JCR Year
2024

Buildings

Open Access since 2011

ISSN

N/A

EISSN

2075-5309

JCR ABBREVIATION

BUILDINGS-BASEL

ISO ABBREVIATION

BUILDINGS-BASEL

Journal information

EDITION

Science Citation Index Expanded (SCIE)

CATEGORY

ENGINEERING, CIVIL

CONSTRUCTION & BUILDING TECHNOLOGY

LANGUAGES	REGION	1ST ELECTRONIC JCR YEAR
English	SWITZERLAND	2020

Publisher information

PUBLISHER	ADDRESS	PUBLICATION FREQUENCY
MDPI	MDPI AG, Grosspeteranlage 5, CH-4052 BASEL, SWITZERLAND	12 issues/year

Journal's performance

Journal Impact Factor

The Journal Impact Factor (JIF) is a journal-level metric calculated from data indexed in the Web of Science Core Collection. It should be used with careful attention to the many factors that influence citation rates, such as the volume of publication and citations characteristics of the subject area and type of journal. The Journal Impact Factor can complement expert opinion and informed peer review. In the case of academic evaluation for tenure, it is inappropriate to use a journal-level metric as a proxy measure for individual researchers, institutions, or articles. Learn more

2024 JOURNAL IMPACT FACTOR

3.1

View calculation

JOURNAL IMPACT FACTOR WITHOUT SELF CITATIONS

2.5

View calculation

Journal Impact Factor Trend 2024

Export

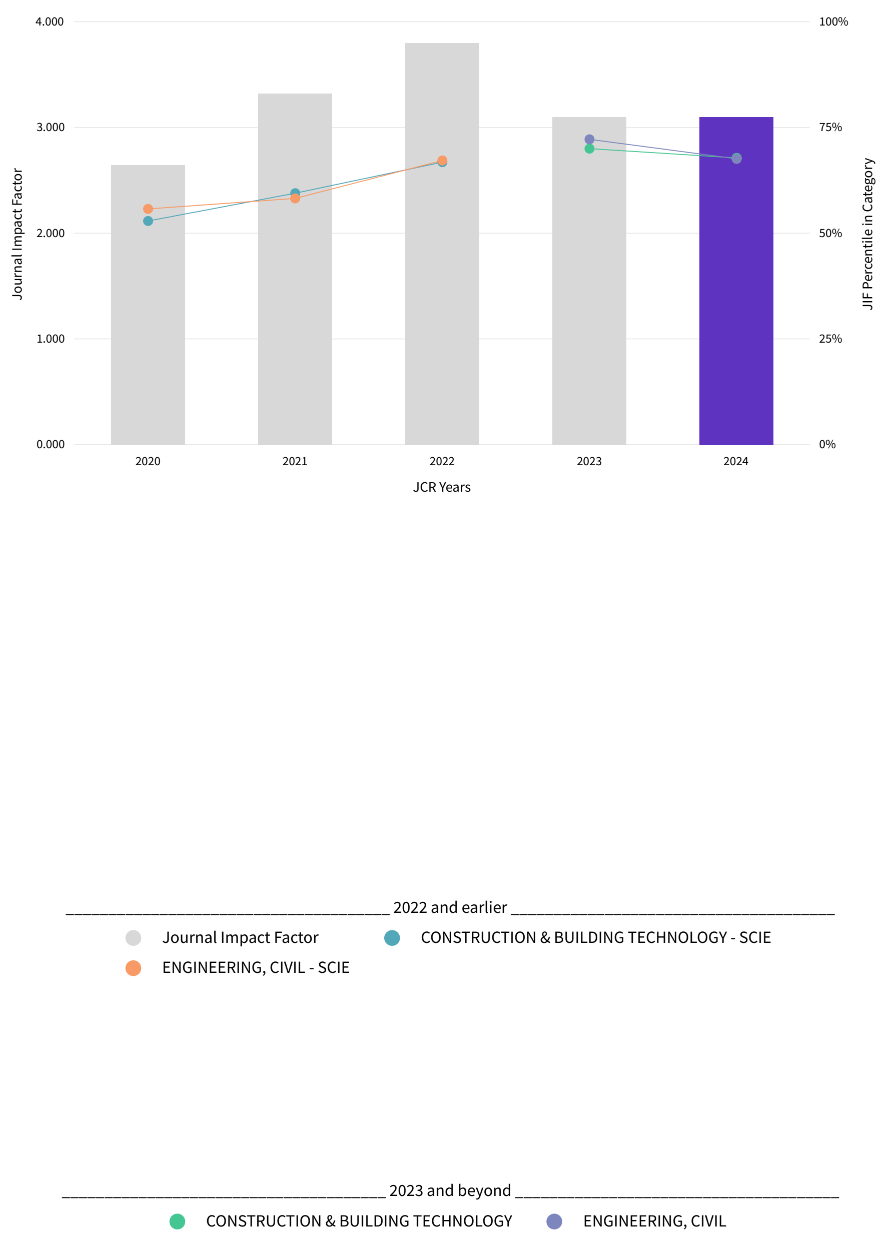
Journal Impact Factor contributing items

Export

Citable items (5,361) Citing Sources (1,861)

TITLE	CITATION COUNT
Digital Twins in Built Environments: An Investigation of the Characteristics,...	75

Yardım



View all years

The Current Development of Structural Health Monitoring for Bridges: A...	68
The Phenomenon of Cracking in Cement Concretes and Reinforced...	58
Internet of Things (IoT), Building Information Modeling (BIM), and...	50
Augmented and Virtual Reality (AR/VR) for Education and Training in the AE...	46
Acceptance Model of Artificial Intelligence (AI)-Based Technologies ...	39
Application of Ultra-High-Performance Concrete in Bridge Engineering:...	37
Effect of Nanographite Conductive Concrete Mixed with Magnetite Sand...	36
Investigating the Use of ChatGPT for the Scheduling of Construction...	34
Analytical Assessment of the Structural Behavior of a Specific Composite Flo...	33

View All in Web of Science

Journal Citation Indicator (JCI)

Export

0.62

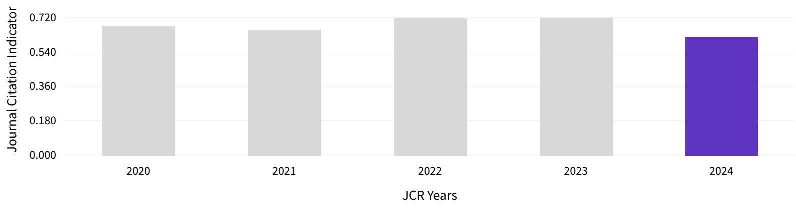
The Journal Citation Indicator (JCI) is the average Category Normalized Citation Impact (CNCI) of citable items (articles & reviews) published by a journal over a recent three year period. The average JCI in a category is 1. Journals with a JCI of 1.5 have 50% more citation impact than the average in that category. It may be used alongside other metrics to help you evaluate journals. Learn more

Total Citations

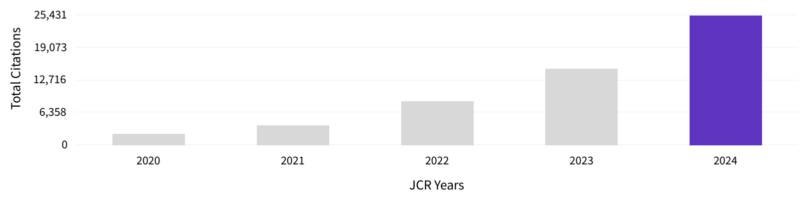
Export

25,431

The total number of times that a journal has been cited by all journals included in the database in the JCR year. Citations to journals listed in JCR are compiled annually from the JCR years combined database, regardless of which JCR edition lists the journal.



View all years



View all years

Citation distribution

Export

The Citation Distribution shows the frequency with which items published in the year or two years prior were cited in the JCR data year (i.e., the component of the calculation of the JIF). The graph has similar functionality as the JIF Trend graph, including hover-over data descriptions for each data point, and an interactive legend where each data element's legend can be used as a toggle. You can view Articles, Reviews, or Non-Citable (other) items to the JIF numerator. Learn more

ARTICLE CITATION MEDIAN

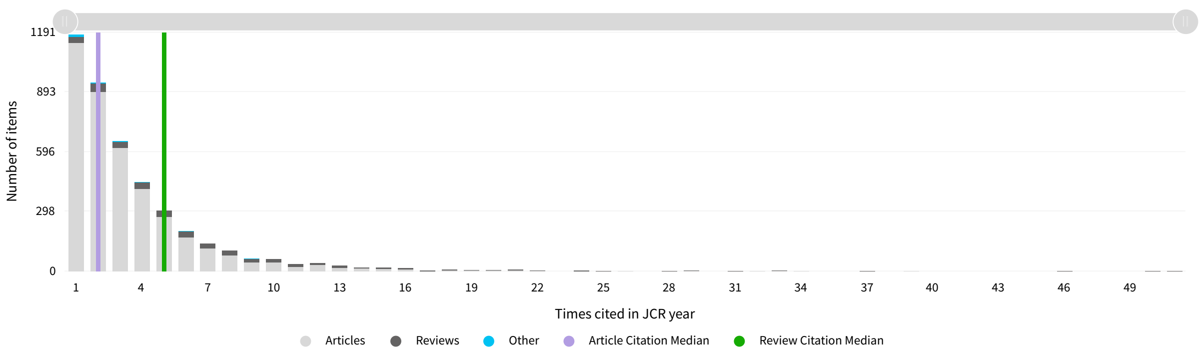
2

REVIEW CITATION MEDIAN

5

UNLINKED CITATIONS

122



TIMES CITED

0

ARTICLES

1,038

REVIEWS

24

OTHER

25

Open Access (OA)

Export

The data included in this tile summarizes the items published in the journal in the JCR data year and in the previous two years. This three-year set of published items is used to provide descriptive analysis of the content and community of the journal. Learn more

Items

TOTAL CITABLE	% OF CITABLE OA
9,429	100.00%

Citations*

TOTAL CITABLE	% OF CITABLE OA
19,336	100.00%

CITABLE

GOLD OPEN ACCESS

9,429 / 99.36%

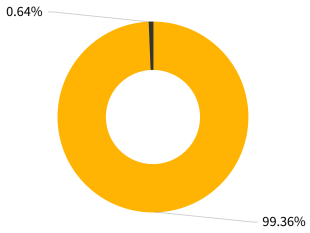
SUBSCRIPTION AND FREE TO READ

0 / 0.00%

NON-CITABLE

OTHER (NON CITABLE ITEMS)

61 / 0.64%



CITABLE

GOLD OPEN ACCESS

19,336 / 99.04%

SUBSCRIPTION AND FREE TO READ

0 / 0.00%

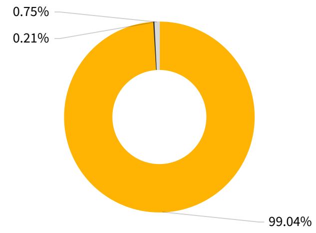
NON-CITABLE

OTHER (NON CITABLE ITEMS)

41 / 0.21%

UNLINKED CITATIONS

147 / 0.75%



*Citations in 2024 to items published in [2022 - 2024]

Rank by Journal Impact Factor

Journals within a category are sorted in descending order by Journal Impact Factor (JIF) resulting in the Category Ranking below. A separate rank is shown for each category in which the journal is listed in JCR. Beginning in 2023, ranks are calculated by category. Learn more

CATEGORY

CONSTRUCTION & BUILDING TECHNOLOGY

31/95

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2024	31/95	Q2	67.9
2023	28/92	Q2	70.1

Rank by JIF before 2023 for CONSTRUCTION & BUILDING TECHNOLOGY

EDITION

Science Citation Index Expanded (SCIE)

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	23/68	Q2	66.9
2021	28/68	Q2	59.56
2020	32/67	Q2	52.99

CATEGORY

ENGINEERING, CIVIL

60/184

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2024	60/184	Q2	67.7
2023	51/182	Q2	72.3

Rank by JIF before 2023 for ENGINEERING, CIVIL

EDITION

Science Citation Index Expanded (SCIE)

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	46/139	Q2	67.3
2021	58/138	Q2	58.33
2020	61/137	Q2	55.84

Rank by Journal Citation Indicator (JCI)

Journals within a category are sorted in descending order by Journal Citation Indicator (JCI) resulting in the Category Ranking below. A separate rank is shown for each category in which the journal is listed in JCR. Data for the most recent year is presented at the top of the list, with other years shown in reverse chronological order. Learn more

CATEGORY

CONSTRUCTION & BUILDING TECHNOLOGY

32/95

JCR YEAR	JCI RANK	JCI QUARTILE	JCI PERCENTILE
2024	32/95	Q2	66.84
2023	25/92	Q2	73.37
2022	27/89	Q2	70.22
2021	32/89	Q2	64.61
2020	28/87	Q2	68.39
2019	29/87	Q2	67.24
2018	25/85	Q2	71.18

CATEGORY

ENGINEERING, CIVIL

67/185

JCR YEAR	JCI RANK	JCI QUARTILE	JCI PERCENTILE
2024	67/185	Q2	64.05
2023	56/182	Q2	69.51
2022	60/179	Q2	66.76
2021	72/175	Q2	59.14
2020	63/172	Q2	63.66
2019	65/172	Q2	62.50
2018	61/170	Q2	64.41

Citation network

Cited Half-life

2.1 years

The Cited Half-Life is the median age of the items in this journal that were cited in the JCR year. Half of a journal's cited items were published more recently than the cited half-life.

TOTAL NUMBER OF CITES

25,431

NON SELF-CITATIONS

20,611

SELF-CITATIONS

4,820

Citing Half-life

6.0 years

The Citing Half-Life is the median age of items in other publications cited by this journal in the JCR year.

TOTAL NUMBER OF CITES

213,098

NON SELF-CITATIONS

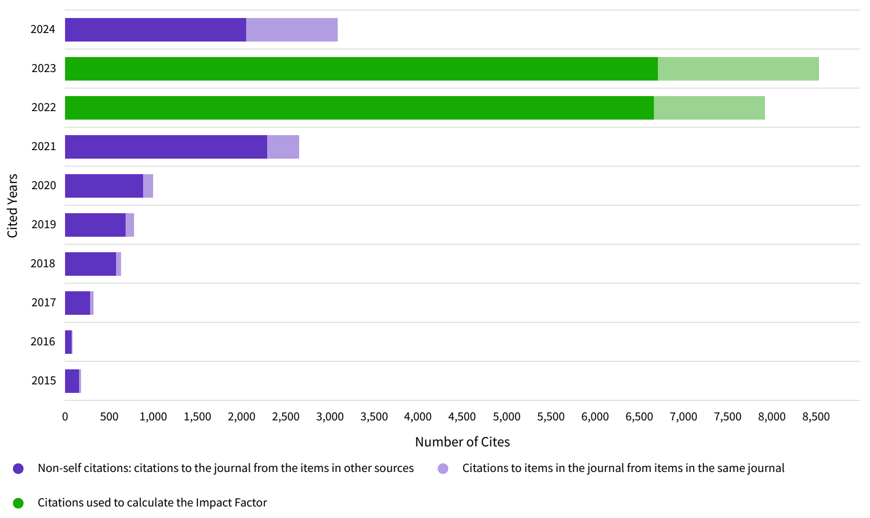
208,278

SELF-CITATIONS

4,820

Cited Half-life Data | Citing Half-life Data

Export

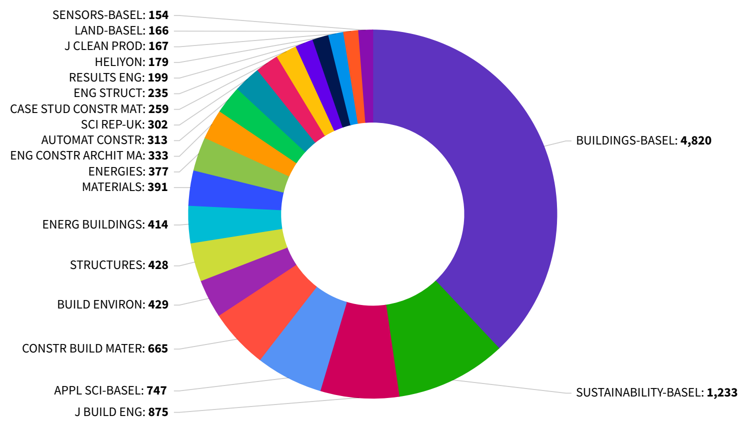


CITED YEAR	# OF CITES FROM 2024	CUMULATIVE %	# OF CITING SOURCES
All years	**25,431 citations**	**100.00%**	**2,235 sources**
2024	3,085 citations	12.13%	476 sources
2023	8,526 citations	45.66%	1,201 sources
2022	7,913 citations	76.77%	1,278 sources
2021	2,648 citations	87.18%	702 sources
2020	992 citations	91.09%	360 sources
2019	777 citations	94.14%	280 sources
2018	632 citations	96.63%	278 sources
2017	320 citations	97.88%	144 sources
2016	79 citations	98.20%	47 sources
2015	178 citations	98.90%	102 sources
Older	281 citations		

Journal Citation Relationships

Cited Data Citing Data

Top 20 journals citing BUILDINGS-BASEL by number of citations



Content metrics

Source data

This tile shows the breakdown of document types published by the journal. Citable Items are Articles and Reviews. For the purposes of calculating JIF, a JCR year considers the publications of that journal in the two prior years. Learn more

4,068 total citable items

	ARTICLES	REVIEWS	COMBINED(C)	OTHER DOCUMENT TYPES(O)	PERCE
NUMBER IN JCR YEAR 2024 (A)	3,806	262	4,068	17	100%
NUMBER OF REFERENCES (B)	182,549	30,370	212,919	179	100%
RATIO (B/A)	48.0	115.9	52.3	10.5	

Average JIF Percentile

Export

The Average Journal Impact Factor Percentile takes the sum of the JIF Percentile rank for each category under consideration, then calculates the average of those values. Learn more

ALL CATEGORIES AVERAGE
67.8

ENGINEERING, CIVIL
67.7

CONSTRUCTION & BUILDING TECHNOLOGY
67.9

Contributions by organizations

Export

Organizations that have contributed the most papers to the journal in the most recent three-year period. Learn more

RANK	ORGANIZATION	COUNT
1	TONGJI UNIVERSITY	245
2	SOUTHEAST UNIVERSITY - CHINA	236
3	EGYPTIAN KNOWLEDGE BANK (EKB)	203
4	CHONGQING UNIVERSITY	162
5	CENTRAL SOUTH UNIVERSITY	152
6	XI'AN UNIVERSITY OF ARCHITECTURE &	147

Contributions by country/region

Export

Countries or Regions that have contributed the most papers to the journal in the most recent three-year period. Learn more

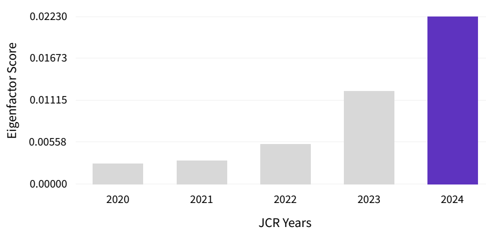
RANK	COUNTRY / REGION	COUNT
1	CHINA MAINLAND	4926
2	AUSTRALIA	482
3	USA	470
4	SOUTH KOREA	445
5	ENGLAND	386
6	ITALY	384
7	SPAIN	307
8	SAUDI ARABIA	286
9	TURKIYE	226

Additional metrics

Eigenfactor Score

0.02230

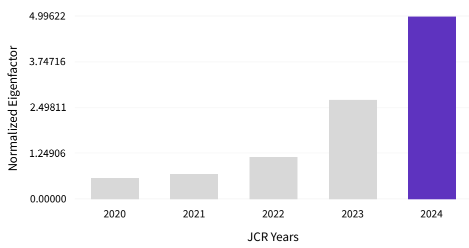
The Eigenfactor Score is a reflection of the density of the network of citations around the journal using 5 years of cited content as cited by the Current Year. It considers both the number of citations and the source of those citations, so that highly cited sources will influence the network more than less cited sources. The Eigenfactor calculation does not include journal self-citations. Learn more



Normalized Eigenfactor

4.99622

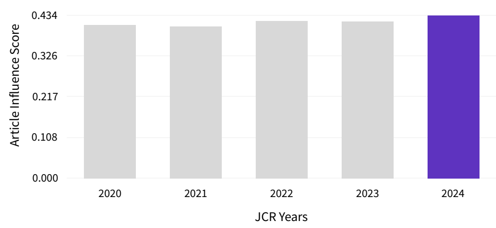
The Normalized Eigenfactor Score is the Eigenfactor score normalized, by rescaling the total number of journals in the JCR each year, so that the average journal has a score of 1. Journals can then be compared and influence measured by their score relative to 1. Learn more



Article influence score

0.434

The Article Influence Score normalizes the Eigenfactor Score according to the cumulative size of the cited journal across the prior five years. The mean Article Influence Score for each article is 1.00. A score greater than 1.00 indicates that each article in the journal has above-average influence. Learn more



5 Year Impact Factor

3.2

View Calculation

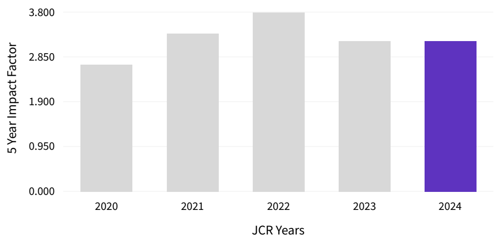
The 5-year Impact Factor is the average number of times articles from the journal published in the past five years have been cited in the JCR year. It is calculated by dividing the number of citations in the JCR year by the total number of articles published in the five previous years. Learn more

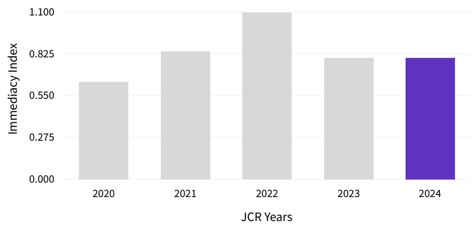
Immediacy Index

0.8

View Calculation

The Immediacy Index is the count of citations in the current year to the journal that reference content in this same year. Journals that have a consistently high Immediacy Index attract citations rapidly. Learn more


5 Year Impact Factor
3.800
2.850
1.900
0.950
0.000
2020
2021
2022
2023
2024
JCR Years


Immediacy Index
1.100
0.825
0.550
0.275
0.000
2020
2021
2022
2023
2024
JCR Years

buildings

MDPI

Article

Sustainable Healthcare Infrastructure: Design-Phase Evaluation of LEED Certification and Energy Efficiency at Istanbul University's Surgical Sciences Building

Cemil Akçay [1,*] and Mahmut Sarı [2]

[1] Department of Architecture, Istanbul University, 34116 Istanbul, Türkiye
[2] Department of Construction, Kırşehir Ahi Evran University, 40100 Kırşehir, Türkiye; mahmutsari@ahievran.edu.tr
* Correspondence: cakcay@istanbul.edu.tr

Abstract

The rapid growth of the global population and associated increases in resource consumption have accelerated environmental degradation, making sustainable design and construction processes increasingly essential. The construction sector holds significant potential for reducing environmental impacts, especially through sustainability-focused certification systems such as LEED. This study evaluates the projected energy efficiency and sustainability performance of the Surgical Sciences Building at Istanbul University's Çapa Campus, which was designed with the goal of achieving LEED Gold certification. The assessment is based on design-phase data and conducted prior to construction. Energy performance analyses were carried out using DesignBuilder software, supported by the LEED Assessment Report and Energy Audit Report. According to simulation results, approximately 30% savings in energy consumption and water usage are expected. In addition, the process-oriented LEED approach is expected to result in a total CO_2 emission savings of approximately 570 tonnes, while renewable energy systems are expected to meet approximately 13% of the building's primary energy demand and reduce CO_2 emissions by approximately 151 tonnes per year. Waste management strategies developed for both the construction and operational phases are aligned with LEED criteria and aim to achieve up to 80% recycling rates. The findings demonstrate that LEED certification, when employed as a process-oriented design and decision-making tool rather than a result-oriented label, can enable sustainable strategies to be integrated from the earliest stages of project development. Particularly for complex healthcare buildings, embedding LEED principles into the design process has strong potential to enhance environmental performance. Although based on a single case study, this research provides valuable insight into the broader applicability of LEED in diverse building types and geographic contexts.

Keywords: LEED certification; energy efficiency; sustainable building design; renewable energy; implicit sustainability; integration; process-oriented approach

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1. Introduction

The rapidly growing world population is expected to reach 9.73 billion by 2064 [1]. The growing population is also increasing demand for societies' needs, goals, and priorities. To meet these demands and ensure competitiveness, the rapid growth of technology and industry has led to a natural increase in CO_2 emissions and waste, which recently has threatened humanity's future in terms of sustainability. According to a report prepared by the International Solid Waste Association (ISWA), the amount of municipal solid waste worldwide is expected to reach 3.8 billion tonnes by 2050 [2]. The report also estimates that sustainable practices, primarily through waste avoidance and comprehensive waste management, could save 108.5 billion dollars annually. Construction and demolition waste accounts for 30–40% of solid waste (67% in America, 36% in Europe, and 30–40% in China), and only 20–30% of this waste can be recycled [3]. If equipped with sustainable design and construction processes, the construction sector has the potential to save approximately 44 billion dollars annually in the global economy, based on this information. Additionally, the construction sector is a sector where disputes frequently occur due to its multi-stakeholder structure and the risks it entails [4,5]. These disputes lead to the cancellation or delayed completion of public and private construction projects, as well as defective and flawed construction, resulting in financial and emotional losses [6]. By implementing sustainable design and construction processes, construction disputes can be prevented, thereby avoiding financial and non-financial losses. The construction sector has the potential to save approximately 44 billion dollars annually by adopting sustainable design and construction processes. Additionally, there is an opportunity to reduce energy consumption in the construction sector by 24% [7].

In order to ensure the design and construction of sustainable buildings, it is necessary to define buildings in detail, covering the design and construction processes. The world's leading assessment system, Leadership in Energy and Environmental Design (LEED), stands out as the system used to evaluate a total of 105,712 buildings to date [8]. In addition to Türkiye not having its own assessment system, the LEED system has been in high demand in recent years. Currently, 1969 buildings based in Türkiye have been assessed, and 15 of these are healthcare buildings have been certified [8]. With the increasing interest in LEED certification in Türkiye, the number of Türkiye-based studies on energy efficiency and LEED certification applications has increased in recent years. In a preliminary study, the development levels of certification systems were examined from the perspective of developing countries (Türkiye, the United Arab Emirates, and India), and the levels of the three developing countries were compared [9]. Aktas and Ozorhon [10] examined the factors contributing to buildings obtaining LEED certification and the challenges faced in six LEED-certified projects in Türkiye. In addition, a performance comparison was made between LEED-NC 2009-certified construction projects in four different countries, including new construction projects in Türkiye, in an effort to understand the differences affecting the performance of projects in different regions [11]. It was observed that sustainable building designs and certification strategies may vary by country depending on the type of project [12]. An analysis of the applicability of LEED's sustainability strategies in the material-selection preferences of 269 LEED-certified projects in Türkiye was conducted, focusing on many categories examined by LEED for sustainable buildings [13]. A study on which criteria should be prioritised for LEED certification of healthcare buildings in Türkiye also indicates that LEED certification is becoming increasingly important in the healthcare sector [14].

A review of the existing literature reveals that studies have been conducted on certified buildings. The absence of studies demonstrating that LEED certification is not only a results-oriented but also a process-oriented tool is noteworthy. LEED's main strength lies in the decisions made during the design phase and the impact of these decisions on construction projects. The originality of this study lies in addressing the gap in the literature by examining the LEED compliance of a public hospital project during the construction phase. The aim of the study is to demonstrate that LEED is not merely a certification awarded to completed buildings but can also serve as a process management tool capable of shaping project decisions in early stages. To this end, the energy efficiency and sustainability performance of the Surgical Sciences Building at Istanbul University's Çapa Campus will be examined using LEED assessments and Energy Audit Reports. By doing so, the study aims to fill gaps in the existing literature, promote a process-oriented sustainability approach, and offer recommendations for improving green building practices in Türkiye.

2. Materials and Methods

The study examined the Istanbul University Çapa Campus Surgical Sciences Building using the case-study method. In this study, two reports were used: the 'LEED Assessment Report' and the 'Energy Audit Report' for the Surgical Sciences Building at Istanbul University Istanbul Faculty of Medicine Çapa Campus. All data related to the building were obtained from the LEED Assessment Report and the Energy Audit Report. The LEED Assessment Report details how the building was evaluated and scored according to LEED criteria, while the Energy Audit Report provides a detailed overview of the building's current energy consumption and energy-saving potential.

The energy performance assessment was conducted using DesignBuilder v7. The simulation study was carried out using the TR_ATATURK-AIRPORT_TMY weather file, which represents the local climate conditions of the project site in Istanbul. The modelled building consists of 283 distinct thermal and HVAC zones; each defined according to the specific functional requirements of the hospital's spatial programme. Heating and cooling setpoint temperatures were maintained at 21 °C and 25 °C, respectively, to reflect health standards and occupant comfort. Occupant density varies by room type, with an average of approximately 18 m^2 per person. Operating schedules also vary depending on space usage. Critical areas such as inpatient rooms are assumed to be occupied 24 h a day, while examination rooms, operating rooms, and general shared areas are modelled with a typical daily occupancy rate of 15 h (06:00–23:00) in line with realistic hospital workflows.

The campus coordinates are approximately 41.015° N latitude and 28.940° E longitude, and it is located at an elevation of approximately 55–65 metres above sea level (Figure 1). The area is part of a gently sloping urban plateau facing south towards the Marmara Sea and is approximately 4 kilometres away in a straight line. Located on the historic peninsula of Istanbul, the Fatih district experiences a humid subtropical/temperate oceanic climate (classified as Cfa/Cfb under the Köppen–Geiger climate classification system), influenced by both Mediterranean and Black Sea climate zones. The district stretches along Istanbul's southern coastline and is densely built-up with limited wind corridors and high urban-heat-island effects. Annual average temperatures range between 14 °C and 16 °C, with January being the coldest month (average ~6 °C) and July–August the hottest (average ~25 °C). Heating is typically required from mid-October to early April, while cooling demand peaks during the summer months, particularly in enclosed, high-occupancy areas such as hospitals.

Figure 1. A Google Earth View of Cerrahi Bilimler Building at Istanbul University.

The energy performance assessment was carried out by DesignBuilder. Figure 2 shows a screenshot from the modelling process. The software is equipped with all the capabilities specified in the G2 Simulation General Requirements of the ASHRAE 90.1-2010 standard [15], which is widely used in Türkiye. In recent years, the ASHRAE 90.1-242 (2022) standard, which treats healthcare facilities as a separate category, has been published.

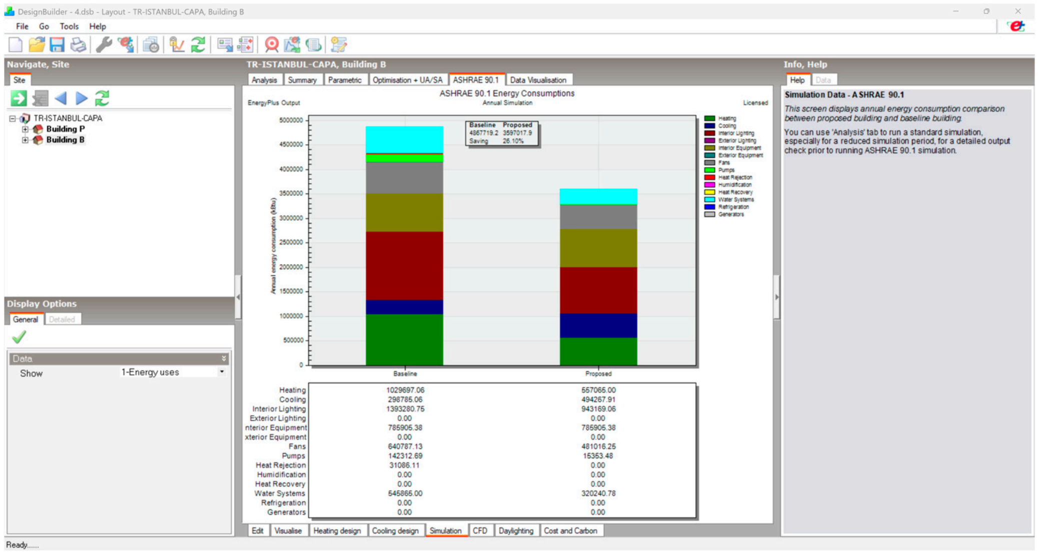

Figure 2. DesignBuilder modelling screen.

The reason for using the ASHRAE 90.1-2010 standard instead of this updated standard is that the former is still in use in current applications in Türkiye and the relevant public institutions have not yet integrated the new standard. The use of a similar standard in recent studies [16,17] also indicates this. During the simulation, reference values obtained from ASHRAE for similar structures were used to determine the energy efficiency of the building when it meets the minimum criteria, and the extent to which the designed building meets these criteria was evaluated. ASHRAE's reference values are provided in Table 1.

Table 1. Reference values from ASHRAE 90.1.2010.

Baseline HVAC System Types				
Nonresidential and More than 5 Floors or >150,000 ft^2			System 7–VAV with Reheat	
Water-Chilling Packages—Efficiency Requirements				
Equipment Type	**Size Category**		**Path A**	**Path**
Water-cooled, electrically operated, centrifugal	≥300 tons and <600 tons		≤0.576 kW/ton ≤0.549 IPLV	≤0.600 kW/ton ≤0.400 IPLV
Lighting Power Densities Using Building Area Method				
Building Area Type			**LPD (W/ft^2)**	
Hospital			1.21	
Baseline System Descriptions				
System	**System Type**	**Fan Control**	**Cooling Type**	**Heating Type**
VAV with reheat	Packaged rooftop VAV with reheat	VAV	Chilled water	Hot-water fossil fuel boiler

3. Results

The Surgical Sciences Building has a model area of 23,930 m^2. The building consists of a total of 10 floors, including 3 floors above ground level and a service floor, and below ground level, a basement, floors 1-2-3, and an isolator floor (Figures 3 and 4). The building has 125 patient beds, 23 intensive care units, and 14 operating rooms. The ground floor consists of a cafeteria, administrative units, endoscopy, urology endoscopy, and breast ultrasound departments. Floors 1-2-3 are planned as patient floors. Each floor has 24 rooms/34 beds, for a total of 72 rooms/102 beds. The utility floor includes a staff dining hall, administrative offices, and technical spaces. The mechanical floor includes a staff cafeteria, administrative offices, and technical areas. The basement floor, which is levelled at −5.00, is defined by an entrance area accessible from within the campus. It consists of an imaging unit and intensive care units. There are a total of 23 intensive care beds and support areas. The imaging unit consists of 1 MRI, 1 CT scan, 2 ultrasound, 2 X-ray, and 2 angiography rooms. The first basement floor has 13 operating rooms, 1 caesarean section operating room, and 2 delivery rooms. The second basement floor has technical areas and sterilisation facilities. Meals are prepared off-site and delivered to the campus. There is a meal distribution area. The third basement floor has a 30-car indoor car park and an archive.

Figure 3. A 3D View of Cerrahi Bilimler Building at Istanbul University.

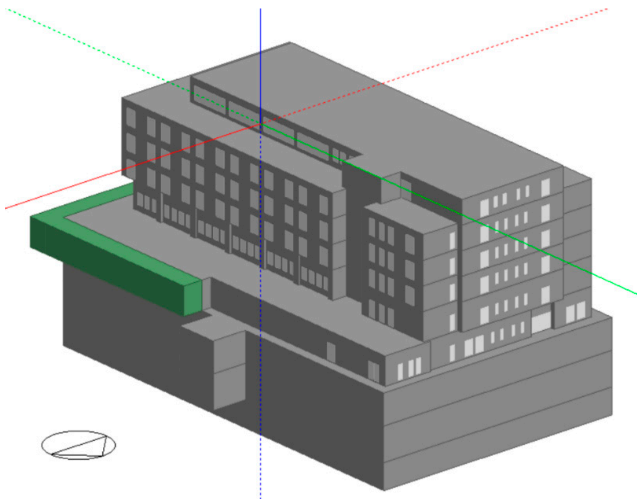

Figure 4. The Çapa Campus of Cerrahi Bilimler Building at Istanbul University (DesignBuilder).

The highest energy consumption in the building is related to lighting, equipment, heating, cooling, fans, and pumps (Figure 5). As a result of the LEED assessment, there are four different certification levels (Table 2). These are 1. Certified (40–49 points), 2. Silver (50–59 points), 3. Gold (60–79 points), 4. Platinum (80–110 points). The LEED criteria for determining these levels are grouped under the following categories:

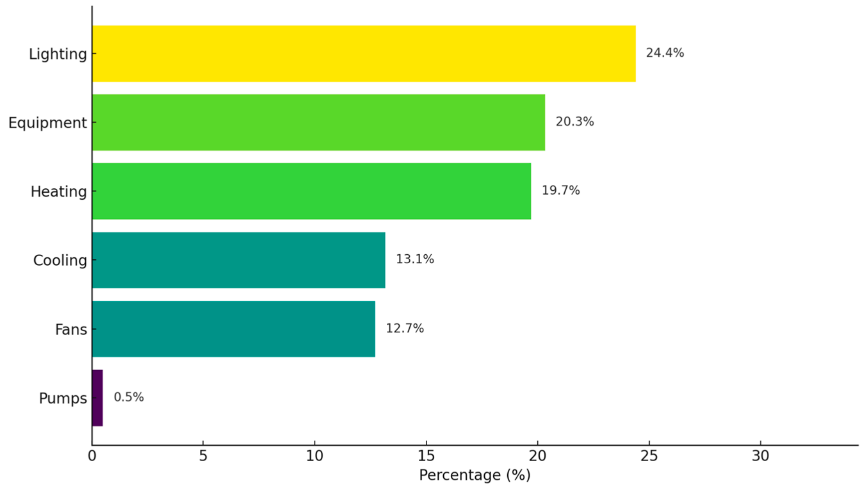

Figure 5. The distribution of the building's energy consumption.

Table 2. LEED Certification Levels by Points.

Certification	Points
Certified	40–49 Points
Silver	50–59 Points
Gold	60–79 Points
Platinum	80–110 Points

The scoring for LEED certification, as shown in Table 3, reveals the results for the Cerrahi Bilimler Hospital. Based on these results, the LEED criteria are grouped under the following categories:

1. Integrative Process:
    - ○ Includes an early analysis of inter-system relationships in order to achieve project results at the desired cost, time, and quality.
2. Location and Transportation:
    - ○ Includes an evaluation of criteria such as access to quality transportation and the presence of electric vehicles in the project's location and transportation sections.
3. Sustainable Sites:
    - ○ Includes an assessment aimed at reducing the effects of deformations such as soil erosion caused by the implementation of the project, protecting natural and historical areas, and creating areas where social and cultural activities can be carried out.
4. Water Efficiency:
    - ○ Includes an assessment of reducing outdoor water consumption, protecting zero- and low-cost drinking water sources, and water conservation.
5. Energy and Atmosphere:

- Includes an assessment of ensuring minimum energy performance, designing an energy project that meets project requirements, and optimising energy performance.

6. Materials and Resources:
   - Includes an assessment of the storage and collection of recycled waste, the provision of environmental product declarations, and the reduction in the impact of the building's life cycle.
7. Indoor Environmental Quality:
   - Includes an assessment aimed at ensuring minimum indoor air quality performance in the project, controlling tobacco smoke, and controlling the use of low-emission materials.
8. Innovation in Design:
   - Includes an assessment aimed at encouraging innovative design strategies that provide high-level benefits to people and the environment in the project.
   - No bolding necessary. Removed.Includes an assessment aimed at promoting projects targeting geographically prioritised areas.

Table 3. Distribution of energy consumption.

No	Category	Reference (kWh)	Design (kWh)	Performance
1	Heating (Natural Gas)	1,029,697.06	557,065.00	45.90%
2	Cooling (Electricity)	298,785.06	494,267.91	−65.43%
3	Lighting (Electricity)	1,393,280.75	943,169.06	32.31%
4	Equipment (Electricity)	785,905.38	785,905.38	0.00%
5	Fans (Electricity)	640,787.13	481,016.25	24.93%
6	Pumps (Electricity)	142,312.69	15,353.48	89.21%
7	Cooling Tower (Electricity)	31,086.11	0.00	100.00%
8	Domestic Hot Water (Natural Gas)	545,865.00	320,240.78	41.33%
11	Total Natural Gas	1,575,562.06	877,305.78	44.32%
12	Total Electricity	3,292,157.12	2,719,712.08	17.39%
13	Total Electricity (with PV system)	3,292.157.12	2,378,774.08	27.74%
	Total	4.867.719.18	3,597,017.86	26.10%

Categories 4, 5, 6, and 7 (Figure 6) are directly related to energy efficiency, materials and resources, and waste management. The total score defined for these categories is 81, and a LEED Platinum certification can only be obtained with a full score from these categories. When examining the Energy and Atmosphere category, it alone accounts for a significant 35 points (32%) of the total scoring (Figure 6).

Due to this high proportion, analyses focused on energy efficiency are of great importance. Within this scope, the building achieves the following energy savings compared to the reference criteria by measuring usage based on operating hours and incorporating renewable energy sources (Table 3).

LEED v4 for BD+C: Healthcare
Project Checklist

Project Name: Istanbul University Istanbul Faculty of Medicine Çapa Campus Surgical Sciences Building
Date:16/08/2024

Y	?	N			
Y			Prereq	Integrative Project Planning and Design	Required
1			Credit	Integrative Process	1
7	**2**	**0**		**Location and Transportation**	**9**
		9	Credit	LEED for Neighborhood Development Location	9
1			Credit	Sensitive Land Protection	1
1	1		Credit	High Priority Site	2
1			Credit	Surrounding Density and Diverse Uses	1
2			Credit	Access to Quality Transit	2
	1		Credit	Bicycle Facilities	1
1			Credit	Reduced Parking Footprint	1
1			Credit	Green Vehicles	1
6	**3**	**0**		**Sustainable Sites**	**9**
Y			Prereq	Construction Activity Pollution Prevention	Required
Y			Prereq	Environmental Site Assessment	Required
1			Credit	Site Assessment	1
	1		Credit	Site Development - Protect or Restore Habitat	1
	1		Credit	Open Space	1
2			Credit	Rainwater Management	2
1			Credit	Heat Island Reduction	1
	1		Credit	Light Pollution Reduction	1
1			Credit	Places of Respite	1
1			Credit	Direct Exterior Access	1
7	**2**	**2**		**Water Efficiency**	**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
1			Credit	Outdoor Water Use Reduction	1
5	2		Credit	Indoor Water Use Reduction	7
		2	Credit	Cooling Tower Water Use	2
1			Credit	Water Metering	1
24	**9**	**2**		**Energy and Atmosphere**	**35**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
3	3		Credit	Enhanced Commissioning	6
18	2		Credit	Optimize Energy Performance	20
	1		Credit	Advanced Energy Metering	1
		2	Credit	Demand Response	2
3			Credit	Renewable Energy Production	3
	1		Credit	Enhanced Refrigerant Management	1
	2		Credit	Green Power and Carbon Offsets	2
8	**10**	**1**		**Materials and Resources**	**19**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
Y			Prereq	PBT Source Reduction- Mercury	Required
	5		Credit	Building Life-Cycle Impact Reduction	5
1	1		Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
1	1		Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
	1	1	Credit	Building Product Disclosure and Optimization - Material Ingredients	2
1			Credit	PBT Source Reduction- Mercury	1
1	1		Credit	PBT Source Reduction- Lead, Cadmium, and Copper	2
1	1		Credit	Furniture and Medical Furnishings	2
1			Credit	Design for Flexibility	1
2			Credit	Construction and Demolition Waste Management	2
9	**7**	**0**		**Indoor Environmental Quality**	**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
2			Credit	Enhanced Indoor Air Quality Strategies	2
3			Credit	Low-Emitting Materials	3
1			Credit	Construction Indoor Air Quality Management Plan	1
2			Credit	Indoor Air Quality Assessment	2
	1		Credit	Thermal Comfort	1
1			Credit	Interior Lighting	1
	2		Credit	Daylight	2
	2		Credit	Quality Views	2
	2		Credit	Acoustic Performance	2
4	**2**	**0**		**Innovation**	**6**
3	2		Credit	Innovation	5
1			Credit	LEED Accredited Professional	1
4	**0**	**0**		**Regional Priority**	**4**
1			Credit	Regional Priority: Specific Credit	1
1			Credit	Regional Priority: Specific Credit	1
1			Credit	Regional Priority: Specific Credit	1
1			Credit	Regional Priority: Specific Credit	1
70	**35**	**5**		**TOTALS** Possible Points:	**110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

Figure 6. LEED v4 for BD + C: Healthcare Project Checklist.

Based on the findings, the annual primary energy consumption for the Surgical Sciences Building was calculated to be 2,719,712.08 kWh/year, according to the preliminary energy performance certificate calculation. The primary energy contribution of the planned photovoltaic systems (PV) for the Surgical Sciences Building has been determined to be 340,938 kWh/year. The simulation of the PVs was carried out using PVsyst version 7.4, a widely recognised software tool for the examination, sizing, and analysis of PV systems. PVsyst provides detailed modelling capabilities, including hourly energy yield simulations based on location-specific meteorological data, shading analysis, module orientation, tilt angle, system losses, and inverter configurations. In our study, simulation parameters were carefully defined, considering the site's exact geographical coordinates, local solar radiation data, system design characteristics (such as PV module type, string configuration, and inverter selection), and detailed loss factors (including temperature-related losses, soiling, mismatch, and cable losses). It is expected that the planned PVs will meet approximately 13% of the building's primary energy needs from renewable sources (Figure 7). The rooftop PV system, consisting of 848 panels, has a total installed capacity of 254 kWp and is expected to produce 340,938 kWh of energy per year. The panels will be installed on the roof at a 30°/45° angle, and no shading is expected. Additionally, a 32.4 kWp solar collector system is planned for hot-water production, with 20 solar collectors expected to generate 46,620 kWh of energy annually. The collectors have a maximum hourly energy output of 32.4 kW, an average daily output of 259 kWh/day, and are expected to save 46,620 kWh of energy annually.

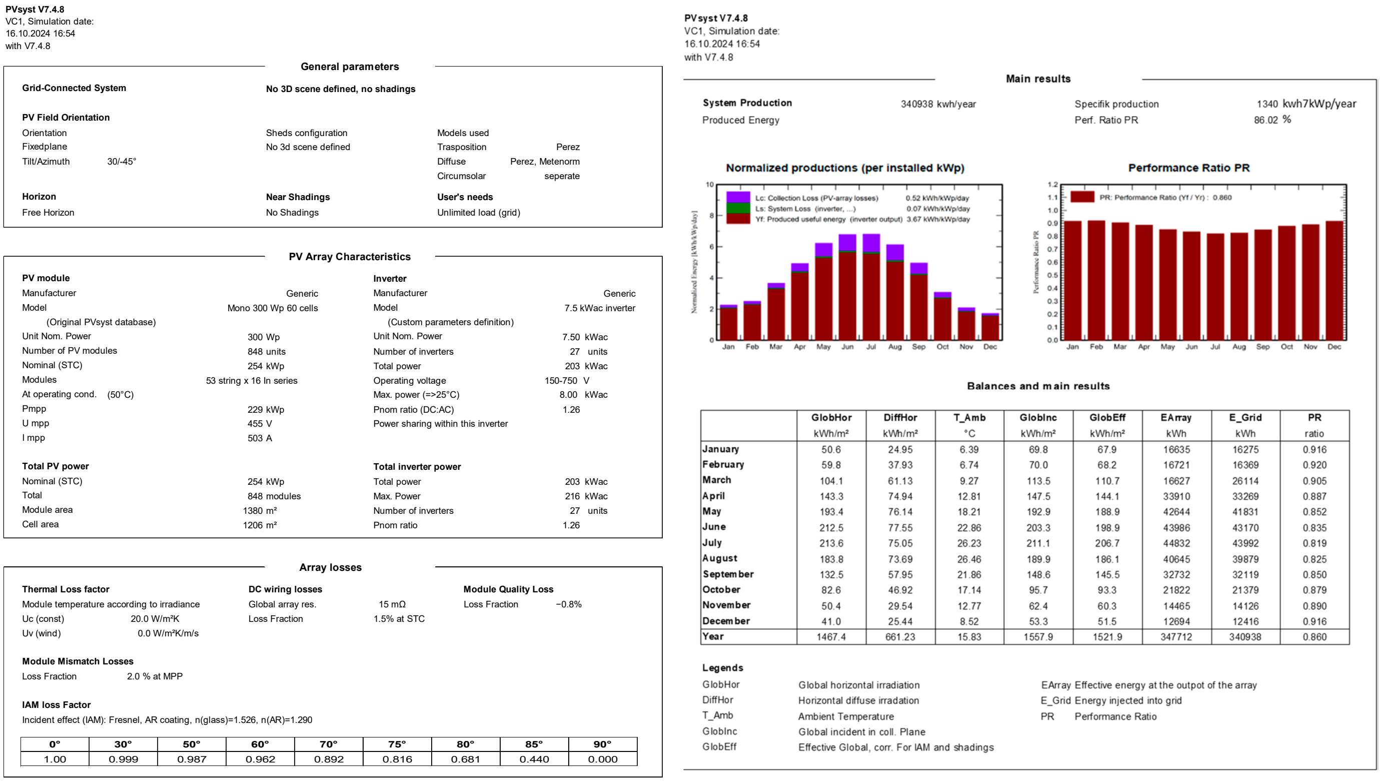

Figure 7. PV Panel Feasibility Report.

Based on monthly rainfall data obtained from meteorological records at the Florya Meteorological Station, the nearest official measurement station to Istanbul University's Çapa Campus [18], the amount of rainwater that can be collected from a 2302 m^2 roof area has been calculated (1):

$$E_R = A_A \times e \times h_N \times \eta \quad (1)$$

E_R: Annual rainfall amount (lt);
A_A: Rainwater collection area (m^2);
e: Roof efficiency coefficient;
h_N: Annual rainfall amount (lt/m^2);
η: Filter efficiency coefficient (0.90).

The irrigation water requirement is met from water sources provided by the municipality. Rainwater harvesting will be carried out using a 20,000-litre rainwater tank to meet irrigation needs. The annual rainwater total is expected to be 1,144,462 litres, and 26.13% of the building's water requirement is expected to be met through rainwater harvesting.

The Surgical Sciences Building scored 9 points in the water efficiency category, achieving a reduction in water consumption of approximately 30%. Waste management strategies have been considered for both the construction and operation phases of the Surgical Sciences Building. During construction, a Waste Management Plan was prepared to ensure the separation, tracking, and recycling of construction and demolition waste. The goal is to divert 75% of total construction waste from landfills. The building was designed with waste separation areas, including dedicated spaces for recyclable and medical waste, during the construction process. An Operational Waste Management Plan has also been developed, supported by staff training and regular monitoring, which achieves an estimated 80% recycling rate for non-hazardous waste. These strategies are consistent with LEED requirements and significantly contribute to the project's sustainability goals. These findings demonstrate that the building has achieved its sustainability goals in terms of waste management. Although it has been found that some LEED-certified buildings consume more energy than non-certified buildings [19], the relationship between energy efficiency and LEED scores has also been examined. LEED-certified buildings generally show a 18–39% reduction in energy consumption compared to non-certified buildings, regardless of certification level [20]. The findings confirm that the high energy efficiency of the Surgical Sciences Building is consistent with its high LEED score potential. In this context, a positive relationship between energy efficiency and LEED certification has been observed.

Energy modelling studies conducted for the Surgical Sciences Building located at Istanbul University's Çapa Campus provide important information about the current state of the building and the strategies planned to reduce its carbon footprint. A detailed analysis of carbon emissions from electricity and natural gas consumption demonstrates LEED compliance during the design process. As a result of the design process, annual natural gas consumption was reduced from 1,575,562.06 kWh in the reference to 877,305.78 kWh in the design, achieving a 44.32% performance improvement. Based on the emission factor (0.234 kg CO_2/kWh [21]), this resulted in a CO_2 emission savings of 163,391.969 kg CO_2/kWh CO_2 emissions were saved. Similarly, the annual total energy consumption was 3,292,157.12 kWh, while in the design it was reduced to 2,719,712.08 kWh, achieving a 17.39% performance improvement. Based on the emission factor (0.442 kg CO_2/kWh [22]), this resulted in a CO_2 emission savings of 253,020.707 kg CO_2/kWh. A total CO_2 emission savings of 416,412.676 kg CO_2/kWh was achieved through the design effect. Additionally, two energy simulation scenarios were developed using DesignBuilder software to assess the impact of the installed PV system: i. A baseline model without renewable systems; ii. The proposed model integrating rooftop PV panels. The annual energy production from PV was simulated to be approximately 340,938 kWh. This amount was subtracted from the building's total electricity demand. Based on the emission factor for electricity (0.442 kg CO_2/kWh), it is estimated that the PV system will reduce annual CO_2 emissions by approximately 150,694.596 kg CO_2/kWh compared to the baseline scenario. It is estimated that a total CO_2 emission savings of 567,107.272 kg CO_2/kWh will be achieved through the design-induced savings. These technologies not only reduce carbon emissions but also contribute to energy independence. The building's energy performance, evaluated according to the ASHRAE 90.1 standard, shows a 26.10% improvement in energy consumption. This improvement highlights the project's priority on energy efficiency and sustainability. Based on the findings, it is clear that LEED certification has positive effects on energy efficiency, water efficiency, and waste management, and makes significant contributions to improving the sustainability performance of buildings.

4. Discussion

In this study, the Surgical Sciences Building located at Istanbul University's Çapa Campus was evaluated in terms of energy efficiency, materials and resources, water efficiency, and sustainability performance using LEED certification standards, and its LEED compliance was examined. The findings show that the design process was found to be in compliance with LEED criteria. This compliance also has the potential to achieve a high score. This demonstrates that LEED certification is an effective process-oriented tool for improving the environmental sustainability of buildings. The use of LEED certification as a process-oriented rather than results-oriented tool has revealed that important decisions in line with LEED criteria can be made prior to implementation. In particular, the approximately 30% reduction in the building's energy and water consumption is consistent with the results of similar studies documented in the literature to date.

However, there appears to be no consensus in the literature on whether a results-oriented approach to LEED certification is effective in achieving energy efficiency. Amiri and Ottelin [23] found that LEED-certified buildings achieved energy savings ranging from 18% to 39%. In contrast, Scofield [19] claimed that some LEED-certified buildings did not meet the expected energy savings. A result-oriented approach revealed inconsistent results, as the effectiveness of LEED certification may vary on a project-by-project basis. Instead, this study suggests that using LEED certification with a process-oriented approach would eliminate this inconsistency. Similarly, in terms of energy and water efficiency, a significant reduction of approximately 30% in energy and water consumption in buildings demonstrates the positive impact of LEED certification on the efficient use of energy and water resources. This aligns with the findings of Gurgun and Polat [24], who demonstrated that Turkish construction projects with LEED certification excel in water efficiency. A 75% construction waste recycling rate and an 80% operational recycling rate in waste management demonstrate the positive impact of LEED certification on waste management practices. This observation is consistent with the existing literature. Ghisellini and Cialani [25] have highlighted the benefits of using a circular economy approach in waste management. This research demonstrates that LEED certification is necessary to achieve sustainability goals in waste management. Additionally, the presence of renewable energy sources was found to meet 12.54% of the building's energy needs and facilitate a reduction of approximately 151 tonnes of CO_2 emissions. Zuo and Zhao [26] align with the current study in highlighting the increasing integration of renewable energy systems into sustainable buildings. These alignments support the idea that the LEED certification can be considered a process-oriented tool applicable across various geographical regions and climates, enabling effective outcomes in energy efficiency, waste management, and water efficiency. The findings of this study reveal that the standards and technical specifications used in the design of the public hospital align with LEED criteria. This study has identified the potential for an implicit sustainability approach in the public hospital project through document-based analysis.

5. Conclusions

In this study, the energy efficiency, materials and resources, water efficiency, and sustainability performance of the Istanbul University Çapa Campus Surgical Sciences Building were measured according to the LEED certification system. As a result of the measurements, the LEED certification compliance of the project was examined at the design stage. The results showed that LEED certification is a successful tool for improving the environmental performance of buildings as a process-oriented tool. The approximately 30% reduction in energy and water consumption in the building is consistent with studies in the literature. The current study contributes significant evidence to the effectiveness and efficiency of the LEED certification system. Additionally, the use of renewable energy sources, which account for 12.54% of the building's total energy consumption and save approximately 151 tonnes of CO_2, demonstrates the significant contribution of renewable energy systems to achieving sustainability goals. Consequently, it is anticipated that the process-oriented LEED procedure will reduce CO_2 emissions by approximately 570 tonnes. The study offers a different approach to the effectiveness debates in the literature by using LEED certification as a process-oriented tool rather than a results-oriented one. The study provides realistic outputs through a special energy simulation for a hospital typology comprising 283 thermal and HVAC zones. A process-oriented LEED-based energy performance analysis offers decision-makers the opportunity for early intervention in a project during the construction phase. This study is unique in that it analyses and simulates PV systems not only from an energy perspective but also from a carbon footprint perspective in terms of carbon dioxide emissions. The simulation of the design phase of public hospitals in Türkiye for LEED-targeted facilities is a pioneering study.

However, the study has some limitations, such as the use of a single case study and dependence on certain assumptions (i. The assumption that energy systems will operate at constant efficiency; ii. The assumption that user behaviour is homogeneous; iii. The assumption that user behaviour is based on hospital building typologies and standard healthcare usage models; iv. The assumption that equipment power is calculated using values taken from standard guidelines and internal loads are used) have been incorporated into the simulation model. The validation of simulation results has not been conducted at this stage, as the building is still under construction. The project has recently progressed from the final design phase to the implementation phase, and therefore, there is currently no post-occupancy measured energy consumption data available to support a comparative evaluation or calibration of the simulation model. However, once the building is operational and sufficient monitoring data has been collected, a validation study will be conducted to ensure the accuracy and reliability of the simulation results. In future studies, the effects of using LEED certification as a process-oriented tool can be examined by investigating its effects on various building types (e.g., residential and industrial buildings) and various geographical locations.

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