One is to limit the amount of light emitted in the direction of the eye. Shielding devices such as the hand, used instinctively, and sun visors improve visibility and restore visual comfort in this way.

The second is to increase the area from which light is emitted. A white glass globe and diffusing panels of white glass or plastic are examples.

The automobile headlights redirected below the line of sight demonstrates the third technique whereby directional control and change in the direction of the beam aid visual comfort. This third method is more efficient; it uses accurate control devices to redirect light in the desired direction. Typical devices are reflectors and refracting lenses that limit the distribution of stray light emitted toward the eye. (Gordon, 2003)

A visual comfort probability (VCP) rating is defined as the percentage of people who, if seated in the least desirable location in an office work space, will find a lighting installation comfortable. VCP depends on the size and shape of the room, the reflectances of room surfaces, and the location and light distribution of the luminaires.

A VCP of 70 or more is recommended for general office use, and 80 or more for office areas using video display terminals (VDTs). Originally tested and validated using lensed fluorescent direct luminaires, VCP is applicable only for direct lighting systems. (Gordon, 2003)

Visual comfort is achieved by limiting not only direct glare but also reflected glare. Reflected glare is excessive uncontrolled luminance reflected from objects or surfaces in the field of view. This includes the reflected luminance from interior surfaces as well as the luminance of the lighting system.

Specular surfaces have reflecting properties similar to those of a mirror. The luminance reflected is the mirrored image of the light source, or of another lighted surface within the reflected field of view.

These properties make specular surfaces useful as reflectors for light control in luminaires, but polished or specular interior surfaces such as desks, countertops, floors, walls, and ceilings introduce problems of reflected glare. Diffuse surfaces prevent highlights and are uniformly bright from all angles of view. (Gordon, 2003)

VDTs are glossy vertical work surfaces. Screen reflections are caused by variations in luminance being “seen” by the screen surface and reflected into the worker’s eyes. Screens that are convex and inclined upward, in particular, reflect into the eyes large areas of ceiling, walls, windows, and the surrounding space. Positioning the screen, adjusting its angle, low reflectance screens, blinds on windows, and dark clothing for workers are techniques that relieve many reflection problems. Reflections caused by the lighting system can be controlled with properly designed, deep- cell parabolic louvers to prevent lamp images from appearing on the VDT screen.

We have seen how the amount of texture and shadow on a surface determines its level of brightness, but that assumes it is seen from a stationary viewing point. When that surface is seen from different viewing angles of slan, its brightness changes. That happens because the surface is perceived as a textural gradient and seeing it at a steeper and steeper angle compresses the surface texture, and less shadow is visible in areas farther down the viewing plane. (Michel, 1995)

It is a different situation, however, when a surface changes in angle to the light source. A glance around a room whose walls are all painted the same color or surfaced with the same material will show how the brightness of a surface is dependent on its angle of slant to the arriving illumination. (Michel, 1995)

The architectural and lighting designer needs to develop proficiency for predicting how illumination will determine the visual appearance of surfaces shaping the human habitat. (Michel, 1995)

3.1 The Lighting

The process through which an energy of light produced from a light source is sent to the target place and the target places are shown, distinguished and colored is called "lighting". "Lighting" is the application of the light to certain objects and surfaces in the most visually effective way. The lighting technique is a widespread field of both science and art which includes the sight features of the human eye regarding the types of light and color; various features and surfaces of light bulbs and light fixtures; light reflection and transmission of the objects; different measurement techniques of aesthetics and architectural concepts; and quite complicated calculations. This above-mentioned technique also benefits from scientific data and information. (Esen, 2000)

In an environment designed regarding the basic principles of the science of lighting, the requirements of the visual comfort of human beings are met. The eye's ability to see increases (the visual acuity and speed increase, the sense of contrast decreases.); the eye health is protected; the risk of visual impairment is prevented; since the visual performance will increase, the productivity of the current deed increases and therefore this provides economic welfare. From a psychological point of view, visual comfort is provided; the user feels happy in the environment where he/she spends time; the accidents regarding the poor eye sight and visual error decrease; and a sense of protection is provided. (Küçükdoğu, 2008)

3.2 The Types of Lighting

Lighting is classified by intended use as general, accent, or task lighting, depending largely on the distribution of the light produced by the fixture.

3.2.1 General Lighting

General lighting provides the required horizontal illuminance over the total area with a certain degree of uniformity. Also known as ambient lighting, it radiates a comfortable level of brightness without glare and allows seeing and walking about safely. The most useful advantage of this type of lighting is the flexibility in rearranging the space. Since illumination is roughly equal everywhere, settlement is relatively easy. (Figure 3.4) (Sezgin,2011)

Since the general lighting system carries all the characteristics of the brightness of the day, it can be likened to daylight. In these type of lighting system, incandescent lamps, fluorescent lighting and HID lamps are used; and the general balance of brightness and the lighting of various surfaces are well balanced. (Figure 3.3)

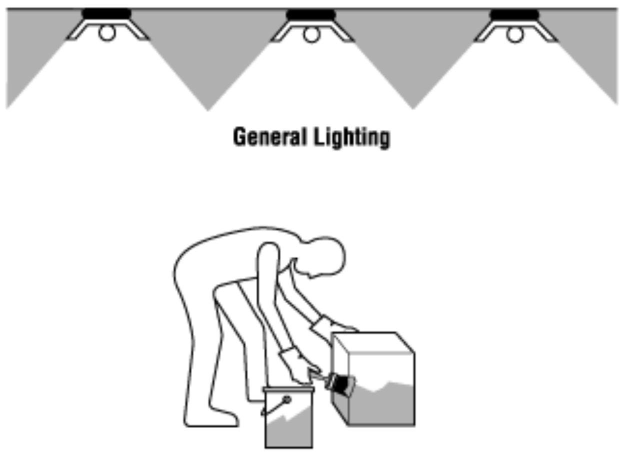


Figure 3.3 : General Lighting

(http://www.ccohs.ca/oshanswers/ergonomics/lighting_general.html)

Figure 3.4 : The Example of General Lighting

(http://www.interlectric.com/general-lighting/l-e-d-lights/t8-leds-general-lighting/)

3.2.2 Task lighting

Local (or task) lighting increases light levels over the work and immediate surroundings. Local lighting often allows the user to adjust and control lighting and provides flexibility for each user. Task lighting uses in offices or working areas. (Figure 3.5)

Figure 3.5 : Task Lighting

(http://www.interlectric.com/general-lighting/l-e-d-lights/t8-leds-general-lighting/)

3.2.3 Accent (localized) lighting

Accent lighting is directional lighting to emphasize a particular object or to draw attention to a part of the field of view. It creates atmosphere in the space by the help of visual interest; light and shadow. It is used to spotlight paintings, houseplants, sculpture, and other prized possessions, or to highlight the texture of a wall. Since it is a very powerful generator of the visual atmosphere it requires attention. Accent lighting requires at least ten times as much light on the focal point as the general lighting around it. Accent lighting is especially used as in the following titles: Modeling, silhouetting, down lighting, wall washing, up lighting and grazing. (Figure 3.6) (Sezgin,2011)

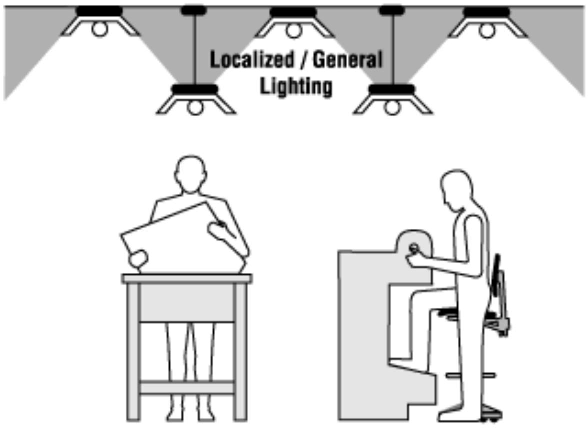


Figure 3.6 : Localized/General Lighting

(http://www.interlectric.com/general-lighting/l-e-d-lights/t8-leds-general-lighting/)

3.3 The Types of Lighting Fixtures

The Types of lighting Fixtures are mentioned in the below table 3.2

Table 3.2 : Types of Lighting (Ünal A. 2009)

TYPE OF LIGHTING	RATE OF THE LIGHT FLOW DISTRIBUTION (%)	
	Indirect	Direct
Direct Lighting	0-10	90-100
Semi-Direct Lighting	40-10	60-90
Diffuse Lighting	40-60	60-40
Semi-Indirect Lighting	60-90	40-10
Indirect Lighting	90-100	0-10

3.3.1 Direct lighting

The upward distribution of the light provided by the lighting source is between 0-10% and the downward distribution is between 90-100%. The ceiling and the walls do not affect the total lighting efficiency. Sharp edged solid shadows and reflection occur. The reflection exhausts the eye and the lighting is not balanced. A glare related to the fixture may develop. Maximum efficiency is provided by using minimum energy. This type of lighting is used in the high-ceilinged buildings, the places which do not need showing their ceilings, factories, workshops, manufacturing shops, streets and gardens. (Figure 3.7) (Esen, 2005)

Figure 3.7 : Direct Lighting

(http://www.minimalisti.com/lighting-2/08/modern-lighting-lamps-design.html/2)

3.3.2 Semi-direct lighting

The upward distribution of the light provided by the light source is between 10-40% and the downward distribution is between 60-90%. The reflection factors of the ceiling and the walls have a low or medium effect on the total lighting efficiency. The nature of the shadows is medium or sharp. Glare develops, and the efficiency is high, but not as high as the direct lighting. The emission of the light provided by the source depends on the type and color of the material of the ceiling and the walls. Medium ceilinged buildings, restaurants, shops, and the places which need showing their walls use this type of lighting. (Figure 3.8)(Alkan, 2010)

Figure 3.8 : Semi-Direct Lighting

(http://www.civilprojectsonline.com/lighting/semi-direct-lighting-ambient-lighting-techniques/)

3.3.3 Diffused lighting

In this type of lighting system, the light axis from the source reaches the working environment in an almost balanced direct and indirect way. The light sources are used with naked or global transmitter devices. The diffused surface reflection factors are more important compared to other lighting models. In order to decrease the effect of the value loss which will occur in the system efficiency, the devices should be cleaned regularly. (Figure 3.9) Since the diffused lighting creates low shadows and provides a diffused lighting distribution, it is especially preferred in the residences. (Ünal A., 2009)

Figure 3.9 : Diffused Lighting

(http://image.slidesharecdn.com/lighting-150123085307-conversion-gate02/95/lighting-10-638.jpg?cb=1422024848)

3.3.4 Semi-indirect lighting

The upward distribution of the light provided by the light source is between 60-90% and the downward distribution is between 10-40%. The reflection factors of the ceiling and the walls have a medium or high effect on the total lighting efficiency. The shadows are soft and no glare develops. The eyes feel comfortable and the lighting in the environment is mostly balanced. The lighting efficiency is low. It is used in the places where people constantly read and write, in the accountant bureaus, libraries and also places where the decorative features of the ceiling and the walls need showing. (Figure 3.10)

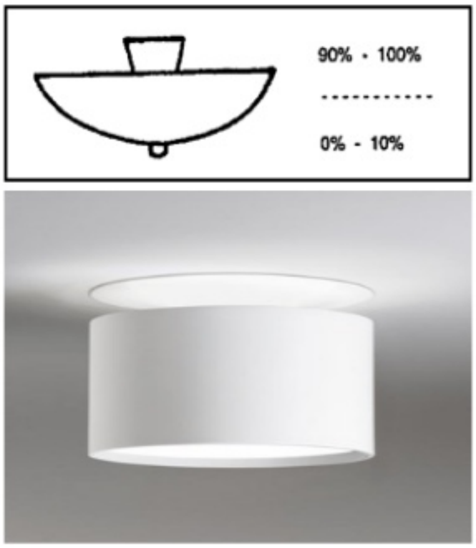


Figure 3.10 : Semi-Indirect Lighting

(http://image.slidesharecdn.com/lighting-150123085307-conversion-gate02/95/lighting-10-638.jpg?cb=1422024848)

3.3.5 Indirect lighting

The indirect lighting is the type of lighting in which almost the entire light axis (90-100%) from the light source indirectly reaches the working environment. The fact that the light reaches the surface by reflecting from several points positively affects the visual comfort measures. The shadowing within the volume is scarcely any, and the distribution of lighting level inside the room is homogeneous. Since the light provided by the source does not directly reach the surface, the glare will not be a problem. (Figure 3.11) For the above-mentioned reason, the inner surface multipliers should be high. Because of the possible contamination on the inner surfaces, the surfaces should be periodically cleaned in order to avoid any increase in losses. (Ünal A. 2009)

Figure 3.11 : Indirect Lighting

(http://image.slidesharecdn.com/lighting-150123085307-conversion-gate02/95/lighting-9-638.jpg?cb=1422024848)

3.4 Lighting sources

Every light around us is produced by a light source. Everything which lightens its surroundings by casting light is a light source. Our biggest light source is the sun. The light sources are divided into two categories as “Natural Lighting” and “Artificial Lighting”.

3.4.1 Natural lighting (daylight)

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. (Kılıçaslan, 2011)

A principal characteristic of daylight is its variability. The color 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. Daylight has two components: sunlight and skylight. Sunlight is the directional beam emitted by the sun; skylight is the diffuse reflection of light from particles in the atmosphere.

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. For critical seeing tasks, sunlight often causes excessive luminance differences that result in discomfort and poor visibility. This high contrast in the field of view inhibits the eye's ability to adjust, leading to visual fatigue and disturbing the accommodation needed for clear vision. Skylight, on the other hand, is a useful source without shielding. Although special building configurations or controls are necessary to make skylight acceptable for horizontal tasks at the workplane or for displaying art, it is used with less control to light noncritical seeing areas such as corridors, stairwells, cafeterias, and seating areas (Gordon, 2003).

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 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. The main goals of the natural lighting of the buildings beside providing physiological and psychological comfort for the users and the reduction of energy consumption are the following:

- Using the sunlight effectively
- Providing the best possible lighting
- Providing glare control by avoiding direct sunlight

- Creating visual contact with the surroundings
- Sensing the quantitative and qualitative differences of the outer lighting during the daylight
- Creating a design coherent with the physical environmental problems such as climate control and noise control
- Reducing the loads of the artificial lighting, heating and cooling systems.

The priorities of these targets can change depending on variables such as the characteristics of the climatic zone, the function of the building, and the hours when the building is used. In order to meet these goals, various methods can be developed regarding the usage of the daylight (Yener, 2008).

The buildings are lightened with sunlight by using windows or roof lights. However, there are other systems used for daylight.

Windows are defined as the vertical or nearly vertical sunlight openings which are located on the outer walls of the building, and aim to provide the intended lighting level in the working environment that is showed in figure 3.12.
Windows are possible for every climatic zone and they have to be handled at the early stages of the design. The view windows located on the eye level and providing outside view, and high windows which do not provide outside view (clerestories) can be studied under this topic. (Yener, 2008)

Figure 3.12 : Windows
(http://inhabitat.com/swedens-umea-university-architecture-academy-punctuated-with-pixelated-windows/

Window size and height above the work surface are factors in daylight design. Of course, as the window becomes larger in size, the amount of daylight increases. But the height of the window is the more significant factor. The higher the window opening, the deeper the daylight can penetrate into the room, and if it is high enough, it may prevent exterior brightness from causing glare. This high-entry light is softened and spread by proper design of the room surfaces. Interreflections between these surfaces cause the brightness patterns to become more uniform; visibility and seeing comfort are increased.

Windows and other daylight openings that are set flush in a wall or ceiling produce excessive contrasts between exterior brightness and the immediately adjacent interior surfaces. This contrast is often harsh and uncomfortable. A softer transition is achieved with the use of splayed jambs, rounded jambs, and deep window wells. Instead of the sharp contrast between adjacent surfaces, these designs provide a zone of intermediate luminance to soften the change (Figure 3.13). (Gordon, 2003)

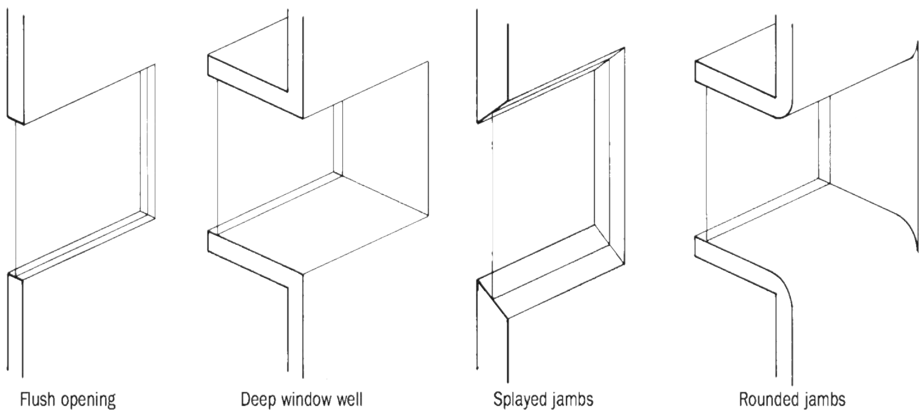


Figure 3.13 Splayed and rounded window jambs soften contrasts.
(Gordon 2003)

The roof lights are the vertical openings located on the roof like the constant openings, lanterns and curved windows, and the main aim is to receive enough and controlled sunlight by not providing exterior view. As the effect of these lights on the building's design and the interior surface arrangement are different, and the distribution of the sunlight they provide is also different from each other. The vertical openings provide proper lighting, and they enable both sunlight and the usage of the sunlight. Regarding the usage of the direct sunlight, certain precautions should be taken in terms of sunlight control and the dissemination of the light. These lights are suitable for the places whose vertical working environments need lightening, for the volumes which need general lighting, for the lighting of three dimensional objects and also for places whose walls are supposed to be used for other purposes rather than lighting. These lights are more suitable for the overcast weather in terms of visual and climatic comfort conditions.

Constant opening is the type of opening in the shape of saw teeth which are created with the co-design of the vertical or curved openings with a curved roof pattern. One of their surfaces is mostly transparent. Depending on their dimensions, the distribution and amount of daylight within the volume changes.

While a properly chosen and implemented, energy-efficient roof light creates a comfortable environment in terms of heating, cooling and lighting, it can also minimize the losses. The climatic zone in which the building is located, the function and the design concept of the building should be properly associated with the roof lights. If the roof lights are turned to the north, the building does not receive sunlight and common daylight cannot be taken inside. The roof lights turned to east provide maximum brightness and solar heat power in the mornings. The roof lights turned to south, on the other hand, provide sunlight and heat at noon. However, in the winter, the roof lights turned to south provide the desired solar power compared to the other directions, but they can cause uninteneded heat gain during summer. (Yener,2008)

Light shelves are designed to prevent sunlight and direct it to the ceiling, and they are vertical or almost vertical elements situated on the inner or outer surfaces. It may be integrated with the facade or placed later. The light shelf is generally placed on the eye level. The underside of the window provide exterior view while the upside serves to let the sunlight in. While the light shelves protect the area close to the window from the sunlight, the reflected light lightens the ceiling. In the winter, the sunlight can reach the volume from the window parts placed on and under the light shelf. (Yener,2008)

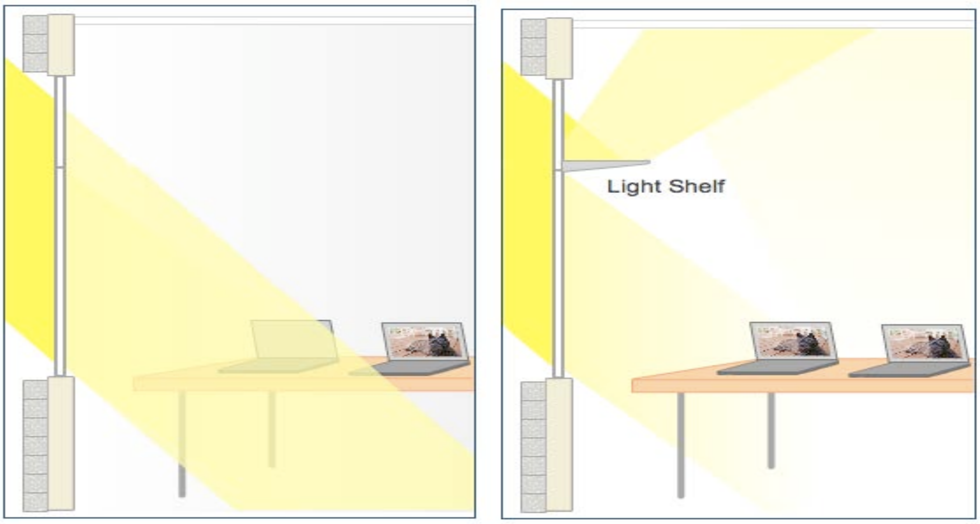


Figure 3.14: a. Lighting without Light Shelf b. Lighting with Light Shelf

(http://myweb.wit.edu/viridis/green_site/projects/2_processes/daylighting/3_light-shelves/light-shelves.html)

In this system, the sunlight is reflected to the ceiling and the deepest parts of the environment with a reflective surface placed on the light shelf made of a vertical or almost vertical plate 2 meters above the floor level at the frontal gap. If the roof light is placed in a way that it will go beyond the front, it can provide shadowing for the direct sunlight coming from unintended angles. (Figure 3.14) (Karslı Tuğlu, 2008)

Tubular skylights deliver natural light to a room where a traditional skylight or vertical glazing is impractical. They consist of three components:

- a Small, clear acrylic dome located on the roof, which allows sunlight to enter;
- an Adjustable cylindrical aluminum shaft that has been treated with a highly reflective coating;
- a Translucent diffuser lens located on the interior ceiling, which disperses light throughout the room.

The dome is typically installed between rafters and joists on the roof, and the adjustable aluminum tube extends from the roof to the ceiling of the interior in Figure 3.15. Sold in kits, tubular skylights minimize heat gain and loss: the aluminum tube radiates any collected exterior heat into the attic, and the sealed shaft allows very little interior heat to escape up. Also, little UV is transmitted to the interior; almost all of the UV rays are absorbed by the dome, shaft, and diffuser materials. (Gordon, 2003)

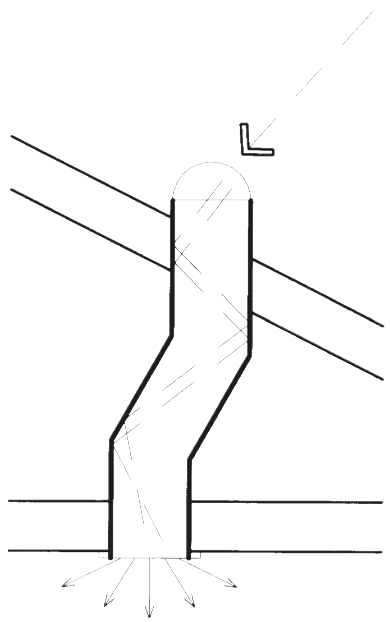


Figure 3.15: Light Tube (Gordon 2003)

In the sunny climates, by implementing a reflective half dome turned toward the sun into the opening and letting the direct sunlight which comes indirectly during winter, more reflection is possible. In the cloudy climatic zones, a thoroughly transparent dome should be used. With the usage of special lenses and geometrical figures, the indirect sunlight can be let in and steered down.

3.4.2 Artificial lighting systems

The artificial lighting needed when the sun sets emerged as a concept with the invention of the fire. Fire which is the first element of artificial lighting gave the humans the power of resistance and made the life easier for them during dark nights. With firstly the invention of life then the invention of light lamp as a step for the development of lighting technology, the concept of artificial lighting has led some changes in the visual perception of the human beings outside its purpose regarding its qualitative and quantitative features and it has also affected people's visual comfort. In accordance with the physiological and psychological effects of light, with its refreshing and peaceful effect on life, the artificial lighting has brought into new values to the open and closed environments during the technological development process. As a result of all these developments, now a new concept has started to emerge called “Lighting Design”. Like architectural design, by leaving the conventional and rigid design and the related calculation methods aside and starting out from real requirements, lighting design can also be described as a study to create a suitable lighting pattern. Today, the lighting design has come to a stage where it will be accepted as a new field of expertise after an effort of over twenty years. Even in few numbers, the lighting designers have accomplished important lighting designs in both our country and the world. (Sirel, 1991)

The lamps providing the artificial lighting are the primary light sources since they give out energy as light. The artificial lighting can be provided in different shapes and from different sources based on the function managed in the volume. With this type of lighting, the brightness required by the function of the working environment can be managed within the needed period, quality and level. (Göker, 2006)

Incandescent lamps are the simplest type of lamp technology. They work by passing electricity through a thin filament, heating it to a temperature that produces light. The enclosing glass bulb contains either a vacuum or an inert gas to prevent oxidation of the hot filament. A typical incandescent lamp is shown in Figure 3.16.

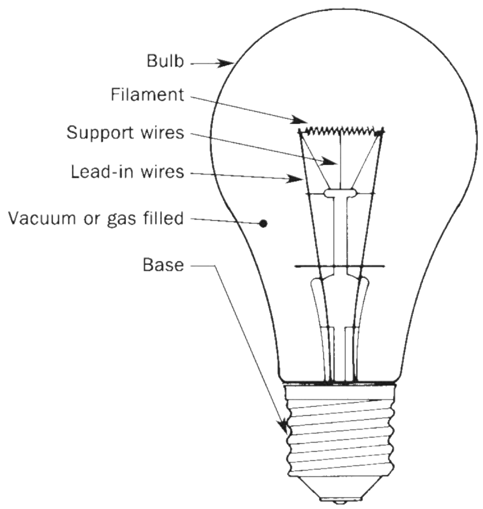


Figure 3. 16 : Incandescent Lamp (Gordon 2003)

Due to its high melting temperature (3.,655 K), tungsten is used for filaments. The higher the temperature at which the filament operates the more light can be emitted but the sooner the lamp fails or burns out. Lamp bulbs originally were evacuated to prevent a reaction of tungsten with oxygen, which would cause the quick evaporation of tungsten. In modern incandescent lamps the bulb is filled with an inert gas which slows bulb blackening. Especially argon, nitrogen and krypton gases are used for this task. Bulb blackening is caused by condensation of evaporated tungsten particles on the inner bulb wall.

Although reduced by the inert gas pressure, the filament evaporation continues throughout life. The tungsten wire becomes thinner, consumes less power and emits less light. This light loss combined with the bulb blackening causes a steady decrease in light output throughout the life of the lamp.

The higher the voltage an incandescent lamp is operated the higher its efficacy causing a high light output. Overvoltage, however, results in shorter lamp life. Under voltage results a lower efficacy causing a low light output but increases lamp life. (Pohl and Zimmermann,2003)

Tungsten lamps and halogen lamps are types of Indascents Lamps. Since the pennant inside the Tungsten incandescent lamp is of tungsten (Volfram) mine, this type is called “Tungsten Lamp”. Today, those lamps which include one of the noble gases, argon, are used. The cost of lighting is excessive and since their optical value is between 10-20 lm/W, they have less light efficiency. That's why they are used in less light-needed places such as houses, restaurants and entrance halls. (Şerefhanoğlu,1974)

Halogen lamp is an incandescent lamp with a selected gas of the halogen family sealed into it. As the lamp burns, the halogen gas combines with tungsten molecules that sputter off the filament and deposits the tungsten back on the filament, rather than on the bulb wall. This keeps the bulb wall clean and at the same time builds up the filament wire to compensate for the evaporative loss that reduces its diameter, thus maintaining relatively constant wattage. The result is a lamp that delivers almost its full light output throughout its life. (Figure 3.17) (Gordon 2003)

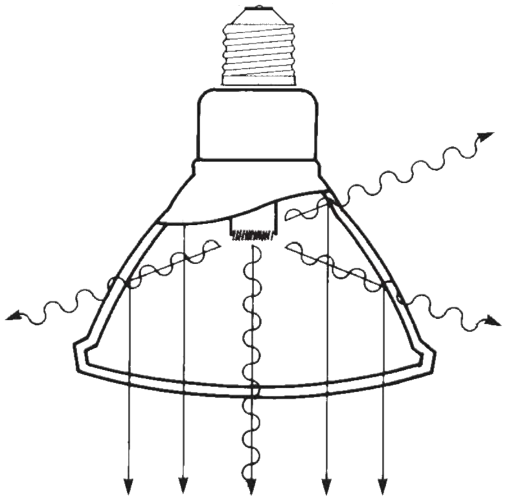


Figure 3.17 : Halogen Lamp (Gordon 2003)

The light production by discharge sources is more efficient than the electric heating method used in filament lamps. Discharge lamps used in architectural lighting are more efficacious and have a longer life.

A fluorescent luminaires or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce shortwave ultraviolet light that then causes a phosphor to fluoresce, producing visible light.

A fluorescent lamp converts electrical power into useful light more efficiently than an incandescent lamp. Lower energy cost typically offsets the higher initial cost of the lamp. The lamp is more costly because it requires a ballast to regulate the flow of current through the lamp (Inman, 1954).

Inside the fluorescent lamp (Figure 3.18) made of glass tube is argon or krypton or in small amounts mercury. Its inner surface is opal-shaped and it has electrodes on each edge. Its optical value is 43 lm/w for 20W, 53 lm/W for 40W. The daylight fluorescent lamp is especially good at showing the colors yellow and red. For this reason it can be used with the incandescent bulbs in the places such as textile, paint industry or art galleries where the color is important. It can be used in places such as schools, offices, libraries and banks in a way to help the sunlight (Alkan, 2010).

It has two types as hot and cold cathode fluorescent lamps. Regarding the cold cathode fluorescent lamps, the voltage decrease in cathode is higher than the decrease in hot cathode. The electrodes in this widefield source is highly durable. The hot cathode is used almost in every fluorescent lamp. The spiral tungsten pennant soaked in a electrode spreading material is at the end of every lamp. It exerts less power. (Alkan,2010)

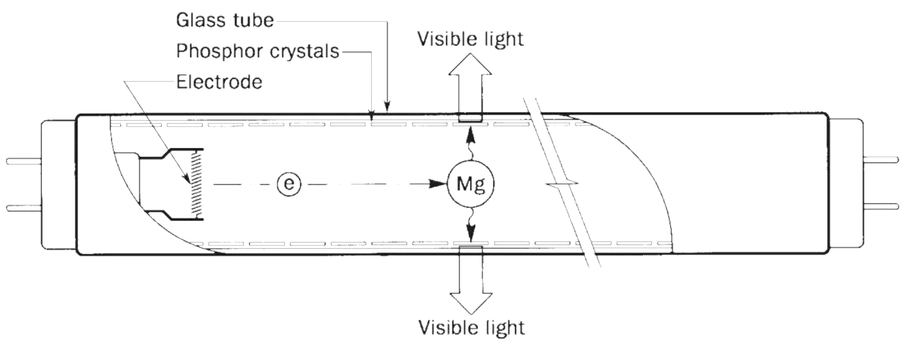


Figure 3.18 : Fluorescent Lamp (Gordon 2003)

With mercury vapour lamps, light is produced by an electric discharge through mercury vapour, resulting in poor quality of a greenish hue. The addition of phosphor coatings on the inside of the bulb improves colour rendering because phosphor complements the red part of the spectrum (Pohl and Zimmermann,2003).

Metal halide lamps are HID lamps, too. They have two envelopes. The inner quartz arc tube contains other metal halides in addition to mercury. Light is generated in the arc tube either with the help of an auxiliary electrode or with the help of a starting impulse. The outer envelope may or may not have a fluorescent powder coating. Metal-halide lamps convert only about ¼ of the input into light. This ratio is smaller if the consumption of the auxiliary is taken into account. Their quality of light depends on the metal halides used in the arc tube. Their colour temperature is 3,000-6.000 K, so their light may be warm, neutral or cool (Majoros, 2011).

High-pressure sodium lamps are manufactured with tube-shaped ellipsoidal bulbs with wattage of between 50 W and 1000 W. The discharge space is a transparent ceramic burner, which is resistant to the aggressivity of sodium. High-pressure sodium lamps achieve a extremely high luminous efficacy up to 130 lm/W, however, they radiate a yellowish colour of light and achieve bad colour rendering. Thus, these lamps are only used in warehouses and similar locations when used in interiors; their main application is outdoors for the illumination of streets and car parks (Pohl and Zimmermann,2003).

These lamps have high efficiency (up to 180 lm/W), quite long life (up to 16000 hours) and reduced running costs. As their name implies sodium in the lamp causes the light to be a yellow color. This might be a problem in cases where color discrimination is essential. LPS is commonly used for road lighting, parking areas etc. They can be used with black & white surveillance cameras. Another advantage is that these lamps can be used in areas where astronomical observations take place since its yellow light can be filtered out. A short warm-up period is needed for the lamp to reach full brightness (Pohl and Zimmermann,2003).

Light emitting diodes (LED) 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 colored LED also white LED's 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 LED's covered with a phosphor layer (Pohl and Zimmermann, 2003).

In contrast to conventional light sources no infrared or ultraviolet light is emitted, the generation of the more or less narrow band light requires low voltage in the region of several volts depending on the color (e.g. 2V for red, 3.6V for blue). Due to their construction LED's are not sensible to mechanical shock. The size of the active light emitting area is typical smaller than 1 mm^2 and acts quasi as a point source (Pohl and Zimmermann,2003) (Figure 3.19).

Figure 3.19 : LED Lamps

(http://www.apartmenttherapy.com/10-bright-ideas-for-led-lighting-190699)

The Advantages of LED’s;

- High light density and brightness
- High efficiency
- Work with low current and low voltage
- Low heat release
- Resistant against the shake and shock
- Do not spread the ultraviolet ray
- Durability
- Easy manageable and programming

3.5 Lighting Criteria of LEED and Other Sustainable Certificate

Offices in general are not exactly the most pleasant environment you would like to be in. Over the years, a pattern has been created for offices and work spaces in general and this pattern shows them as very simple spaces without much color and without an inviting atmosphere. Still, some companies and architects try to change that image and so amazing offices are created.

Sustainability is a necessary and new subject for the office buildings. People works for hours in office buildings. And they spends a lot of time in this buildings time than their houses. Therefore, the sustainability word is important for offices.

Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations.
Sustainability is important to making sure that we have and will continue to have, the water, materials, and resources to protect human health and our environment.

Sustainable design is an exciting area of architecture and building which is 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. (http://www.morganlovell.co.uk/knowledge/whitepapers/sustainable-office-design-unlocking-performance-and-productivity)

Sustainable design creates products, places, processes and systems which optimise human well-being now and in the future without compromising the well-being of the planet.

Architecture is one of the most exciting, visible and burgeoning areas for sustainable design with a rich array of techniques, systems, technologies and materials already in place that can drastically reduce the effects buildings have on the environment while bringing about a step change in comfort and efficiency. Buildings can be self sufficient in energy, purifying their own air, and treating at least some of their own waste.
(http://www.morganlovell.co.uk/knowledge/whitepapers/sustainable-office-design-unlocking-performance-and-productivity)

With this sustainability terms, the sustainable office increased. There are many sustainable office building in Turkey. the first sustainable office building in Turkey is Unilever Office building in Istanbul.

Unilever Turkiye Green Office Building (Figure 3.20) constructed with the subject of sustainability within the framework of social responsibility, is the first project to gain the right to receive LEED certificate. The Green Office Building which is the indication of the value Unilever gives to the people and environment has LEED Silver certificate.

Figure 3.20 : Unilever Center Office building in Turkey

(www.segatech.com.tr)

Regarding the design, planning and construction, Unilever building was completed in 1,5 years. 35% power saving was managed in comparison to an ordinary office building in terms of the power used for HVAC, and 15% saving was managed according to the international ASHRAE standards. However, it was 40% more insulated than an ordinary office building. In order to prevent the losses of manpower and energy, all the equipment inside the building is monitored via building automation system, and any error or irregularity can be realized and intervened on the spot. With the solar panels built on the roof, the water can be heated and therefore power saving is managed. In order to reduce the energy cost, the equipment from Energy Star were used.

In Unilever building, 41% water saving was managed according to EPA (Environmental Protection Agency). The reasons are the following:

* the usage of water-saving armatures and waterless urinals
* the collection and usage of rain water in the toilets and garden irrigation while reducing the usage of city water supply
* the usage of less water-consuming plants and the rain water regarding the landscape design. (Thanks to the stored water supply, city water supply is not needed for the irrigation.)

In order to increase the inner air quality, over 30% fresh air was provided according to the ASHRAE standards. Energy saving systems were chosen in order to manage this implementation. With 100% fresh-aired and heat recovery air conditioning stations, the interior quality was increased. Several precautions were taken on the roof and landscape in order to reduce the effect of heat island.

By organizing activities such as café, hairdresser's, bank, travel agency, car washing, etc the efficiency and the health standard of the staff were increased and since the staff could manage all of their requirements and needs inside the building without going out, the satisfaction and the comfort of the staff were provided. All of the above-mentioned precautions reduced the staff's need to travel and indirectly reduced the CO_2 emission. Over 20% usage of local materials also had an effect and reduced the CO_2 emission. The environmental friendly construction materials with the least percentage and effect on human life were used.

By organizing start-up activities and making plans regarding the inner air quality management, all the equipment were managed to be tested according to ASHRAE and IESNA standards, and therefore the health and security of the personnel were increased. Thanks to the improved waste management plan, all the waste was parsed out and recycled. The gases of mechanical equipments are also chosen from the ones with no damage on the ozone layer.

The office floors on Unilever building were designed according to the open-plan office system. (Figure 3.21) By locating all the tables in a way they can see the sun and the view, the efficiency of the staff and the satisfaction of the workplace were increased. While this building was designed, it was expected to manage 35% saving regarding the lighting energy in terms of office buildings. The lighting energy also affected the total energy saving and thanks to this saving 30% CO_2 emission was expected. Energy saving was managed with solar sensors and graduated lighting. By using efficient lighting armature lamps, the intensity of lighting power was reduced in 20%. (Figure 3.22)

Energy saving was managed by choosing the appropriate equipment for both electrics and mechanics in the office spaces. In order to prevent the light noise spreading through the atmosphere and to increase the energy saving, special armatures called “full cut off” were used in the outer spaces.

Figure 3.21 : Open Plan Offices in Unilever Building

(www.entegreplus.com)

Figure 3.22 : Open Plan Offices in Unilever Building

(www.entegreplus.com)

Constructing the buildings with traditional construction technology is one of the main reasons for the increase in global warming over the world, climate change and depletion of energy resources. Construction sector, in an effort to reduce negative effects which has been caused by itself, has developed an innovative solution called green building notion, in order to be in harmony with nature, sustainable, environmentally friendly and efficient in use of natural resources. (Anbarcı, Giran and Demir, 2012)

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. Two of the most known green building certification systems are US based LEED and UK based BREEAM. Both systems share the common goal of making industry professionals avoid the products and implementations that may negatively affect the quality of life of future generations, while they create living and working environments for all of us. (Ilıcalı and Somalı, 2009)

The determination of which evaluation system to choose for a green building planned to be built is an important decision. A wrongly chosen system may cause some difficulties in terms of applicability and cost, and it may negatively affect both the cost and the design quality of the construction. On the other hand, the implementation of the efficient system can increase the design quality, minimize the damage which may occur towards the environment, and also create a building which covers more healthy conditions for the residents (Ilıcalı and Somalı,2009). The Sustainable certificates instructions are showed in the table 3.3.

Table 3.3 : The Sustainable Certificates Instructions

(http://astudentoftherealestategame.com/wp-content/uploads/2010/10/Comparison.jpg)

	LEED	**BREEAM**	**Green Star**	**CASBEE**
Launch Date	1998	1990	2003	2004
Ratings	Certified / Silver / Gold / Platinum	Pass/Good/ Very Good/ Excellent/ Outstanding	One Star / Two Star / Three Star / Four Star / Five Star /Six Star	C / B- / B+ / A / S
Weightings	All credits equally weighted, although the number of credits related to each issue is a defacto weighlight	Applied to each issue category (consensus based on scientific / open consultation)	Applied to each issue category (industry survey based)	Highly complex weighting system applied at every level
Information Gathering	Design / management team or Accredited Professional	Design / management team or assessor	Design team	Design / management team
Third-Party Valuation	N / A	BRE	GBCA (Green Building Council of Australia) nominated assessors	Third-party agencies e.g., JSBC (Japan Sustainable Building Consortium)
Certification Labeling	USGBC (United States Green Building Council)	BRE	GBCA	JSBC
Update Process	As required	Annual	Annual	As required
Governance	USGBC	UK Accreditation Service (UKAS)	GBCA	JSBC
Required Qualification	Passed exam	Competent persons scheme	Training scheme and exam	N / A
Assessor / AP CPD Requirements	No CPD requirements	Carry out at least one assessment per year	Status renewed every three years	N / A

3.5 LEED AND LIGHTING

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. For example, LEED NC rates new construction, while LEED EB is applicable to existing buildings. Each category is comparatively rigorous and can add cost to the project depending on the level of certification sought and the experience level of the team. (http://www.betterbricks.com/graphics/assets/documents/RatingSystem_Final.pdf)

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 centers- 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 (Uyan, 2010).

The LEED new construction major categories and credits;

- **Location and Transportation (LT)**
    - LT Credit: LEED for Neighborhood Development Location (Up to 16 points)
    - LT Credit: Sensitive Land Protection (1 point)
    - LT Credit: High Priority Site (2 points)
    - LT Credit: Surrounding Density and diverse uses (up to 5 points)
    - LT Credit: Access to Quality Transit (up to 5 points)
    - LT Credit: Bicycle Facilities (1 point)
    - Lt Credit: Reduced Parking Footprint (1 point)
    - LT Credit: Green Vehicles (1point)

- **Sustainable Sites (SS)**

    - SS Credit: Construction Activity Pollution Prevention (required)
    - SS Credit: Site Assessment (1 point)
    - SS Credit: Site Development-Protect or Restore Habitat (up to 2 points)
    - SS Credit: Open Space (1 point)
    - SS Credit: Rainwater Management (up to 3 points)
    - SS Credit: Heat Island Reduction (up to 2 points)
    - SS Credit: Light Pollution Reduction (1 point)

- **Water Efficiency (WE)**

    - WE Credit: Outdoor Water Use Reduction (required)
    - WE Credit: Indoor Water Use Reduction (required)
    - WE Credit: Building – Level Water Metering (required)
    - WE Credit: Outdoor Water Use Reduction (up to 2 points)
    - WE Credit: Indoor Water Use Reduction (up to 6 points)
    - WE Credit: Cooling Tower Water Use (up to 2 points)
    - WE Credit: Water Metering (1 point)

- **Energy and Atmosphere (EA)**

    - EA Credit: Fundamental Commissioning and Verification (required)
    - EA Credit: Minimum Energy Performance (required)
    - EA Credit: Building-Level Energy Metering (required)
    - EA Credit: Fundamental Refrigerant Management (required)
    - EA Credit: Enhanced Commissioning (up to 6 points)
    - EA Credit: Optimize Energy Performance (up to 18 points)
    - EA Credit: Advanced Energy Metering (1 point)
    - EA Credit: Demand Response (up to 2 points)
    - EA Credit: Renewable Energy Production (up to 3 points)
    - EA Credit: Enhanced Refrigerant Management (1 point)
    - EA Credit: Green Power Carbon Offsets (up to 2 points)

- **Materials and Resources (MR)**
    - MR Credit: Storage and Collection of Recyclables (required)
    - MR Credit: Construction and Demolition Waste Management Planning (required)
    - MR Credit: Building Life-cycle Impact Reduction (up to 5 points)
    - MR Credit: Building Product Disclosure and Optimization-Environmental Product Declarations (up to 2 points)
    - MR Credit: Building Product Disclosure and Optimization-Sourcing of raw materials (up to 2 points)
    - MR Credit: Building Product Disclosure and Optimization-Material ingredients (up to 2 points)
    - MR Credit: Construction and Demolition Waste Management (up to 2 points)

- **Indoor Environmental Quality (EQ)**
    - EQ Credit: Minimum Indoor Air Quality Performance (required)
    - EQ Credit: Environmental Indoor Tobacco Smoke Control (required)
    - EQ Credit: Enhanced Indoor Air Quality Strategies (up to 2 points)
    - EQ Credit: Low-Emitting Materials (up to 3 points)
    - EQ Credit: Construction Indoor Air Quality Management Plan (1 point)
    - EQ Credit: Indoor Air Quality Assessment (up to 2 points)
    - EQ Credit: Thermal Comfort (1 point)
    - EQ Credit: Interior Lighting (up to 2 points)
    - EQ Credit: Daylight (up to 3 points)
    - EQ Credit: Quality Views (1 point)
    - EQ Credit: Acousting Performance (1 point)

- **Innovation (IN)**
    - IN Credit: Innovation (up to 5 points)
    - IN Credit: LEED Accredited Professional (1 point)

- **Regional Priority (RP)**

    - RP Credit: Regional Priority (up to 4 points) (Leed Version 4, 2013)

LEED version 4 are to lighting categories; light pollution reduction, optimize energy performance, Advanced Energy Metering, demand response, fundamental commissioning and verification, minimum energy performance, interior lighting, daylight, quality views.

Light pollution reduction;

This credit applies to new construction (1 point), core and shell (1 point), schools (1 point), retail (1 point), data centers (1 point), warehouses and distribution centers (1 point), hospitality (1 point), healthcare (1 point). This credit requires to increase night sky access, Improve nighttime visibility, and reduce the consequences of development for wildlife and people (LEED Version 4, 2013).

The lighting design must avoid light trespass from exterior luminaires onto neighbouring property. As well as prevent sky glow from both interior and exterior luminaires (Philips,2012).

In LEED 2009, 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 <.01 fc, 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 very sensible and dark-sky friendly. In LEED V4, there is only a vertical foot candle requirement, with clear guidance on how the calcgrids should be built, or you can comply by using fixtures with an appropriate bug rating.

A similar alternate compliance method to the up light requirement is provided– you can specify fixtures with an appropriate Bug rating for the Lighting Zone and distance to the LEED boundary, and forgo summing up light / down light lumens for every fixture on the site. (http://www.maxpierson.me/2013/08/01/leed-v4-for-the-lighting-designer/)

Optimize energy performance;

This credit applies to new construction (1-18 point), core and shell (1-18 point), schools (1-16 point), retail (1-18 point), data centers (1-18 point), warehouses and distribution centers (1-18 point), hospitality (1-18 point), healthcare (1-20 point).

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. (LEED V4).

In requirements there is an option for small to medium office building. This option is ASRAE 50% advanced energy design guide for small to medium office building. This credits 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) (LEED Version 4, 2013).

Interior lighting;

This credit applies to new construction (1-2 point), schools (1-2 point), retail (2 point), data centers (1-2 point), warehouses and distribution centers (1-2 point), hospitality (1-2 point), healthcare (1 point). This credit intends to promote occupants productivity, comfort, and well-being by providing high-quality lighting (LEED Version 4, 2013).

This credit incorporates the former Controllability of Systems – Lighting credit (IEQ 6.1), with the further requirement spaces have bi-level switching (http://www.maxpierson.me/2013/08/01/leed-v4-for-the-lighting-designer/).

This credit includes two option. These are; lighting control and lighting quality. The owner of the project can select one or both of the fallowing two option,

Option 1. Lighting Control (1 point)

For at least 90% of individual occupant spaces, provide individual lighting controls that enable occupants to adjust the lighting to suit their individual tasks and preferences, with at least three lighting levels or scenes (on, off, midlevel). Midlevel is 30% to 70% of the maximum illumination level (not including daylight contributions).

For all shared multi occupant spaces, meet all of the following requirements.

- Have in place multi zone control systems that enable occupants to adjust the lighting to meet group needs and preferences, with at least three lighting levels or scenes (on, off, midlevel).
- Lighting for any presentation or projection wall must be separately controlled.
- Switches or manual controls must be located in the same space as the controlled luminaires. A person operating the controls must have a direct line of sight to the controlled luminaires.

A. For al regularly occupied spaces, use light fixtures with a luminance of less than 2,500 cd/ m^2 between 45 and 90 degrees from nadir. Exceptions include all wash fixtures properly aimed at walls, as specified by manufacturer’s data, indirect up lighting fixtures, provided there is no view down into these up lights from a regularly occupied space above, and any other specific applications (i.e. adjustable fixtures).

B. For the entire project, use light sources with a CRI of 80 or higher. Exceptions include lamps or fixtures specifically designed to provide colored lighting for effect, site lighting, or other special use.

C. For at least 75% of the total connected lighting load, use light sources that have a rated life (or L70 for LED sources) of at least 24.000 hours (at 3- hour per start, if applicable).

D. Use direct-only overhead lighting for 25% or less of the total connected lighting load for all regularly occupied spaces.

E. For at least 90% of the regularly occupied floor area, meet or exceed the fallowing thresholds for area-weighted average surface reflectance: 85% for ceilings, 60% for walls, and 25% for floors

F. If furniture is included in the scope of work, select furniture finishes to meet or exceed the following tresholds for area-weighted average surface reflectance: 45% for works surfaces, and 50% for movable partitions

G. For at least 75% of the regularly occupied floor area , meet a ratio of average wall surface illuminance (excluding fenestration) to average work plane (or surface, if defined) illuminance that does not exceed 1:10. Must also meet strategy E, strategy F, or demonstrate area-weighted surface reflectance of at least 60% for walls.

H. For at least 75% of the regularly occupied floor area, meet a ratio of average ceiling illuminance (excluding fenestration) to work surface illuminance that does not exceed 1:10. Must also meet option E, option F, or demonstrate area-weighted surface reflectance of at least 85% for ceilings. (LEED Version 4, 2013).

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 fallowing;

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

The advanced energy metering must have the following characteristics.

- Meters must be permanently installed, record at intervals of one hour or less, and transmit data to a remote location.
- Electricity meters must record both consumption and demand. Whole-building electricity meters should record the power factor, if appropriate.
- The data collection system must use a local area network, building automation system, wireless network, or comparable communication infrastructure.
- The system must be capable of storing all meter data for at least 36 months.
- The data must be remotely accessible.
- All meters in the system must be capable of reporting hourly, daily, monthly, and annual energy use. (LEED Version 4, 2013).

Demand response;

This credit intends to increase participation in demand response technologies and programs that make energy generation and distribution systems more efficient, increase grid reliability, and reduce greenhouse gas emissions. Design building and equipment for participation in demand response programs through load shedding or shifting. On-site electricity generation does not meet the intent of this credit.

Case 1. Demand response program available (2 points)

Participate in an existing demand response (DR) program and complete the following activities.

- Design a system with the capability for real-time, fully-automated DR based on external initiation by a DR Program Provider. Semi-automated DR may be utilized in practice.
- Enroll in a minimum one-year DR participation amount contractual commitment with a qualified DR program provider, with the intention of multiyear renewal, for at least 10% of the estimated peak electricity demand. Peak demand is determined under EA Prerequisite Minimum Energy Performance.
- Develop a comprehensive plan for meeting the contractual commitment during a Demand Response event.
- Include the DR processes in the scope of work for the commissioning authority, including participation in at least one full test of the DR plan.

Case 2. Demand response program not available (1 point)

Provide infrastructure to take advantage of future demand response programs or dynamic, real-time pricing programs and complete the following activities.

- Install interval recording meters with communications and ability for the building automation system to accept an external price or control signal.
- Develop a comprehensive plan for shedding at least 10% of building estimated peak electricity demand. Peak demand is determined under EA Prerequisite Minimum Energy Performance.
- Include the DR processes in the scope of work for the commissioning authority, including participation in at least one full test of the DR plan.

Contact local utility representatives to discuss participation in future DR programs.

Daylight;

This credit intends To connect building occupants with the outdoors, reinforce circadian rhythms, and reduce the use of electrical lighting by introducing daylight into the space. This credit provide manual or automatic (with manual override) glare-control devices for all regularly occupied spaces.

Option 1. Simulation: Spatial Daylight Autonomy (2–3 points, 1-2 points Healthcare)

Demonstrate through annual computer simulations that spatial daylight $autonomy_{300/50\%}$ ($sDA_{300/50\%}$) of at least 55%, 75%, or 90% is achieved. Use regularly occupied floor area. Healthcare projects should use the perimeter area determined under EQ Credit Quality Views. Points are awarded according to Table 3.4.

Table 3.4 : Points for Daylight Floor Area: Spatial Daylight Autonomy (LEED Version 4, 2013).

New Construction, Core and Shell, Schools, Retail, Data Centers, Warehouses & Distribution Centers, CI, Hospitality		Healthcare	
sDA (for regularly occupied floor area)	Points	sDA (for perimeter floor area)	Points
55%	2	75%	1
75%	3	90%	2

And

Demonstrate through annual computer simulations that annual sunlight $exposure_{1000,250}$ ($ASE_{1000,250}$) of no more than 10% is achieved. Use the regularly occupied floor area that is daylit per the $sDA_{300/50\%}$ simulations.

The sDA and ASE calculation grids should be no more than 2 feet (600 millimeters) square and laid out across the regularly occupied area at a work plane height of 30 inches (76 millimeters) above finished floor (unless otherwise defined). Use an hourly time-step analysis based on typical meteorological year data, or an equivalent, for the nearest available weather station. Include any permanent interior obstructions. Movable furniture and partitions may be excluded.

Option 2. Simulation: Illuminance Calculations (1–2 points)

Demonstrate through computer modeling that illuminance levels will be between 300 lux and 3,000 lux for 9 a.m. and 3 p.m., both on a clear-sky day at the equinox, for the floor area indicated in Table 3.5. Use regularly occupied floor area. Healthcare projects should use the perimeter area determined under EQ Credit Quality Views.

Table 3.5 : Points for daylit floor area: Illuminance calculation (LEED Version 4, 2013)

New Construction, Core and Shell, Schools, Retail, Data Centers, Warehouses & Distribution Centers, CI, Hospitality		Healthcare	
sDA (for regularly occupied floor area)	Points	sDA (for perimeter floor area)	Points
75%	1	75%	1
90%	2	90%	2

Quality Views;

This credit intends to give building occupants a connection to the natural outdoor environment by providing quality views.

Requirements

Achieve a direct line of sight to the outdoors via vision glazing for 75% of all regularly occupied floor area.

View glazing in the contributing area must provide a clear image of the exterior, not obstructed by frits, fibers, patterned glazing, or added tints that distort color balance.

Additionally, 75% of all regularly occupied floor area must have at least two of the following four kinds of views:

- Multiple lines of sight to vision glazing in different directions at least 90 degrees apart;
- Views that include at least two of the following: 1.flora, fauna, or sky; 2. movement; and 3. objects at least 25 feet from the exterior of the glazing;
- Unobstructed views located within the distance of three times the head height of the vision glazing; and
- Views with a view factor of 3 or greater, as defined in “Windows and Offices; A Study of Office Worker Performance and the Indoor Environment.”
- Include in the calculations any permanent interior obstructions. Movable furniture and partitions may be excluded. Views into interior atria may be used to meet up to 30% of the required area. Achieve a direct line of sight to the outdoors via vision glazing for 75% of all regularly occupied floor area.
- View glazing in the contributing area must provide a clear image of the exterior, not obstructed by frits, fibers, patterned glazing, or added tints that distort color balance.

3.5.2 BREEAM and LIGHTING

BREEAM (Building Research Establishment’s Environmental Assessment Method) was developed in the United Kingdom in 1990 and is the building environmental assessment method with the longest track record. BREEAM covers a range of building types including: offices, homes, industrial units, retail units, and schools. Other building types can be assessed using Bespoke BREEAM (“bespoke” is another word for custom-made). When a building is assessed, points are awarded for each criterion and the points are added for a total score. The overall building performance is awarded a “Pass”, “Good”, “Very Good” or “Excellent” rating based on the score. (Fowler and Rauch, 2006)
BREEAM major categories of criteria for Design and Procurement include the following:

- Management (commissioning, monitoring, waste recycling, pollution minimization, materials minimization)

- Health & Wellbeing (adequate ventilation, humidification, lighting, thermal comfort)
- Energy (sub-metering, efficiency and CO_2 impact of systems)
- Transport (emissions, alternate transport facilities)
- Water (consumption reduction, metering, leak detection)
- Materials (asbestos mitigation, recycling facilities, reuse of structures, facade or materials, use of crushed aggregate and sustainable timber)
- Land Use (previously used land, use of remediated contaminated land)
- Ecology (land with low ecological value or minimal change in value, maintaining major ecological systems on the land, minimization of biodiversity impacts)
- Pollution (leak detection systems, on-site treatment, local or renewable energy sources, light pollution design, avoid use of ozone depleting and global warming substances) (BREEAM ,2011)

3 dimensional main titles for the lighting in the BREEAM green building evaluation system are the following:

1- Health and Wellbeing (HEA)
2- Energy (ENE)
3- Pollution (POL)

3.5.3 Green Star and Lighting

The Green Star rating system, launched in 2003 by the Green Building Council of australia (GBCa), can be used to register and potentially certify a broad range of building types, including new building design and construction, interior fitouts, and existing building retrofits. it is a green building rating systems that assesses key attributes by predicting building performance. Each rating tool reflects a different market sector (office, retail, multi-unit residential, etc.). The objectives of the Green Star SA rating tools are to: establish a common language and standard of measurement for green buildings, promote integrated, whole building design, raise awareness of green building benefits, recognize environmental leadership, and reduce the environmental impact of development.

Green Star SA Certification is a formal process which involves a project using a Green Star SA rating tool to guide the design or construction process during which a documentation-based submission must be submitted as proof of the achievement. A "Design" certification can be submitted for and awarded at the end of the design phase of the project. At the end of construction, a project can submit for and be awarded "As Built" certification, certifying that all green building strategies were in fact incorporated into the final building. (https://www.melbourne.vic.gov.au/BuildingandPlanning/Planning/formsfees/Documents/GreenStarandABGRFactSheet.pdf)

Green Star major categories of criteria for Design and Procurement include the following:

- Management (Green Star Accredited Professional, Commitment to performance, Commissioning & Tuning, Construction Environmental Management, Operational Waste, Metering and Monitoring, User and Maintenance Information)
- Indoor Environment Quality (IEQ) (Quality of Internal Air, Reduced Exposure to Pollutants, Thermal Comfort, Acoustic Comfort, Lighting Comfort, Visual Comfort, Hazardous Materials, Quality of Amenities, Ergonomics)
- Energy (Greenhouse Gas Emissions)
- Transport (Walkable Neighborhoods, Alternative Transport)
- Water (Potable Water)
- Materials (Construction and Demolition Waste, Flooring, Assembles, Furniture, PVC, Timber, Recovered Products and Materials)
- Land Use and Ecology (Site Selection)
- Emissions (Impacts From Refrigerants, Light Pollution)
- Innovation

Green Star version 4 are to lighting categories; lighting comfort, Visual Comfort, greenhouse gas emissions, light pollution, Peak Electricity Demand, Metering and Monitoring,

3.5.6 CASBEE and Lighting

The Comprehensive Assessment System for Built Environment Efficiency (CASBEE) is an evaluation and rating system for environmental performance of buildings and the built environment. It attempts to take an eco- efficiency approach to performance analysis. CASBEE was established by a research committee in 2001 as part of a joint industrial, government, academic project. CASBEE for New Construction (NC) was the first assessment tool, published in 2003. There is now a range of rating tools available, covering: houses, new construction, existing buildings, renovation and temporary construction, heat island relaxation, schools, urban development and cities. In 2012, CASBEE for Market Promotion was released which is a simplified version of CASBEE for Existing Building, designed for people involved in dealing real estate. CASBEE - NC currently has three assessment stages: preliminary design, execution design and construction completion.

There are two main assessment categories:

- Q: Environmental Quality of the Building. This evaluates "improvement in living amenity for the building users, within the hypothetical enclosed space (the private property)."

    - Q1 Indoor Environment
        1. Sonic Environment
        2. Thermal Confort
        3. Lighting and Illumination
        4. Air Quality
    - Q2 Quality of Services
        1. Service Ability
        2. Durability and Reliability

3. Flexibility and Adaptability

- Q3 Outdoor Environment
  1. Preservation and Creation of Biotope
  2. Townscape and Landscape
  3. Local Characteristics and Outdoor Amenity

- LR: Environmental Load Reduction of the building. This evaluates "negative aspects of environmental impact which go beyond the hypothetical enclosed space to the outside (the public property)."

  - LR1 Energy
    1. Building Thermal Load
    2. Natural Energy Utilization
    3. Efficiency in Building Service System
    4. Efficient Operation

  - LR2 Resources and Materials
    1. Water Resources
    2. Reducing Usage of Non-Renewable Resources
    3. Avoiding the Use of Materials with Pollutant Content

  - LR3 Off-site Environment
    1. Consideration of Global Warming
    2. Consideration of Local Environment
    3. Consideration of Surrounding Environment

3.6 The Assessment of the Chapter

People are tend to spend more time in the office buildings in comparison to other environments. The lighting has a huge effect on our eye, mental and physical health. That's why the lighting design and criteria are among the most important chapters which have to be designed properly. There are some issues which have to be considered carefully when it comes to lighting design. This chapter is related to those issues. Firstly, light and lighting are mentioned in the chapter. “What is light? What is color? How does it reach the eye? How do we see? What is glare?” are the questions which were answered in this chapter. Then the subject of “lighting” was analyzed. The types and the ways of lighting were mentioned. Lighting was divided into two categories as daylight and artificial lighting. Lastly artificial lighting was analyzed. The types of artificial lighting and the types of lamps were studied in detail. In conclusion, with figures and tables in detail, this chapter analyzes the issues which have to be known in order to design the office lighting.

Since our resources started to run out and our health quality started to decrease, sustainability have become the most important criterion. In order to approve this subject and criterion, certificates and criteria were formed. The lighting criteria are among the most important issues. First of all in this chapter, the meaning of sustainability was defined, its importance was mentioned and it was exemplified with the first office building with a certificate in Turkey and its lighting criteria. Later 4 certificates (LEED, BREEAM, Green Star, CASBEE) prepared on this matter were specified. Their methods of scoring, release dates and places, forming companies were compared. One by one LEED especially in more detail the general index of the certificates were summarized; the chapters were mentioned; and the lighting titles were specified with their indexes and details analyzed mostly with tables.

4. CASE STUDY: THE EVALUATION OF THE OFFICE BUILDINGS

In this chapter, the office buildings were analyzed and evaluated according to ASHRAE/IES Standard 90.1-2007 used in the LEED certificate lighting criteria and the types of offices. This study was created by the inspiration from The Optima Project which was an example study designed by Philips. Firstly, The Optima Project was mentioned. Later, ERKE Design with a LEED certificate and then a certified public accountancy company Denge without a certificate were analyzed. In the conclusion chapter, these three offices were compared and the results were defined.

4.1 The Optima Project (Hypothetical)

The Optima Project is a hypothetical mid-rise office project in Southern Europe, designed with the objective of securing LEED certification while meeting EN12464-1 workplace lighting standards, without extraordinary construction expenditure or methodology.

The building sits on a predominantly East-West axis, with an elongated floor plate of about 1500 square meters. A 600mm x 600mm grid ceiling is suspended at 2.7 meters above the floor.

The Optima organization is a forward-thinking enterprise with a typical workforce in terms of age and office tasks. The workspace program includes cell offices and open plan areas, conference and meeting rooms, circulation areas and reception, as well as supporting mechanical and utility spaces.

To maximize daylight and views, open office work areas with minimal dividing partitions occupy the North and South exposure; cell offices; meeting rooms, and conference spaces are limited to the East and West exposures and the core interior area. Furniture, paint, and ceiling finishes are of high reflectance: 85% for ceilings, 60% for walls, and 30% for the floor and 50% for furniture, including work surfaces. (Philips, 2012)

The layout diagram in the figure 4.1 illustrates a typical floor, identifying the specific locations where lighting and energy performance have been calculated. The table opposite shows the area of each type of space, the lighting power allowance under ASHRAE/IES Standard 90.1-2007, the connected power for the Optima lighting design, and the percentage savings (Philips, 2012).

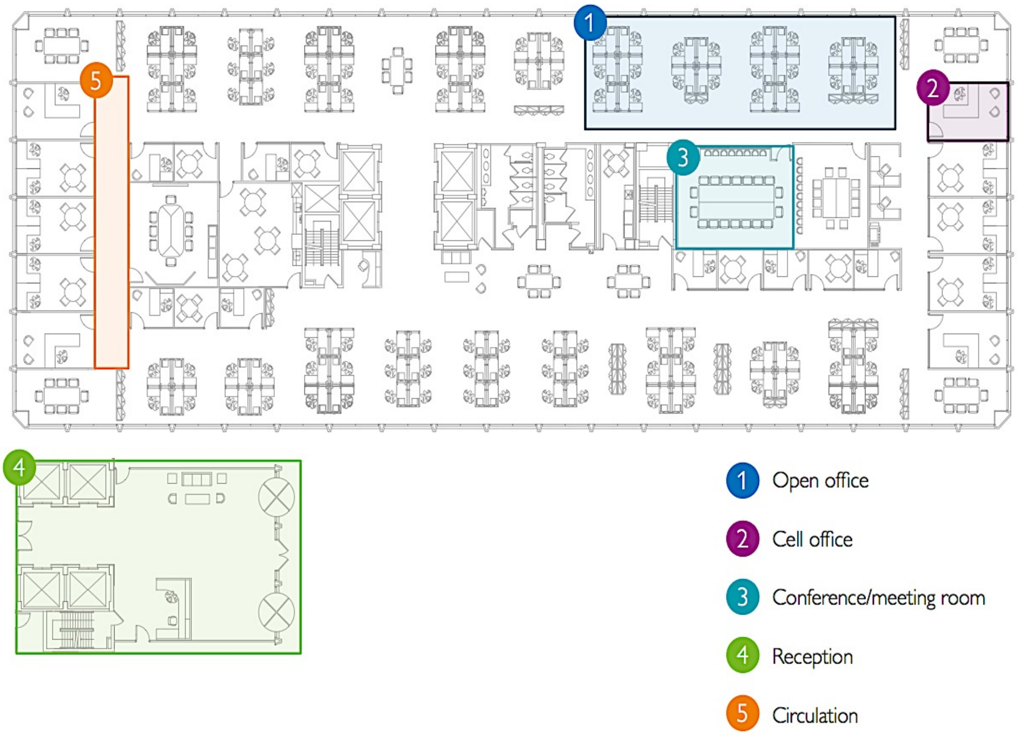


Figure 4.1 : The Optima Project Layout (Philips,2012)

The Optima lighting design addresses three objectives, applying the principles described earlier.

• A high quality visual environment for the building occupants
• Maximum LEED points
• Cost-effective lighting in terms of both construction and operation.

The lighting result exceeds the EN12464-1 standard in terms of illuminance, uniformity, and glare control (among other metrics). Wall wash and downlight luminaires help to balance the brightness of walls; this more focused illumination also introduces elements of visual interest. The lighting design and luminaire selection also meet LEED lighting quality parameters (CRI, Life, Reflectances, work plane/wall illuminance, and work plane/ceiling illuminance) (Philips, 2012).

Most luminaires in the design feature LED sources, which improve luminaire efficacy by 20-40%, compared to similar luminaires with conventional sources. The general lighting uses 4000K white light with CRI of 80 or higher, designated by the color code of 840 in the tables that follow (Philips, 2012).

Combining a task/ambient lighting approach with high efficacy luminaires reduces the connected lighting load by 37% below the ASHRAE/IES Standard 90.1-2007 allowance and provides for individual control. Controls, including both occupancy sensing and daylight harvesting, further reduce energy consumption by an estimated 20-30%, compared to the baseline controls required by LEED. The combined energy savings are estimated at more than 50%. Detail is provided in the Lighting Controls Performance Narrative (Philips, 2012).

Assuming that all other building systems performed as well as the lighting, EA Credit 1 would be worth the maximum 19 points.

Daylight and views are provided by the building orientation, fenestration, sun control, and furniture layout (Philips,2012).

Open offices layout with the lighting is in the figure 4.2 and 4.3 below.

Energy efficient design in an open plan office locates luminaires so that the primary working areas are appropriately illuminated; the circulation spaces around them can receive less light (and so use less energy). For effective daylight harvesting, luminaires need to be arranged into separately controlled zones corresponding to the penetration of daylight into the area (Philips,2012).

In the recessed scheme, PowerBalance 300mm x 1200mm LED luminaires, shielded by white smart pyramid louvers, provide the primary illumination (Philips,2012).

In the pendant scheme, Arano direct/indirect luminaires use high efficiency T5 fluorescent lamps (4000K) with a 70% direct / 30% indirect distribution.The luminaire has a slim 150mm x 1200mm profile (Philips,2012).

In figure 4.4, In both schemes, the luminaires form two rows parallel to the window wall.This provides excellent task coverage and uniformity for flexible location of the workstations, while facilitating daylight control. Low wattage TaskFlex desk-mounted luminaires provide individually controllable lighting for personal preference (and increased satisfaction), as well as for more difficult visual tasks. A line of low wattage LuxSpace LED downlights illuminates the interior wall, balancing window brightness and delineating the primary circulation path (Philips,2012).

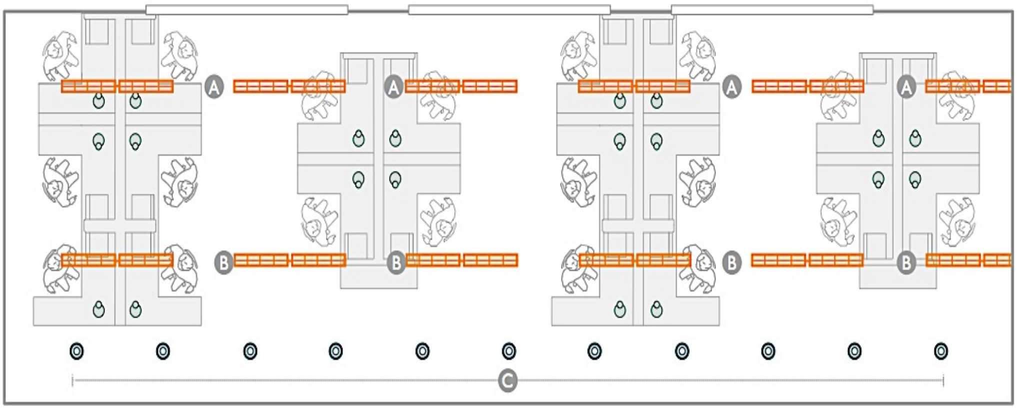


Figure 4.2 : Optima Project Open Plan Office Floorplan Recessed Scheme (Philips,2012)

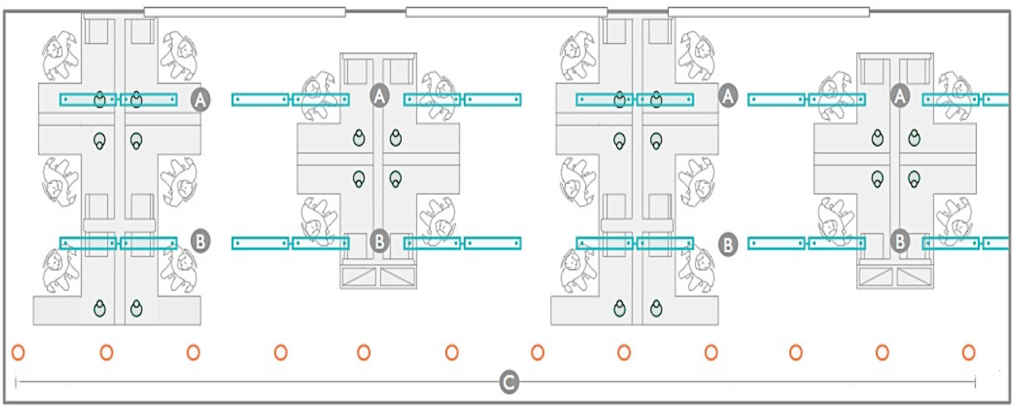


Figure 4.3 : Optima Project Open Plan Office Floorplan Pendant Scheme (Philips,2012)

Luminaire		Nominal Size	Source	Luminaire			Rated Life
				Watts	Lumens	LPW	
	Recessed Scheme - PowerBalance	300W x 1200L	LED 840	31	3400	110	50000
	Pendant Scheme- Arano	150W x 1200L	25W T5 Eco 840	30	2258	75	25000
	Downlight – LuxSpace Decorative	150 dia	LED 830	15	878	59	50000
	Downlight – LuxSpace Open	150 dia	LED 840	15	1076	72	50000
	Desk –TaskFlex	500H x 550Ext	LED 830	8	370	46	50000

Figure 4.4 : The Optima Project Open Plan Office Lighting Analyses (Philips,2012)

Cell office layout with the lighting is in the Figure 4.5 below. Maintaining a bright feeling in a cell office improves user comfort and satisfaction.A major challenge is arranging luminaires in a regular pattern so they provide appropriate illumination with minimal energy usage. This design uses PowerBalance 600mm x 600mm luminaires which use high efficiency LED modules. Low wattage TaskFlex desk-mounted luminaires provide individually controllable lighting for personal preference (and increased satisfaction), as well as for more difficult visual tasks. Ceiling lighting is controlled in two zones: the two perimeter luminaires dim in response to daylight, and all luminaires turn off when the office is unoccupied. The design approach also serves for small meeting rooms of similar size in Figure 4.6 (Philips,2012).

Luminaire		Nominal Size	Source	Luminaire			Rated Life
				Watts	Lumens	LPW	
	Recessed - PowerBalance	600W x 600L	LED 840	25	2800	112	50000
	Desk - TaskFlex	500H x 550Ext	LED 840	8	370	46	50000

Figure 4.5 : The Optima Project Cell Office Lighting Analyses (Philips,2012)

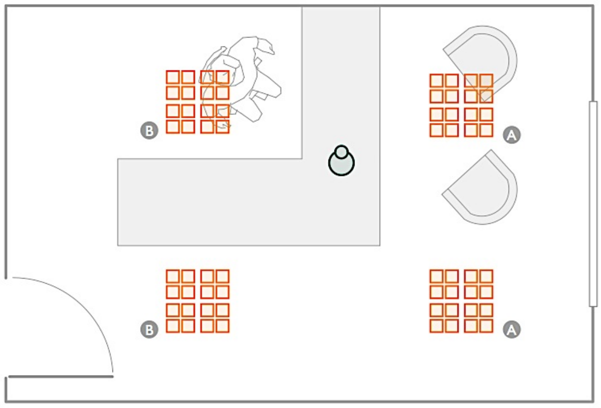


Figure 4.6 : The Optima Project Cell Office Layout (Philips,2012)

Meeting rooms support face-to-face interaction, as well as visual tasks on both horizontal and vertical surfaces. These spaces also provide a diversion from everyone’s routine work areas. This design lights the main conference table using three distinctive LumiStone LED pendants with a 75% direct/25% indirect light distribution.SmartFormT5 fluorescent wall washers illuminate walls on three sides, while Lux Space down lights highlight the fourth wall (Philips,2012).
Meeting room layout with the lighting is in the figure 5.7 below.

In figure 5.8, A multi-scene dimming control provides five distinct control channels for the central pendants and each wall. An occupancy sensor, integrated with the multi-scene system, turns lights off when the space is no longer occupied.

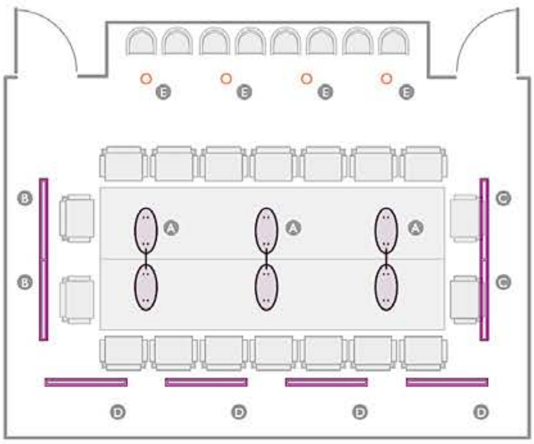


Figure 4.7 : The Optima Project Meeintg/Conferance Layout (Philips,2012)

Luminaire		Nominal Size	Source	Luminaire			Rated Life
				Watts	Lumens	LPW	
	Pendant – LumiStone	330W x 1500L	LED 840	38	4000	105	50000
	Downlight – LuxSpace	150 dia	LED 840	15	1076	72	50000
	Linear Wall Wash – SmartForm	90W x 1200L	25W T5 Eco 840	30	2179	73	25000

Figure 4.8 : The Optima Project Meeting/Conference Room Lighting Analyses (Philips,2012)

Reception layout with the lighting is in the in figure 4.9 below. Reception lighting orientates visitors to the building and establishes the forward-looking image of the Optima organization. This design uses luminaires that are both decorative and functional to serve as way-finders.The prominent, undulating DayWave LED downlight pendant clearly announces the reception desk for visitors. Supplemented by a TaskFlex desk- mounted adjustable luminaire, the DayWave pendants also provide ample task illumination for the receptionist (Philips,2012).

Similarly, a pair of DayZone LED luminaires with a circle-in-a-square design locate and illuminate the elevator vestibule. Simple LuxSpace LED downlights fill in with ambient illumination, while adjustable accent StyliD LED luminaires light up corporate art in key locations in figure 4.10 (Philips,2012).

Multi-scene dimming control with integral time switch allows for different lighting arrangements for primary and after-work hours, as well as nighttime security (Philips,2012).

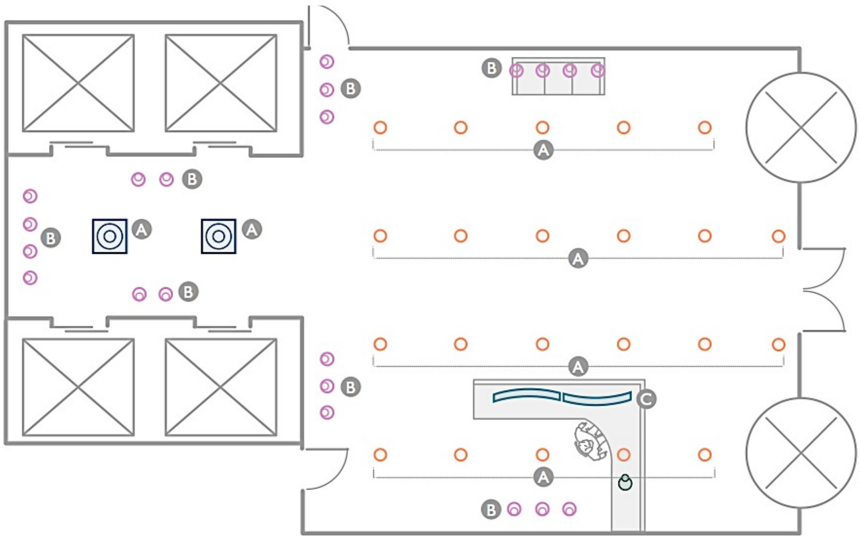


Figure 4.9 : The Optima Project Reception Layout (Philips,2012)

Luminaire	Nominal Size	Source	Luminaire Watts	Luminaire Lumens	Luminaire LPW	Rated Life
Pendant - DayWave	150W x 1450L	LED 840	166	4000	24	50000
Downlight - LuxSpace	150 dia	LED 840	15	1076	72	50000
Downlight - StyliD	150 dia	LED 840	30	1279	43	50000
Recessed - DayZone	600W x 600L	LED 840	29	2000	69	50000
Desk - TaskFlex	500H x 550Ext	LED 840	8	370	46	50000

Figure 4.10 : The Optima Project Reception Lighting Analyses (Philips,2012)

Circulation layout with the lighting is in the figure 4.11 below. Circulation spaces are among the most difficult to light well, whilst reducing energy for LEED credit. This design uses simple LuxSpace LED downlights fitted with a decorative glass disk below the aperture.Although the decorative element reduces the average illuminance by about 20%, the glowing disk creates a more interesting environment, increases light on faces and walls, and meets EN12464-1 standards.The circulation space thus serves as a brief respite from ordinary work areas as office occupants move through it (Philips,2012).

A time switch keeps corridor lights turned on during normal business hours. After hours, an occupancy sensor linked to the adjacent spaces maintains lighting at a dimmed level until all linked spaces are no longer occupied. (Figure 4.12)

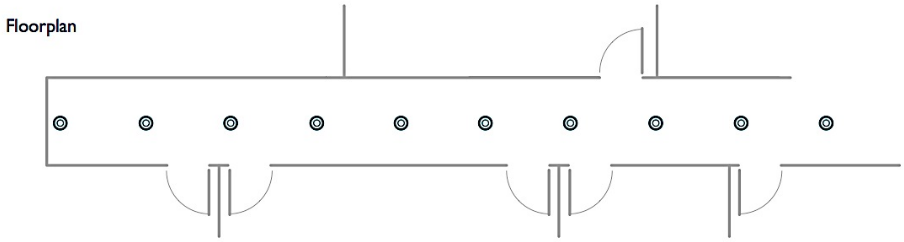


Figure 4.11 : The Optima Project Circulation Layout (Philips,2012)

Luminaire		Nominal Size	Source	Luminaire			Rated Life
				Watts	Lumens	LPW	
◎	Downlight- LuxSpace Decorative	150 dia	LED 840	15	878	59	50000

Figure 4.12 : The Optima Project Circulation Lighting Analyses (Philips,2012)

To satisfy the pre-requisite, the overall building design must demonstrate a 10% improvement in building energy performance compared to a baseline performance simulation according to ANSI/ASHRAE/IESNA Standard 90.1-2007 and must also comply with mandatory provisions notably lighting controls. Standard 90.1-2007 is the minimum requirement for energy codes in the United States. Key lighting provisions of Standard 90.1-2007 are noted in the Glossary, on page 35. Projects may use local energy codes for LEED certification provided the code is demonstrated to be equivalent to Standard 90.1-2007(prior approval required). (Philips,2015)

To earn points under this credit, the overall building design must demonstrate additional energy reductions beyond the prerequisite (using the same simulation methodology). A 12% reduction earns 1 point. Each 2% additional reduction earns 1 point, up to a maximum of 19 points (for a 48% reduction).

The lighting systems were analyzed in the optima project. All the lightings used at the office were measured as watt according to the sections of the office. Watt in every square meter was calculated according to ASHRAE/IES Standard 90.1-2007. Fractions were ignored during the calculations.

The appropriate watt in every square meter was calculated according to ASHRAE/IES Standard 90.1-2007. The fractions were ignored during the calculations. Watt changes in every type and section of the office according to ASHRAE/IES Standard 90.1-2007. As shown at table 4.1, appropriate watt according to ASHRAE and the current watt at the office were compared and when compared the amount of power savings were put forward. The cell offices show the best amount of saving with 52% in the Optima Project. The least saving is the other section with 19%. The savings were 40% at the open offices, 34% at the meeting room, 19% at the corridors and 31% at the reception. The lighting power saving of the Optima project is 37% in total, which is a pretty high rate in comparison to the desired 10% according to LEED certificate. It will take 12 points from this section.

Table 4.1 : The Lighting Energy Savings Calculation of Optima Project

Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Open Office	873	50	11,9	10412	6275	40%
Cell Offices	238	14	11,9	2835	1350	52%
Meeting Room	170	10	14,1	2391	1585	34%
Corridors	72	4	5,2	391	318	19%
Reception	211	12	14,1	2980	2069	31%
Other	168	2	9,8	1166	1049	10%
Total	1732	%100	–	20175	12646	37%

4.2 ER-KE Design in Istanbul (With Certificate)

ERKE is one of the Turkey´s leading company provides electrical project design and green building consulting. They work with prominent developers, contractors and decision makers to help them make better decisions and deliver sustainable success they desire. ERKE Green Academy is ERKE´s new headquarters but what is more special about the building is ERKE provides its own office as a case study for environmentally sound building materials, products and systems where people can visit and experience the green building applications (Figure 4.13). The building is also training center for sustainable buildings. A 400 m2 office building is the first development in Istanbul certified under LEED-NC, achieved a Platinum rating. It accommodates up to 26 employees over three stories of open plan office space. The overall design of the development creates a distinctive identity for Kisikli and set it apart from the adjacent properties in a very positive way. (ERKE Design,2015)

Figure 4.13 : ERKE Design Office Building (ERKE Design Photo Archive)

ERKE is a four-story building which includes both cell and open-plan offices within itself. The lighting systems are designed according to this office model. The floors include roof, first floor, ground floor and basement. On these floors are meeting rooms, working areas, training room, reception, circulation, garage, rest rooms, system storages (water, heating and power) and kitchen.

The building was turned into everything in every possible way in addition to lighting in terms of sustainability. The reasons why the building is sustainable are the following:

- All the materials used are consistent with nature and they are harmless to human life.
- The emission of the paint used for inner walls are low.
- The power and water saving is highly managed.
- Water tanks were built on the sub-division of the landscape part outside the building, and among the pebble stones on this surface the rain water runs and fills the water tanks. Therefore the rain water is used within the building.

The Layout diagram illustrates the basement floor in figure 4.14, the ground floor in figure 4.15, the first floor in figure 4.1 and the roof in figure 4.17. a Typical floor, identifying the specific locations where lighting and energy performance have been calculated. The table opposite shows the area of each type of space. The green box refers to open-plan offices, the orange refers to cell offices, the blue refers to conference/seminar room, the pink refers to reception, the yellow refers to circulation areas, the purple refers to meeting room

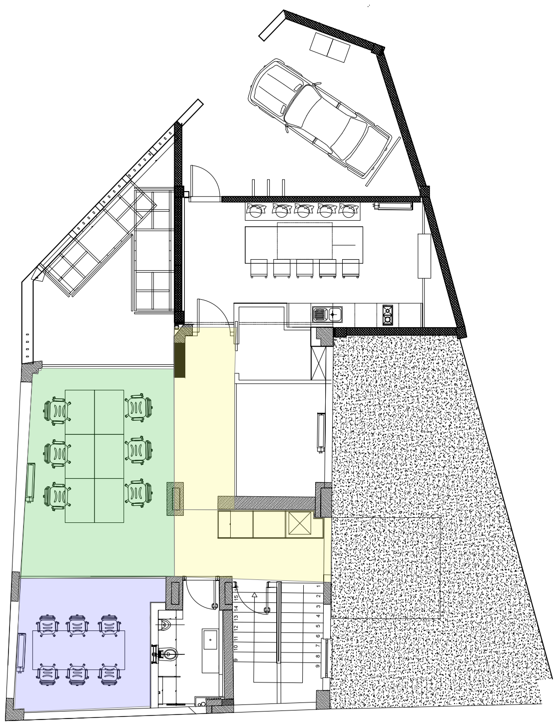


Figure 4.14 : The ERKE Desing Office, Basement Layout

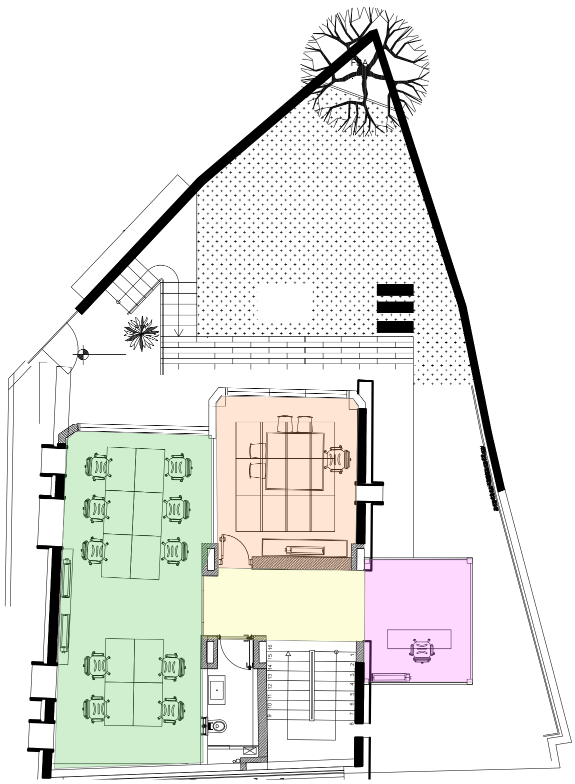


Figure 4.15 : The ERKE Desing Office, Ground Floor Layout

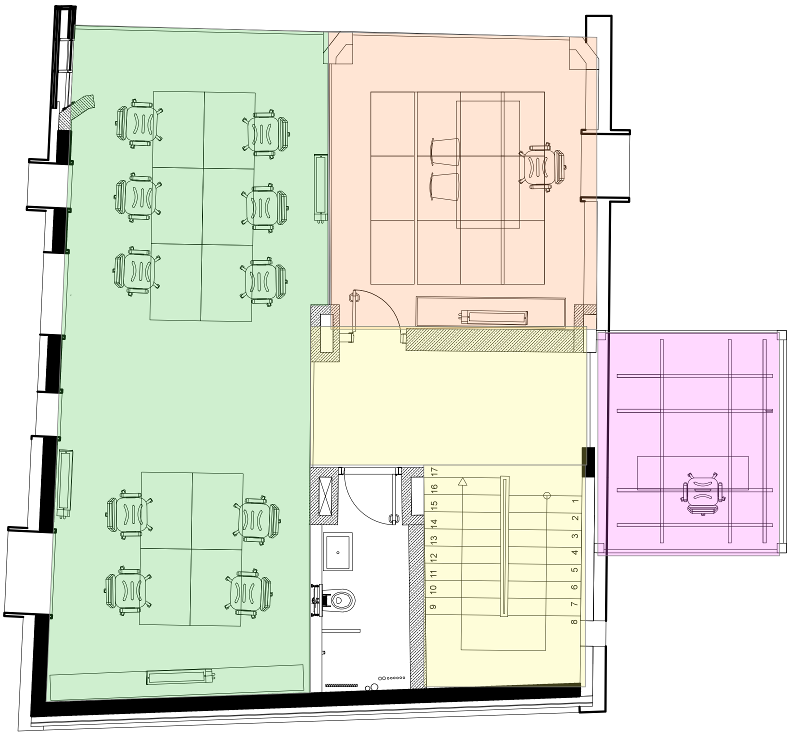


Figure 4.16 : The ERKE Desing Office, First Floor Layout

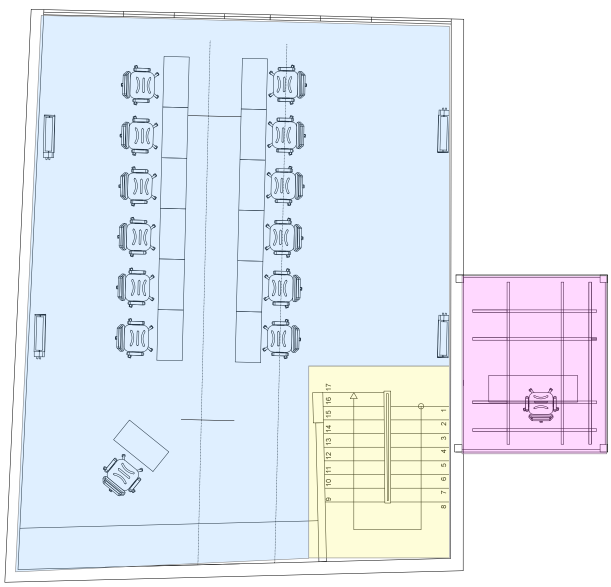


Figure 4.17 : The ERKE Desing Office, Roof Layout

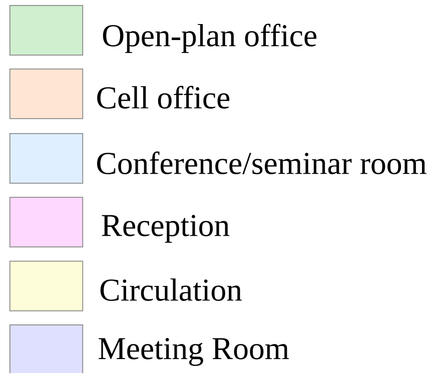


Figure 4.18 : The ERKE Desing Office Layout Explanation

While designing the lighting system, the artificial and natural lightings were seen as a whole and designed together. The lighting system of the building was not only considered within the lighting criteria of the certificates but also designed with additional features. The natural lighting was highly taken notice. The daylight was used in the efficient amount from the efficient angles and in the right places. The design criteria were determined for the daylight and the building was located accordingly. These criteria are the following:

- heat gain-loss balance
- glare control
- visual quality
- usage of the landscape and daylight

The Furniture within the building were located according to the entrance side of the daylight. The shape and the location of the windows were planned in the most efficient way by calculating the daylight angle. Automatic shadowing systems were used. The silent engines are controlled by solar power, full-dim curtains are present, and 100% glare control was managed. Power saving is provided. The windows have triple thermal glasses with argon gas. The artificial lighting used in the building are in harmony with the daylight. The locations of the tables, chairs and the electronic devices in the working and meeting rooms were designed in a way causing minimum damage to the eyes without any glare and also to the mental health of the user without any disturbance (Figure 4.19).

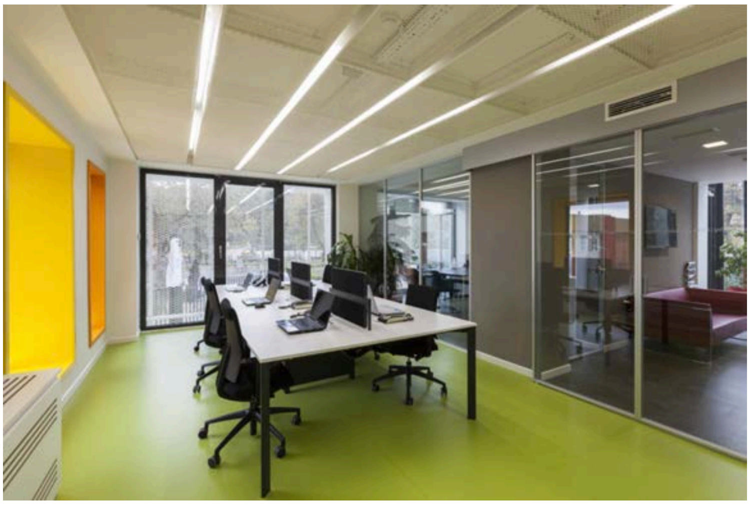


Figure 4.19 : ERKE Office (ERKE Design Photo Archive, 2015)

All the artificial lighting systems used for the ceiling are LED lighting systems with presence and daylight sensors. When the presence is detected, depending on the daylight data, system switches on to have the 500 lux of illumination intensity and 0,7 of uniformity and it dims. Regarding the curtains, curtain groups with motors and daylight-sensitive sensor were used. Curtain groups with 2 east and 1 south motor, positions automatically depending on the outside daylight sensor to prevent the glare.

In figure 4.20, In the kitchen, on the other hand, there is no need for artificial lighting as long as there is daylight owing to the ceiling window. This window also provides natural ventilation.

Figure 4.20: ERKE Office Kitchen (Idil Bakır Photo Archive, 2015)

The ERKE building lighting design addresses three objectives, applying the principles described earlier;

- A high quality visual environment for the building occupants.
- Maximum LEED points
- Cost-effective lighting in terms of both construction and operation.

The lighting design and luminaire selection also meet LEED lighting quality parameters. (CRI, Life, Reflectances, Illumination)

The LEED results of ERKE building are summarized in the table 4.2 below. In the table, light pollution reduction isn't scope because the light pollution reduction part is relevant with exterior lighting. In EA Prerequisite 2, Achieved 63% reduction in lighting power, compared to ASHRAE/IES Standard 90.1 – 2007. In EA Credit 1, Achieved 63% reduction in lighting power, compared to ASHRAE/IES Standard 90.1 – 2007. Sensing and daylight harvesting controls satisfy this credit. Controllability of Systems of Lighting, Individually controlled artificial lighting systems satisfy. Fenestration and interior configuration satisfy in

IEQ Credit 8.1 and IEQ Credit 8.2. Luminaire specification and illumination distribution satisfy in Pilot Credit 22

Table 4.2: The LEED certification Criteria with the results of ERKE Office

Credit	Description	Result
SS Credit 8	Light Pollution Reduction	Not in Scope
EA Prerequisite 2	Minimum Energy Performance	Achieved 63% reduction in lighting power, compared to ASHRAE/IES Standard 90.1 – 2007.
EA Credit 1	Optimize Energy Performance	Achieved 63% reduction in lighting power, compared to ASHRAE/IES Standard 90.1 – 2007. Sensing and daylight harvesting controls satisfy this credit.
IEQ Credit 6.1	Controllability of Systems -Lighting	Individually controlled artificial lighting systems satisfy this credit.
IEQ Credit 8.1	Daylight and Views - Daylight	Fenestration and interior configuration satisfy this credit.
IEQ Credit 8.2	Daylight and Views – Views	Fenestration and interior configuration satisfy this credit.
Pilot Credit 22	Interior Lighting – Quality	Luminaire specification and illumination distribution satisfy this credit.

The ERKE office lighting systems layout's are the below, the green box refers to open office spaces in basement in figure 4.21,ground floor in figure 4.22 and first floor in figure 4.23.

Inside the open-plan offices, multiple lightings on the ceilings located just above the desks were designed in a way each person could switch on and off his/her side individually.(figure 4.26,27)

Individual luminaries dim in order to supply the value of the illumination intensity when its controlling sensor detects the presence. Besides, it can be controlled from personal computers. This provides power saving to a great deal. (Figure 4.25) According to table 4.3, In the basement plan, the luminaire is EAE task armature. (Table 4.4). This luminaire can be controlled by personal computers. It has a slim 1200x300x70 mm profile. (Figure 4.26,27)

In the Ground floor plan, the luminaires are EAE LED band armature and led armature. This luminaires also can be controlled by personal computers. (Figure 4.21)

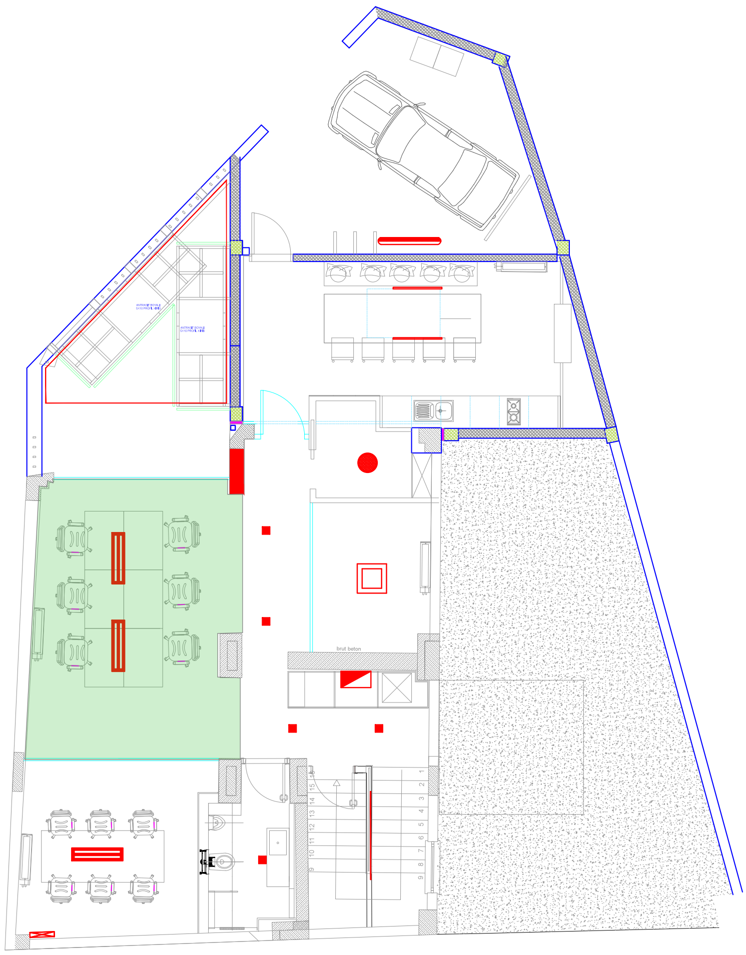


Figure 4.21 : The ERKE Desing Open Office, Basement Layout

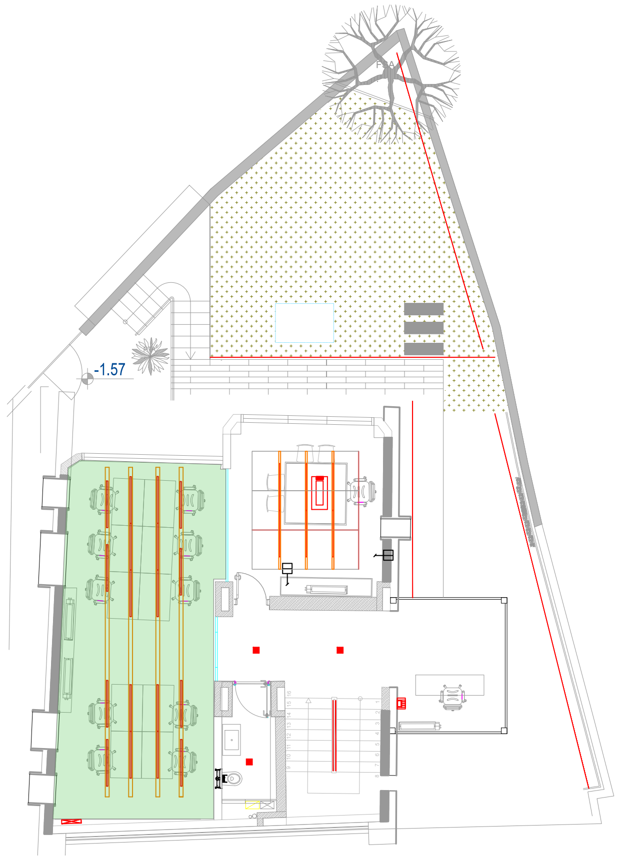


Figure 4.22 : The ERKE Desing Open Office, Ground Floor Layout

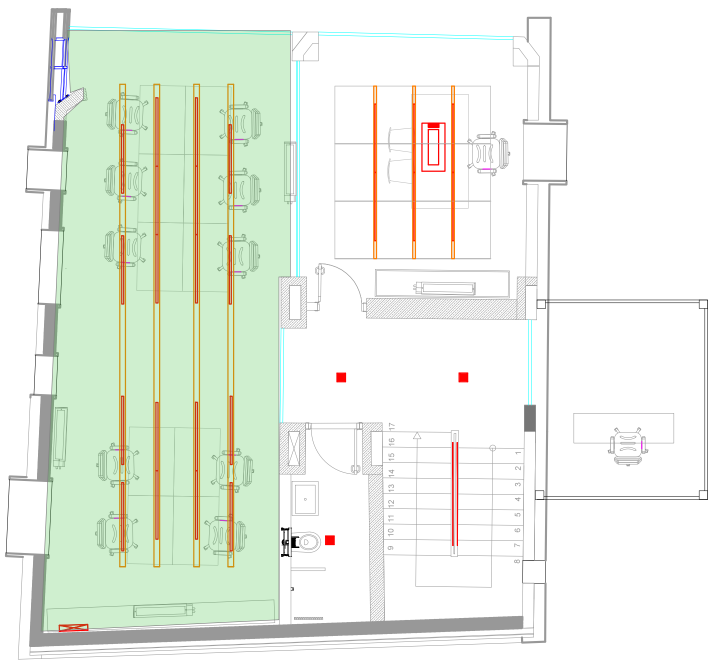


Figure 4.23 : The ERKE Desing Open Office, First Floor Layout

The lighting systems were analyzed in the ERKE office in the table 4.3. All the lightings used at the office were measured as watt according to the sections of the office. Watt in every square meter was calculated according to ASHRAE/IES Standard 90.1-2007. Fractions were ignored during the calculations.

According to the table 4.4, the Lighting power energy savings in open office in Basement floor is 78%, in ground floor is 46% and the first floor is 50%. The best saving energy is in basement floor with 78% saving. At all of the open offices power was saved. The usage of controllable artificial lightings with LED and daylight sensors; proper and sufficient usage of daylight; the design of artificial lighting in a way to support the daylight are the most important reasons of the power saving.

Table 4.3: ERKE Design Open Office Lighting Systems Analyses

Luminaire	**Nominal Size**	**Source**	**Watts**	**Lumens**	**Volt**	**Rated Life**
 EAE LED Armature	1200x300x70	SMD LED	43	3462	220-240	50000
EAE LED Armature	1.2 M	SMD LED	14	3400	22	50000
EAE LED Band Armature	8.5 M	SMD LED	10	3400	22	50000

Table 4.4: ERKE Design Open Office Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Basement	33	8	12	396	86	%78
Ground Floor	39	10	12	468	252	%46
First Floor	42	11	12	504	252	%50

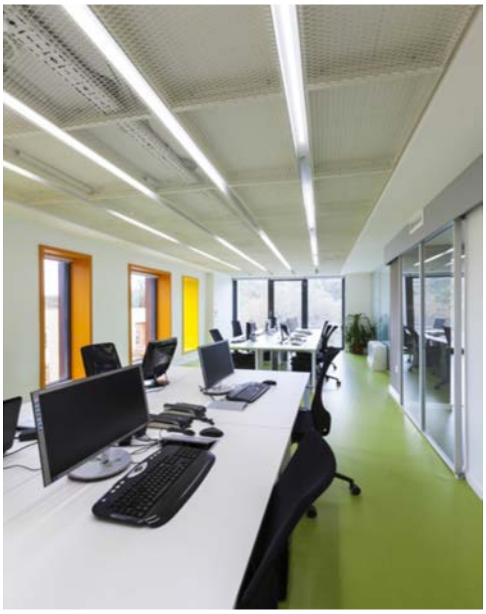


Figure 4.24 : Open Office in Ground Floor
(ERKE Design Photo Archive, 2015)

Figıre 4.25 : Open Office in Basement
(ERKE Design Photo Archive, 2015)

Figure 4.26 : EAE Armature
(Idil BAKIR Photo archive, 2015)

Figure 4.27 : EAE Armature
(Idil BAKIR Photo archive, 2015)

The ERKE office lighting layout's are the below, the orange box refers to open office spaces in figure 4.28 and figure 4.29.

In the cell office sections, individual floor standing lamps with sensors were used near the study desks. If the ambient light level is insufficient when the presence is detected, system interferes independently of automation system throuh its presence and daylight sensors. Also it's individually controllable. (Figure 4.30)

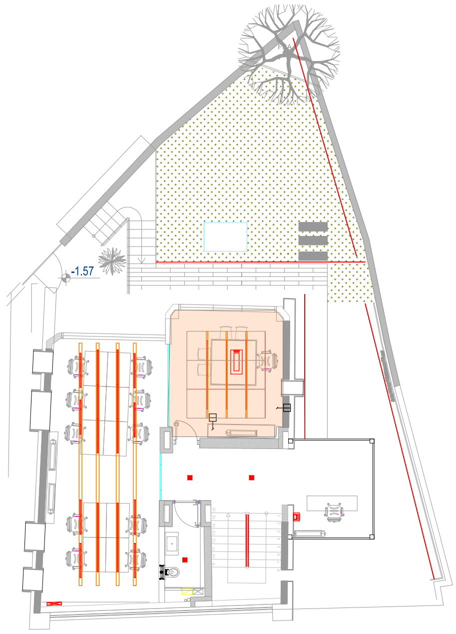


Figure 4.28 : ERKE's Lighting Cell Office Layout in Ground Floor

Figure 4.29 : ERKE's Lighting Cell Office Layout in First Floor

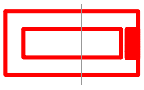
Figure 4.30 : ERKE Cell Office
(ERKE Design Photo Archive,2015)

The lightings used at the cell offices were shown on table 4.6 with their features and symbols on the layouts. The calculations of the lighting power on table 4.5 were added to the number showing the power of the lighting written on the “watt” section, and were multiplied with square meter. At the cell offices located at both ground floor and first floor, and used as manager offices show 36% lighting power saving.

Table 4.5 : ERKE Design Open Office Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Ground Floor	18	5	12	216	139	36%
First Floor	18	5	12	216	139	36%

Table 4.6 : ERKE Design Cell Office Lighting Systems Analyses

Luminaire	Nominal Size	Source	Watts	Lumens	Volt	Rated Life
 VEKSAN LED Floor Standing Armature	180x40x84 cm	SMD LED	3X55	8750	220-240	60000
EAE LED Armature	1.2 m	SMD LED	14	3400	22	50000
EAE LED Band Armature	3 m	SMD LED	10	3400	22	50000

The ERKE office lighting layout are the below, the purple box refers to meeting room space in the figure 4.31.The meeting room are of the basement floor in the ERKE's office building. In the meeting room one luminaire is used and with that luminaire to be provided energy saving. This luminaire is the table top led armature were designed in a way each person could switch on and off his/her side individually.

Individual luminarie dim in order to supply the value of the illumination intensity when its controlling sensor detects the presence. Besides, it can be controlled from personal computers. This provides power saving to a great deal. It has open and switch. It also uses in the open offices.

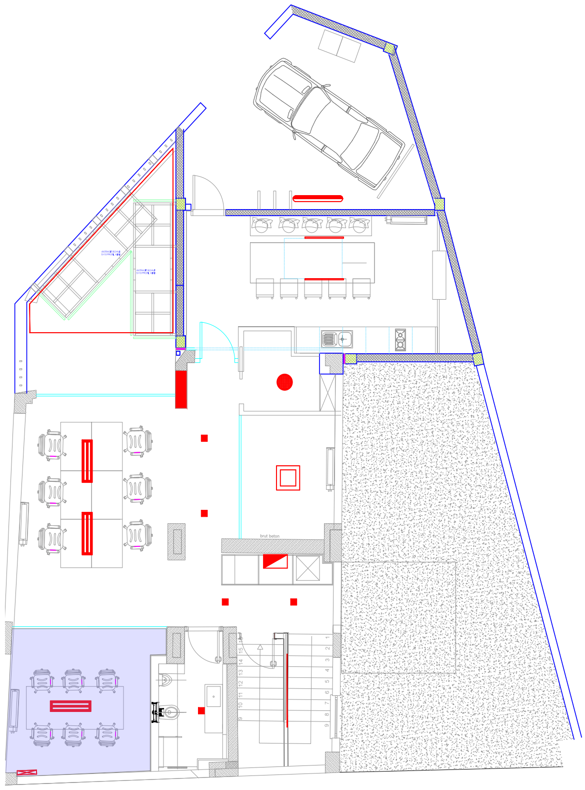


Figure 4.31 : ERKE's Lighting Meeting Room Layout in Basement

The lightings used at the meeting room were shown on table 4.7 with their features and symbols on the layouts. The calculations of the lighting power on table 4.8 were added to the number showing the power of the lighting written on the "watt" section, and were multiplied with square meter. At the meeting room located at basement show 70% lighting power saving. The usage of controllable artificial lightings with LED and daylight sensors; proper and sufficient usage of daylight; the design of artificial lighting in a way to support the daylight are the most important reasons of the power saving.

Table 4.7: ERKE Design Meeting Room Lighting Systems Analyses

Luminaire	Nominal Size	Source	Watts	Lumens	Volt	Rated Life
 EAE LED Armature	1200x300x70	SMD LED	43	3462	220-240	50000

Table 4.8: ERKE Design Meeting Room Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Basement	13	3	11	143	43	70%

The ERKE office lighting layout's are the below, the blue box refers to seminar room space in the figure 4.32. In the seminar room located on the loft, the daylight is efficiently used thanks to the roof windows and natural ventilation is provided. It has a transparency value of 45% and heat transmission index value of 1.4 W/ m2. It provides 100% daylight. These windows and their curtains have also light and presence sensors. In addition, they have rain sensors. When it rains, the windows are automatically closed. As in all parts of the building, this system can be controlled from the computers as well. (Figure 4.33 and 4.34) It can also be controlled with a remote control. Led lightings with sensors were also used.

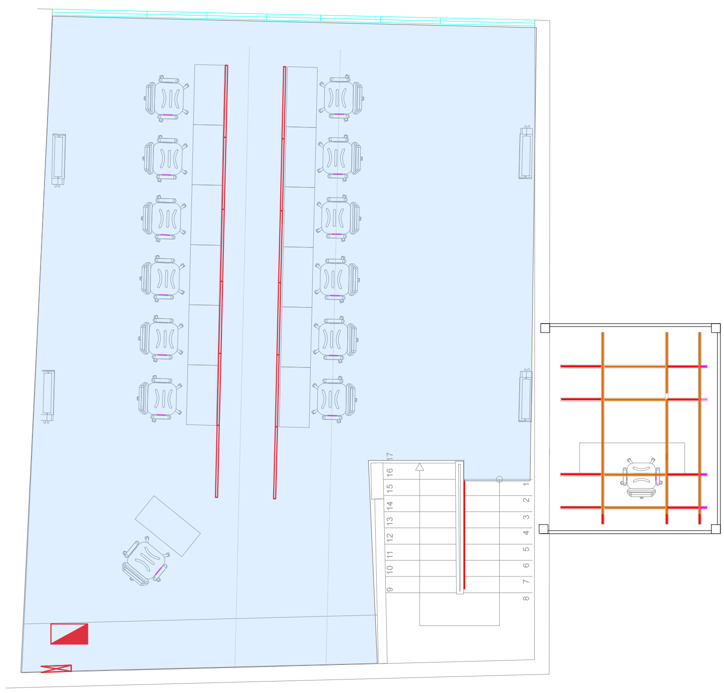


Figure 4.32: ERKE's Lighting Seminar Room Layout in the Roof

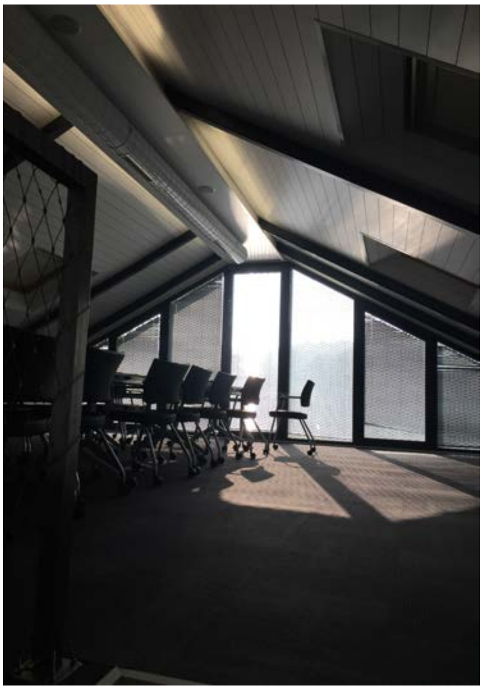


Figure 4.33: The Seminar Room in the Roof
(ERKE Design Photo Archive,2015)

Figure 4.34: the Roof Windows
(Idil BAKIR Photo Archive,2015)

The lightings used at the seminar room were shown on table 4.9 with their features and symbols on the layouts. The calculations of the lighting power on table 4.10 were added to the number showing the power of the lighting written on the “watt” section, and were multiplied with square meter. At the seminar room located at roof, show 88% lighting power saving. . The usage of controllable artificial lightings with LED and daylight sensors; proper and sufficient usage of daylight with the roof window; the design of artificial lighting in a way to support the daylight are the most important reasons of the power saving.

Table 4.9: ERKE Design Seminar Room Lighting Systems Analyses

Luminaire	**Nominal Size**	**Source**	**Watts**	**Lumens**	**Volt**	**Rated Life**
EAE LED Armature	1.2 m	SMD LED	14	3400	22	50000

Table 4.10: ERKE Design Meeting Room Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Roof	90	22	15	1350	168	88%

The ERKE office lightings layouts are the below, the pink box refers to reception space in the figure 4.35. The reception are of the ground floor in the ERKE's office building. In the reception has high ceiling and the ceiling are of the first floor of the building. (Figure 4.36) The band led lighting luminaires is used. it can be controlled from personal computers and it has light sensors. And the daylight uses proper for the illumination of reception. It can also provide energy saving.

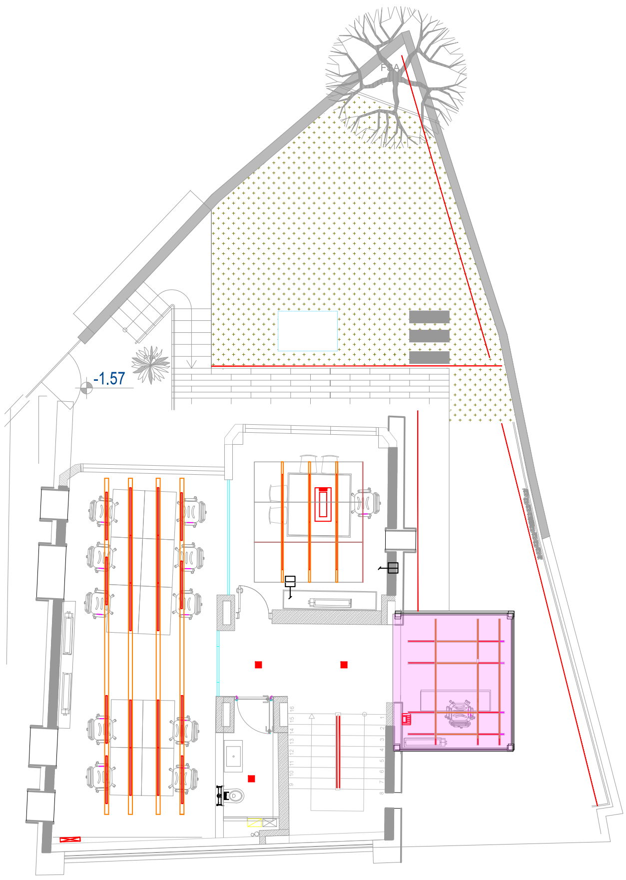


Figure 4.35: ERKE's Lighting Reception Layout in the Ground Floor

Figure 4.36: the Roof Windows (ERKE Design Photo Archive,2015)

The lightings used at the reception were shown on table 4.11 with their features and symbols on the layouts. The calculations of the lighting power on table 4.12 were added to the number showing the power of the lighting written on the "watt" section, and were multiplied with square meter. At the reception located at ground floor show 15% lighting power saving. . The usage of controllable artificial lightings with LED and daylight sensors; proper and sufficient usage of daylight; the design of artificial lighting in a way to support the daylight are the most important reasons of the lighting power saving.

Table 4.11: ERKE Design Reception Lighting Systems Analyses

Luminaire	Nominal Size	Source	Watts	Lumens	Volt	Rated Life
EAE LED Armature	1.2 m	SMD LED	14	3400	22	50000
EAE LED Band Armature	3 m	SMD LED	10	3400	22	50000

Table 4.12: ERKE Design Reception Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Ground Floor	11	3	14	154	130	15%

The ERKE office lightings layout's are the below, the yellow box refers to circulation spaces in the basement in figure 4.37, in the ground floor in figure 4.38, in the first floor in figure 4.39. LED lighting was used through the corridors. When the presence is detected depending on the daylight data, system switches on to have the 200 lux of illumination intensity. Automation is controlled. (Figure 4.40)

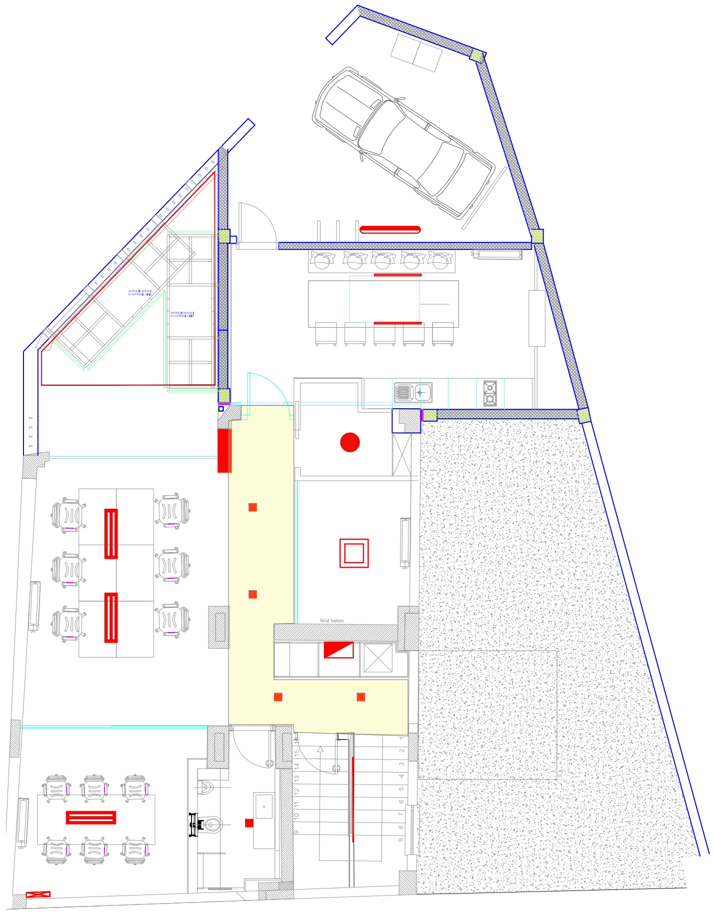


Figure 4.37 : ERKE's Lighting Circulation Areas Layout in the Basement

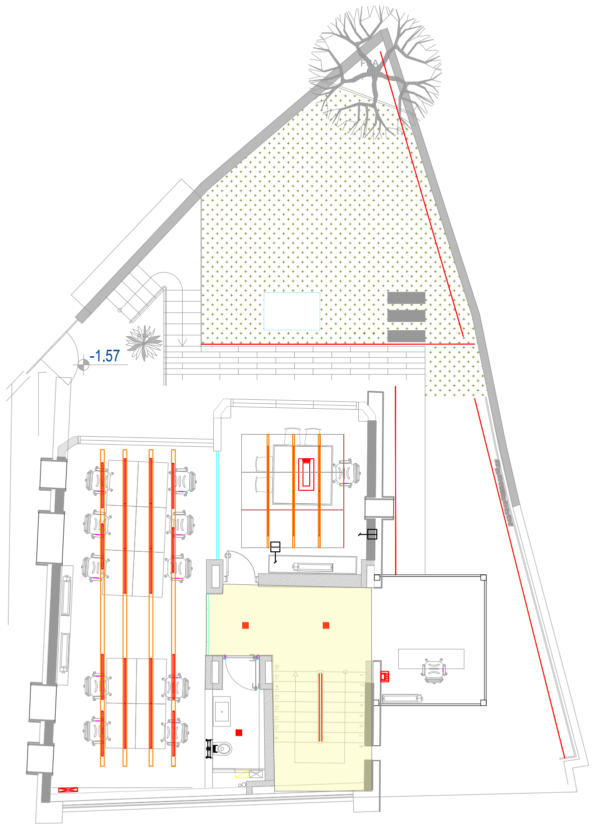


Figure 4.38 : ERKE's Lighting Circulation Areas Layout in the Ground Floor

Figure 4.39 : ERKE's Lighting Circulation Areas Layout in the First Floor

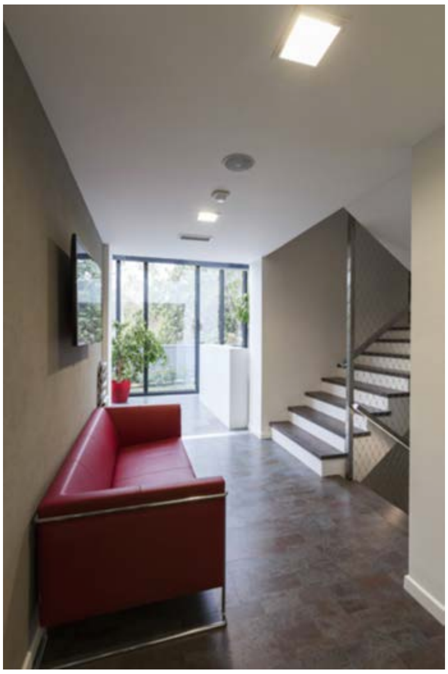


Figure 4.40 : ERKE Office Corridor (ERKE Photo Archive, 2015)

The lightings used at the corridors were shown on table 4.13 with their features and symbols on the layouts. The calculations of the lighting power on table 4.14 were added to the number showing the power of the lighting written on the "watt" section, and were multiplied with square meter. At the corridors located at ground floor, basement, first floor show 15% lighting power saving. . The usage of controllable artificial lightings with LED and daylight sensors; proper and sufficient usage of daylight; the design of artificial lighting in a way to support the daylight are the most important reasons of the lighting power saving.

Table 4.13 : ERKE Design Circulation Areas Lighting Systems Analyses

Luminaire	**Nominal Size**	**Source**	**Watts**	**Lumens**	**Volt**	**Rated Life**
EAE LED Armature	1.2 m	SMD LED	14	3400	22	50000
EAE Piramit LED Armature	20x20 cm	LED	11.4	3400	220-240	50000

Table 4.14 : ERKE Design Circulation Areas Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Basement Floor	15	2	5	75	46	39%
Ground Floor	10	3	5	50	23	54%
First Floor	8	2	5	40	23	43%

The lighting systems were analyzed in the ERKE office. All the lightings used at the office were measured as watt according to the sections of the office. Watt in every square meter was calculated according to ASHRAE/IES Standard 90.1-2007.

The appropriate watt in every square meter was calculated according to ASHRAE/IES Standard 90.1-2007. The fractions were ignored during the calculations. Watt changes in every type and section of the office according to ASHRAE/IES Standard 90.1-2007. As shown at table 4.15, appropriate watt according to ASHRAE and the current watt at the office were compared and when compared the amount of power savings were put forward. The seminar room shows the best amount of saving with 88% in the ERKE office. The least saving is the other section with 15% in reception. The savings were 57% at the open offices, 35% at the cell office, 70% at the meeting room, 23% at the corridors and 61% at the other section. The lighting power saving of the ERKE office is 63% in total, which is a pretty high rate in comparison to the desired 10% according to LEED certificate. It will take 19 points from this section.

Table 4.15 : The Lighting Energy Savings Calculation of ERKE Office

Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Open Offices	114	29	12	1368	590	57%
Cell Offices	36	9	12	432	278	36%
Meeting Room	13	3	11	143	43	70%
Seminar Room	90	22	15	1350	168	88%
Corridors	33	8	5	120	92	23%
Reception	11	3	14	154	130	15%
Other	103	0.2	10	1030	392	61%
Total	400	100%	–	4597	1693	63%

4.2 Denge Office in Izmir (Without Certificate)

Denge is a certified consultant company in Izmir. Denge office situated at thirteen floor in Punta Residence. This 800 m^2 office was designed by Matt Architectural Firm who design the Punta Residence. 35 people works in this company. And the settlement of the working areas is done according to 35 people’s comfort and suitable working conditions.

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

The location of the building situated very convenient for fluent usage of daylight. In this office for abundant working, the ergonomic chairs and working tables is used by workers. The reception is a large and very pleasant designed space to give the good impression the visitors.

While designing the lighting system, the artificial and natural lightings were seen as a whole and designed together. The office benefit from daylight. Within the day the daylight uses quite efficient. The spotlights systems use a lot to provide esthetic view. The spotlights are the LED lighting spots. Because of that the energy spent less than the other spotlights. Over the Every worker has a spotlights and they working very comfortable without glare. But the disadvantages of these spotlights is heating. The summer the temperature can increase with these spotlights. The corridors, reception and the cell offices, The wall fixtures use to illuminate the paintings. these create a esthetic view and illuminate corridors also.

The Furniture within the building were located according to the entrance side of the daylight. The shape and the location of the windows were planned in the most efficient way by calculating the daylight angle. . The locations of the tables, chairs and the electronic devices in the working and meeting rooms were designed in a way causing minimum damage to the eyes without any glare and also to the mental health of the user without any disturbance.

The Layout diagram illustrates a typical space, identifying the specific locations where lighting and energy performance have been calculated. The table opposite shows the area of each type of space. The green box refers to open-plan offices, the orange refers to cell offices, the pink refers to reception, the yellow refers to circulation areas, the purple refers to meeting room in the figure 4.41.

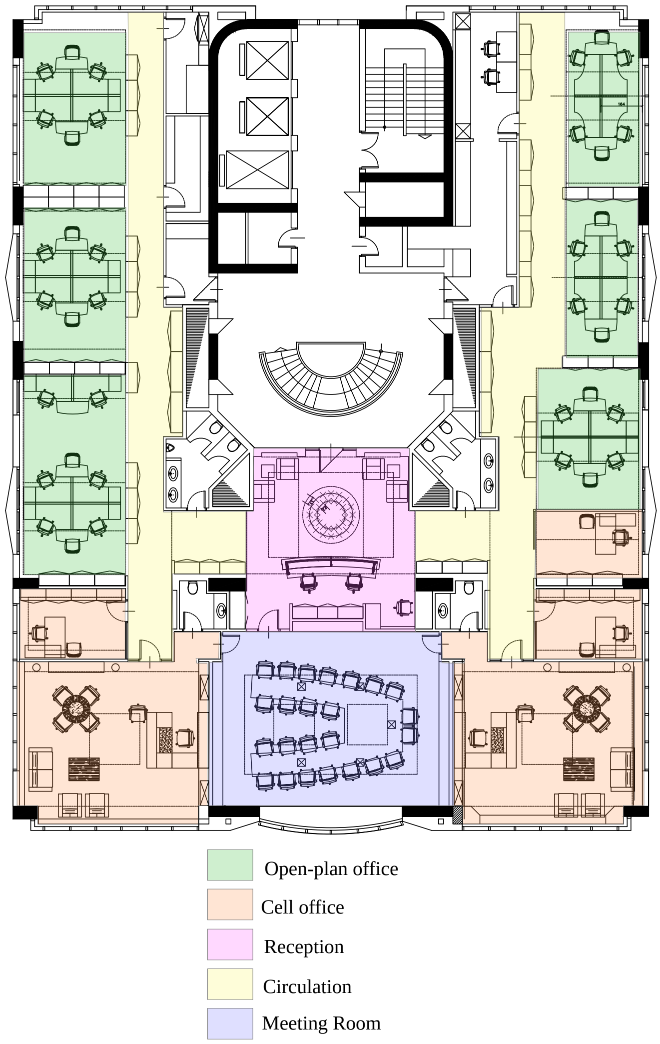


Figure 4.41: Denge Office Layout

The DENGE office lighting layout's are the below, the green box refers to open office spaces in the figure 4.42.The five open office are of in the Denge office. In the open offices, Spotlights use a lot. Over Every worker has spotlights. And they are working very comfortable without glare. The spotlights provide esthetic view. The spots are the LED lighting spots. Because of that the energy spent less than the other spotlights. If it's a sunny day the artificial lightings can't use. The daylight can be sufficient. And this is relevant with the wright designing of windows and the direction of building. It's a very important for energy savings. The top of the every table it has a drop ceiling and the spotlights are fixed in this places. (Figure 4.43,44) The top of the closets is used the tiny spotlights. These spotlights also use led lighting

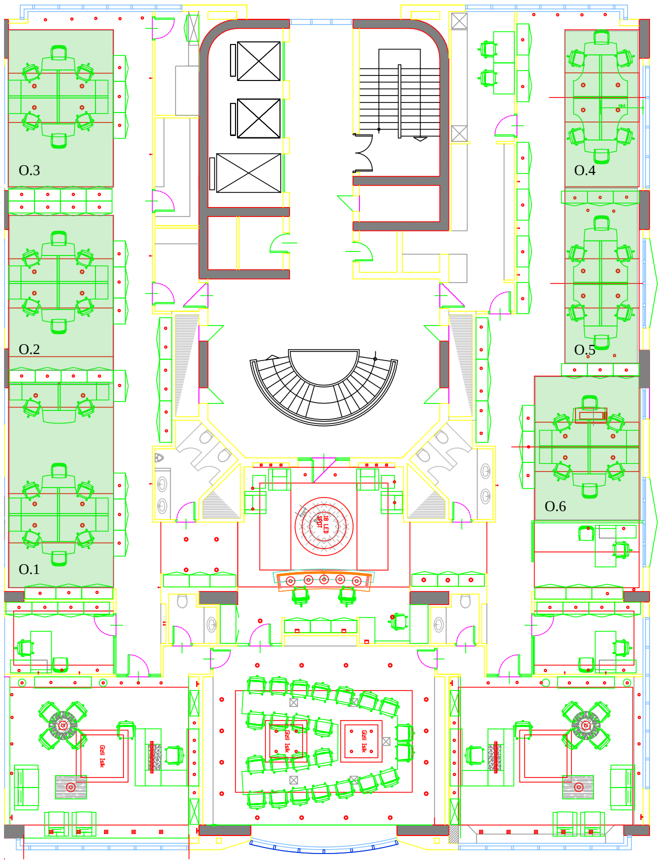


Figure 4.42 : Denge , Open Office Lighting Layout

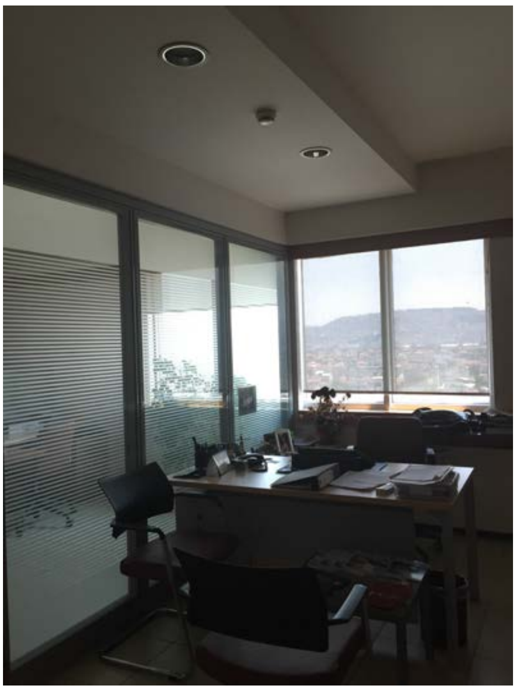


Figure 4.43 : Denge Open Offices

Figure 4.44 : Denge Open Offices

(Idil BAKIR Photo Archive, 2015)

The lightings used at the open offices were shown on table 4.16 with their features and symbols on the layouts. The calculations of the lighting power on table 4.17 were added to the number showing the power of the lighting written on the "watt" section, and were multiplied with square meter. At the open office 1 show 68%, open office 2 show 31%, open office 3 show 41%, open office 4 show 56%, open office 5 show 12%, open office 6 show 53% lighting power saving. . The usage of controllable artificial lightings with LED and proper and sufficient usage of daylight; the design of artificial lighting in a way to support the daylight are the most important reasons of the lighting power saving.

Table 4.16 : Denge Open Office Lighting Systems Analyses

Luminaire	**Nominal Size**	**Source**	**Watts**	**Lumens**	**Volt**	**Rated Life**
 NASSA LED SPOTLIGHT	Radius 19.5	LED	18	2000	85-265	50000
 NASSA LED SPOTLIGHT	Radius 15.5	LED	20	2000	86-265	50000

Table 4.17 : Denge Open Office Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Office 1	34	4	12	408	132	68%
Office 2	28	4	12	336	232	31%
Office 3	30	4	12	360	212	41%
Office 4	25	3	12	300	132	56%
Office 5	20	3	12	240	212	12%
Office 6	20	3	12	240	112	53%

DENGE office lighting layout's are the below, the orange box refers to open office spaces in figure 4.45. In managers cell offices, it has six type of lighting fixtures. There are round and square spotlights, wall (painting) fixtures, two types of ceiling lightings, led band lightings. The top of the working table has round spotlights and ceiling light. The manager can work confortable without glare and her/his eye that isn't disturbed by lighting. In 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. (Figure 4.46)

In The other cell offices, there are spotlights and the wall (painting) fixtures. The top of the every table it has a drop ceiling and the spotlights are fixed in this places. The top of the closets is used the tiny spotlights. These spotlights also use led lighting.

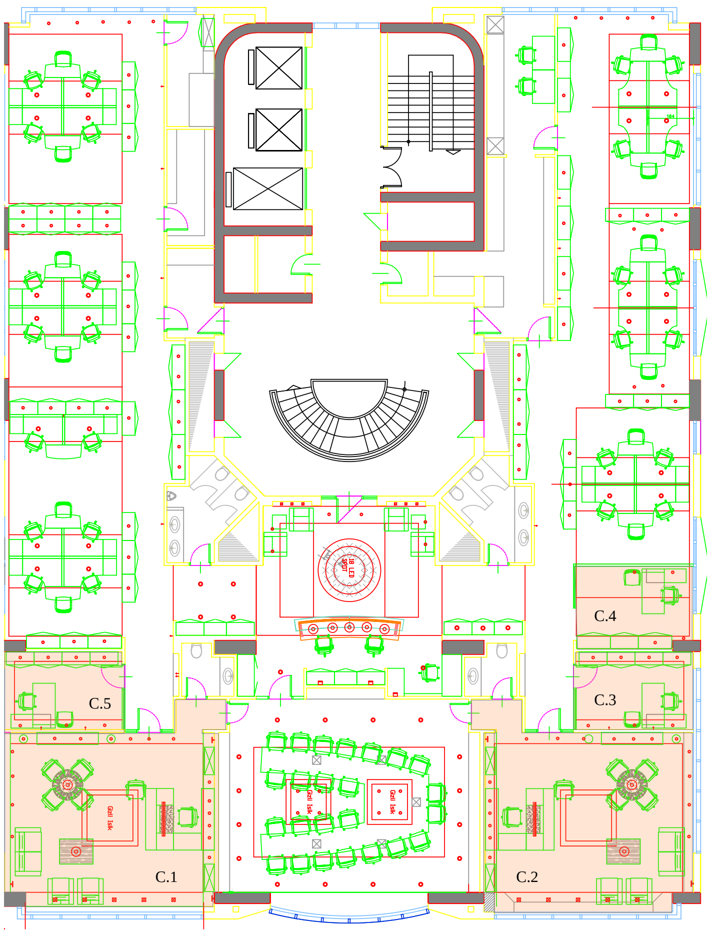


Figure 4.45 : Denge , Cell Office Lighting Layout

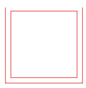
Figure 4.46 : Denge Cell Office
(Idil BAKIR Photo Archive, 2015)

The lightings used at the cell offices were shown on table 4.19 with their features and symbols on the layouts. The calculations of the lighting power on table 4.18 were added to the number showing the power of the lighting written on the “watt” section, and were multiplied with square meter. At the cell office 1 show 59% loss, cell office 2 show 59% loss, cell office 3 show 18%, cell office 4 show 18%, cell office 5 show 18%, lighting power loss.

Table 4.18 : Denge Cell Office Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Cell Office 1	49	6	12	588	933	59% loss
Cell Office 2	49	6	12	588	933	59% loss
Cell Office 3	12	2	12	144	170	18% loss
Cell Office 4	12	2	12	144	80	18% loss
Cell Office 5	12	2	12	144	170	18% loss

Table 4.19 : Denge Cell Office Lighting Systems Analyses

Luminaire	**Nominal Size**	**Source**	**Watts**	**Lumens**	**Volt**	**Rated Life**
 NASSA LED SPOTLIGHT	13X13X8 cm	LED	20	2000	85-265	50000
 NASSA LED SPOTLIGHT	Radius 15.5	LED	20	2000	86-265	50000
 NASSA Jupiter Ceiling lighting	35x35x37 cm	Energy Smart Bulb	40	475	220-240	8000
 PHILIPS	206x117x5 cm	Fluorescent	28	2900	230	24000
 NASSA Wall Fixture	53x52x29 cm	4xE4	2x20	2000	230	24000
 NASSA Band LED Lighting	16 m (4x5 m piece)	3x300 LED	14,4 (1 m)	475	12	24000

The Denge office lighting layout’s are the below, the purple box refers to meeting room in figure 4.47. In the meeting room, a lot of spotlights were used. It has a drop ceilings which has concealed lightings. The space of lightings was choose according to chairs and tables places. The Furniture within the meeting room were located according to the entrance side of the daylight. The shape and the location of the windows were planned in the most efficient way by calculating the daylight angle. (Figure 4.48)

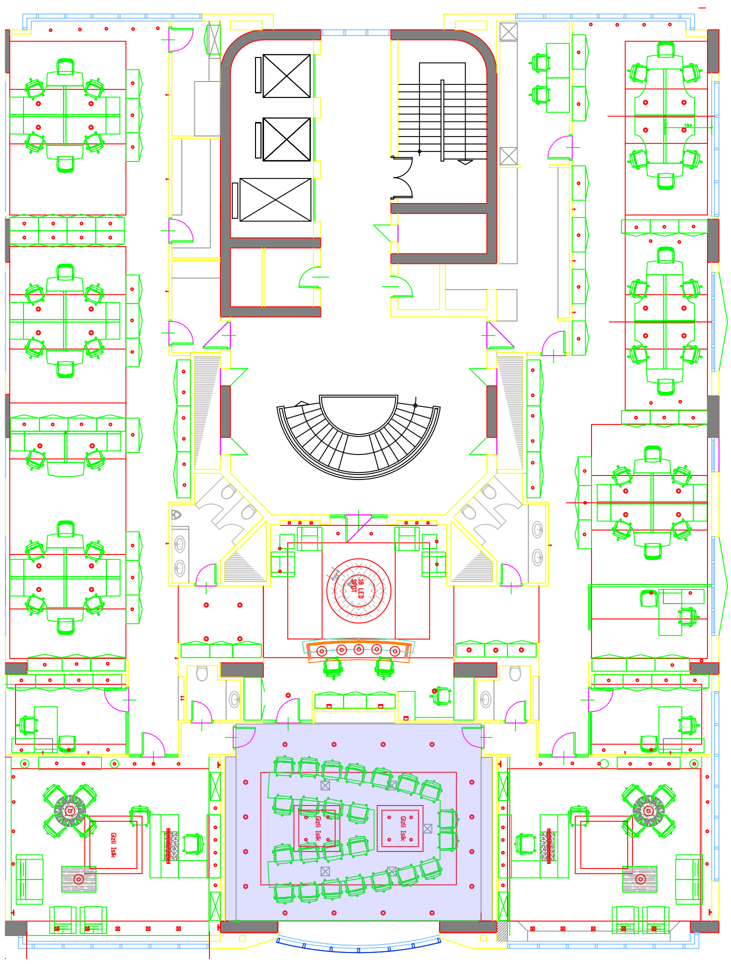


Figure 4.47 : Denge , Meeting Room Lighting Layout

Figure 4.48 : Denge Meeting Room

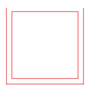
(Idil BAKIR Photo Archive, 2015

The lightings used at the meeting room were shown on table 4.21 with their features and symbols on the layouts. The calculations of the lighting power on table 4.20 were added to the number showing the power of the lighting written on the "watt" section, and were multiplied with square meter. At the meeting room show 21% loss in lighting power.

Table 4.20 : Denge Meeting Room Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Meeting Room	65	8	11	715	872	21% loss

Table 4.21 : Denge Meeting Room Lighting Systems Analyses

Luminaire	**Nominal Size**	**Source**	**Watts**	**Lumens**	**Volt**	**Rated Life**
 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 (4x5 m piece)	3x300 LED	14,4 (1 m)	475	12	24000

The DENGE office lighting layout's are the below, the pink box refers to meeting room in the figure 4.49. The Reception is the entrance of the office building. The Entrance, more than any other space, gives the office building its character and is the public face of both the building and the company. In addition to an inviting light setting, both the luminaire design and the lighting scheme form the first impression of the visitor.

In the entrance of the Denge Office's reception there is a very esthetic 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. The side of the door, there is two niches with the spotlights. This space doesn't see the daylight. This is negative design for the saving energy. And this is so exhaustive for the eye of the workers. (Figure 4.50)

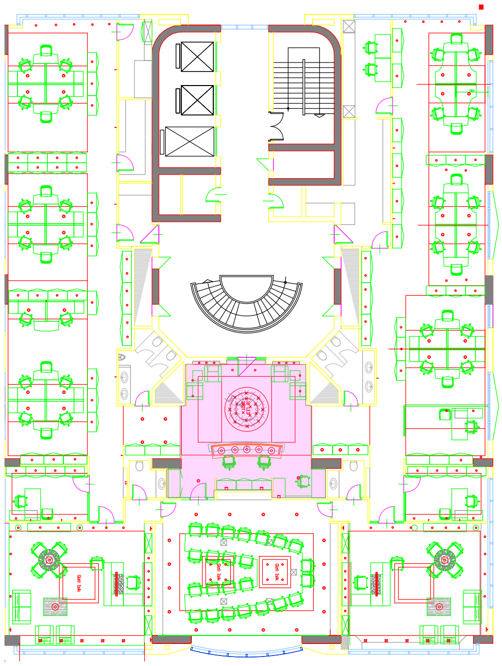


Figure 4.49 : Denge , Reception Lighting Layout

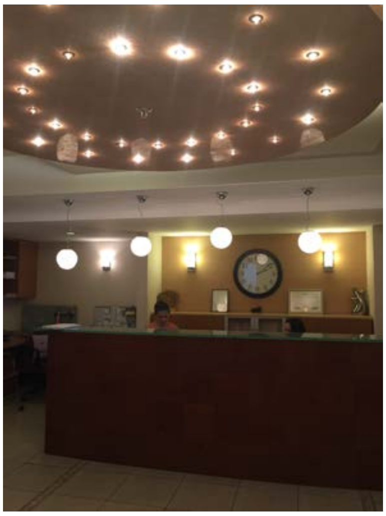


Figure 4.50 : Denge Reception

(Idil BAKIR Photo Archive, 2015)

The lightings used at the reception were shown on table 4.22 with their features and symbols on the layouts. The calculations of the lighting power on table 4.23 were added to the number showing the power of the lighting written on the “watt” section, and were multiplied with square meter. At the reception show 9% loss in lighting power.

Table 4.22 : Denge Reception Lighting Systems Analyses

Luminaire	Nominal Size	Source	Watts	Lumens	Volt	Rated Life
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	35x35x37 cm	Energy Smart Bulb	40	475	220-240	8000
NASSA Wall Lighting	10x10x18 cm	Halogen	20	2000	230	50000
NASSA Spotlight	6x6x8 cm	LED	20	2000	86 - 265	50000
NASSA Band LED Lighting	16 m (4x5 m piece)	3x300 LED	14,4 (1 m)	475	12	24000

Table 4.23 : Denge Meeting Room Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Reception	45	6	14	630	691	9% loss

The DENGE office lighting layout's are the below, the yellow box refers to circulation space. 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 as seen as Figure 4.51.

Figure 4.51 : Denge Corridors
(Idil BAKIR Photo Archive, 2015)

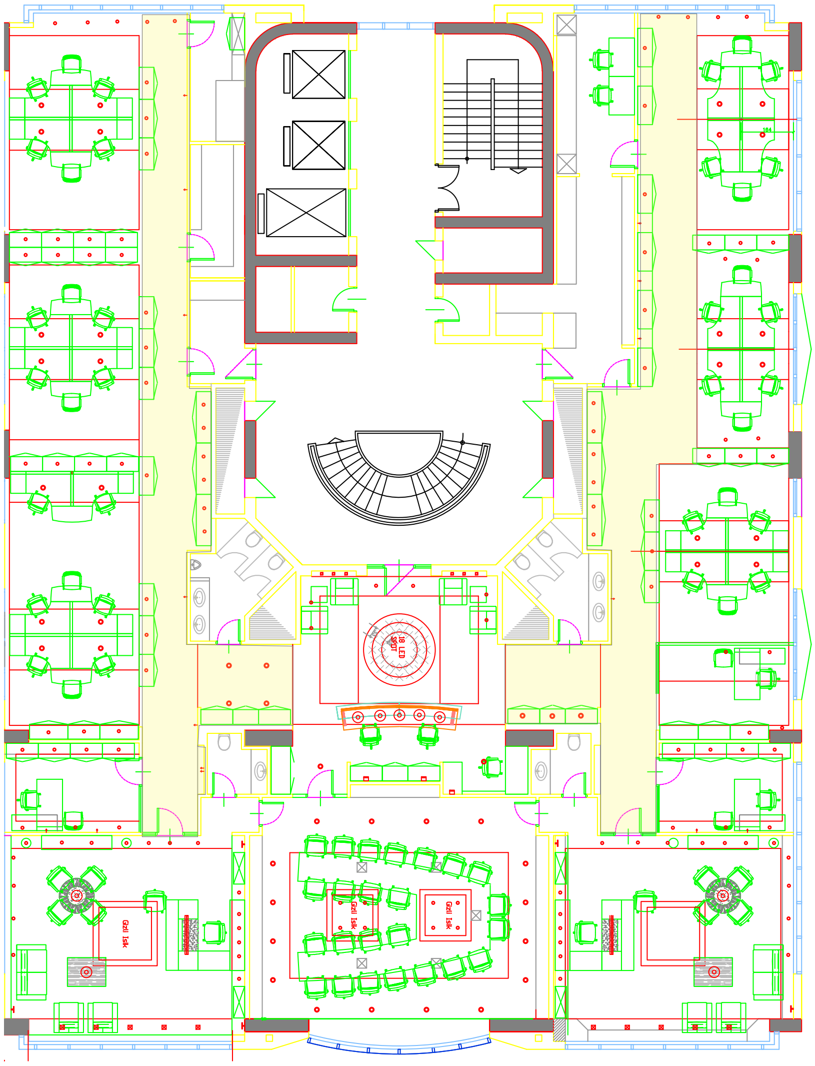


Figure 4.52 : Denge , Corridors Lighting Layout

The lightings used at the corridors were shown on table 4.24 with their features and symbols on the layouts. The calculations of the lighting power on table 4.25 were added to the number showing the power of the lighting written on the “watt” section, and were multiplied with square meter. At the corridors show 100% loss in lighting power.

Table 4.24 : Denge Corridors Lighting Systems Analyses

Luminaire	**Nominal Size**	**Source**	**Watts**	**Lumens**	**Volt**	**Rated Life**
 NASSA Wall Fixture	53x52x29 cm	4xE4	2x20	2000	230	24000
 NASSA LED SPOTLIGH T	Radius 15.5	LED	20	2000	86-265	50000
 NASSA Wall	10x10x18 cm	Halogen	20	2000	230	50000

Table 4.25 : Denge Meeting Room Lighting Energy Analyses

Lighting Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Corridors	102	13	5	510	1025	100% loss

The lighting systems were analyzed in the Denge office. All the lightings used at the office were measured as watt according to the sections of the office. Watt in every square meter was calculated according to ASHRAE/IES Standard 90.1-2007.

The appropriate watt in every square meter was calculated according to ASHRAE/IES Standard 90.1-2007. The fractions were ignored during the calculations. Watt changes in every type and section of the office according to ASHRAE/IES Standard 90.1-2007.

As shown at table 4.26, appropriate watt according to ASHRAE and the current watt at the office were compared and when compared the amount of power savings were put forward. The open offices show the best amount of saving with 45% in the ERKE office. The other saving is the other section with 5% in reception. There are another spaces doesn’t make any savings there are loss from lighting power. There were 3% loss at the cell offices, 21% loss at the meeting room, 100% loss at the corridors, 9% at the reception and 5% loss in the other spaces. 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. It is inadequate rate to take points from this section of LEED certificate.

Table 4.26 : The Lighting Energy Savings or loss Calculation of Denge Office

Space	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
			W/M^2	Watts		
Open Offices	157	20	12	1884	1032	%45
Cell Offices	134	17	12	2278	2286	% 0.3 loss
Meeting Room	65	8	11	715	872	% 21 loss
Corridors	102	13	5	510	1025	% 100 loss
Reception	45	6	14	630	691	% 9 loss
Other	297	37	10	2970	2820	% 5
Total	800	%100	–	8987	8726	%3

4.4 The Assessment of the Chapter

This chapter was based on an designed but unbuilt project called Optima Project by Philips. Optima Project was divided into office types and sections and it was analyzed according to lighting criteria of LEED certificate. The layouts of the departments were individually prepared and all the lightings used in it were presented with their features. The lighting powers were calculated considering their square meters according to ASHRAE/IES Standard 90.1-2007. The same lighting analysis applied in this project was also applied to ERKE Design office in İstanbul and Denge certified public accountant office building. Layouts were created with lighting projects and lighting and power analyses were made according to office types and sections. Lastly, energy savings and LEED certificate criteria of the 3 types of offices were compared; a table was formed with its results. That's how the differences between an office building with a certificate and an office building without one were put on the table.

The Optima Project, the above-mentioned imaginary hypothetic project designed by Philips, ERKE Design Office with LEED certificate in İstanbul, and Denge certified public accountancy office building without a certificate were all presented with lighting projects, analyzed regarding lighting in terms of sustainability, and measured in terms of their lighting power. According to the results, while the table 4.28 indicates 63% lighting energy saving in total regarding ERKE Design Office, DENGE office only shows 3% energy saving. Table 4.27 indicates saving from all of the offices. Even though Denge Office is not sustainable, they have provided saving only by using the efficient types of light.

According to he LEED certificate, in the criteria of optimize energy performance, the saving must be 10% in general office buildings. The optima project and ERKE office are provided this rate. The optima project can get 12 points. ERKE office can get 19 points but with the 3% saving, Denge office isn’t provided this rate. Denge Office consumes more than enough lighting power. According to the results, while the other offices save energy in the meeting rooms and corridors, Denge Office consumes more than enough energy. Especially in the corridors section, the over-used wall lightings and spotlights indicates a 100% over-used lighting.

Table 4.29 shows the interior lighting criteria of LEED certificate's implementation and evaluation on these three projects. While ERKE Office Buildings includes all of the lighting criteria such as Controllability of Lighting Systems, interior lighting quality, optimize energy performance, daylight and view, Denge Office does not. Erke Office set up an automation system for lighting control, connected all the lighting systems to this center and also the daylight. The lighting levels and lighting quality were designed by evaluating the calculated results. In the Denge office, The Artificial Lighting Systems aren’t controlled. The office building was located according to the calculations made in order to get the efficient and sufficient daylight; the window sizes and places are arranged according to the entrance of the daylight; roof windows were used in the seminar room section. As a result, ERKE Office Building highly provided all of the sustainable lighting criteria.

Table 4.27 : The Lighting Energy Savings Comparison of the Offices

Space	Area m^2	Standard 90.1 Allowance Watts	Connected Watts	Savings
The Optima Project	1732	20175	12646	37%
ERKE Office	400	4597	1693	63%
Denge Office	800	8987	8726	3%

Table 4.28 : The Lighting Energy Savings Comparison of the Offices According to Office Sections

Office Section	Office Name	Area m^2	% of Total	Standard 90.1 Allowance		Connected Watts	Savings
				W/M^2	Watts		
Open Office	The Optima Project	873	50	12	10412	6275	40%
	ERKE Office	114	29	12	1368	590	57%
	Denge Office	157	20	12	1884	1032	45%
Cell Office	The Optima Project	238	14	11,9	2835	1350	52%
	ERKE Office	36	9	12	432	278	36%
	Denge Office	134	17	12	2278	2286	% 0.3 loss
Meeting Room	The Optima Project	170	10	14,1	2391	1585	34%
	ERKE Office	13	3	11	143	43	70%
	Denge Office	65	8	11	715	872	% 21 loss
Reception	The Optima Project	211	12	14,1	2980	2069	31%
	ERKE Office	11	3	14	154	130	15%
	Denge Office	45	6	14	630	691	% 9 loss
Corridors	The Optima Project	72	4	5,2	391	318	19%
	ERKE Office	33	8	5	120	92	23%
	Denge Office	102	13	5	510	1025	% 100 loss

Table 4.29 : The Assessment of The Offices With The LEED Sustainable Lighting Criteria

Credit	**Description**	**Project Name**		
		The Optima Project	ERKE Office	Denge Office
SS Credit 8	Light Pollution Reduction	Not in Scope	Not in Scope	Not in Scope
EA Prerequisite 2	Minimum Energy Performance	Achieved 37% reduction in lighting power	Achieved 63% reduction in lighting power	Achieved 3% reduction in lighting power
EA Credit 1	Optimize Energy Performance	Achieved 37% reduction in lighting power	Achieved 63% reduction in lighting power	Achieved 3% reduction in lighting power
IEQ Credit 6.1	Controllability of Systems - Lighting	Individually controlled artificial lighting systems	Individually controlled artificial lighting systems	The Artificial Lighting Systems aren’t controlled.
IEQ Credit 8.1	Daylight and Views - Daylight	Suitable Fenestration and interior configuration	Suitable Fenestration and interior configuration	Insufficient
IEQ Credit 8.2	Daylight and Views – Views	Suitable Fenestration and interior configuration	Suitable Fenestration and interior configuration	Insufficient
Pilot Credit 22	Interior Lighting – Quality	Suitable Luminaire specification and illuminance distrubition	Suitable Luminaire specification and illuminance distrubition	Insufficient

5.CONCLUSION

The subject of sustainability first appeared with a very limited understanding towards reducing the economic effects of environmental negativities in the 1970's. However, it now encompasses a wider area. It brought new developments in the fields of architecture, interior architecture and design; created a new trend and caused the beginning of a new period. The technological advanced of the Industrial Revolution, the increase in the number of buildings and the number of people in the cities and therefore caused the development of the building sector. On the other hand, the resources started to run out, pollution occurred and the buildings started to have negative effects on the environment. Because of the increase in consumption, energy losses occurred. Energy crises around the world broke out. The lighting covers the biggest part of the energy loss. The lighting systems should be evaluated according to their meeting of the expectations of the lighting system designs and this evaluation should be managed properly.

Today, on the other hand, the advancement in technology and the importance of communication have led to some differences regarding the understanding of the term “office”. Especially with the time management gaining importance as a result of Industrial Revolution, offices have moved to homes and the number of office building have increased. People started to spend more time in a work environment. That's why lighting carries great importance in the offices. The wrong artificial lighting used in the offices throughout the day causes energy loss, light pollution, and high CO_2 emission. It also has negative effects on human eye and mental health.

With the appearance of the subject of sustainability, the certificates that evaluate and review this term have been comprised. In this research the certificates that are most popular have been briefly explained. These certificates are CASBEE, Green Star, BREEAM and LEED. In Turkey, the most prevalent and the detailed certificate that analyses lighting criterion is LEED. Other sections of the certificate are not discussed.

In this case study, only the lighting systems have been studied. The criteria about lighting energy that are included in the LEED certificate chapters are a huge contribute when it is efficiently considered. The calculation of the lighting energy for offices in the LEED V4 certificate are done by using the numbers of the lighting energy density chapter in the ASHRAE/IES standard 90.1-2007. In order to consider adequate savings of lighting energy in accordance with lighting power density, the said savings has to be 10% or more. To earn 1 point in LEED V4 lighting energy criteria, an office building has to make 12% reduction, each 2% additional reduction earns 1 point, up to a maximum of 19 points.

In this Study, This is based on a hypothetical Optima Project, which is created by a lighting company. The comparison in this case study is between the two offices, ERKE, with the LEED certificate, and DENGE, wıthout it. The main criterıa for the evaluation of these two offices are that they both have all the office types and sections of the ASHRAE/IES standard 90.1-2007. The energy savings and loss of the artificial office lighting systems has been calculated and then divided into office sections and types, according to the ASHRAE/IES standard 90.1-2007 which are included in the LEED certificate’s lighting criteria. The offices sampled here in have been analyzed and compared in accordance with these criteria.

The comparison in this case study is between the three offices, ERKE with the LEED platinum certificate, DENGE without it and the hypothetical Optima Project. The main criteria for the evaluation of these three offices are that they both have all the office types and sections of the ASHRAE/IES standard 90.1-2007. The wattage of the artificial lighting systems of these three offices has been calculated while the systems were in use. In the sections of the LEED certificate, the ASHRAE/IES standards 90.1-2007 of lighting power density proportions have been used. According to these proportions, the square meter configuration of these offices types and sections have been taken into account. The results of these measurements have been multiplied with lighting wattage and thus the lighting energy savings and loss have been configured.

As a result of this evaluation, the most lighting energy saving in value for open offices has been made by ERKE offices with 57%. For Denge Office, the number is 45% and for the Optima Project, it is 40%. For cell offices, the lighting energy saving in value has been made by the Optima Project with 52%. For ERKE Office, this saving is 36% and for Denge Office , it is 0,3%. The most successful energy saving through individually controlled artificial lighting with sensor of daylight for meeting rooms that has been made by ERKE Office with a 70% in values. For the Optima Project, this saving is 34%. In Denge office, this percentage changes drastically a 21% loss. For reception areas, the lighting energy saving of the Optima Project is 31%, for ERKE Office it is 15% but the Denge office has not saved any lighting energy, there is 9% loss. Finally, in circulation areas, the lighting energy saving of the Optima Project is 19%, for ERKE Office, it is 3%. Denge office has 100% loss in lighting energy saving. This percentage is considerably high. It is a significant loss both economically and environmentally. For all three offices, 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.

Regarding all office areas, the Optima Project has 37%, ERKE Office has 63% lighting energy savings. Although only causing a lighting energy saving in open office areas and losing energy in other areas, Denge office energy saving is 3% in total. This number is not sufficient for LEED certificate, which has a criterion of 10%. The other two offices provide the amount of percentage to be adequate for this certificate. According to the grading of this certificate, the Optima Project gets 12 points. ERKE Office gets19 points in this criterion.

This research pointed out that for making a sufficient lighting energy saving and getting an adequate point from the LEED V4 certificate offices that were reviewed case study must fulfill these criteria.

- Individually controlled artificial lighting systems
- Suitable and efficient luminaire specification
- The usage of daylight sensor of artificial lighting systems
- Artificial lighting with on-off button for each person
- Illumination distribution
- Suitable fenestration and interior configuration

ERKE Office efficiently provides these criteria. In Optima Project, the lighting energy savings are lesser, the Optima Project is missing the usage of daylight sensor of artificial lighting and individually controlled artificial lighting with on-off button criteria. Denge Office only fulfills suitable fenestration and interior configuration criteria. The most important for lighting energy saving is suitable and efficient luminaire specification. Because of it’s 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 less spotlights should be used, their lamps should be replaced by LED lights. In the cell offices, less spotlights should be used and when it comes to individual lightings, less-energy using lightings should be preferred. That's how the energy performance in the office can be optimized. If a budget is managed at first with the above-mentioned suggestions, financial savings can be managed in short time. The eye exhaustion and screen glare of the employees will disappear and the work efficiency will increase.

As seen as a result of the study, certificate and the criteria of the standards are applied in the efficient way. If the efficient systems are designed, the lighting energy cost highly decreases. It both provides economic benefit and prevents energy loss. As mentioned in the criteria, providing these requirements carries great importance for the lighting control. Controllable systems should be designed in the buildings, 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 study 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. The office owners should give great attention to the issue of lighting, provide financial budget, embrace the subject of sustainability and be conscious about the implementation of criteria by researching certificate studies.

Lastly, 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 we spend most of our time, lighting systems that provide us 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.

BIBLIOGRAPHY

Alkan, İ., 2010, Ofis Mekanlarında Işık ve Renk İlişkisinin Görsel Konfora Etkisi, Yüksek Lisans Tezi,MSÜ Güzel Sanatlar Fakültesi, İstanbul, 112p. (Published)

Anbarcı, M., Giran, Ö. and Demir, İ. H., 2011-2012 Uluslararası Yeşil Bina Sertifika Sistemleri ile Türkiyedeki Bina Enerji Verimliliği Uygulaması, e-journal of New World Sciences Academy NWSA, Engineering Sciences , İstanbul, 369-383p.

ASHRAE/IES, 2007, Standard 90.1for Energy Standard for Buildings Except Low-Rise Residential Buildings, USA

BREEAM, 2011, New Construction Technical Manual, United Kingdom.

BREEAM, 2009, Europe commercial Assessor Manual, United Kingdom.

BREEAM, 2010, International Bespoke, United Kingdom.

CASBEE, 2008, New Construction, Japan

Çete, N., 2004, Çalışma Ortamlarında Verimliliğin Arttırılmasının Büro Mekanlarıyla İlişkilendirilmesi, Yüksek Lisans Tezi, YTÜ Fen Bilimleri Enstitüsü, İstanbul (Unpublished).

EN 12464-1, 2002, Light and Lighting – Lighting of Work Places, European Committee for Standardization.

Esen, A., 2000, Aydınlatma Ders Notları, MSÜ Fen Bilimleri Enstitüsü, İstanbul

Dökmeci, V. Dülgeroğlu, Y. and Akkal, B., 1991, Şehir Merkezi Transformasyonu, İstanbul, 46p (summary inpress).

BIBLIOGRAPHY(cont.)

Dökmeci, V. Dülgeroğlu, Y. and Akkal, B., 1993, Şehir Merkezi Transformasyonu ve Büro Binaları, Literatür yayıncılık İstanbul,141p (published).

Duffy, F. Cave, C. and Worthington, J (Eds.).,1976, Planning Office Space London p.47 (Architectural Press).

Fowler, K. M. and Rauch, E.M., 2006 Sustainable Building Rating Systems Summary, Completed by the Pacific Northwest National Laboratory, The U.S. Department of Energy, 47p.

Gordon, G., 2003, Interior Lighting for Designers, John Wiley & Sons, Inc., New Jersey, 292p.

Green Star, 2013, Performance Summary of Categories and Credits, Australia

Göker, M., 2006, Mimari Yapılarda Saydamlık ve Işığın İç Mekana Etkisi, Sanatta Yeterlik Tezi, MSGSÜ Fen Bilimleri Enstitüsü, İstanbul, 233p.

Ilıcalı, E. and Somalı, B., 2009, LEED ve BREEAM Uluslararası Yeşil Bina Değerlendirme Sistemlerinin Değerlendirilmesi, IX. Ulusal Tesisat Mühendisliği Kongresi, İzmir. 1081,1088p.

Inman, G. E., 1954, Fluorescent Lamps, Past, Present, and Future, General Electric Review, 34-38p.

Karslı Tuğlu, H.U., 2008, . Sürdürülebilir Mimarlık Çerçevesinde Ofis Yapılarının Değerlendirilmesi ve Çevresel Performans Analizi için Bir Model Önerisi, MSGSÜ Fen Bilimleri Enstitüsü, Sanatta Yeterlik Tezi, İstanbul, 295p.

Kılıçaslan, U.G., 2011, Aydınlatma Tasarımı Kriterlerinin Hastane Mekanlarnda İrdelenmesi, Yüksek Lisans Tezi, MSÜ Güzel Sanatlar Fakültesi, İstanbul,159p. (Published)

BIBLIOGRAPHY(cont.)

Küçükdoğu, M. Ş., 2008, Temel Aydınlatma Bilgileri-1, Yüksek Lisans Tezi, Kültür üniversitesi, istanbul.

LEED, 2013, Version 4 Reference Guide for Building Design and Construction

Majoros, A., 2011, Artificial Lighting Lecture Notes, Budapest University of Technology and Economics Faculty of Architecture Department of Building Energetics and Services

Michel, L., 1995, Designing With Space and Light, John Wiley & Sons, USA, 304p

Öztürk, K., 1999, Açık Planlı Büro Aydınlatması Üzerine Bir İnceleme, Yüksek Lisans Tezi, MSGSÜ Fen Bilimleri Enstitüsü, İstanbul (Unpublished).

Philips, 2012, Lighting for LEED Application Guide for Sustainable Offices, New York, 19p.

Pohl, W. and Zimmermann, A., 2003, SynthLight Handbook Artificial Lighting Munich, 66p.

Sirel, Ş., 1992, Aydınlığın Niteliği, Yapı Fiziği Uzmanlık Enstitüsü, 1. Bölüm Kitapçık no:14.

Sirel, Ş., 1991, Aydınlatmada Enerji Kaybı, Yapı Fiziği Uzmanlık Enstitüsü, Kitapçık 3, 2p.

Sirel, Ş., 1997, Aydınlatma Sözlüğü, YEM Yayınları, 11p.

Sirel, Ş., 1997, Müzelerde ve Bürolarda Aydınlatma, YFU Enstitüsü, Kitapçık no:8, 4p.

BIBLIOGRAPHY(cont.)

Şerefhanoğlu, S. M., 1974, Yapay Işık Kaynakları ve Bakım Sorunu, Mimarlık Dergisi, Elektrik Mühendisliği, 210p.

Şerefhanoğlu, S. M., 1991, Ofis Yapılarında Gürültü Denetimi, Arredamento Dekorasyon, Ofis'91 Dergisi, 16-17p

Şerefhanoğlu, S. M., 1991, Çalıştığımız Mekânlarda Konfor, Arredamento Dekorasyon, Ofis'91 Dergisi, 19-22P

Sezgin, G., 2011, The Analyses of Store Lighting Design: The Emotional Responses in the Context of Customer Characteristics, Post Graduate Thesis, Çankaya University Interior Architecture, 117p.

Toffler, A., 1996, Ekonominin Çöküşü Eko-Spazm, İnsan Yayınları, İstanbul, 128p. (Published)

Uyan, F., 2010, Binalarda Aydınlatma Sistemlerinin, Sürdürülebilirliklerini Değerlendirme İlkeleri, Yüksek Lisans Tezi, İTÜ Fen Bilimleri Enstitüsü, İstanbul, 95p (Published).

Yaman, Ö. D., 2011, BREEAM Yeşil Bina Derecelendirme Sisteminin Aydınlatma Yaklaşımı, ERKE Tasarım, İstanbul, 20p.

Ünal, A., 2009, Aydınlatma Tasarım ve Proje Uygulamaları, Birsen Yayınevi, Istanbul, 284p.

Yener, A.K., 2008, Binalarda Günışığından Yararlanma Yöntemleri,
Çağdaş Teknikler VIII. Ulusal Tesisat Mühendisliği Kongresi 231 Sempozyum Bildirimi, 11p

Yıldız, B. 2003, İstanbul'daki Ofis Binalarının Performans Değerlendirmesi, Post Graduate Thesis, YTÜ Fen Bilimleri Enstitüsü, (published).

INTERNET BIBLIOGRAPHY

http://www.artinaid.com/2013/04/what-is-light-or-electromagnetism/ Access date: 25.10.2014

http://astudentoftherealestategame.com/ Access date: 25.10.2014

http://www.betterbricks.com/graphics/assets/documents/RatingSystem_Final.pdf Access date: 01.09.2014

https://www.melbourne.vic.gov.au/BuildingandPlanning/Planning/formsfees/Documents/GreenStarandABGRFactSheet.pdf / Access date: 09.06.2015

http://glamox.com/uk/solutions/entrance-areas-and-foyers Access date: 09.06.2015

http://www.uffizi.com Access date: 20.10.14

http://all-that-is-interesting.com/famous-designs-frank-lloyd-wright/2 Access date: 10.8.14

http://bene.com/pics/planning-design/cellular-office.gif Access date: 2.12.2014

http://www.zappoffice.nl/fotos-en-video/ Access date: 15.06.15

http://www.mydesignweek.eu/inside-the-google-office-in-tel-aviv/#.VZFNKutYCfQ Access date: 10.06.15

http://www.homedit.com/10-amazing-offices-design-around-the-world/)

Access date: 10.02.15

https://aviator-sunglasses.net/uv-protection/protect-your-eyes-from-solar-radiation-part-ii/attachment/eye_structure/ Access date:13.04.2015

http://www.ccohs.ca/oshanswers/ergonomics/lighting_general.html

Access date:08.01.2015

http://www.interlectric.com/general-lighting/l-e-d-lights/t8-leds-general-lighting/ Access date:24.03.15

http://www.minimalisti.com/lighting-2/08/modern-lighting-lamps-design.html/2) Access date:21.01.15

http://www.civilprojectsonline.com/lighting/semi-direct-lighting-ambient-lighting-techniques/ Access date:21.07.14

http://image.slidesharecdn.com/lighting-150123085307-conversion-gate02/95/lighting-10-638.jpg?cb=1422024848 Access date:29.03.15

http://inhabitat.com/swedens-umea-university-architecture-academy-punctuated-with-pixelated-windows/ Access date:29.03.15

http://myweb.wit.edu/viridis/green_site/projects/2_processes/daylighting/3_light-shelves/light-shelves.html Access date: 09.04.15

http://www.apartmenttherapy.com/10-bright-ideas-for-led-lighting-190699 Access date: 09.04.15

http://www.morganlovell.co.uk/knowledge/whitepapers/sustainable-office-design-unlocking-performance-and-productivity Access date: 19.04.15

www.segatech.com.tr Access date:17.06.15

www.entegreplus.com Access date:17.06.15

http://www.maxpierson.me/2013/08/01/leed-v4-for-the-lighting-designer/) Access date: 24.05.15

CIRRICULUM VITAE

Personal Information:

Nationality: Türkiye Cumhuriyeti
Date Of Birth: 25.10.1988
Place of Birth: İzmir

Education:

1999/2005 İzmir Tevfik Fikret College ve Science College

2005/ 2010 Yeditepe University Fine Arts Faculty Industrial Product Design

2011/ 2015 Yaşar University Architecture Faculty Interior Architecture Master Programme

Interests:

Design, Architecture, Pilates, Dance, Piano

Lamguages:

English, French

Computer Skills:

Archi-cad, Auto-cad, Rhino, Photoshop, Piranesi, Artlantis, Sketchup, Office Programs

APPENDICES

Appendix 1 BREEAM Certificate And Lighting Criteria

BREEAM's lighting subjects are shortly explained below.

Being Healthy and Good

HEA 4: Ultrasonic lighting

The Aim of this criteria to reduce the risk of the health problems deriving from the vibrant lights of the fluorescent lamps.

The evaluation of this criteria; All the fluorescent and compact fluorescent lamps should be equipped with ballasts working with a frequency over 30 kHz. The vibrations of the fluorescent and compact fluorescent lamps equipped with these ballasts are too fast to be caught with human eye. The sound they create are also in a frequency human ears cannot process. Today's widely used electronic ballasts generally work with a frequency over 40 kHz.

HEA 5: Indoor and outdoor lighting levels

The Aim of this criteria; to manage visual performance and comfort regarding lighting design.

The evaluation criteria

1. Indoor and outdoor lighting levels should be designed according to local regulations. If there is no local regulation regarding lighting, the lighting should be designed by considering the criteria defined under EN 12464-1 and 2 European Standard in table 1 (Yaman, 2011).

2- In the study areas where the computers are often used, the lighting design should minimize the reflection from the screens and the effect of glare. The limitations should be considered according to values defined under EN 12464-1 and 2.

3- The lighting regularity should be equal to or higher than 0.7 in the study areas. In the places such as circulation or resting zones surrounding the study areas, the lighting regularity should be equal to or higher than 0.5.

HEA 6: Lighting zones and lighting control

The Aim of this criteria to create a lighting design which can provide easy and accessible control to building users.

The evaluation of this criteria; Zoning is designed in a way that lighting will be available for different user control for the following areas:

1. Office and circulation areas
2. Different zoning for each of 4 study areas (4 people) in the office buildings (if the number of people who will work in the office area during the project is not certain, the area should be zoned regarding the fact that there will be one study area in each 10 m2. For example, in an office covering an area of 40m2, the lighting control should be managed with 4 different lighting zones.)
3. The areas, such as atrium and window, which take sunlight in
4. Libraries, book storages and shelves, reading areas, and the areas where the library officers work
5. Seminar, conference and presentation rooms

Table 1 : EN12464-1

EN 12464-1	**Em (lux)**	**Ra**
Offices		
Fields of Reading, Writing and Information	500	80
Fields of Technical Drawing	750	80
Fields of Computer Sciences	500	80
Archive	200	80
Retail sales buildings		
Fields of Sales	300	80
General Spaces		
Corridors	100	80
Ticket sale Offices	300	80
Restaurants and Hotels		
Reception, Vault, Officer Desk	300	80
Kitchen	500	80
Libraries		
Reading Areas	500	80
Closed Parking Lots		
Parking Lots	75	20
Training Buildings		
Classes, Teacher's Rooms	300	80

ENERGY 2- Parking lots, common areas

ENE 4: Outdoor Lighting

The Aim of this criteria to provide efficiency for armatures and elements used in order to enlighten the outdoor areas of the building, and to determine its features

The Evaluation Criteria

1- All the lighting lamp performances which are used for the lighting of vehicle and pedestrian roads and whose color feedback index is Ra 60 or more should be minimum 50 lm/W.

2. if the color feedback indexes of the lamps used for lighting armatures and lightings with projections are Ra 60 or higher, the lamp performance should be minimum 70 lm/W; if they are lower than Ra 60, the lamp performance should be minimum 80 lm/W.

3. if the lighting powers of outdoor routing, sign and uplight lighting armatures are equal or higher than 25W, the lamp performance should be minimum 60lm/W; if they are lower than 25W, the lamp performance should be 50lm/W.

Color Feedback Index: At night, the sensitivity of the eye which looks ahead slides through the blue zone of the visual spectrum. Within this concept, lamps with low color feedback spectrum, such as the ones with sodium vapor, sucks the yellow and red wave length of the visual spectrum, and they should have a higher exit lumen than a lamp with a higher color feedback index.

4. All the outer lighting armatures should be automatically controlled with a time relay or daylight sensor.

Pollution

POL 7: reduction of night lighting pollution

The Aim of this criteris; Concentration of the outdoor lighting only around lighting area; minimization of upside lighting devices; reduction of unnecessary light pollution, energy consumption and discomfort towards neighbor areas.

Evaluation Criteria:

1-Exterior Lighting, CIE 150-2003 (Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations)

The Aim of this criteria; to manage an energy-efficient harmless lighting area with the redirection of the light only towards the needed area and prevention of light loss towards the sky; not to negatively affect people's comfort and health with the minimization of glare in the eye; to maintain the naturality of the mystery of the night. (Yaman, 2011)

2- Specially located billboards should be lightened according to the following criteria:

a- surface lighting regularity of the specially located billboards should have the following values specified at the following table 2 :

Table 2 : Lighting Regularity (BREEAM, 2010)

Type of Lighting	Area of illumination	Regularity ofd Lighting
Indoor	Over 1,5 m2	10:1
Indoor	Till 1,5 m2	6:1
Outdoor	Over and between the light source	1,5:1

b- surface maximum glare values of the specially located billboards should have the following values specified at the following table 3 :

Table 3 : Maximum Glare Levels (CD/ m2) (BREEAM, 2010)

Area of Illumination (m2)	Zone E1	Zone E2	Zone E3	Zone E4
Till 10 m2	100	600	800	1000
Over 10 m2	Unspecified	300	600	600

3. All the outdoor lighting armatures except for the security lighting should be automatically deactivated between 11 pm and 7 am.

4- The security lighting which will be active between 11 pm and 7 am should be designed on the low lighting level specified on CIE 150-2003 ve CIE 126-1997 in table 4 (Yaman, 2011).

Table 4 : CIE 150:2003 (BREEAM, 2010)

ZONE	Intensity of E (lux)		Concentration I (cd)		Increasing Light rate URL %	Glare (cd/m2)	
	Between 7 am-11pm	Between 11pm-7am	Between 7 am- 11pm	Between 11pm-7am		facade	Signal lights
E1	2	0	2500	0	0	0	50
E2	5	1	7500	500	5	5	400
E3	10	2	10000	1000	15	10	800
E4	25	5	25000	2500	25	15	1000

Lighting comfort

This credit is a revision of the two lighting credits found in Green Star – Office Interiors v1.1 - IEQ-5 ‘High Frequency Ballasts’ and IEQ-6 ‘Electric Lighting Levels’.

Flickering lights, lights that render color poorly, and discomfort glare can result in a number of negative health impacts for building occupants, such as headaches, general fatigue and eye strain. Under the ‘Lighting Comfort’ credit, points are awarded where processes and strategies are in place to ensure that all lights are flicker- free, and render color accurately, and where discomfort glare is minimized. Points are also awarded where processes are in place to measure, monitor and manage lighting levels and ensure optimal lighting levels within a building's regularly occupied spaces. Different spaces and activities require different amounts of light and facilities management teams must ensure appropriate lighting levels are maintained in accordance with space use. (Green Star, 2013)

Visual comfort;

This credit is an amalgamation and expansion of three credits present in Green Star – Office Interiors v1.1 - IEQ-3 'Daylight', IEQ-4 'Daylight Glare Control' and IEQ-7 'External Views'. While access to daylight in a space is good for occupants, it is also important to include glare control systems to avoid the disruption or discomfort that can result from excessive glare. Striking the balance between natural light provision and glare minimization has traditionally been challenging for designers, and the amalgamation of these issues under a single credit will help to address this challenge (Green Star, 2013).

The 'Daylight & Views' credit encourages and rewards the provision of well-lit spaces that offer appropriate levels of natural daylight for the tasks regularly performed by building occupants (Green Star, 2013).

Evidence suggests that building occupants benefit from visual connections to the outdoors which offer a greater sense of time, weather and access to contextual focal points in the distance. Natural light and access to views external to the immediate workspace can help to prevent fatigue (Green Star, 2013).

Access to views can be provided externally or internally, such as via clear lines of sight to a courtyard or atrium. In addition to measuring the levels of daylight access in regularly occupied spaces, building owners or managers must also be able to demonstrate that they have made information and guidance available to building occupants or tenants on how they can maximise the benefits of the daylight within their space. This includes the development of guidance documentation which offers suggestions on how to best utilise views and daylight spaces (low partitions, no walls or shelving in front of windows, etc) (Green Star, 2013).

Greenhouse Gas Emissions;

This credit addresses the predicted energy consumption of lighting, equipment and supplementary systems. For offices, points are awarded based on the greenhouse gas emission reduction relative to the prescribed four star NABERS Energy benchmark. For other types of fitouts, a simple method is provided to calculate reductions in energy use. The ‘Greenhouse Gas Emissions’ credit is a conditional requirement for Green Star – Interiors PILOT.

Under the credit, the greenhouse gas emissions (GHG) generated by a building are calculated and compared against a GHG emission baseline.

The baseline is determined using historical greenhouse gas emissions data from comparable buildings and is taken to represent an ‘average performer’ within the market. Where no comparable buildings exist, historical data from the building itself can be used to determine average performance. Buildings are awarded points where a percentage decrease in GHG emissions relative to the ‘average performer’ benchmark can be demonstrated (Green Star, 2013).

In addition to benchmarking a building against average GHG performance for comparable buildings operating within the same climatic conditions, the ‘Greenhouse Gas Emissions’ credit will allow building owners to set and measure GHG emissions targets for their building over time (Green Star, 2013).

Peak electricity demand;

Peak demand refers to the maximum amount of electricity consumed by an electrical system at any one point in time and represents the accumulated demand of many electrical supply points across a system. ‘Network peak demand’ is the accumulated peak demand of all buildings and infrastructure on a supply network and is specified and monitored by electricity suppliers. The ‘Peak Electricity Demand’ credit recognizes and rewards operational practices that reduce peak demand on electricity supply infrastructure. A building's peak demand is determined by calculating its annual peak demand ratio and power factor, and comparing these results to a pre-defined benchmark. Points are awarded where the building's peak demand performance meets the network's peak demand ratio benchmark. Guidance is provided to teams in calculating peak electricity demand performance and completing the associated Green Star calculator (Green Star, 2013).

Light pollution;

This credit addresses an issue that is not covered in the Green Star - Office Interiors v1.1 rating tool, but that is addressed by other Green Star rating tools via the Emi-7 'Light Pollution' credit – that of light pollution from internal and external sources.

The 'Light Pollution' credit rewards operational practices that minimize direct and indirect light pollution during the night-time.

According to the International Dark Sky Association (IDA), light pollution is defined as any adverse effect resulting from the use of artificial lighting, such as sky glow, glare, light trespass and light clutter. Light pollution not only wastes energy, it also disrupts global wildlife and ecological balance and has been linked to negative human health outcomes.

Under the credit, points are awarded for operational practices that limit the impact of external light pollution during the performance period. The Australian Standard AS4282 – 1997 Control of Obtrusive Effects of Outdoor Lighting provides guidelines to address the effects of light pollution.

In addition to external light pollution, points may be achieved where operational and management practices that eliminate light pollution from internal sources are in operation throughout the performance period. As such, all internal lighting that can cause light pollution impacts must be automatically turned off when the building is unoccupied (certain exclusions apply and are outlined within the rating tool) (Green Star, 2013).

Monitoring and metering;

Quality monitoring strategies together with well calibrated metering systems are critical to the successful and sustainable operation of a building. Usage information from water and energy meters can act as a meaningful deterrent to wasteful behaviour and is a powerful tool to raise awareness of the financial and environmental benefits of reduced water and energy use.

Through metering and monitoring systems, facilities management teams can monitor water and energy use, conduct audits and manage consumption. Effective monitoring and metering strategies also offer a solid method for detecting leaks in water and energy systems, and are an effective means by which to fine tune operational procedures.

The 'Ongoing Monitoring and Metering' credit rewards the installation of water and energy meters and the implementation of metering and monitoring strategies that inform facilities management teams about usage patterns for their building. The credit rewards both a basic monitoring strategy that relies on regular readings, and an automated monitoring strategy that relies on automated data collection and interpretation (Green Star, 2013).

Lighting and illumination;

Evaluate efficient use of natural light (use of daylight), countermeasures against direct glare from light fixtures and direct daylight (glare countermeasures), the quantity and balance of brightness (illuminance), and the control of brightness and lighting positions (lighting control) (Casbee,2008).

Natural energy utilization;

Energy Efforts to reduce the energy load caused by the operation of the building are classified into 1 Building Thermal Load, 2 Natural Energy Utilization, 3 Efficiency in Building Service System and 4 Efficient Operation, which are all evaluated. Reductions in CO_2 emissions caused by energy consumption are to be evaluated under LR3 ‘ Consideration of Global Warming.’ (Casbee,2008).

Natural Energy Utilization evaluates efforts for direct use of natural energy (light and ventilation etc.) and converted use of renewable energy (solar generation, heat use etc.) (Casbee,2008).

Efficiency in building service system – lighting System;

Uses ERR values, calculated from CEC, and Point values for various equipment to evaluate the level of efficiency improvement in air conditioning, ventilation, lighting, hot water supply, elevators. For apartments, evaluate the CEC values or Point values of equipment, or the specifications and planned content of installed devices (Casbee,2008).

Consideration of surrounding environment - light pollution;

“3.1 Noise, Vibration and Odor” evaluates noise, vibration and odor generated by the operation of the building. “3.1.1 Noise” and “3.1.2 Vibration” base assessment on the degree of reduction of vibration and noise generated by the operation of building equipment etc., relative to the regulation standards of the Noise Regulation Law, Vibration Regulation Law and other ordinances. Assessment of “3.1.3 Odor” is based on concentrations of designated malodorous substances under the Offensive Odor Control Law, and on the odor index. (Casbee,2008).

3.2.1 Restriction of Wind Hazards" evaluates countermeasures against wind hazards in buildings thought likely to cause such hazards, and the efficacy of those countermeasures. 3.2.2 Restriction of Sunlight Obstruction" evaluates the level of measures taken to restrict the impact of sunlight obstruction on adjacent buildings and the surrounding area caused by the shadow of the building (Casbee,2008).

3.3 Light Pollution" evaluates countermeasures to restrict light pollution, such as light leakage from building exterior lighting, billboard lighting and the building itself, and glare of sunlight reflecting from building walls. Assessment is based on Ministry of the Environment guidelines (Casbee,2008)

Appendix 2 Green Star Certificate And Lighting Criteria

Green Star's lighting subjects are shortly explained below.

Lighting comfort

This credit is a revision of the two lighting credits found in Green Star – Office Interiors v1.1 - IEQ-5 'High Frequency Ballasts' and IEQ-6 'Electric Lighting Levels'.

Flickering lights, lights that render color poorly, and discomfort glare can result in a number of negative health impacts for building occupants, such as headaches, general fatigue and eye strain. Under the 'Lighting Comfort' credit, points are awarded where processes and strategies are in place to ensure that all lights are flicker- free, and render color accurately, and where discomfort glare is minimized. Points are also awarded where processes are in place to measure, monitor and manage lighting levels and ensure optimal lighting levels within a building's regularly occupied spaces. Different spaces and activities require different amounts of light and facilities management teams must ensure appropriate lighting levels are maintained in accordance with space use. (Green Star, 2013)

Visual comfort;

This credit is an amalgamation and expansion of three credits present in Green Star – Office Interiors v1.1 - IEQ-3 'Daylight', IEQ-4 'Daylight Glare Control' and IEQ-7 'External Views'. While access to daylight in a space is good for occupants, it is also important to include glare control systems to avoid the disruption or discomfort that can result from excessive glare. Striking the balance between natural light provision and glare minimization has traditionally been challenging for designers, and the amalgamation of these issues under a single credit will help to address this challenge (Green Star, 2013).

The ‘Daylight & Views’ credit encourages and rewards the provision of well-lit spaces that offer appropriate levels of natural daylight for the tasks regularly performed by building occupants (Green Star, 2013).

Evidence suggests that building occupants benefit from visual connections to the outdoors which offer a greater sense of time, weather and access to contextual focal points in the distance. Natural light and access to views external to the immediate workspace can help to prevent fatigue (Green Star, 2013).

Access to views can be provided externally or internally, such as via clear lines of sight to a courtyard or atrium. In addition to measuring the levels of daylight access in regularly occupied spaces, building owners or managers must also be able to demonstrate that they have made information and guidance available to building occupants or tenants on how they can maximise the benefits of the daylight within their space. This includes the development of guidance documentation which offers suggestions on how to best utilise views and daylight spaces (low partitions, no walls or shelving in front of windows, etc) (Green Star, 2013).

Greenhouse Gas Emissions;

This credit addresses the predicted energy consumption of lighting, equipment and supplementary systems. For offices, points are awarded based on the greenhouse gas emission reduction relative to the prescribed four star NABERS Energy benchmark. For other types of fitouts, a simple method is provided to calculate reductions in energy use. The ‘Greenhouse Gas Emissions’ credit is a conditional requirement for Green Star – Interiors PILOT.

Under the credit, the greenhouse gas emissions (GHG) generated by a building are calculated and compared against a GHG emission baseline.

The baseline is determined using historical greenhouse gas emissions data from comparable buildings and is taken to represent an ‘average performer’ within the market. Where no comparable buildings exist, historical data from the building itself can be used to determine average performance. Buildings are awarded points where a percentage decrease in GHG emissions relative to the 'average performer' benchmark can be demonstrated (Green Star, 2013).

In addition to benchmarking a building against average GHG performance for comparable buildings operating within the same climatic conditions, the 'Greenhouse Gas Emissions' credit will allow building owners to set and measure GHG emissions targets for their building over time (Green Star, 2013).

Peak electricity demand;

Peak demand refers to the maximum amount of electricity consumed by an electrical system at any one point in time and represents the accumulated demand of many electrical supply points across a system. 'Network peak demand' is the accumulated peak demand of all buildings and infrastructure on a supply network and is specified and monitored by electricity suppliers. The 'Peak Electricity Demand' credit recognizes and rewards operational practices that reduce peak demand on electricity supply infrastructure. A building's peak demand is determined by calculating its annual peak demand ratio and power factor, and comparing these results to a pre-defined benchmark. Points are awarded where the building's peak demand performance meets the network's peak demand ratio benchmark. Guidance is provided to teams in calculating peak electricity demand performance and completing the associated Green Star calculator (Green Star, 2013).

Light pollution;

This credit addresses an issue that is not covered in the Green Star - Office Interiors v1.1 rating tool, but that is addressed by other Green Star rating tools via the Emi-7 'Light Pollution' credit – that of light pollution from internal and external sources.

The 'Light Pollution' credit rewards operational practices that minimize direct and indirect light pollution during the night-time.

According to the International Dark Sky Association (IDA), light pollution is defined as any adverse effect resulting from the use of artificial lighting, such as sky glow, glare, light trespass and light clutter. Light pollution not only wastes energy, it also disrupts global wildlife and ecological balance and has been linked to negative human health outcomes.

Under the credit, points are awarded for operational practices that limit the impact of external light pollution during the performance period. The Australian Standard AS4282 – 1997 Control of Obtrusive Effects of Outdoor Lighting provides guidelines to address the effects of light pollution.

In addition to external light pollution, points may be achieved where operational and management practices that eliminate light pollution from internal sources are in operation throughout the performance period. As such, all internal lighting that can cause light pollution impacts must be automatically turned off when the building is unoccupied (certain exclusions apply and are outlined within the rating tool) (Green Star, 2013).

Monitoring and metering;

Quality monitoring strategies together with well calibrated metering systems are critical to the successful and sustainable operation of a building. Usage information from water and energy meters can act as a meaningful deterrent to wasteful behaviour and is a powerful tool to raise awareness of the financial and environmental benefits of reduced water and energy use.

Through metering and monitoring systems, facilities management teams can monitor water and energy use, conduct audits and manage consumption. Effective monitoring and metering strategies also offer a solid method for detecting leaks in water and energy systems, and are an effective means by which to fine tune operational procedures.

The ‘Ongoing Monitoring and Metering’ credit rewards the installation of water and energy meters and the implementation of metering and monitoring strategies that inform facilities management teams about usage patterns for their building. The credit rewards both a basic monitoring strategy that relies on regular readings, and an automated monitoring strategy that relies on automated data collection and interpretation (Green Star, 2013).

Appendix 3 CASBEE Certificate And Lighting Criteria

Casbee's lighting subjects are shortly explained below.

Lighting and illumination;

Evaluate efficient use of natural light (use of daylight), countermeasures against direct glare from light fixtures and direct daylight (glare countermeasures), the quantity and balance of brightness (illuminance), and the control of brightness and lighting positions (lighting control) (Casbee,2008).

Natural energy utilization;

Energy Efforts to reduce the energy load caused by the operation of the building are classified into 1 Building Thermal Load, 2 Natural Energy Utilization, 3 Efficiency in Building Service System and 4 Efficient Operation, which are all evaluated. Reductions in CO_2 emissions caused by energy consumption are to be evaluated under LR3 ' Consideration of Global Warming.' (Casbee,2008).

Natural Energy Utilization evaluates efforts for direct use of natural energy (light and ventilation etc.) and converted use of renewable energy (solar generation, heat use etc.) (Casbee,2008).

Efficiency in building service system – lighting System;

Uses ERR values, calculated from CEC, and Point values for various equipment to evaluate the level of efficiency improvement in air conditioning, ventilation, lighting, hot water supply, elevators. For apartments, evaluate the CEC values or Point values of equipment, or the specifications and planned content of installed devices (Casbee,2008).

Consideration of surrounding environment - light pollution;

“3.1 Noise, Vibration and Odor” evaluates noise, vibration and odor generated by the operation of the building. “3.1.1 Noise” and “3.1.2 Vibration” base assessment on the degree of reduction of vibration and noise generated by the operation of building equipment etc., relative to the regulation standards of the Noise Regulation Law, Vibration Regulation Law and other ordinances. Assessment of “3.1.3 Odor” is based on concentrations of designated malodorous substances under the Offensive Odor Control Law, and on the odor index. (Casbee,2008).

3.2.1 Restriction of Wind Hazards” evaluates countermeasures against wind hazards in buildings thought likely to cause such hazards, and the efficacy of those countermeasures. 3.2.2 Restriction of Sunlight Obstruction” evaluates the level of measures taken to restrict the impact of sunlight obstruction on adjacent buildings and the surrounding area caused by the shadow of the building (Casbee,2008).

3.3 Light Pollution” evaluates countermeasures to restrict light pollution, such as light leakage from building exterior lighting, billboard lighting and the building itself, and glare of sunlight reflecting from building walls. Assessment is based on Ministry of the Environment guidelines (Casbee,2008)

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Ebru ALAKAVUK (Supervisor)

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Ecehan ÖZMEHMET

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Eray BOZURT

Prof. Dr. Behzat GÜRKAN

Director of the Graduate School

TEXT OF OATH

I declare and honestly confirm that my study, titled "The Evaluation of the Office Buildings According to LEED Certificate Lighting Criteria" and presented as a Master's Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions, that all sources from which I have benefited are listed in the bibliography, and that I have benefited from these sources by means of making references.