Discover Environment

Case Study

Evaluation of LEED-certified office buildings in Turkey in terms of sustainable material use

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Abstract
Environmental issues such as ozone depletion, global warming, water pollution, and melting glaciers in the polar regions have been exacerbated by industrial and chemical activities, as the Industrial Revolution led to unlimited use of our limited natural resources. Approaches have been developed to solve human and environmental health problems. Efforts are underway to minimize the adverse effects of buildings on the environment. This process helps reduce materials' environmental damage and select environmentally friendly materials. For these reasons, producing recyclable, ecologically friendly, and energy-saving materials has gained importance. This article used a case study method to analyze sustainable material usage using twenty LEED-certified office projects in Turkey. Twenty new buildings, including Certificate One, Silver Three, Gold Eight, and Platinum Eight, have been evaluated regarding sustainable materials according to LEED criteria. Tables containing material and resource application principles have been created to assess the selected buildings in terms of sustainable material principles, and these prepared tables provide information about sustainable material use. The evaluation is based on eight criteria and sources of LEED material, including recyclable materials, renewable materials, rapidly renewable, certified wood, regional materials, construction waste management, and re-use of materials. As a result of the study, it was determined that 95% to 75% of the five categories with the weakest application among the eight basic materials and resource principles failed to be below the desired level and should be improved.

Keywords Sustainability · Environment · Sustainable materials · LEED evaluation system · LEED criteria

1 Introduction

Materials are essential components of building construction. Building materials are often chosen based on functional, technical, and financial requirements. However, it has been evaluated in terms of sustainability as an essential issue in recent years. Since the construction industry directly or indirectly causes a significant part of environmental degradation, it must use construction and building methods that are less harmful to the environment. In this context, it should be able to undertake the responsibility of contributing to sustainable development with the materials it chooses [1].

It is essential to contribute to producing sustainable, healthy buildings for both the residents and the environment by reducing the impact of environmental degradation by using sustainable building materials. Facilities that use approximately 40% of the natural resources extracted in industrialized countries significantly impact the environment [2].

It has been observed also in the United States, where buildings represent 39 percent of total primary energy consumption and 70 percent of electricity consumption [3]. According to the USGBC, between 45 and 65% of the waste generated

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is caused by construction [4]. Examinations were carried out on the categories and criteria of 5 office buildings in Turkey that received the LEED certificate. The data revealed that the categories with the lowest score percentages among the certificate categories were material and resource and indoor Air quality [5]. Study made in India Energy consumed during transportation Approximately 4–8% of the energy of brick production, for distances of 50–100 km. Transport energy required for transporting high-energy materials such as steel and cement is marginal compared to the energy expended during production [6]. At the same time, using the wrong materials causes unhealthy indoor environments and can lead to health problems for those living and working in the buildings. This situation may lead to low productivity [7]. In addition, the construction industry consumes 40% of natural stone, gravel, and sand and 25% of raw timber in the building production process worldwide. The construction industry's impact on the environment is significant [8].

The selection of environmentally sustainable building materials is essential for achieving the desired level of environmental performance. Sustainable building materials are natural materials with low energy consumption and maintenance costs. Another critical point is that they can be easily removed and recycled during demolition [9].

Sustainable materials must be environmentally friendly and reduce environmental hazards without releasing pollutants or other emissions that affect human health and comfort throughout the life cycle. People are indoors 90% of the time. Today, the return of indoor conditions significantly impacts their well-being and performance [10].

In addition, sustainable building materials are mainly derived from renewable energy sources. Materials should also be sustainable throughout their life cycle and use less energy in manufacturing [9].

The study aims to encourage the selection of materials that will contribute to sustainability, such as the use of recycled, renewable, or regional materials. The purpose of this is to reduce the production of new materials that harm the environment. Environmental awareness has pushed the construction industry to find solutions to reduce carbon emissions and negative impacts on the environment [11]. According to research conducted at the Konya Scientific Center in Turkey in the field of resource protection. Recycled materials are collected, and construction waste is carried out by the construction waste management plan. The building contains recycled steel and concrete, making up 45% of the total material. 100% of construction materials are produced locally in Türkiye. Hence the fuel consumption and environmental pollution caused by materials transportation is reduced to a minimum. The use of local materials is an advantage for contribution to the country's economy. 75% of solid waste is collected and recycled [12]. Most green materials are made from recycled materials, which help the environment by utilizing waste energy more efficiently. Additionally, the energy required for their manufacturing is minimized [13].

The production of new materials and the energy transported are one of the causes of ecological problems. Another aim of this study is to support the use of renewable materials. Some materials are difficult to recycle and may cause excess energy, cost, and environmental problems. Construction and demolition waste management is another important factor as it helps collect reusable materials and protect the environment. In addition, another important factor is the use of certified materials in the selection of wooden materials, thus contributing to the protection of forests. The benefits of using sustainable building materials can be described as building a longer-lasting structure with less maintenance. Using sustainable building materials will save energy and costs in the long run. It is a fact that green buildings built sustainably are healthier and more comfortable. It is possible to minimize waste through sustainability. Most sustainable building materials are recyclable materials.

2 Sustainability concept and sustainable building material

2.1 Sustainability concept

The terms "sustainability" and "green," commonly used interchangeably, have garnered recognition in the realms of architecture, engineering, and construction over the past few decades [14]. In addition, the concept of sustainability is related to the protection and development of environmental, social, and economic resources to meet the needs of current and future generations, and these three concepts constitute the three components of sustainability [15]. Sustainability and "Ecological" are often used interchangeably, but sustainability has a broader meaning. Sustainability means creating environmentally responsible, healthy, fair, and equitable places. It means looking at the renewal of the built environment from its natural, human, and economic aspects. It means finding systems and solutions that support the quality of life for everyone. Applying sustainable development principles to building construction supports reducing resource consumption, waste generation, and environmental impacts; it also aims to guarantee the high quality and utility of the built-up areas. When evaluating the dynamics of the construction industry, it is fundamental to consider the close interaction between living and non-living structures. These relations consist of material and energy, information, and resource flows, and it is necessary to understand the evolutionary dynamics of the building as a system. Building quality should be ensured, considering natural resources, social needs, and national history [16].

The three basic principles used to express the concept of sustainability are shown in Fig. 1 below. These three principles were introduced by John Elkington in 1998 in his book Cannibals with Forks: The Triple Bottom Line of 21st Century Business. The term has been applied to socially responsible organizations that characterize all projects in the built environment. The concept of three pillars involves the long term and evaluates the potential impacts and best practices of the following three types of resources [17].

2.2 Sustainable building material

Applying sustainable development principles to building construction supports reducing resource consumption, waste generation, and environmental impacts; It also aims to guarantee the high quality and utility of built areas. According to the research done on environmentally friendly materials such as biocomposites and petroleum-based composites green building materials or biocomposites containing organic, natural, non-toxic compounds have been shown to significantly degrade indoor air quality (IAQ) and overall human health impacts, whereas this has not been observed with carbon-based composites. The results indicate that switching from a fully hybrid biocomposite to a fully petroleum-based composite could reduce indoor and outdoor human health impacts by more than 50% [18]. When evaluating the dynamics of the construction industry, it is important to consider the close interaction between living and non-living structures. This interaction consists of flows of materials and energy, information and resources, and it is necessary to understand the evolutionary dynamics of the building as a system. In this regard, construction quality should be ensured by considering natural resources, social needs, and national history [16]. However, the sustainable building should be able to:

- Make the most of energy resources and natural capital.
- Some of the energy resources should be obtained from nature.
- Must use renewable and local materials.
- It should reduce CO2 emissions and waste generation.
- It must become part of the historical and cultural context of the environment [16]. The applied energy coefficients and the life of the building materials expressed in MJ / kg and years, respectively, are presented in Table 1.

In terms of ecologically sustainable building materials, building materials consume a lot of energy during the production phase. As seen in Table 1, asphalt is the second most energy-consuming material after aluminum. This means that these materials consume more energy than the production phase. To obtain ecologically sustainable materials,

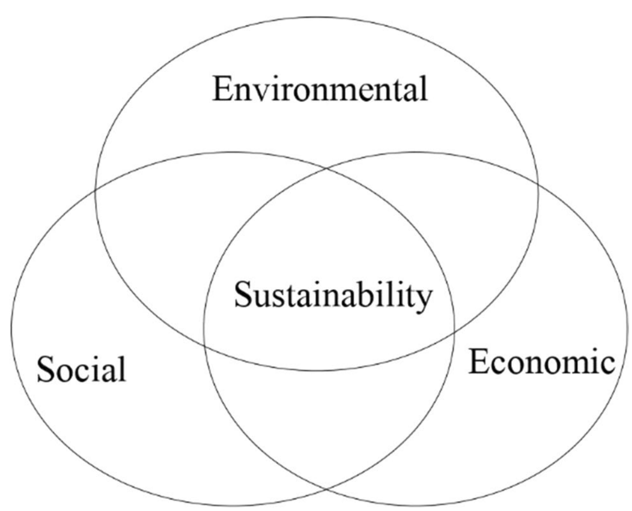

Fig. 1 The triple bottom line of sustainability [17]

Table 1 Amount of Energy used to produce building materials and their lifespan [16]

Material type`	Embodied Energy (MJ/kg)	Lifetime of materials (Years)
Pebble	0.2	75
Concrete	1.2	75
Structural Steel	32.0	75
Asphalt	50.2	75
Hollow concrete bricks	0.7	75
Hollow clay bricks	2.5	75
Ceramic floor and wall tiles	2.5	75
Ceramic Tile—Roof Coverings	2.5	20
Pot made of sandy stone	18.93	75
Cam	15.9	40–50
Raw aluminum	191.0	50
Timber-dried veneer in an autoclave	–	50
Cement plaster	7.8	5
Cork slabs	–	40

materials with the lowest embodied energy should be preferred [19]. Lastly, sustainable building materials typically consist of natural materials that have low energy consumption and minimal maintenance costs. These materials should also be easily disassembled and recyclable during demolition. The embodied energy consumption of building materials encompasses both the initial energy consumption and the recurring energy consumption [20].

3 LEED and green building certificate systems

3.1 LEED

LEED is the green building certification program and a globally recognized standard for the design, construction, and operation of high-performance green buildings and neighborhoods. LEED provides a program project teams can apply to achieve healthy, highly efficient, and cost savings for green buildings. LEED certification is a globally recognized symbol of sustainability success [21]. Leed is Adopted in the United States and many other countries to designate "green buildings," with 1.85 million square feet of construction area worldwide, it is the most widely used green building system in a rating system [22].

The US Green Building Council (USGBC) is a non-profit organization founded in 1993. By March 2000, 12 buildings had been certified under the pilot program. Extensive corrections were made during the pilot period and LEED 2.0 was released in March 2000. After researching existing programs (especially British BREEAM and Canadian BEPAC) and measurement methods, the Council began developing a specific system for US buildings [23]. As seen in Table 2, LEED,

Table 2 LEED Rating system version variants since 1998 [23]

LEED version	Release date
LEED ncv1.0 LEED ncv2.0 LEED ncv2.2	1998
LEED v3	2005–2009
LEED v4	Introduced in November 2013, new projects can be selected between LEED 2009 and LEED v4 until October 31, 2016 New projects registered after October 31, 2016, must use LEED v4
LEED v4.1	2019

which started in 1998 by showing the green certification path for new buildings, is now used not only in the United States but also in many countries around the world. It is an evaluation system that covers many building types and the entire life cycle of the building. The LEED evaluation method, which is currently in its version phase, provides an evaluation of the built environment by considering not only the building but also the LEED neighborhood development. LEED is a 100-point weighted system. In addition to these 100 points, 10 additional points can be earned. These 10 points can be achieved through innovations in the design and local priority categories. Additionally, some prerequisites must be met. A project that does not meet these prerequisites is not accepted for evaluation [24].

Leed evaluation is based on six categories Building Design and Construction (BD+C), Interior Design and Construction (ID+C), Building Operations and Maintenance (O+M), Neighborhood Development (ND), Homes, and Cities [25]. Each of the evaluation systems offers different solutions suitable for various project types and scopes. Leed generally has nine categories: 1- Integrative process 2- Location and transportation 3- Sustainable lands 4- Water efficiency 5- Energy and atmosphere 6- Materials and resources 7- Indoor quality 8- Innovation 9- Regional Priorities. The Table 3 shows 3 Certification scores and levels [11].

3.2 Green building certification systems

A green building is commonly described as a structure that conserves energy, promotes ecological practices, and supports sustainability [19]. Since the sustainability of a building can only be evaluated depending on the local environment in which the building is located, countries have green systems where they organize ecological structures according to their legal systems. They develop their local plans to suit their market conditions and needs. Green buildings are essential for communities because sustainable energy, water, and materials significantly impact the environment and human health.

The construction sector has developed ecological construction projects compatible with nature, capable of using energy efficiently, and aimed at protecting the health of the people who live and work there with certification systems [18].

The importance of green building can be understood more clearly from the resources spent by facilities in the United States of America and the proportion of waste created by them:

- 14% of drinking water consumption
- 30% of waste generation
- 40% of raw material usage
- 38% of carbon dioxide emission
- 24% to 50% of energy use
- 72% of electricity consumption

It is possible to reduce environmental damage by building green buildings. In most cases, green buildings create environmental improvement and advance human health. A study by the New Buildings Institute showed that the average energy use intensity (energy consumed per unit area) in green buildings is 24% lower than in typical buildings. The following results were obtained from the research on 12 US General Services Administration portfolio green buildings.

- 26% less energy use
- 27% higher user satisfaction
- 13% lower maintenance cost
- 33% lower carbon dioxide emission (CO_2) 5 [17]. Today, there are more than thirty local evaluation systems used by different countries, the scores are listed in Table 4 below [26].

Table 3 LEED Evaluation system [25]

Assessment	Points
Certified	40–49 Points
Silver	50–59 Points
Gold	60–79 Points
Platinum	80 + Points

Table 4 Different evaluation systems apply differently in climates and geographical conditions [26]

Country	Evaluation systems used
United States	LEED, GBI, Energy star
Australia	Green star, AGBR
United Kingdom	BREEAM
Hong Kong	BEAM
Japan	CASBEE
Taiwan	EEWH
Singapore	BCA
Philippine	Philippine green building Council
Europe	European environment agency
Korea	KGBC
India	IGBC
Turkey	ÇEDBİK, SEEB-TR

4 Methods

The research is conducted using a case study methodology. This type of method is suitable for this study because it explores and examines data in projects. Within the scope of the study, aimed to determine whether sustainable materials are successfully implemented within the range of projects that have received the LEED green building certificate. Different levels of LEED certification were used in the research. Twenty new projects with certification have been selected. The data were collected from the American Green Building Council (USGBC), Green Building Association (ÇEDBİK), and Green Building Information Gateway (GBIG). The sustainable material essential criteria for analyzing this research are listed below.

- Collection and storage of recycled materials (mandatory)
- Building reuse—reusing existing walls, floors, and roof: 3 points
- Building reuse—reuse of internal non-structural elements: 1 point
- Construction waste management: 2 points
- Reuse of materials: 1 point
- Recycled content: 2 points
- Use of regional materials: 2 points
- Rapidly renewable materials: 1 point
- Use of certified wood: 1 point

In addition to the LEED basic scores, their scores from the material section were evaluated to observe whether they successfully implemented the categories listed above. For example, the category "Use of regional materials" has a score of 2/2 ″ and if a project received a total score in this category, it was considered to have been successfully implemented. If a project gets 1/2, it is considered well-implemented. The last option is regarded as low implementation if a project receives 0/2. In other words, symbols were created to simplify it. These characteristics indicate the success level of a projFect. The plus sign " + " indicates good use of sustainable material in each project category. Likewise, the plus-minus sign " ± " indicates moderate use of sustainable materials for each type. Finally, the minus sign "−" indicates sustainable material low use of each category. LEED has different evaluation criteria for buildings with other functions, such as schools, offices, hospitals, and homes. Similar office project types have been selected to obtain the correct results from the study. Another selection criterion is that all projects have been established in the new construction category and are among the highest-rated projects Table 5.

Table 5 Model description [11, 27]

Names of buildings	Overall score	Materials and resources section points	Location of building	Date the certificate was issued	Certification level
Official residence of the presidency of the Turkish grand national assembly	46	6 / 14	Ankara	16 April 2015	Certified
Li Fung center	54	6 / 14	Istanbul	17 July 2011	Silver
Erke green academy adnan menderes airport terminal	56	8 / 14	Erke Green Academy	24 December 2015	Silver
Kosıfler plaza kavacik	51	4 / 14	Istanbul	17 December 2018	Silver
Otokoç headquarters building	62	6 / 14	Istanbul	12 January 2018	Gold
Erke green academy chamber of commerce	70	7 / 14	Erke Green Academy	17 Nisan 2018	Gold
Tüpraş Rd administration building	60	4 / 14	Kocaeli	28 May 2014	Gold
Basf Dılovası administration building	72	10 / 14	Kocaeli	18 July 2011	Gold
Turk telekom ankara	60	2 / 14	Ankara	11 February 2020	Gold
Eurasia tunnel operation and maintenance center	64	5/ 14	Istanbul	21 July 2017	Gold
Selenium retro	60	7 / 14	Istanbul	09 May 2018	Gold
Vega business center	65	4 / 14	Istanbul	27 April 2017	Gold
Erke green academy	82	5 / 14	Istanbul	06 September 2013	Platinum
Tandem textile factory office department	80	6 / 14	Istanbul	06 April 2018	Platinum
T. Garanti bank red crescent office building	85	6 / 14	Ankara	29 July 2017	Platinum
Eser holding Inc	92	8 / 14	Ankara	14 February 2011	Platinum
Prokon-Ekon group of companies headquarters	89	6 / 14	Ankara	15 February 2016	Platinum
Bursagaz administration building	83	4 / 14	Bursa	13 April 2017	Platinum
Turkish contractors association headquarters	83	4 / 14	Ankara	29 May 2014	Platinum
Afyon cement administrative building	81	8 / 14	Afyonkarahisar	6 September 2017	Platinum

5 introducing the study and investigation of LEED certified office buildings in Turkey for the use of sustainable materials

5.1 Introduction of the study

The 20 selected Leed Certified buildings have the New Construction (Leed-NC) certificate type. Certified GNAT Presidential Official Residence received 6 points out of 14 points allocated to the materials and resources section of LEED. Silver Certified Izmir Adnan Menderes Airport Terminal received 8 points, Li Fung Center received 6 points, and Kosifler Plaza Kavacık received 4 points. Otokoç Head Office Building, which received the Gold Certificate, has 6 points, Izmir Chamber of Commerce has 7 points, Tüpraş Rd Management Building has 4 points, Basf Dılovası Management Building has 10 points, Türk Telekom Ankara has 2 points and Vega Business Center has 4 points. Eurasia Tunnel Operation and Maintenance Center and Selenium Retro received 7 points. Platinum Certified Erke Yeşil Academy Building has 5 points, Tandem Textile Factory Office Section, T. Garanti Bank Kızılay Office Building and Prokon-Ekon Group of Companies Headquarters have 6 points. Eser Holding Head Office and Afyon Cement Administrative Building received 8 points. Bursagaz New Administration Building and Turkish Contractors Association Headquarters have 4 points. These 20 buildings that received Leed Certificate in Turkey applied to V3-LEED 2009 to receive the certificate and are explained in detail in Table 6

5.2 Examining LEED certified office buildings in Turkey for the use of sustainable materials

This section evaluates 20 buildings with the highest category scores, registered under Turkey's LEED certificate under new construction. The total 20 projects, consisting of one LEED New Construction certified building, three new buildings awarded a Silver Certificate, eight new buildings awarded a Gold Certificate, and eight new buildings awarded a Platinum Certificate, were selected and examined. LEED has different evaluation criteria for building types, such as schools, offices, hospitals, and homes. Since there are other evaluation criteria for different categories, similar types of office projects were selected to obtain accurate study results. Selected projects are current projects with high levels of certification scores. These structures are; the Official Residence of the Presidency of the Turkish Grand National Assembly, Li Fung Center, Izmir Adnan Menderes Airport Terminal, Kosifler Plaza Kavacık, Otokoç Headquarters, Izmir Chamber of Commerce, Tüpraş Rd Management Building, Basf Dilovası Management Building Turk Telekom Ankara, Eurasia Tunnel Operation and Maintenance Center, Selenium Retro, Vega Business Center, Erke Green Academy, Tandem Textile Factory Office Department, T. Garanti Bank Red Crescent Office Building, Eser Holding Inc., Prokon-Ekon Group of Companies Headquarters, Bursagaz New Management Building, Turkish Contractors Association Headquarters, andAfyon Cement Administrative Building. The selected structures were analyzed regarding the material criteria in LEED, the score they earned, and the adequacy level of sustainable material use of these scores. In line with the results obtained, it is aimed to increase the use of sustainable materials.

5.2.1 Evaluation of the case in terms of sustainable materials and resources criteria

Within this evaluation's scope, each project's scores from the material and resource section of the LEED certificate were used. The principle of reuse of existing floors and roofs and non-structural interior elements was implemented in only four projects. In Li Fung Center, it has been successfully applied on 95% of existing floors and ceilings. In addition, the principle of reuse of existing foundations and roofs and non-structural interior elements was used at a rate of 75% in

Table 6 A score of reuses of existing walls, flooring, and roof and Evaluation of reuse of interior non-structural elements [27]

Names of evaluating buildings	Reuse of existing walls, floors, and roof (Points)	Used percentage (%)	Reuse of non-internal structural elements (Points)	Used rate (%)
Li Fung center	3/3	95		
Otokoç headquarters building	2/3	75		
Basf Dilovasi administrative building	3/3	95	1/1	50
Erke green academy	2/3	75		

Otokoç Headquarters, 95% in Basf Dilovası Management Building, and 75% in Erke Yeşil Akademi. However, 50% of non-structural interior elements were used in Basf Dilovası Administration Building. As a result, out of twenty projects, the reuse of existing walls, floors, and roofs within the scope of sustainable materials was implemented in only four buildings, and it is seen in 1 project that interior non-structural elements are reused. Usage rates are seen in Table 6 below.

This section examines the level of use and material reuse category of each project in waste management construction. Construction waste management was implemented in fourteen buildings out of twenty projects. The usage level is between 75% and 50%. However, material reuse is implemented in only two out of twenty projects, with rates ranging from 10 to 5%. To summarize, these twenty projects have successfully implemented construction waste management. On the other hand, material reuse was implemented in only two buildings, as seen in Table 7 below.

This section focuses on evaluating the use of recycled content and regional materials. Recycled materials are used in seventeen projects, with a percentage ranging from 20 to 10%. On the other hand, 20% of regional materials were used in all buildings. As a result, it is seen that recycled materials are applied in most of the projects except the Li Fung Center, Turk Telekom Ankara, and Erke Green Academy. The category of using regional materials is the most thoroughly implemented in all twenty projects and is described in Table 8 below.

This section examines the use of rapidly renewable materials and certified wood. As a result of researching these two categories, it was seen that between 2.5% and 1.2% of rapidly renewable materials were used in four projects. The results obtained show how poorly this category applies to all buildings. On the other hand, the use of certified wood could be higher as only three projects were implemented with 50% usage. To summarize, sixteen of twenty projects fail in rapidly renewable materials use. According to the result, seventeen projects must be increased in certified wood material use. The results are shown in Table 9 below.

As a result, it shows in Table 6, Table 7, Table 8, and Table 9, how each project uses eight materials and resource requirements. The first required category is the reuse of existing floors and roofs; only four projects were used in this category. The second category, the reuse of non-internal elements, is the only category that still needs improvement, as only 1 out of 20 projects is used. The third category is construction waste management, which was successfully implemented in 14 projects. The fourth category is the reuse of materials, and it needs to be used more as it is applied in only two projects. The fifth category, which includes recycling processes, has been successfully implemented in 17 projects using recycled materials. The sixth category is regional materials, the only category where all projects have been successfully used. The seventh category is rapidly renewable materials, and it is seen that only four projects in this category are used. These results show that the seventh category is among the weakest application categories among the other nine categories. Certified wood, the ninth and last category, needs to be implemented more, as only three projects are used. Table 10 shows the scores received by each project.

Table 7 Construction waste management and evaluation of material reuse [27]

Names of Evaluating Buildings	Construction waste management (Points)	Used percentage(%)	Reuse of materials (Points)	Used percentage(%)
Official residence of the presidency of the Turkish grand national assembly	2/2	75		
Li Fung center	1/2	50		
Erke green academy adnan menderes airport terminal	2/2	75	1/2	5
Otokoç headquarters building	1/2	50		
Erke green academy chamber of commerce	2/2	75		
Basf Dilovasi administrative building	2/2	75		
Eurasia tunnel operation and maintenance center	1/2	50		
Selenium retro	2/2	75		
Tandem textile factory office section	2/2	75		
T. Garanti bank red crescent office building	2/2	75		
Eser holding Inc	2/2	75	2/2	10
Prokon-Ekon group of companies headquarters	2/2	75		
Turkish contractors association headquarters	2/2	75		
Afyon cement administrative building	2/2	75		

Table 8 Assessment of recycled inclusion and use of regional materials [27]

Names of evaluating buildings	Contains recycled materials (Puan)	Used percentage(%)	Use of regional materials (Points)	Used percentage(%)
Official residence of the presidency of the Turkish grand national assembly	2/2	20	2/2	20
Li Fung center			2/2	20
Erke green academy adnan menderes airport terminal	2/2	20	2/2	20
Otokoç headquarters building	1/2	10	2/2	20
Erke green academy chamber of commerce	2/2	20	2/2	20
Kosifler Plaza Kavacik	2/2	20	2/2	20
Tüpraş Rd administration building	2/2	20	2/2	20
Basf Dilovasi administrative building	2/2	20	2/2	20
Turk Telekom Ankara			2/2	20
Eurasia tunnel operation and maintenance center	2/2	20	2/2	20
Selenium retro	2/2	20	2/2	20
Vega business center	2/2	20	2/2	20
Erke green academy			2/2	20
Tandem textile factory office section	2/2	20	2/2	20
T. Garanti bank red crescent office building	2/2	20	2/2	20
Eser holding Inc	2/2	20	2/2	20
Prokon-Ekon group of companies headquarters	2/2	20	2/2	20
Bursagaz new administration building	2/2	20	2/2	20
Turkish contractors association headquarters	2/2	20	2/2	20
Afyon Cement administrative building	2/2	20	2/2	20

Table 9 Assessment of the use of rapidly renewable materials and certified wood [27]

Names of evaluating buildings	Rapidly renewable materials usage (Points)	Used Percentage (%)	Certified use of wood (Points)	Used percentage (%)
Erke green academy adnan menderes airport terminal	1/1	1,2		
Erke green academy chamber of commerce			1/1	50
Selenium retro			1/1	50
Erke green academy	1/1	2,5		
Turkish CONTRACTORS ASSOCIATION HEADQUArters	1/1	2,5	1/1	50
Afyon cement administrative building	1/1	2,5		

According to the evaluation, the status of 20 LEED-certified office building projects according to nine material categories is listed below:

- Collection and storage of recycled materials (mandatory) used in all projects.
- Using building elements (used in 4 projects)
- Use of non-structural elements (used in 1 project)
- Construction waste management (used in 14 projects)
- Reuse of materials (used in 2 projects)
- Recycled content (used in 16 projects)
- Use of regional materials (used in all 20 projects)
- Rapidly renewable materials (used in 5 projects)
- Use of certified wood (used in 3 projects)

Table 10 Evaluation of the Case Study in terms of Sustainable Material Criteria [11, 27]

Case study criteria for what is a sustainable material	Official residence of the presidency of the Turkish Grand national assembly	Li Fung center	Erke green academy adnan menderes airport terminal	Kosıfler Plaza Kavacık	Otokoç headquarters building	Erke green academy chamber of commerce	Tüpraş Rd administration building	Basf Dılovası administration building	Turk Telekom Ankara	Avrasya tunnel operation and maintenance center	Selenium retro	Vega business center	Erke green academy	Tandem textile factory office department	T. Garanti bank red crescent office building	Eser holding Inc	Prokon-Ekon group of companies headquarters	Bursagaz new administration building	Turkish contractors association headquarters	Afyon cement administrative building
Recycled materials collection and storage								Required for all projects												
Using building elements	0	3	0	0	2	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0
Using non-structural elements	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Construction waste management	2	1	1	0	1	2	0	1		1	2	0	0	2	2	2	2	0	2	2
Reuse of materials	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Recycled content	2	0	0	2	1	2	2	2	0	2	2	2	0	2	2	2	2	2	2	2
Use of regional materials	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rapidly renewable materials	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	1
Use of certified wood	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0

5.2.2 Evaluation of the case within the scope of sustainable materials and resources principles

In this part of the article, the LEED-certified buildings that comprise the sample are analyzed using sustainable materials. The data obtained were compared within the framework of sustainable material principles applied in each project, and the findings were interpreted within the scope of sustainable material principles. First, the total points each project has received in LEED, especially from the material section, are listed. Second, to assess the impact on sustainable material use, symbols were created to explain whether each was used adequately. Characters are determined by getting full, half, or zero points in the materials section of the project. For example, if the recycled content credit of the project is 2/2, it should receive a total score (See Table 12), symbolically determined as "+." If the project gets 1/2 of this credit, it is symbolically determined as "±." Similarly, if it receives 0/2 of the credit, it is symbolically designated "–." Finally, each project's sustainable material principles usage adequacy has been listed. In Table 11, the evaluation indicator for the structures examined within the scope of sustainable materials is expressed.

According to the results of the examinations, sustainable materials in structures and eight LEED principles are evaluated according to their usage scores. The principles of sustainable building materials must be followed from the design stage to the end of the construction and demolition periods. As stated in LEED, sustainable material principles in building design are achieved by applying specific methods. One of these criteria is whether the material to be used in the building is regional or exported from abroad. Reuse of materials, preference for rapidly renewable materials, use of certified wood, recycled content, use of internal non-structural elements (columns, beams, load-bearing walls, roof, and all ingredients except foundation), re-use of the structural system, flooring, ceiling or many matters such as the recycling, collection, and storage of construction site debris or demolition waste, such as interior walls, must be addressed within the scope of compliance with economic and sustainable material principles. In this perspective, priority should be given to sustainable materials and resources until demolition. In this part of the article, 20 new buildings with LEED certificates and use were selected and evaluated in Table 12 regarding LEED material principles. In the table, each category's way and service levels are assessed and classified as the following categories.

- Good use
- Medium use
- Low usage

5.2.3 Result and discussion

Until this stage, general information was given about the projects constituting the sample, and then a brief evaluation was made of the materials according to LEED criteria. In the next stage, tables show how many points each project received from the material and resource section. Considering the scores of each project in the LEED material category, the use rate of sustainable materials was analyzed. When the sustainable material scores of LEED-certified structures are compared with the LEED material and resource scores, it is seen that the ranking is not the same. In this case, it has been proven that sustainable material principles often remain at a low rate in structures that have received LEED certification. This study showed that a project with a high level of platinum in LEED has a low implementation rate within the scope of sustainable materials analysis, as explained in Table 13 below.

After evaluating the use of materials and resources of 20 new construction office buildings with LEED certification in Turkey, the percentage of level usage in each category was determined. Three different rating levels are formed: Successful, moderately successful, and Unsuccessful use. Successful use means the project gets full marks in the materials and resources category. Moderate use implies that the project received half of the total score. Unsuccessful use means that the project received zero points. However, the assessment of each level generally represents all projects. Percentages are the result of the evaluation made over 20 projects. For example, the reuse of the building reuse of existing walls, floors, and roofs was fully implemented in 2 projects. In this case, the percentage of this value in the sample was found (2/ 20 × 100). The result

Table 11 Evaluation indicator

Application mark	Application class
+	Good use
±	Medium use
-	Low usage

Table 12 Sustainable material principles are used in adequacy assessment

Names of Evaluating Buildings	Collection and storage of recycled materials	Building reuse - reusing existing walls, floors, and roof	Building reuse - reuse of internal non-structural elements Construction waste	Construction waste management	Reuse of materials	Recycled content	Use of regional materials	Rapidly renewable materials	Use of certified wood
Official Residence of the Presidency of the Turkish Grand National Assembly	Required for all projects	-	-	+	-	+	+	-	-
Li Fung center		+	-	±	-	-	+	-	-
Izmir Adnan Menderes Airport Terminal		-	-	±	±	-	+	+	-
Otokoç Headquarters Building		±	-	±	-	±	+	-	-
Izmir Chamber of Commerce		-	-	+	-	+	+	-	+
Kosifler Plaza Kavacik		-	-	-	-	+	+	-	-
Tüpraş Rd Administration Building		-	-	-	-	+	+	-	-
Basf Dilovasi Administrative Building		+	+	±	-	+	+	-	-
Turk Telekom Ankara		-	-	-	-	-	+	-	-
Eurasia Tunnel Operation and Maintenance Center		-	-	±	-	+	+	-	-
Selenium Retro		-	-	+	-	+	+	+	+
Vega Business Center		-	-	-	-	+	+	-	-
Erke Green Academy		±	-	-	-	-	+	+	-
Tandem Textile Factory Office Section		-	-	+	-	+	+	-	-
T. Garanti Bank Red Crescent Office Building		-	-	+	-	+	+	-	-
Eser Holding Inc.		-	-	+	+	+	+	-	-
Prokon-Ekon Group of Companies Headquarters		-	-	+	-	+	+	-	-
Bursagaz New Administration Building		-	-	-	-	+	+	-	-
Turkish Contractors Association Headquarters		-	-	+	-	+	+	+	+
Afyon Cement Administrative Building		-	-	+	-	+	+	+	-

A plus sign ″+″ indicates that the project uses sustainable materials well in each category. Likewise, the plus-minus sign ″±″ indicates the sustainable medium use of materials in each category. Finally, the minus sign ″—″ indicates the low use of sustainable materials in each category. As a result, the class with the minus ″—″is the reuse of non-structural interior elements', and the second is the ″reuse of existing walls, floors and roofs. The third category, the most minus of which is ″—″, is the reuse of materials. However, the category with the most plus ″+″ is the use of regional materials. When we evaluate Table 12 by projects, it is seen that the Basf Dilovası Administration Building received full marks in the Reuse of the Building categories—reuse of non-internal structural elements, recycled content, use of regional materials, and use of certified wood. It was concluded that Selenium Retro, Eser Holding Inc, Turkish Contractors Association Headquarters, and Basf Dilovası Administration Building were the most successful projects regarding the adequacy of using sustainable materials and resources principles among the selected projects. Erke Green Academy, Izmir Chamber of Commerce, Eser Holding Inc., and Afyon Cement Administrative building are seen to be the second highest scoring projects in terms of adequacy of using sustainable materials and resource principles.

shows that the rate of successful reuse of the building's existing walls, floors, and roofs is 10% of all projects in the case. It was concluded that it was only half implemented in 2 projects, and the medium-successful utilization rate was 10% among all projects. It was observed that 16 projects remained in zero use. According to this result, it has been determined that among all projects, the reuse rate of the existing walls, floors, and roofs of the building is 80% unsuccessful.

Table 13 Result and discussions of the sample

LEED sustainable materials and resources principles	Evaluating three different levels of use of LEED materials and resources (over 20 projects)		
	Successful use	Medium success use	Failed use
Collection and storage of recycled materials	Required in All Projects		
Building reuse—reusing existing walls, floors, and roof	2/20 10% Success	2/20 10% Medium success	16/20 80% Failed
Building reuse—reuse of interior non-structural elements	1/20 5% Success	0/20 0% Medium success	19/20 95% Failed
Construction waste management	9/20 45% Success	5/20 25%Medium success	6/20 30% Failed
Reuse of materials	1/20 5% Success	1/20 5% Medium success	18/20 90% Failed
Recycled content	15/20 75% Success	1/20 5% Medium success	5/20 20% Failed
Use of regional materials	20/20 100% Success	20/20 0% Medium success	20/20 Failed %0
rapidly renewable materials	5/20 25% Success	0/20 0% Medium success	15/20 75% Failed
Use of certified wood	3/20 15% Success	0/20 0% Medium success	15/20 85% Failed

6 Conclusion

Using sustainable materials means that green materials are preferred in the design and construction of buildings to reduce the damage to the environment, climate, and human health throughout the life of the building and its users. The building technology and the decisions taken early in the building design process can sometimes be the most critical decisions regarding the ecological potential of the building. In other words, actions taken at the beginning of the planning process that need to consider green building ideals lead to not using sustainable materials during construction projects. Ecological material improves product and service quality through better design while reducing environmental impact throughout its life cycle. Sustainable material aims to build "environmentally friendly, healthy for work and life" green buildings. In this context, designers interested in sustainable materials should use sensitive materials that do not disturb ecological cycles. Although the application of sustainable materials principles is insufficient to construct a sustainable building, the application of sustainable materials principles is essential for the successful implementation of an ecologically sustainable building. Structures where the principles of sustainable materials are applied successfully increase the success of the certification systems. It is essential to consider LEED evaluation criteria and sustainable materials principles. The design process should be improved, considering the LEED material criteria. For example, practices such as using recycled waste, the preference for certified wood products and rapidly renewable materials, and the effective management of construction waste during demolition positively affect the project's sustainability. The most crucial benefit of using sustainable materials is protecting the environment and human health.

The study aims to encourage the selection of materials that will contribute to sustainability, such as using recycled, renewable, or regional materials. To get the right results from the study, similar types of office projects were selected, and an example was set by selecting twenty office buildings among the projects with the LEED system different level certificates and the highest score at their level. The study listed the building name, overall score, material and resources score, building location certificate type, typology, version registered in LEED, and the certificate level for all projects. Within the framework of 20 selected projects, a sample was created and analyzed according to ecological and sustainability features. The nine principles and scores of LEED materials and resources in the third part were evaluated. As a result, it is seen that the materials and resources department received low scores in all the projects that we discussed within the scope of the study, which received LEED certification. In this context, re-using the building—reusing internal non-structural elements was unsuccessful in 80% of the twenty projects examined. In addition, the category of building reuse—reuse of existing walls, floors, and roofs was 95% Failed. Similarly, the reuse of materials has resulted in 90% of failures. In addition, it was concluded that using rapidly renewable materials was 75% unsuccessful. Certified wood is among the results obtained, with a failure rate of 85%. Failure to under-apply the categories mentioned above is the main reason for the overall low score in the material and resource category in the LEED rating system. On the other hand, it is seen that the use of regional materials gives 100% successful results. Recycled content was 75% successful. Finally, a 45% successful utilization rate was achieved in construction waste management.

In today's world, where the number of registered projects is increasing daily, Architecture students need to receive the necessary education and have sufficient knowledge about LEED and other certification systems. Researchers and LEED experts can delve further into the Materials and Resources section and will be able to increase the level of sustainable Materials use.

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Declarations

Competing interests The authors declare no competing interests.

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