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LEED certification analysis for an existing building: Credit opportunities and recommendations

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ABSTRACT

The leadership in energy and environmental design (LEED) is a widely adopted green building certification system. LEED certification assesses buildings across five primary categories, which include sustainable site planning, efficient water usage, energy and atmosphere efficiency, material and resource utilization, and indoor air quality. Based on the results of this assessment, buildings that accumulate sufficient points across these categories can receive LEED certification. It is crucial to reduce resource and energy consumption in the certification process while maintaining building comfort. In the report announced by the U.S. Green Building Council (USGBC), the country with the most LEED certification projects in 2022 is China with 1121 projects, followed by India with 323 projects, and Canada with 248 projects. According to the USGBC 2023 database, a total of 1249 buildings in Turkey have received LEED certification. This paper focuses on the evaluation of an existing office building within the framework of LEED certification and calculating its LEED score. The building has been assessed against the stipulated criteria, and recommendations have been provided to facilitate the attainment of LEED certification. According to the studies carried out, it has been calculated that the existing office building can achieve a total of 47 points according to the LEED V4.1: operations and maintenance (O+M) version and can obtain a LEED certificate with this score. If the possibilities and suggestions are examined, it is assumed to be possible to increase the current score by 12 points.

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1. INTRODUCTION

According to the International Energy Agency's (IEA) 2023 tracking clean energy progress report, the operations of buildings account for 30% of global final energy consumption and 26% of global energy-related emissions [1]. At the same time, it accounts for 42% of water consumption, 50% of greenhouse gas emissions, 40% of drinking water pollution, 24% of air pollution and 50% of chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) emissions [2]. Increased energy consumption is becoming a critical factor in mitigating climate change and is threatening the achievement of countries' national targets for reducing energy consumption. Due to the global energy crisis, existing buildings must reduce their energy consumption [3]. Internet of Things (IoT)-based energy management systems and smart lighting systems can create important opportunities for reducing the energy consumption of existing buildings [4]. Smart lighting and effective energy management are made possible by IoT, which refers to a network of sensors, software and other technologies that are connected to and exchange data with other devices/requests over the internet. Smart lighting systems with control modules, distributed light and motion sensors, and microcontrollers will provide a significant opportunity for LEED certification credits [5]. Green building certification programs, such as LEED, provide an effective way of implementing intelligent energy management systems that help to reduce the energy consumption of existing buildings quickly and cost-effectively [6]. Positioned as a key player in the global landscape of green building certification systems, LEED is designed to reduce the negative environmental impact of buildings and improve energy efficiency. Widely recognized as the preeminent building rating tool in the United States, LEED has gained increasing prominence both domestically and internationally. Its market share continues to grow, reflecting the growing

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recognition and adoption of sustainable building practices on a global scale [7].

Approximately 35% of LEED credits are dedicated to addressing climate change issues, with a further 20% specifically dedicated to improving human health. In addition, 15% of credits focus on sustainable practices related to water resources, while 10% contribute to the preservation of biodiversity. Another 10% of LEED credits are dedicated to promoting the green economy, underscoring the importance of environmentally responsible business practices. The remaining 5% is dedicated to promoting community well-being and conserving natural resources. This distribution reflects the LEED certification system's comprehensive approach to addressing diverse and interrelated facets of sustainability in the built environment. LEED credits cover a range of critical elements, including mitigating climate change, promoting human health, managing water resources, conserving biodiversity, supporting the green economy, and enhancing social and natural resource sustainability [8].

Figure 2 shows the LEED O+M V4.1 rating table with the required credits for existing buildings. The score table in Figure 2 is displayed along with the number of credits required. High points are shown in dark brown and low points are shown in light brown. Headings in green are mandatory for LEED certification. According to this table, apart from the mandatory topics, the highest score can be achieved under the topics of energy performance and indoor environmental quality performance. These are followed by issues related to water and transport. Accordingly, the improvements to be made in the energy performance of existing buildings to achieve LEED certification are the potential improvements with the highest point yield. The LEED certification system is a central framework that has been carefully designed to not only reduce the use of resources in buildings but also to raise standards of indoor air quality, particularly in offices where people spend a significant part of their daily lives [9]. This systematic approach to sustainable design and construction has garnered attention and acclaim, with research consistently showing a significant increase in occupant satisfaction in certified buildings compared to their non-certified counterparts [10]. In the evolving landscape of the real estate market, LEED certification has emerged as a defining factor influencing stakeholder decisions and preferences. The United States Green Building Council (USGBC) estimates that approximately five million people currently occupy LEED-certified buildings, underscoring the widespread impact of this certification on the built environment [11]. This research begins an exploration of the practicalities of LEED certification by examining an existing office building. The evaluation process involves a meticulous examination of the multiple criteria included in the various categories of the LEED certification rating system. This comprehensive analysis serves as a baseline for understanding the building's current status about the coveted certification. To assess the building's viability for LEED certification, precise measurements were taken to calculate the potential points achievable within the existing structural and operational framework. Strategic recommendations were then formulated to address and fill gaps in categories where points were lacking. This tailored approach ensures a nuanced and effective strategy to successfully navigate the certification process [8].

Energy consumption, a critical aspect of sustainable building practices, was subjected to a detailed assessment. This involved categorizing and analyzing the amount of energy used in the building, paving the way for targeted improvements in line with the stringent LEED standards. In addition to the technical assessment, the study delves into the procedural intricacies of achieving LEED certification. Necessary procedures and processes are discussed in detail, providing a roadmap for stakeholders seeking to navigate the certification journey. By addressing the building's compliance with the established criteria and suggesting improvements, this study contributes significantly to the broader discourse on sustainable building practices and highlights the tangible benefits of LEED certification in promoting healthier, greener workplaces and buildings [8].

An examination of the studies on different topics aimed at ensuring sustainability through energy efficiency in buildings showed that the studies mainly consisted of the following topics as green rating systems, policies, techniques, technologies and strategies used to increase energy efficiency to achieve sustainability in buildings, environmental impacts, economic impacts and studies to improve the comfort, health and well-being of building occupants. To reduce material consumption, increase renewable energy and achieve better results for green building development, the LEED green building certification system was identified as the most widely used rating system to achieve sustainable development goals in buildings [12]. In 2018, Kim et al. conducted work on the reduction of building energy consumption through the management of building heating, ventilation and air conditioning (HVAC) systems within the framework of the LEED certification process. In this study, a LEED-certified building was examined, a dynamic simulation of the HVAC systems was performed, and a building energy model was created. The real-time energy consumption of the building in South Korea was monitored and compared with the dynamic simulation results. During the performance check, it was found that the cooling pump runs continuously at the maximum flow rate when cooling is required. However, the flow rate should be designed to increase as the number of AHU operations increases. After identifying the performance deficiencies in the HVAC system, the operation of the fan and cooling pumps was analyzed through dynamic simulation and it was observed that the energy consumption was reduced by 5.3% with the commissioning of the HVAC system [13]. In [14], Tolga et al. proposes an analysis up to 20% energy savings can be achieved with thermal insulation.

In 2013, Cardenas et al. developed a methodology for LEED for healthcare facilities. For this purpose, a preliminary assessment was carried out in the energy and atmosphere category before starting the certification process in new and existing healthcare facilities. The main parameters evaluated in this category are the commissioning of building energy systems, energy performance, use of renewable energy and basic refrigerant method. In addition, a list of necessary steps for the LEED certification process was developed. Once the requirements were met, electricity consumption was assessed by interviewing administrative and nursing staff in five major hospitals in Medellin, Colombia. The annual energy consumption of the hospitals was determined and an average energy performance index was calculated. Potential energy savings were also identified [15]. In 2015, Rashawn et al. conducted an energy benchmarking study for LEED-certified residential buildings in Manitoba, Canada. The annual water consumption data of the buildings were recorded and compared with the consumption density index for Manitoba. At the end of the study, it was confirmed that the energy consumption of LEED-certified buildings was lower than that of standard residential buildings [16]. Vosoughkhosravi et al. studied a LEED-certified university building and compared it with non-LEED-certified buildings. They found that the LEED-certified building had higher energy consumption than the non-LEED-certified building, but also had a higher satisfaction rating for overall comfort. It was concluded that the high energy consumption of the LEED-certified building was due to its low score in the Energy and Atmosphere category, and its better performance in overall comfort satisfaction was due to its acceptable score in the Indoor Environmental Quality category [17]. In their research, Weilin et al. investigated the influence of LEED certification on office rental values in China. Their findings revealed that, on average, the rental premium for LEED-certified buildings was 19.5% higher than that for non-LEED buildings [18].

In this study, Section 2 gives the LEED application process for readers, while Section 3 explains the evaluation of the office buildings with O+M. Lastly, the conclusion remarks are elucidated in Section 4.

2. LEED APPLICATION PROCESS

LEED certification can be applied at any stage of the building design and construction process. However, early application makes it easier to apply the building criteria to the project and achieve certification. The LEED certification process begins with registration of the system while the project is still in the design phase. Once the required documentation has been collected and the application completed, green business certification Inc. (GBCI) reviews the documentation. Figure 1 shows the steps in the application process [19]. The LEED certification process begins with the online registration of the project and consists of six basic stages.

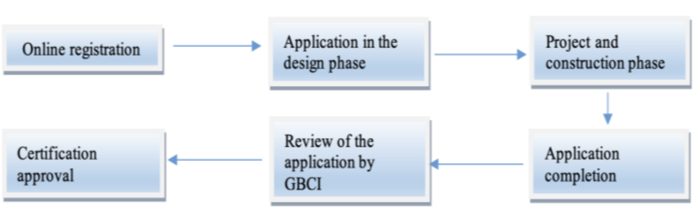

Fig. 1. LEED certification application process [19].

2.1. Needs Program and Concept

It is at this stage that the project site is identified and development decisions are made. Incorporating the LEED design criteria into the building design and construction process at this stage offers the investor convenience and time savings to achieve the desired certification [19].

Sustainable Sites	Rainwater Management (1)	Heat Island Reduction (1)	Light Pollution Reduction (1)	Site Management (1)		
Location and Transportation	Transportation Performance (14)					
Water Efficiency	Water Performance (15)					
Energy and Atmosphere	Energy Efficiency Best Management Practices (Required)	Fundamental Refrigerant Management (Required)	Energy Performance (33)	Enhanced Refrigerant Management (1)	Grid Harmonization (1)	
Indoor Environmental Quality	Minimum Indoor Air Quality (Required)	Environmental Tobacco Smoke Control (Required)	Green Cleaning Policy (Required)	Indoor Environmental Quality Performance (20)	Green Cleaning (1)	Integrated Pest Management (1)
Materials and Resources	Purchasing Policy (Required)	Facility Maintenance and Renovations Policy (Required)	Waste Performance (8)	Purchasing (1)		
Innovation	Innovation (1)					

Fig 2. LEED O+M score table for existing buildings, rating for certification can be split up four sections certified (40-49 points), silver (50-59 points), gold (60-79 points), and platinum (80+) [8].

Proper management of this phase makes it easier for the project to score in the sustainable category. Green building implementation meetings should be held under the leadership of the LEED consultant assigned to this phase. These meetings will help determine the distribution of tasks among the project disciplines by the LEED certification goal. The first LEED scorecard is determined and entered into LEED online at this stage and the process is formally launched. All prerequisites must be met and the testing and commissioning team should be involved in the project [19].

2.2. Preliminary Projects

This phase follows the LEED goals and green building criteria applied in the previous process. Design development meetings and analysis studies are conducted. Draft energy and daylighting modelling reports, task and responsibility tables, water savings calculations, and sustainable materials calculations are prepared. Energy-saving systems identified as a result of the modelling should be applied to the building [19].

2.3. Final Project

This phase is essentially the process of finalizing the decisions made during the pre-project process and incorporating the identified systems into the project. Final energy and daylighting modelling reports are completed and all LEED criteria are integrated into the material specifications and plans [19].

2.4. Tender Documents

Work on the LEED design criteria has been completed at this stage and submitted to GBCI on LEED Online for review. By GBCI's comments, revisions and additional work will be completed and resubmitted as necessary, and LEED design work will be finalized following GBCI's final decision.

2.5. Construction

The design criteria applied to the project during construction should be applied with the same care during construction. Waste management, indoor air quality, and material specifications should be carefully monitored to achieve the highest possible score. During the testing and commissioning phase, measurement and control studies should be carried out and the results of modelling studies should be verified. Maintenance and operations manuals and tenant building use guides are prepared by training the testing and commissioning team. After the related reports are completed, the LEED construction process is completed and delivered again through LEED online [19].

2.6. Certification

If the applications for LEED design and construction criteria submitted through LEED Online are approved, a LEED certificate will be awarded. Building occupants and visitors should be educated about the LEED green building criteria. If desired, the investor can reapply for the LEED certificate for existing buildings to review the operation of the building after a few years [19].

3. EVALUATION OF THE OFFICE BUILDING ON LEED V4.1 EXISTING BUILDINGS OPERATIONS AND MAINTENANCE

In this section, the scores obtained from the credits in the LEED categories are calculated as a sample office building. The office building shown in Figure 3 was constructed in 2012 in Istanbul/Şişli. The project concept is designed as a cultural, entertainment and business center. The building consists of four basement floors with parking, three basement floors with cinema, one connecting floor, nine office floors, one terrace floor, one engine room floor and one attic floor.

The total construction area of the project shown below is 19,383.22 m^2. The LEED V4.1 EB: O + M (LEED V4.1 Existing Buildings Operations and Maintenance) version prerequisite and credit table shown in Table 5 including the points. Accordingly, the office building has been assessed against the LEED certification system. The assessment is based on the LEED V4.1 EB: O + M format and version. However, as this version is still under development, the LEED V4 EB: O + M and LEED V4: BD + C (LEED Building Design and Construction) versions were used for some credits where the methodology is not clear [20]. The typical office floor of the building with the concept of office and culture is shown in Figure 4.

Fig. 3. Şişli culture, entertainment and business center project.

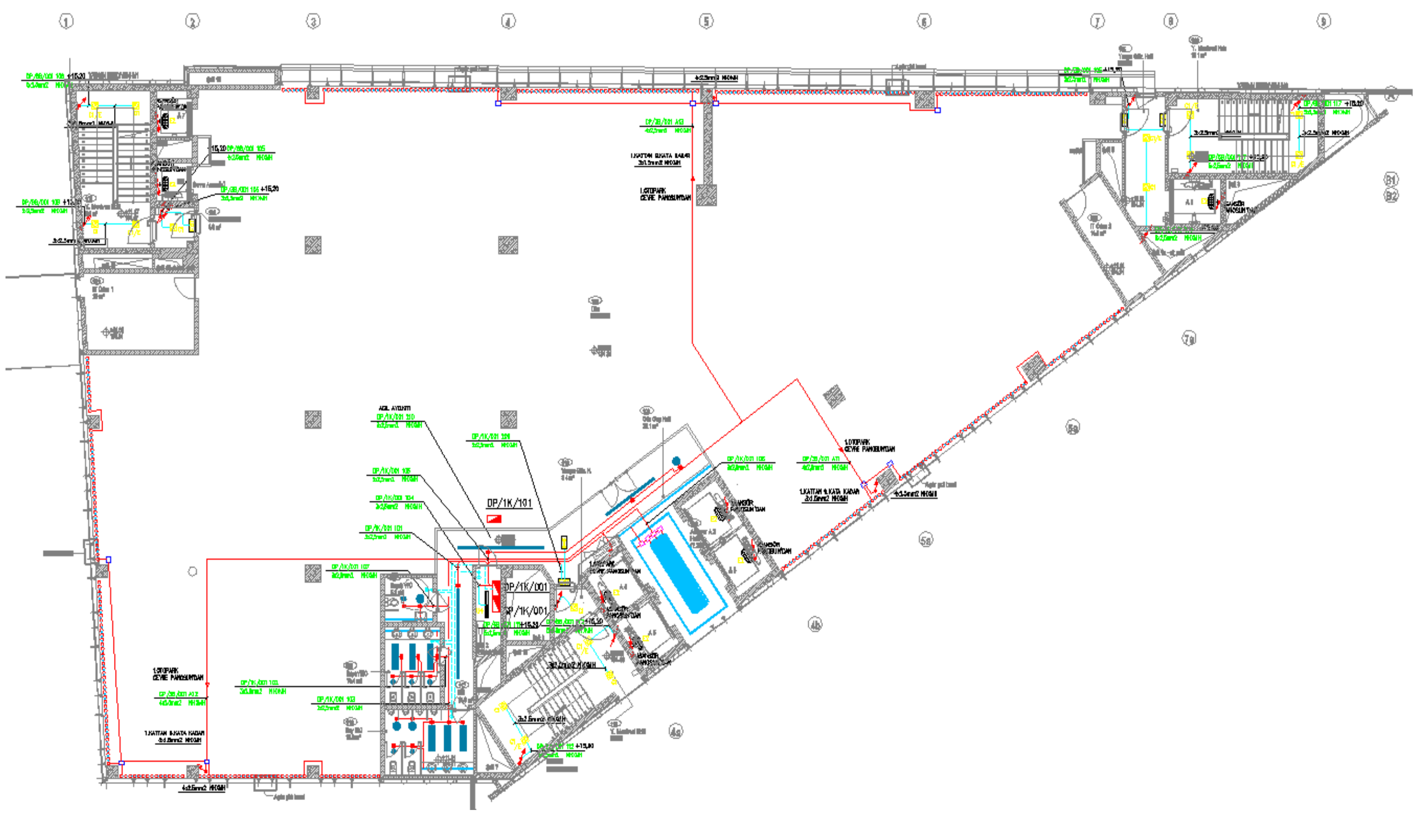

Fig. 4. AutoCAD drawing of an office building's typical office floor.

3.1. Location and Transportation

A survey of the building's occupants was carried out to calculate the score for this category. According to the data obtained from the building management, the number of building users is approximately 600 people. Accordingly, the required number of responses was determined as 600 × 0.208 = 124.8 using the corresponding equation. However, 104 people were surveyed in all rented offices, as surveys were not allowed. The number of people to be interviewed is calculated using Equation (1),

$$MNPP = 100 \times \frac{0.25}{NE \div 500} = 100 \times \left(\frac{0.25}{\frac{600}{500}}\right) = \%20.8 \quad (1)$$

The questions asked in the survey are as follows:
a) Return and return distances (km)
b) Types of vehicles used in departure and return
c) Transportation satisfaction

After receiving the questionnaire answers, CO_{2e}valuations were obtained for each building with the help of Equation (2).

$$For\ the\ route\ CO2_e(I_{bs}) = \frac{CO2_e(I_{bs})}{mile} \times DT(mile) \quad (2)$$

By using Equation (3), CO_{2e}values in one direction were calculated. Finally, Equation (4) was used to determine the $CO2_e(I_{bs})$ value in one direction for a building user.

$$IP = \frac{\text{CTR}}{NR} \quad (3)$$

$$OWPBUV = \frac{OWTEBU}{NPS} \quad (4)$$

Where, minimum number of people to poll is *MNPP*, number of employees gives *NE*, distance traveled denotes *DT*, for individual passengers CO_{2e} (I_{bs}) is *IP*, composed for total routes is *CTR*, the number of routes is *NR*, one-way project for a building user CO_{2e} (I_{bs}) value is *OWPBUV*, one-way total for each building user CO_{2e} (I_{bs}) value is *OWTEBU*, and lastly the number of people surveyed gives *NPS*.

According to the survey table, the value of $CO2_e$ (I_{bs}) in one direction for a building user was calculated as 5.30. According to LEED criteria, the transportation performance score is 90. According to the transportation performance value, the LEED score that can be obtained is 13. The achievement of this score was because the business center is approximately 300 m away from the bus stops and the Istanbul M2 metro line.

3.2. Sustainable Environment

3.2.1. Storm Water Management

There is no rainwater treatment in the building. Stormwater is sent directly to the sewer. No return on points can be obtained from this loan. It is foreseen that the green roof application will provide a return on points from this loan.

3.2.2. Heat Island Reduction

The studied building does not have a green roof. The roof of the building is pitched and it is shown in Figure 5. The area of the roof is approximately 165 m^2. The total area outside the roof is approximately 220 m^2. The building has a hard floor area of about 120 m^2. The roof is highly reflective. As there is no vegetation on the roof, this value is taken as 0. For thermal insulation, sprayed insulation has been applied to the roof. The criterion that provides the points return from this loan is evaluated using Equation (5) below [21].

$$\frac{Unroofed\ areas}{0.50} + \frac{High\ reflective\ roof\ area}{0.75} + \frac{Planted\ roof\ area}{0.50} \geq Pavement\ floor\ area + Roof\ area \quad (5)$$

According to this;

$$(220 \div 0.50) + (0 \div 0.75) + (0 \div 0.50) >= 120 + 165$$

When the values specified in Equation (5) are written instead of the values, it is seen that the relevant criterion cannot be met.

Fig. 5. The view of the office building roof.

There are approximately 100 m^2 of landscaped grounds around the building. A gardener is employed for weekly maintenance. There are no energy generation systems on the site, such as solar thermal panels, photovoltaics or wind turbines. Given the slope of the roof, it is necessary to use roofing material with a high solar reflectance index (SRI) value. According to Figure 5, a material with an initial SRI of 82 should be used as it enters the low slope group. Although the roofing material is concrete tiles, it has an SRI value of 25. Therefore, it cannot be considered a highly reflective roof. There is no vegetation on the roof. The equipment on the roof should be installed in the shade.

3.2.3. Light Pollution Reduction

For this credit, the lighting calculation for the facades of the building has been assessed during the design phase. Accordingly, point can be obtained from this credit. In Figure 6, two facade luminaires are used with simulated positions for the south facade. The luminaires are positioned with light in mind. Instead of using a large number of luminaires, two high-performance lighting solutions have been proposed. The luminaire wattages are 1078 W and the luminous flux is 10000 lumens. This design ensures that there is no light pollution in the environment. According to the simulation, the average luminous intensity is calculated to be 198 lux and sufficient luminous flux is provided. It is also recommended that LED luminaires be used for lighting. LED luminaires are widely used in commercial lighting systems because of their long-life, high-energy efficiency and flexibility of design and control [22].

The illuminance calculation was made for the fixture to be used in the building facade fixture. According to the calculations made, it is calculated that two luminaires will provide the necessary illumination without causing light pollution.

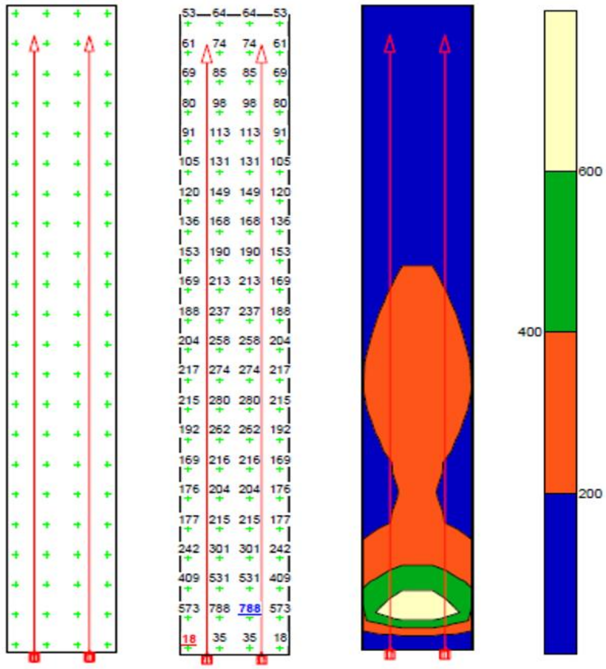

Fig. 6. South facade lighting simulation lighting layout.

3.3. *Water Efficiency*

Water meter data was used to determine water consumption for the project. Total potable water consumption was recorded monthly for one year. To calculate water consumption, data in liters and m^3 were converted to gallons. Monthly water consumption in kWh, liters, m^3 and gallons is shown in Table 1. As water consumption in kWh is included in heating and cooling, pure water consumption is not included in the calculation. The reference water consumption has been calculated according to the consumption of water-consuming equipment in Table 2. In addition to Table 2, the consumption of the special toilet faucet is also included. The following data were used to calculate the water performance value.

The actual consumption values calculated according to Table 1 are approximately 29 times the reference water consumption. Since there is no more than 120% according to the criterion, no points can be obtained from this category.

According to the current situation, the applications to be made to provide savings can be suggested as follows.

i. Flow stabilizers and flow aerators
ii. Automatic battery sensors
iii. Control with timed connections
iv. Reservoir and urinal systems that consume less water

Table 1. Monthly water consumption values of office buildings.

	Month	*Year*	*Water consumption (kWh)*	*Water consumption (lt.)*	*Water consumption (m^3)*	*Total water consumption (gallon)*
1	June	2018	1,415,164	2.788,406	19,045	5,767,256.83
2	July	2018	1,415,171	2.893,275	19,316	5,866,532.32
3	August	2018	1,415,187	2.971,796	19,506	5,937,454.16
4	September	2018	1,415,194	3.063,187	19,746	6,024,982.19
5	October	2018	1,415,194	3.167,767	20,054	6,133,955.67
6	November	2018	1,433,153	3.281,547	20,363	6,245,622.12
7	December	2018	1,470,441	3.379,067	20,632	6,342,429.13
8	January	2019	1,507,563	3.476,298	20,916	6,443,122.39
9	February	2019	1,541,419	3.571,026	21,184	6,538,928.14
10	March	2019	1,591,927	3.743,596	21,697	6,720,005.83
11	April	2019	1,596,710	3.779,800	21,797	6,755,980.69
12	May	2019	1,596,733	3.939,081	22,208	6,906,604.74
	Total		17,813,856	40.054,846	246,464	75,682,874.22

Table 2. Building annual water consumptions according to the energy policy act (EPAct).

Water consumption equipment	*Daily use*	*Flow rate*		*Quantity / Time*	*Number of users*	*The number of visitors*	*Total water requirement (lt.)*	*Total water requirement (gallon)*
Closet (man)	2	6	liter/flush	1	375	50	5,100	1,346.4
Urinal	2	3.8	liter/flush	2	375	50	6,460	1,705.44
Closet (woman)	3	6	liter/flush	3	225	35	14,040	3,706.56
Faucet	3	8.3	liter/minute	0.25	600	35	3,953	1,043.559
Special faucet	2	1	liter/minute	0.25	600	-	300	79.2
Kitchen faucet	10	8.3	liter/minute	0.25	9	-	187	49.302
Shower machines		9.5	liter/minute	5	-	-	0	0
Dishwasher	3	15	liter/washing	16	1	-	720	190.08
Daily use	-	-	-	-	-	-	3,0760	8,121
Annual working days	-	-	-	-	-	-	312	312
Total yearly							9,597,003	2,533,608.79

3.4. Energy and Atmosphere

The following prerequisites must be met for the energy and atmosphere category.

- Energy efficiency management applications
- Basic refrigerant management

An advanced metering system has been installed in the building for energy efficiency management applications. Consumption data measured by the meters is transferred to the building management system (BMS) system and daily energy consumption is reported. A minimum of 36 months of meter data can be stored in the system. This is a requirement for LEED. No CFC based refrigerant equipment is used in the office building. This requirement is provided for LEED.

Total building energy consumption (electricity, water, natural gas) was measured and recorded over the installed meters. The meters are calibrated within the range recommended by the manufacturer. Energy consumption for the energy performance score was measured monthly for a year. Greenhouse gas emissions and source energy determine the energy performance score for the LEED. While, the total energy consumption is calculated in Table 3, the gas consumption values are given in Table 4.

LEED points are calculated based on the project's score for each metric; the greenhouse gas emissions score and the energy source score are 50% dependent on the energy performance score. To calculate greenhouse gas emissions, electricity, water and natural gas consumption was calculated in gallons and converted to greenhouse gas emissions using the EPA interface [23].

Accordingly, the annual equivalent greenhouse gas emission calculated at the interface is 76,575.014 metric tons of CO_2 equivalent ($mTCO_{2e}$). A comparative consumption scheme is generated in Figure 7 for the CO_2 emissions corresponding to the calculated greenhouse gas emissions.

In the office building, cooling is provided by a variable refrigerant volume (VRF) system, split air conditioners and air handling units. R410A gas was selected as the refrigerant. The ODP value of R410A is 0. According to the formula, the LCODP value was calculated as 0. The global warming potential (GWP) value is 2000 for 100 years. Refrigerants used in heating, ventilation, air conditioning and refrigeration (HVAC&R) equipment should be identified to minimize or eliminate emissions of compounds that contribute to ozone depletion and climate change. The combination of all new and existing HVAC&R equipment serving the project in the SI unit system shall meet the criteria set out in Table 5 and Table 6 [24-25].

The LCODP value was calculated to be 0 according to the formula. The GWP value is 2000 per 100 years.

In this case, the LCGWP value was calculated by proportioning the refrigerant condition according to the load values for each HVAC equipment given in Table 7. The calculation was made according to SI units. In a 10 horse power (HP) system with R410A, the total gas charge is calculated as follows [26]. The external unit gas charge is 8.4 kg. Additional gas charge, average pipeline length is 30 m. The average refrigerant amount is calculated as 0.059 kg x 20 = 1.18 kg since the average refrigerant amount is 20 m and 1/2" pipe length is 0.059 kg. Since the average length of the pipe with a diameter of 1/4"is 10 m and the amount of refrigerant in the 1/4" pipe is 0.022 kg, the total refrigerant amount is calculated as 0.022 kg x 10 = 0.22 kg. Since the average length of the pipe with a diameter of 1/4" along the line is 10 m (10 m, 1/4") x 0.022 (kg) x 10 = 0.22 kg. Total gas charge in the system = 8.4 + 1.18 + 0.22 = 9.8 kg.

Table 8 shows the total power and annual electricity consumption of pumped heating, air conditioning and ventilation systems on a site basis. Room energy densities were calculated according to site areas. The refrigerant charge was calculated according to the power value of each unit to determine the improved cooling management criterion. The 10 HP system is designed for office equipment. Using Table 6, Table 7 and its equation, the criterion based on the weighted average of the building for more than one piece of equipment was calculated and a value of 3025.26 was obtained. The corresponding calculation is shown in Table 7. According to the calculation, 3025.26 > 13 improved cooling management criteria could not be achieved and no points could be obtained from this credit.

The annual electricity consumption of the office building is shown in Figure 8. These values have been obtained from the BMS. The daily consumption of electricity, water and natural gas from the BMS system is filtered on a monthly and on-site basis. Single line graphs in the project package were used to compare energy consumption by site. As shown in Figure 8, the areas with the highest energy consumption are offices. The areas with the lowest consumption are uninterruptible power system (UPS) systems. The annual electricity consumption planned during the project design phase was calculated using the installed power values by separating the loads connected to the panels as lighting, socket, equipment, motor and sub-panel load. The planned electricity consumption according to single-line diagrams is shown in Table 9.

Annual energy consumption is calculated using the Boğaziçi electricity consumption calculator interface [27]. Table 9 shows the annual electricity consumption designed by districts and load types.

Table 3. Energy consumption is calculated for greenhouse gas emissions.

Consumption type	*Energy consumption*	*Unit*	*Gallon*
Electricity	1,922,879.00	kWh	51,917.73
Natural gas	37,663.00	m^3	9,949,434.71
Water	17,813,856.00	kWh	480,974.11
Water	40,054,846.00	lt	10,574,479.34
Water	246,464.00	m^3	65,108,394.88
Total			86,165,200.78

Table 4. Natural gas consumption data.

	Month	*Year*	*Natural gas consumption (m^3)*	*Total natural gas consumption (gallon)*
1	December	2017	7,835	2,069,771.95
2	January	2018	8,365	2,209,782.05
3	February	2018	7,495	1,979,954.15
4	March	2018	6,639	1,753,824.63
5	April	2018	4,406	1,163,933.02
6	May	2018	0	0.00
7	June	2018	0	0.00
8	July	2018	0	0.00
9	August	2018	0	0.00
10	September	2018	0	0.00
11	October	2018	0	0.00
12	November	2018	2,923	772,168.91
	Total		37,663	9,949,434.71

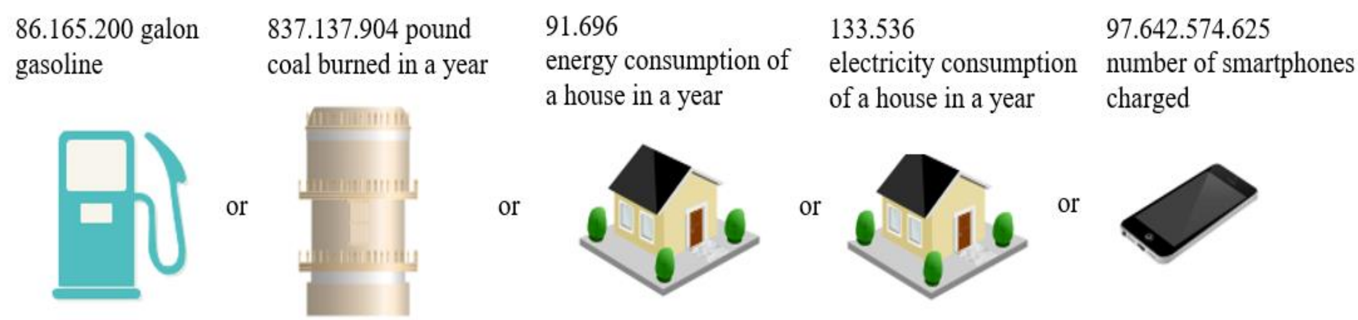

Fig. 7. Consumption scheme for CO_2 emissions corresponding to calculated greenhouse gas emissions.

Table 5. Improved cooling management benchmark table.

Abbreviations	*Formulas and description for benchmark*
Formula-1	$p^{LCGW} + p^{LCOD}$ X $5^{10} \le 13$
Formula-2	$LCGWP + LCODP$ X $10^5 \le 13$
Formula-3	$LCODP = [ODP_r$ x $(L_r$ x $Life + M_r)$ x $R_c]/Life$
Formula-4	$LCGWP = [GWP_r$ x $(L_r$ x $Life + M_r)$ x $R_c]/Life$
LCODP	Ozone depletion potential lifecycle (kg CFC 11/kW/year)
LCGWP	Global warming potential lifecycle (kg CO_2/kW/year)
ODP_r	Refrigerant ozone depletion potential
L_r	Refrigerant leak rate (supposed 2 %)
M_r	Cooling loos at the end of life (supposed 10 %)
R_c	Refrigerant charge (kg)
-	Device life is 10 years unless otherwise stated

Table 6. Criteria based on the weighted average of building for multiple equipment.

Abbreviations	*Formulas and description for criteria*
Formula	$\frac{\sum(LCGWP + LCODP\ x\ 10^5)xQ_{unit}}{Q_{total}} \le 13$
Q_{unit}	HVAC equipment cooling capacity (kW)
Q_{total}	Total HVAC equipment cooling capacity (kW)

Table 7. HVAC&R refrigerant charge quantity calculated by equipment powers.

HVAC equipment power	*Global warming potential calculated for HVAC equipment (100 years)*	*HVAC equipment power*	*Global warming potential calculated for HVAC equipment (100 years)*	*LEED criteria based on building weighted average for multiple equipment (Table 6)*
0.10 kW	302.526	22.00 kW	66555.72	
0.10 kW	302.526	22.00 kW	66555.72	
0.10 kW	302.526	0.75 kW	2268.945	
0.10 kW	302.526	0.10 kW	302.526	
1.50 kW	4537.89	0.10 kW	302.526	
0.50 kW	1512.63	0.10 kW	302.526	
0.16 kW	484.0416	0.10 kW	302.526	
0.10 kW	302.526	0.10 kW	302.526	
5.50 kW	16638.93	0.10 kW	302.526	
5.50 kW	16638.93	0.10 kW	302.526	
5.50 kW	16638.93	0.10 kW	302.526	
2.50 kW	7563.15	0.10 kW	302.526	
2.20 kW	6655.572	0.10 kW	302.526	
5.50 kW	16638.93	1.00 kW	3025.26	
5.50 kW	16638.93	75.20 kW	227499.552	
11.00 kW	33277.86	110.40 kW	333988.704	
0.10 kW	302.526	5.50 kW	16638.93	3025.26
0.16 kW	484.0416	5.50 kW	16638.93	
4.00 kW	12101.04	1.50 kW	4537.89	
4.00 kW	12101.04	1.50 kW	4537.89	
4.00 kW	12101.04	1.50 kW	4537.89	
5.50 kW	16638.93	3.00 kW	9075.78	
5.50 kW	16638.93	3.00 kW	9075.78	
5.50 kW	16638.93	388.10 kW	1174103.406	
7.50 kW	22689.45	104.40 kW	315837.144	
8.80 kW	26622.288	5.50 kW	16638.93	
3.80 kW	11495.988	2.20 kW	6655.572	
22.80 kW	68975.928	1.00 kW	3025.26	
8.00 kW	24202.08	1.50 kW	4537.89	
22.00 kW	66555.72	0.10 kW	302.526	
22.00 kW	66555.72	32.00 kW	96808.32	
22.00 kW	66555.72	83.90 kW	253819.314	
22.00 kW	66555.72	19.40 kW	58690.044	

Table 8. Annual electricity consumption and energy density of HVAC & R equipment by office space.

Location	*Pump Heating System Annual Electricity Consumption (kWh)*	*Conditioning System Annual Electricity Consumption (kWh)*	*Ventilation System Annual Electricity Consumption (kWh)*	*Area(m^2)*	*Energy Density (kWh/m^2)*
Public areas	107,993.28	-	261,602	4,440.22	83.24
Carpark	-	349,769.28	292,226.96	4,216.4	69.31
Cinema	-	1,495,787.52	1,085,977.2	1,972.3	550.61
Restaurant	-	3,969,156	173,272.8	816.7	212.16
Offices	128,947.2	832,515.36	83,009.76	7,937.6	83.24
Building annual energy density (kWh/m^2)	5.57	299.99	93.54	19,383.22	-

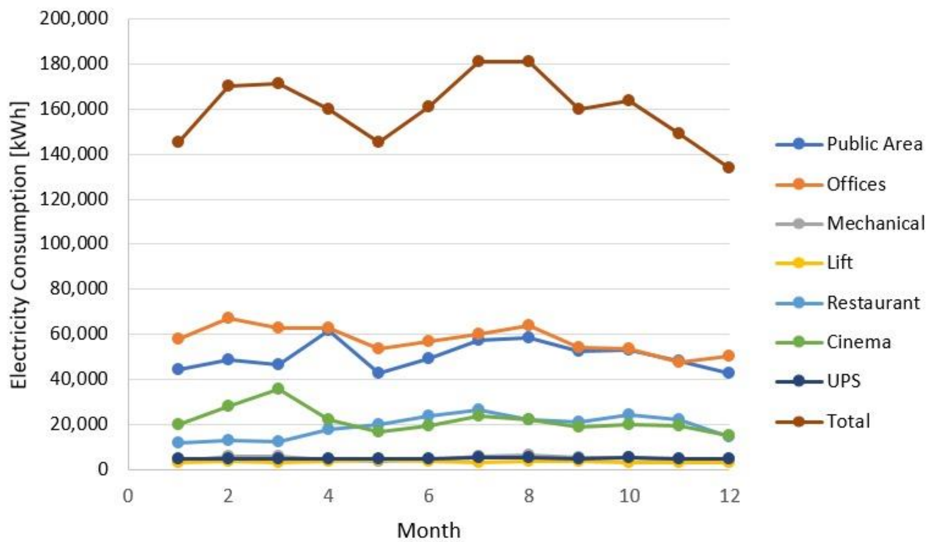

Fig. 8. Monthly electricity consumption figures by district.

Table 9. Planned annual electricity consumption values according to load types.

Planned annual electricity consumption (kWh)	*Lighting*	*Socket*	*Equipment*	*Panel*	*Source*	*Diversity*	*Planned Consumption (kWh)*	*Real Consumption (kWh)*	*Difference (%)*
Public areas	457,390.08	344,332.80	196,116.48	96,768.00	BB-1 Busbar	0.80	875,685.89	604,645.20	76.18
Offices	0.00	0.00	0.00	6,843,432.96	BB-2 Busbar	0.80	5,474,746.37	690,575.00	87.39
Carpark	293,126.40	176,117.76	25,804.80	0.00	BB-1 Busbar	0.80	396,039.17	-	-
Cinema	42,497.28	27,095.04	0.00	2,257,920.00	BB-1 & BB-2	0.80	1,862.009.86	260,259.10	86.02
Restaurant	0.00	0,00	0.00	4,016,323.58	BB-3 Busbar	0.80	3,213,058.87	229,116.70	92.87
Mechanical	-	-	453,616.13	-	BB-1 Busbar	0.80	362,892.90	56,675.14	84.38
Lift	-	-	-	1,028,160.00	BB-1 & MDSB-3	0.80	822,528.00	39,598.99	95.19
UPS	-	-	-	93,864.96	-	0.80	75,091.97	58,119.26	22.60
Total	793,013.76	547,545.60	675,537.41	14,336,469.50	-	0.80	10,465,642.41	1,938,989.39	81.47

The office building is supplied by two own substations with a capacity of 1250 kVA. The TR-1 transformer feeds the main distribution switchboard (MDSB)-1 main distribution board and the TR-2 transformer feeds the MDSB-2 and MDSB-3 main distribution boards. At the same time, the system is supported by two 1100 kVA generators for power continuity. The generators are supplied to the switchboards via the electromechanical interlocking system installed at the entrance to the MDSB main switchboards. The outputs for the office meter boards are taken from the BB-2 busbar, which is supplied by MDSB-2. The diversity of the BB-2 busbar, with a current capacity of 1600 A, was selected as 0.8. There is only one bill for the office building. The filtered meters in the office meter panels on the floors and metered areas are metered. The outputs for the restaurant meter panels are taken from the BB-3 busbar supplied by the MDSB-1. The diversity of the BB-3 busbar, with a current capacity of 1600 A, has been selected as 0.8. Outputs for general field loads, mechanical loads and lifts are mainly taken from the BB-1 busbar supplied by MDSB-1. The diversity of the BB-1 busbar with a current capacity of 1600 A was selected as 0.8.

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The loads were categorized by type of use and the installed power values were calculated. The annual designed power consumption values are obtained by multiplying the loads by the selected concurrency factors and applying the resource diversity. Compared to Table 9, there is a saving of approximately 80% when comparing the designed building electricity consumption data with the measured electricity consumption data from the BMS. Compared to the designed building, more than 10% of electricity has been saved. The building is expected to achieve a maximum of 33 points.

4. CONCLUSIONS

LEED certification is a green building certification that stands for the design of leadership in energy and environmental aspects. To obtain this certification, buildings must comply with and implement the rules set by the USGBC. In this study, an existing office building located in the Şişli district of Istanbul was evaluated according to the LEED O+M certification. According to the evaluations;

- It is predicted that the building can receive 13 points in the location and transportation category, while 1 point can be received in the sustainable environment category.
- It has been calculated that this 1 point from the environmental category can be achieved through the light pollution reduction credit.
- It is expected that no points will be awarded for stormwater management and site management. 2 points can be gained by creating a site management project with appropriate shading and planting on the roof. In the water efficiency category, consumption was benchmarked against the base building model. However, as the difference exceeded the LEED rate, it was determined that no points could be earned in this category. For the energy and atmosphere category, the building's annual consumption of water, natural gas and electricity was examined.
- This consumption was converted into greenhouse gas emissions and compared. According to the electricity consumption data, it was observed that there was a decrease in electricity consumption in March, April and May for all load categories. It was observed that the total consumption of electrical energy is higher in winter. It is predicted that this consumption will decrease, especially with the regulations to be made in the control of the HVAC systems. When the office building is evaluated within the general LEED framework, it is seen that it provides energy-efficient management practices and basic cooling requirements.
- It is estimated that 33 points can be achieved in the energy and atmosphere category if the building energy simulation is carried out. It is very important in this category that the BMS system is installed in the building.
- As there is no LEED Accredited Professional (AP) involved in the project, there are no points available in the Innovation category. If a LEED AP is involved in the project, an additional point can be earned.

Based on all research, the entire office building is expected to achieve 47 out of 100 points in the LEED V4.1: Operations and Maintenance version. It is envisaged that the existing office building will be able to achieve LEED certification if an application is made. It is also possible to increase the current score by 12 points, depending on the arrangements and proposals to be made. The office building has the potential to achieve LEED Silver certification with a total of 59 points. The building can improve its score with a purchasing policy for materials and resources, a green cleaning policy, integrated pest management for indoor environmental quality, and the hiring of an accredited LEED professional.

The spread of the most widely used green building certification systems in the world, such as LEED, and the increase in applications for these systems are important for sustainability in buildings. Monitoring a building within the framework of LEED credits will increase the effective use of energy and prevent the waste of resources.

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