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COMPARATIVE STUDY FOR BIM-BASED LEED INDUSTRIAL BUILDING AND NON-LEED INDUSTRIAL BUILDING

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Abstract: This study intends to do architectural and structural designs of a sustainable industrial building using BIM and LEED as well as compare the LEED industrial building and non-LEED industrial building. In this scope, the additional costs related to water and energy efficient systems were analyzed to calculate the respective break-even points. Literature review and case study were performed to achieve the research objective. In the case study, a reinforced concrete industrial building was designed via Autodesk Revit 2021 considering the selected sustainability criteria under the LEED v4.1 BD+C for New Construction rating system. The LEED industrial building can fulfill 31 credits and 8 prerequisites which allow to obtain 73 points and LEED Gold certificate. The initial cost of LEED industrial building is 154.222.607 TL while the initial cost of non-LEED industrial building is 139.080.060 TL. Break-even point for the cost of energy-efficient systems utilized in the LEED industrial building is 14 years. Break-even point for the cost of water-efficient systems utilized in the LEED industrial building is 8 years. Results contribute to the architecture, engineering and construction industry and literature by providing constructive information about the design requirements and energy, water, and cost performance of the LEED industrial buildings.

Keywords: BIM, Building Information Modeling, LEED, Green building assessment systems, Sustainable Building, Industrial buildings

BIM Tabanlı LEED Endüstriyel Bina ve LEED Olmayan Endüstriyel Bina İçin Karşılaştırmalı Çalışma

Öz: Bu çalışma BIM ve LEED kullanarak sürdürülebilir bir endüstriyel binanın mimari ve statik tasarımlarını yapmayı ve LEED endüstriyel bina ve LEED olmayan endüstriyel binayı karşılaştırmayı amaçlamaktadır. Bu kapsamda, su ve enerji verimli sistemlerle ilgili ek maliyetler analiz edilerek ilgili başabaş noktaları hesaplanmıştır. Araştırma amacını gerçekleştirmek için literatür taraması ve vaka çalışması yapılmıştır. Vaka analizinde, betonarme bir endüstriyel bina Autodesk Revit 2021 ile Yeni İnşaat için LEED v4.1 BD+C değerlendirme sistemi altındaki seçilen sürdürülebilirlik kriterleri göz önünde bulundurularak tasarlanmıştır. LEED endüstriyel binası, 73 puan ve LEED Gold sertifikası almayı sağlayan 31 kredi ve 8 ön koşulu yerine getirebilmektedir. LEED endüstriyel binanın başlangıç maliyeti 154.222.607 TL iken, LEED olmayan endüstriyel binanın başlangıç maliyeti 139.080.060 TL'dir. LEED endüstriyel binasında kullanılan enerji verimli sistemlerin maliyeti için başabaş noktası 14 yıldır. LEED endüstriyel binasında kullanılan su verimli sistemlerin maliyeti için başabaş noktası 8 yıldır. Sonuçlar, LEED endüstriyel binalarının tasarım gereksinimleri ve enerji, su ve maliyet performansı hakkında yapıcı bilgiler sağlayarak mimarlık, mühendislik ve inşaat endüstrisine ve literatürüne katkıda bulunur.

Anahtar Kelimeler: YBM, Yapı Bilgi Modellemesi, LEED, Yeşil bina değerlendirme sistemleri, Sürdürülebilir bina, Endüstriyel binalar

1. INTRODUCTION

Construction industry is one of the largest energy-consuming sector. Buildings generate 38% of greenhouse gas (GHG) emissions as well as consume 30–40% of energy and 40–50% of

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all raw materials (UN Environment and International Energy Agency 2017, Global Alliance for Buildings and Construction 2019). Building energy consumption in some coutries, which utilize high amount of traditional biomass, reaches as much as 80% of total final energy use (IEA, 2022). In global, residential buildings, commercial buildings, and transportation cause 21.4%, 18.1%, and 28.6% energy consumption as well as 17.6%, 18.6%, and 28.0% carbon release, respectively (Alliance to Save Energy (ASE), 2009). According to the report of UN International Energy Agency in 2017, developed and developing countries cause over 50-150 ton CO_2/terajoule and 150 ton CO_2/terajoule carbon release (IEA, 2017). However, the energy-carbon densities of existing buildings are more than 20 tons of CO_2 per terajoule (IEA, 2022) which shows that global temperature would increase more than 2 ° C by 2050 (UN Environment and International Energy Agency, 2017).

Studies indicated that if no preventive measure is taken to increase building energy performance in the construction industry, energy demand is expected to rise by 50% until 2050 (IEA 2022). On the contrary, enhancing the energy performance of commercial and industrial buildings by 10% would help achieve a saving of $20 billion and prevent carbon emissions equal to those caused by 30 million vehicles (Energy Star, 2022). Limiting the global temperature rise to 2ºC would require an estimated 77% reduction in total carbon emissions in the building industry by 2050 compared to today's level (Energy Star, 2022). Global climate ambitions declared in the Paris Agreement require a 30% increase in energy usage per square meter of buildings until 2030 in order to decrease the high amount of carbon emissions generated by buildings and construction industry (UN Environment and International Energy Agency, 2017). For this reason, the architecture, engineering, and construction (AEC) industry has emphasized on the green buildings with the aim of decreasing energy, water, raw material, and carbon emissions consumption. Green buildings are defined as *"healthy facilities designed and built in a resource-efficient manner, using ecologically based principles"* (Kibert 1994). In other words, green buildings are high performance sustainable structures (EPA, 2016) designed to preserve energy, water, materials, and land during their life cycles, and provide healthy environments for their occupants through implementing sustainability principles (Seyis and Ergen 2017). Further, the aim of sustainability or sustainable development is to *"meet the needs of the present without compromising the ability of future generations to meet their own needs*" (UN WECD, 1987).

Even though the interest in green buildings has been escalating in the last decades, the roots of this phenomenon depend on the end of the nineteenth century. R. Buckminster Fuller (1895–1983), one of the most important figures in the sustainable design or environmental design, constituted the foundation for the green building revolution. In his designs, he focused on conserving resources, using renewable energy in the form of sun and wind, using lightweight, ephemeral materials (e.g., bamboo, paper, and wood), and design for deconstruction. The geodesic dome of R. Buckminster Fuller is described as the lightest, strongest, and most cost-effective structure ever designed (Kibert 2016). For this reason, R. Buckminster Fuller is called as the "father of environmental design".

Environmental design or sustainable design is defined as the "*conception and realization of ecologically, economically, and ethically responsible expression as part of the evolving matrix of nature*" (McDonough, 1992). The Conseil International du Bâtiment (CIB) described sustainable construction as "*creating and operating a healthy built environment based on resource efficiency and ecological design*" (Kibert 1994). Sustainable construction ultimately aims at mitigating natural resource consumption by considering the role and potential interface with ecosystems (Kibert 2016). Accordingly, sustainable construction principles include reducing resource consumption, reusing resources, using recyclable resources, protecting nature, eliminating toxics, applying life-cycle costing, and focusing on quality (Kibert 1994).

Research demonstrated that buildings designed according to the sustainability principles result in 33-39% less carbon emissions, 40% less water use, 24-50% less energy use, and 70%

less solid waste production compared to traditional buildings (Kibert, 2016; WGBC, 2013). Hence, green building rating systems (GBRSs) are developed in order to contribute to the sustainable built environment and promote green buildings. A study of Singh et al. (2010) conducted with a total of 263 office workers to measure the effects of green buildings on health demostrated that, when the indoor air quality (IQA) of the office was improved considering the LEED standard, (1) the average monthly absenteeism value of the employees due to asthma and respiratory allergies decreased from 1.12 to 0.49, and (2) the average value of absenteeism due to depression and stress decreased from 0.93 to 0.47; and (3) the productivity rates increased from -0.80% to 2.18%. This study also presented that a 2.98% increase in productivity can provide an extra 38.98 working hours per year for each staff working in sustainable offices (Singh et al., 2010). Similarly, another study performed by researchers in the Stanford University showed that the absenteeism due to the illness of students studying at sustainable schools decreased by 87% and the competency of students increased by 90% (Greening America's Schools, 2006).

While green buildings provide healthy environments for their occupants, they contribute significantly to the economy as they are designed in a resource efficient manner. According to the report of the World Green Building Council (WGBC) in 2016, the economic contributions of sustainable offices to their employees are classified in six different ways: (1) decrease in the number of days off work, (2) decrease in layoffs, (3) decrease in medical complaints, (4) decrease in medical costs, (5) decrease in physical complaints, and (6) increase in profit rate (WGBC, 2016). The report of the World Green Building Council in 2013 presented that the occupancy rate of sustainable offices designed according to international GBRSs is 2%-23.1% higher than conventional offices (WGBC, 2013). This report showed that the sales prices of sustainable offices and residences are 30%-35% more valuable than traditional offices and residences (WGBC, 2013). Similarly, another research demonstrated that teacher applications to sustainable schools increased by 74% and the positive image of these schools in the society increased by 72% (NAAEE, 2016). According to the European Commission report published in 2015, global energy efficiency measures can save approximately 280-410 billion Euros in energy expenditure. This value is equal to almost twice the annual electricity consumption of the USA. Accordingly, creating 1.7-2.5 million new jobs by 2030 can be possible by applying global energy efficiency measures (European Commission, 2015).

Research proved that GBRSs facilitate in evaluating building performance and meeting with the requirements of sustainable built environment (Worden et al, 2020). However, green buildings designed according to the GBRSs need collaboration of multiple technical disciplines which elevate the levels of interdependency and interconnectedness of project team members (Seyis, 2015). Therefore, design processes of green buildings are generally much more convoluted than traditional buildings that in turn cause variety of difficulties and additional management challenges (Seyis and Ergen, 2017). At this point, continuous information flow between multidisciplinary teams is highly critical to overcome such problems which may result in unproductiveness in the sustainable construction projects (Seyis, 2020).

Building Information Modeling (BIM) provides an efficient collaborative working environment for multidisciplinary project teams of sustainable construction projects (Seyis, 2019). BIM is defined as a process, system, and product by the US National Institute of Building Scinces (NBIS). BIM helps practitioners handle with the escalated levels of interdependency and interrelatedness in the various technical disciplines in the sustainable construction projects designed considering GBRSs throughout providing data curation, acquisition, and transfer (Seyis, 2020). Previous research showed that BIM ensures sustainability professionals track green building certification process (Seyis, 2019) and accordingly streamlines the green building certification process (Azhar et al., 2010), and facilitates the GBRSs-based sustainable design and construction (Solla et al., 2019; Jalaei et al., 2015). Further, using BIM in the design, construction, and operation phases of the GBRSs-based projects aids in reducing carbon emissions released from buildings, fulfilling the arduous requirements of GBRSs, and contributing sustainable built environment and circular economy (Seyis 2022, Lu et al 2017, Azhar et al 2010, Wong and Fan 2013).

Although sustainable design and construction requirements of industrial buildings are much more complicated than the other building types, none of the previous works addresses using BIM for sustainable industrial building designed considering the GBRSs, and examines the differences between water and energy consumptions of traditional industrial buildings and sustainable industrial buildings. Such a study would provide valuable insights about the design requirements and energy, water, and cost performance of the industrial buildings designed according to the GBRSs.

The research objective of this study is to (1) do architectural and structural designs of a sustainable industrial building using Building Information Modeling (BIM) and Leadership in Energy and Enviromental Design (LEED), and (2) compare the costs of LEED industrial building and non-LEED industrial building. In this scope, the additional costs related to water and energy efficient systems were analyzed to calculate the respective break-even points. In this study, non-LEED industrial building refers to the traditional industrial building, the prior version of the case study building, designed without implementing sustainability principles whereas LEED industrial building refers to the case study building redesigned considering the LEED v4.1 BD+C for New Construction rating system. This research contributes to the AEC industry and literature by (1) providing constructive information about the design requirements and energy, water, and cost performance of the LEED industrial buildings and (2) presenting the discrepancies in energy and water consumptions and related costs between LEED industrial buildings and non-LEED industrial buildings. Accordingly, this study would highlight the importance of industrial buildings designed according to the GBRSs that in turn would add value to the sustainable built environment.

2. LITERATURE REVIEW

Previous research showed that total energy consumption in 2018 raised by 317% compared with the total energy consumption in 1949 globally (US Department of Energy, 2019). According to a study in the US, manufacturing industry is responsible for the 30% of the total energy consumption of country. This research also demonstrated that daily water consumption of manufacturing industry in the US is nearly 15.900 million gallon which equates to 4% of the total daily water consumption of the US. These studies proved that industrial buildings cause much higher amount of energy and water consumption as well as carbon release than the other industries (Alliance to Save Energy (ASE), 2009). For this reason, the number of industrial buildings designed according to the green building rating systems has been increasing globally (Sustainable buildings market study, 2019). In 2016, the US Green Building Council announced that there are over 1.755 LEED certified industrial buildigs and 2.710 industrial buildings applied for the LEED certification in global. Moreover, there are 5399 industrial building projects applied for LEED certification in the US (Statista, 2021).

The tendency in the AEC industry is to the sustainable industrial building design and construction. The importance of designing nearly carbon neutral and energy- and water-efficient industrial buildings has been already highlighted by the policy- and decision-makers (U.S. DOE, Energy Information Administration, 2002; Alliance to Save Energy (ASE), 2009; U.S. Dept. of Energy, 2014; Copenhagen Resource Institute, 2014). However, design requirements of sustainable industrial buildings may much more complex than the conventional industrial buildings. For this reason, using BIM for sustainable industrial building design and construction helps multidisiciplinary project teams work efficiently and collaboratively as well as streamlines processes that in turn ensures decrease in time and cost related non-value added activities caused by the GBRSs (Seyis 2019). In fact, continuous communication and information flow between the multidisiplinary teams throughout the project delivery process of sustainable construction projects is highly important for the successful completion of the projects (Seyis 2015).

However, a limited number of studies on integrating BIM and GBRSs exist in the literature. In one of the similar studies on this subject domain, a 15-storey residential building using LEED v4 BD+C for New Construction rating system and BIM was designed, and performed comparative analyses about water and energy consumption and related costs for the LEED building and non-LEED building (Seyis 2022). Another research investigated the potential of BIM-based energy analysis tools (i.e., Autodesk Revit Green Building Studio, eQUEST, EnergyPlus, IES-VE) for a 4-storey residential building designed according to the LEED v4 BD+C for Multifamily Midrise rating system (Seyis et al 2021). A similar study examined the potential of building energy simulation tools (i.e., Tas, EnergyPlus, IES-VE) for BREEAM v2011 and LEED v2009 certification processes (Schwartz and Raslan 2013). Likewise, another previous research investigated the functions of fourteen BIM tools for energy, carbon emissions, natural ventilation, daylighting, and acoustics performance of the green buildings designed according to the LEED v3 (Lu et al. 2017). A more recent study conducted by Wang et al (2019) compared eleven sustainable industrial buildings' evaluation characteristics in Chinese cigarette manufactures according to the outputs from simulations on the energy consumption and energy saving potential.

Even though some studies on BIM-based green buildings designed according to the international GBRSs exist in the literature, there is no research addressing the usage of BIM for sustainable industrial building designed considering LEED v4.1 BD+C for New Construction rating system. Such a study would present the value and importance of BIM-based sustainable industrial buildings, promote sustainable industrial buildings designed according to the GBRSs, and contribute to the development of the sustainable built environment. This research examined the requirements for a BIM-based sustainable industrial building designed in accordance with the principles of LEED v4.1 BD+C for New Construction rating system, and performed comparative analyses for the costs of LEED industrial building and non-LEED industrial building.

3. RESEARCH METHODOLOGY

A literature review and a case study were conducted with the aim of achieving the research objectives of this study. The reason of reviewing literature is to collect information and criticize the previous studies on this topic. The reason of performing a case study is to identify specific problems, if exist, and understand particularized information about the relevant subject (Yin., 1994). In addition, a case study ensures researchers strengthen the findings of literature review.

3.1. Literature review

In the first step of this research, a literature review was performed using Web of Science core collection and Scopus databases and all documents including journal articles, conference proceedings, scientific reports, and books published by 2022 were investigated.The following keywords were used for reviewing literary: green industrial*, sustainable industrial*, sustainable manufacturing plant, green manufacturing plant, LEED industrial*, LEED manufacturing plant, LEED factory, sustainable factory, green factory, energy efficient industrial*, resource efficient industrial*, BIM-based sustainable*, BIM-based green*, BIM-based energy efficient*, non-LEED*, non-green*, green building rating*, green building assessment*, green building certification*, building information model*, BIM, Building Information Modeling, and LEED. Each publication was manually reviewed to select the proper data source.

3.2. Case Study

In the second step of this research, a case study was applied for performing comparative analyses for the LEED industrial building and non-LEED industrial building. Within the scope of the case study, a 3D model of a reinforced concrete drug manufacturing plant was redesigned via Autodesk Revit 2021 according to the LEED v4.1 Building Design and Construction (BD+C). LEED was selected as the green building rating system in this research because LEED is the most widely applied and a well-accepted international GBRS globally (Kibert, 2016; Ansah et al., 2019). Autodesk Revit was used for the creating 3D model of this industrial building as this software is a well-accepted BIM tool (Seyis et al 2021). 2D.dwg files of the industrial building were utilized for developing its 3D model. Architectural and structural plans were included in the 3D model, but MEP (mechanical, electrical and plumbing) plans were not included. The initial cost, energy, and water consumptions of the project were evaluated via Microsoft Excel.

4. IMPLEMENTING LEED ON THE BIM-BASED INDUSTRIAL BUILDING DESIGN

4.1. Project Details

The project consists of three blocks which are A, B, and C. All three blocks have a common area on the floors below the ground level (2nd basement and 1st basement floors). In addition, Block A includes the production units and laboratory, and has a ground floor and one floor. Block B includes office rooms and has a ground floor and two identical floors. Block C includes the kitchen and dining hall, and has one floor. The building is located in Istanbul, Turkey. Gross floor area of the project is 83.000 square meter. Figure 1 presents render of the 3D model for the sustainable industrial building designed according to the LEED v4.1 BD+C via Revit 2021. Figure 2-4 show floor plan details of Block A, B, and C, respectively.

Figure 1:
Render of the 3D model for the industrial building in Autodesk Revit

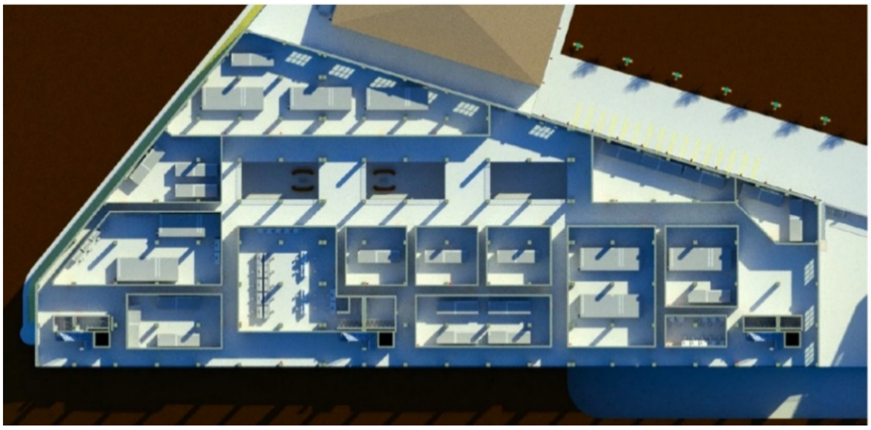

Figure 2:
Ground and 1st floor plan details of Block A

Figure 3:
1st and 2nd floor plan details of Block B

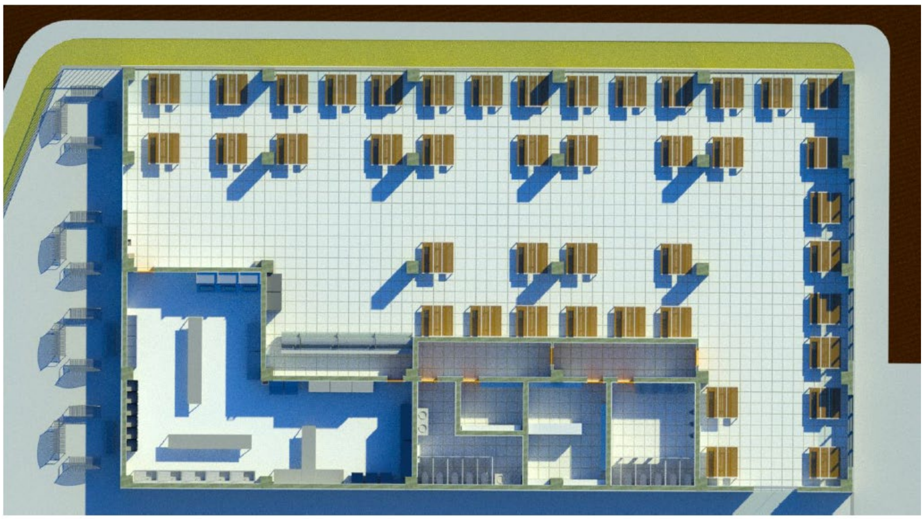

Figure 4:
Floor plan details of Block C

4.2. LEED v4.1 BD+C for New Construction Details

In this study, requirements of 31 credits and 8 prerequisites in LEED v4.1 BD+C for New Construction rating system were fulfilled in the redesigned industrial building. Accrodingly, this LEED industrial building can collect 73 points out of 110 points and be awarded with the LEED Gold certificate. The checklist (i.e., scorecard) of the project is given in Figure 5. This checklist shows the credits and prerequisites which are within the scope and out of scope of this project. In this checklist, "Y" means "YES" and refers to the credits and prerequisites whose requirements are fulfilled in the industrial building. "N" states "NO" and indicates the credits and prerequisites whose requirements are not met in the industrial building. "?" presents "MAYBE" and points out the credits whose requirements can be performed in the project. In this study, none of the credits and prerequisites are identified as "MAYBE" because the focus of this research is to determine the credits and prerequisites which are applied to the redesigned industrial building (i.e., case study building).

LEED v4.1 BD+C
Project Checklist

Project Name: Industrial Building Design Using BIM and LEED

Y	?	N			
		N	Credit	Integrative Process	1
0	0	0		**Location and Transportation**	**14**
		N	Credit	LEED for Neighborhood Development Location	0
Y			Credit	Sensitive Land Protection	1
		N	Credit	High Priority Site and Equitable Development	0
Y			Credit	Surrounding Density and Diverse Uses	5
Y			Credit	Access to Quality Transit	5
Y			Credit	Bicycle Facilities	1
Y			Credit	Reduced Parking Footprint	1
Y			Credit	Electric Vehicles	1
0	0	0		**Sustainable Sites**	**9**
		N	Prereq	Construction Activity Pollution Prevention	Required
		N	Credit	Site Assessment	1
Y			Credit	Protect or Restore Habitat	2
Y			Credit	Open Space	1
Y			Credit	Rainwater Management	3
Y			Credit	Heat Island Reduction	2
		N	Credit	Light Pollution Reduction	0
0	0	0		**Water Efficiency**	**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
Y			Credit	Outdoor Water Use Reduction	2
Y			Credit	Indoor Water Use Reduction	6
Y			Credit	Optimize Process Water Use	2
Y			Credit	Water Metering	1
0	0	0		**Energy and Atmosphere**	**6**
		N	Prereq	Fundamental Commissioning and Verification	Required
		N	Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
		N	Prereq	Fundamental Refrigerant Management	Required
		N	Credit	Enhanced Commissioning	0
		N	Credit	Optimize Energy Performance	0
Y			Credit	Advanced Energy Metering	1
		N	Credit	Grid Harmonization	0
Y			Credit	Renewable Energy	5
		N	Credit	Enhanced Refrigerant Management	0

0	0	0		**Materials and Resources**	**11**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Credit	Building Life-Cycle Impact Reduction	5
		N	Credit	Environmental Product Declarations	2
Y			Credit	Sourcing of Raw Materials	2
Y			Credit	Material Ingredients	2
		N	Credit	Construction and Demolition Waste Management	0
0	0	0		**Indoor Environmental Quality**	**12**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
Y			Credit	Enhanced Indoor Air Quality Strategies	2
Y			Credit	Low-Emitting Materials	3
		N	Credit	Construction Indoor Air Quality Management Plan	0
		N	Credit	Indoor Air Quality Assessment	0
Y			Credit	Thermal Comfort	1
Y			Credit	Interior Lighting	2
Y			Credit	Daylight	3
Y			Credit	Quality Views	1
		N	Credit	Acoustic Performance	0
0	0	0		**Innovation**	**5**
Y			Credit	Innovation	5
		N	Credit	LEED Accredited Professional	0
0	0	0		**Regional Priority**	**4**
Y			Credit	Regional Priority: Surrounding density and diverse uses	1
Y			Credit	Regional Priority: Thermal comfort	1
Y			Credit	Regional Priority: Reduced parking footprint	1
Y			Credit	Regional Priority: Rainwater management	1
0	0	0		**TOTALS** Possible Points:	**73**

fied: 40 to 49 points, **Silver**: 50 to 59 points, **Gold**: 60 to 79 points, **Platinum**: 80 t

Figure 5:
LEED v4.1 BD+C checklist

LEED v4.1 BD+C for New Construction rating system includes eight categories which are *Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation*, and *Regional Priority*. The category of *Location and Transportation* intends to provide occupants a more sustainable environment through decreasing land usage and carbon emissions caused by transportation (USGBC 2021). The industrial building designed within the scope of this case study can achieve 14 out of 32 points from *Location and Transportation*. The main reason of such high amount of point loss from this category is not implementing the requirements of "LEED for neighborhood development" since this study only addresses one industrial facility rather than focusing on its neighboorhood.

The purpose of *Sustainable Sites* is to provide the natural environment of the project to be valued and respected during the project lifecycle (USGBC 2021). The redesigned industrial building (i.e., case study building) can gain 9 out of 10 points from the *Sustainable Sites* category. However, the requirements of “construction activity pollution prevention” which is a prerequisite of the *Sustainable Sites* category could not be fulfilled in the case study because this research addresses only design phase of the industrial building. Essentially, all prerequisites in the relevant rating system must be met in the building/project in accordance with the LEED procedure; otherwise, the project would not achieve LEED certification. If this study would include both design and construction phases of the industrial building, the requirements of this prerequisite should be fulfilled.

The principles in the *Water Efficiency* category aim at diminishing water consumption in the project through implementing water use reduction strategies and examining non-potable and alternative water sources (USGBC 2021). For this purpose, rainwater harvesting system, grey water recycling system, and water-efficient fixtures were utilized in the building design. Accordingly, the redesigned industrial building (i.e., case study building) can earn 11 out of 11 points from the *Water Efficiency* category. This means the case study building was redesigned as a water-efficient building that in turn contributes to the protection of the natural water sources.

The intend of *Energy and Atmosphere* is to lessen the usage of fossil fuels and contribute energy-efficient buildings throughout applying cutting-edge strategies (USGBC 2021). For this purpose, double glass photovoltaic modules placed on the windows on the southern façade of the building and skylights on the roof as well as solar panels placed on the roof of the parking space (Figure 1). Accordingly, the industrial building redesigned within the scope of the case study can accomplish 6 points out of 33 from the *Energy and Atmosphere* category. The reason of attaining less points from the *Energy and Atmosphere* category is not to include mechanical, electrical and plumbing (MEP) drawings in the building design and only focuses on design phase of the industrial building within the scope of the case study. Accordingly, the requirements of three prerequisites in the *Energy and Atmosphere* category, which are “fundamental commissioning and verification”, “fundamental refrigerant management”, and “minimum energy performance”, are not met in this project. If the MEP drawings are included within the scope of the industrial building design, the case study building would be much more energy-efficient.

The *Material and Resources* category intends to mitigating negative environmental impacts of building materials throughout their life-cycles. More explicitly, the *Material and Resources* category aims at reducing the embodied energy and other effects relevant with the extracting, processing, transporting, maintaining, and disposing building materials (USGBC 2021). For this purpose, low-carbon emission and/or carbon-neutral interior and exterior coatings, recycled rebars, and autoclaved aerated concrete were utilized in the building design which assure to design nearly carbon-neutral industrial building. Accordingly, the industrial building designed within the scope of the case study can achieve 11 points out of 13 from the *Material and Resources* category. Even though high points can be accomplished in this category, the requirements of “storage and collection of recyclables”, which is the prerequisite in the *Material and Resources* category, is not fulfilled in the case study as this research focuses on the design phase of the industrial building. However, it should be highlighted that the requirements of “storage and collection of recyclables” should be fulfilled if the case study would cover the construction phase.

The goal of *Indoor Environmental Quality* is to improve the surroundings of occupants through implementing innovative design strategies and focusing on the environmental factors including air quality, lighting quality, acoustic design that have a significant impact on the way occupants learn, work, and live (USGBC 2021). Accordingly, fulfillment of credits in the *Indoor Environmental Quality* category ensures occupants more healthy, comfortable, and liveable indoor environments. The industrial building (i.e., case study building) can earn 12 points out of 16 from this category by using materials, which are nearly carbon neutral and do not consist of volatile organic compounds (VOCs), in the redesign of the industrial building. Additionally, if MEP drawings are included within the scope of building design, the indoor environmental quality of the industrial facility would be better. This is because smart technologies such as sensors, smart carbon monoxide monitor, automatic humidity control system, and smart air conditioner could be utilized in the facility that ensure better air quality in indoor enviroments.

The last two categories are *Innovation* and *Regional Priority* which are called as bonus categories. This means the project team do not have to fulfill the requirements of these two categories which are optional. The *Innovation* category aims at achieving environmental performance by employing contemporary strategies which are not addressed in the LEED rating system (USGBC 2021). In order to meet with the requirements of this category in the case study, first, double glass photovoltaic modules were placed on all windows on the southern façade and three skylights on the roof of Block A of the industrial building (Figure 1). This innovative strategy ensures energy production in the industrial building. Second, solar energy produced by the solar panels placed on the roof of the parking space is used for charging the electric vehicles (Figure 1). Accordingly, the redesigned industrial building can earn 5 points out of 6 from the *Innovation* category. One point loss is due to the lack of LEED Accredited Professional (AP) in the project.

The *Regional Priority* category intends to designing the building/project based on its local environmental, social equity, and public health priorities (USGBC 2021). Actually, Regional Priority credits are the existing LEED credits and determined considering the location of the building. LEED offers the following credits within the scope of Regional Priority category for this industrial building according to its location: ”surronding density and diverse uses”, “thermal comfort”, “reduced parking footprint”, and “rainwater management”. The requirements of these four credits were achieved in the redesigned industrial building. Accordingly, 4 points out of 4 can earn from this category.

5. RESULTS and DISCUSSION

The costs for the energy and water consumptions of the LEED industrial building (i.e., case study building) and non-LEED industrial building (i.e., traditional industrial building) were calculated in this study. The initial cost of the building covers the rough construction works and the finishing works (e.g., low-carbon emission and/or carbon-neutral interior and exterior coatings, solar panels, lightening, rainwater harvesting system, grey water recycling system, solar windows, water-efficient fixtures, and electric car charger). All calculations were done considering the preliminary design of LEED industrial building and non-LEED industrial building. Hence, the expected error in the cost calculations is nearly ±10%. Energy and water consumption amounts of the non-LEED industrial building were evaluated by using data from a factory with similar size and function. Further, production in the industrial facility is not taken account in this study.

Cost analysis was evaluated according to the tenders gathered from the various suppliers. Most of the carbon-neutral and low-carbon-emission products as well as water and energy efficient products and technologies are imported and/or internationally based. For this reason, the Dollar currency was fixed to 8.30TL and Euro currency was fixed to 9.79TL considering the exchange rates of Central Bank of the Republic of Turkey in September 1st 2021 due to the floating exchange rates.

Comparing initial cost:

The initial cost of the industrial building redesigned according to the LEED v4.1 BD+C rating system is 154.222.607 TL while the initial cost of the non-LEED industrial building (i.e., conventional industrial building) is 139.080.060 TL. In this study, the initial cost of LEED industrial building does not include the LEED certification fee. Using green materials and advanced technological equipments for fulfilling the sustainability principles is the reason of cost increase. However, when the energy and water consumptions for both industrial buildings are compared (Table 1-2-3-4, Figure 6-7), it is crystal clear that the LEED industrial building is much more energy and water efficient than the non-LEED industrial building in the long run. In addition, as the demand for green buildings increases, the types and variety of the sustainable materials and products (including water and energy efficient technologies) escalate that in turn facilitates sustainability professionals easily access cheaper goods fit for purpose. Further, it should be noted that separately calculating the expenses directly related to the LEED criteria is really hard since all materials (including concrete and rebars) and equipments/products in the case study building were selected considering the requirements of LEED v4.1 BD+C. This means LEED expenses are intertwined with the cost of finishing works and rough construction works in the sustainable construction projects.

Comparing water consumption:

Table 1 presents the comparison for montly water consumption and related expenses of the LEED industrial building and non-LEED industrial building. Table 2 demonstrates the yearly water consumption cost of LEED industrial building and non-LEED industrial building. Figure 6 shows the break-even point graph for the cost of water-efficient products/systems utilized in the LEED industrial building. Water consumption may cover humidification, irrigation, indoor plumbing fixtures and fittings, domestic hot water, boiler, reclaimed water, and process water used for dishwashers, clothes washers, pools, and relevant subsystems (USGBC 2021). Additionally, a rainwater harvesting system is used in the LEED industrial building. Montly amount of precipitation was received from the Turkish State Meteorological Service. According to break-even point calculation for the cost of water-efficient products/systems utilized in the LEED industrial building (Figure 6), if only water-efficient products/systems in the case study building are examined, the break-even point of this project is 8 years.

Table 1. Comparison for montly water consumption and related cost of LEED industrial building and non-LEED industrial building.

Month	Non-LEED industrial building		LEED industrial building	
	Water consumption (cubic meter)	Cost (TL)	Water consumption (cubic meter)	Cost (TL)
January	3.510	44.482,93	2.692	34.111,08
Februray	3.920	49.678,94	3.177	40.262,85
March	4.110	52.086,85	3.462	43.872,21
April	4.410	55.888,81	3.873	49.079,37
May	4.640	58.803,65	4.125	52.275,25
June	4.770	60.451,16	4.252	53.880,61
July	5.020	63.619,46	4.606	58.369,80
August	4.930	62.478,88	4.502	57.060,59
September	4.530	57.409,60	3.973	50.354,24
October	3.840	48.665,09	3.088	39.136,58
November	4.010	50.819,53	3.373	42.752,43
December	3.420	43.342,34	2.540	32.190,82

Table 2. Yearly water consumption cost of LEED and non-LEED industrial building.

Year	Non-LEED industrial building	LEED industrial building
	Water consumption cost (TL)	Water consumption cost (TL)
0	0	714.512
1	647.727,25	1.267.857,83

2	1.295.454,50	1.821.203,66
3	1.943.181,76	2.374.549,49
4	2.590.909,01	2.927.895,32
5	3.238.636,26	3.481.241,15
6	3.886.363,51	4.034.586,98
7	4.534.090,76	4.587.932,81
8	5.181.818,02	5.141.278,64
9	5.829.545,27	5.694.624,47
10	6.477.272,52	6.247.970,30

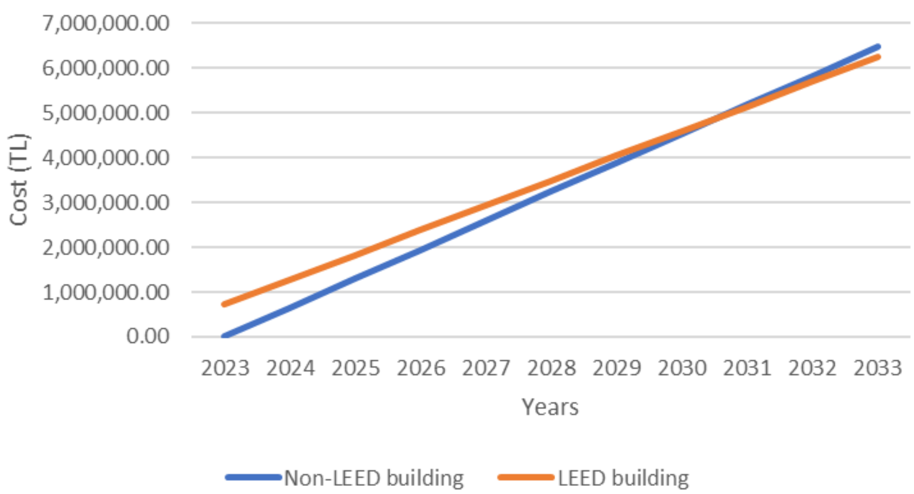

Figure 6:
Break-even point for the cost of water-efficient systems utilized in the LEED industrial building

Comparing energy consumption:

Table 3 presents the comparison for montly energy consumption and related expenses of the LEED industrial building and non-LEED industrial building. Table 4 demonstrates the yearly energy consumption cost of the LEED industrial building and non-LEED industrial building. Figure 7 shows break-even point graph for the cost of energy-efficient systems utilized in the LEED industrial building. Energy consumption may cover the usage of electricity, natural gas, chilled water, steam, fuel oil, propane, and biomass (USGBC 2021). For evaluating yearly energy consumption, some constant numbers were utilized which are active energy unit price (0.648683₺/kwh), distribution fee (0.20003₺/kwh), TRT share (0.02₺/₺), electricity consumption tax (0.05₺/₺), and value-added tax (0.18₺/₺). Further, electricity production from the solar panels and windows is considered. According to break-even point calculation for the cost of energy-efficient systems utilized in the LEED industrial building (Figure 7), if only energy-efficient products/systems used in the redesigned building (i.e., case study) are examined, the break-even point of this project is 14 years. If MEP drawings are included within the scope of redesigning the industrial building, break-even point for the cost of energy-efficient products/systems utilized in the LEED industrial building would be much earlier than 14 years.This is because smart technologies could be utilized in the MEP design of the case study building which would make the structure more energy-efficient.

Table 3. Comparison for montly energy consumption and related cost of LEED industrial building and non-LEED industrial building.

Month	Non-LEED industrial building		LEED industrial building	
	Energy consumption (kwh)	Cost (TL)	Energy consumption (kwh)	Cost (TL)
January	98.000	105.702,35	25.654,65	27.670,99
Februray	91.000	98.152,18	18.654,65	20.120,82
March	98.000	105.702,35	25.654,65	27.670,99
April	124.369	134.143,33	34.848,06	37.586,96
May	128.975	139.111,61	39.454,30	42.555,23
June	124.369	134.143,33	34.848,06	37.586,96
July	128.975	139.111,61	39.454,30	42.555,23
August	128.975	139.111,61	39.454,30	42.555,23
September	124.369	134.143,33	34.84806	37.586,96
October	98.000	105.702,35	25.654,65	27.670,99
November	94.500	101.927,27	22.154,65	23.895,91
December	98.000	105.702,35	25.654,65	27.670,99

Table 4. Yearly energy consumption cost of LEED and non-LEED industrial building.

Year	Non-LEED industrial building	LEED industrial building
	Energy consumption cost (TL)	Energy consumption cost (TL)
0	0.0	14.428.035,0
1	1.442.653,7	14.823.162,3
2	2.885.307,3	15.218.289,5
3	4.327.961,0	15.613.416,8
4	5.770.614,6	16.008.544,0
5	7.213.268,3	16.403.671,3
6	8.655.922,0	16.798.798,5
7	10.098.575,6	17.193.925,8
8	11.541.229,3	17.589.053,0
9	12.983.882,9	17.984.180,3
10	14.426.536,6	18.379.307,5
11	15.869.190,3	18.774.434,8
12	17.311.843,9	19.169.562,0
13	18.754.497,6	19.564.689,3
14	20.197.151,2	19.959.816,5
15	21.639.804,9	20.354.943,8
16	23.082.458,6	20.750.071,0
17	24.525.112,2	21.145.198,3
18	25.967.765,9	21.540.325,5
19	27.410.419,6	21.935.452,8
20	28.853.073,2	22.330.580,1

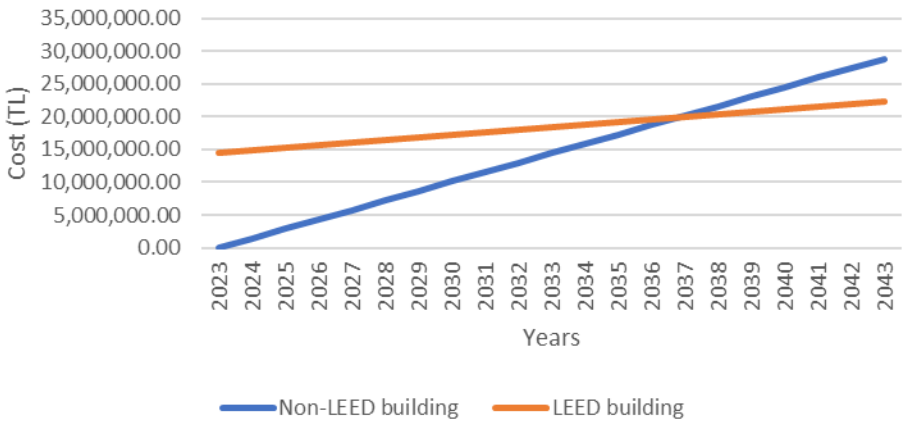

Figure 7:
Break-even point for the cost of energy-efficient systems utilized in the LEED industrial building

6. CONCLUSIONS

This research presents (1) architectural and structural designs of a sustainable industrial building using LEED v4.1 BD+C for New Construction and BIM, and (2) the differences for the costs of energy and water consumptions, and initial project cost of the LEED industrial building and non-LEED industrial building. In this scope, a literature review and a case study were performed. This research makes an important contribution to the AEC industry and literature by (1) providing constructive information about the design requirements and energy, water, and cost performance of the LEED industrial buildings and (2) presenting the discrepancies in the costs of energy and water consumptions between LEED and non-LEED industrial buildings. Accordingly, this study highlights the importance of industrial buildings designed according to the GBRSs that in turn would add value to the sustainable built environment. Professionals interested in the sustainable built environment could benefit from the results of this research.

The practices applied in this study provide to meet with the sustainability requirements of LEED v4.1 BD+C for a large-scale reinforced concrete industrial building. The LEED industrial building is able to accomplish 31 credits and 8 prerequisites. Accordingly, this building can obtain 73 points and LEED Gold certificate. The initial cost of the LEED industrial building is 154.222.607 TL whereas the initial cost of non-LEED industrial building is 139.080.060 TL. The escalation in the initial cost of the LEED industrial building is due to the use of cutting-edge sustainable materials, water- and energy-efficient products/technologies in the building design. According to the break-even point analyses, if only water-efficient products/systems utilized in the case study building are examined, the break-even point of the LEED industrial building is 8 years. This means the owner of the LEED industrial building would make a profit from operating this facility after 8 years of the construction of the project except from the production in the factory. However, if only energy-efficient products/systems utilized in the case study building are examined, the break-even point of the LEED industrial building is 14 years. If MEP plans are included within the scope of redesigning the industrial building, break-even point for the energy-efficient products/systems cost would be much earlier than 14 years. Moreover, the owner would pay less water and electricity bills during facility management process (including the first 14 years) of this LEED industrial building.

Limitations of this study can be summarized as (1) developing the 3D model based on the 2D structural and architectural drawings without using MEP drawings, (2) not performing building energy analysis and life-cycle assessments (LCAs), and (3) not considering construction and facility management phases of the project. If MEP plans, energy analysis, and LCAs are included within the scope of this work, the LEED industrial building could be more energy-, water-, and resource-efficient as well as release less carbon emissions in the long run. Further, if construction and facility management phases are considered within the scope of this research, more prerequisites and credits (e.g., construction activity pollution prevention, storage and collection of recyclables, fundamental commissioning and verification, and enhanced commissioning) would be achieved. Accordingly, such improvements in the scope of this study would provide to accomplish higher points in the LEED v4.1 BD+C.

One of the future works of this research would be including energy analysis and life-cycle assessments within the scope of comparing LEED and non-LEED industrial buildings that ensures more realistic outputs about this subject domain. The other future research direction would be analyzing different types of LEED and non-LEED buildings such as hospitals, schools, shopping malls, and office buildings. Another future work could be addressing the integrated usage of BIM and different international green building rating systems (e.g., BREEAM (Building Research Establishment Environmental Assessment Method), Energy Star, and DGNB (Deutche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building Council))) for industrial buildings, and comparing the industrial building performance designed according to various GBRSs.

CONFLICT OF INTEREST

Author(s) approve that to the best of their knowledge, there is not any conflict of interest or common interest with an institution/organization or a person that may affect the review process of the paper.

AUTHOR CONTRIBUTION

Senem Seyis contributes to the identification and management of the concept and design process of the research, data collection and analysis, interpretation of the results, preparation of the manuscript, critical analysis of the intellectual content, final approval, and full responsibility.

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REFERENCES

1. Alliance to Save Energy (ASE), Promoting Energy-Efficient Buildings in the Industrial Sector (2009). Written by Aiming Zhou, Vestal Tutterow, Jeffrey Harris, Paul Bostrom. https://forum.cee1.org (Accessed in: 12.01.2022)

2. Alliance to Save Energy (ASE), Promoting Energy-Efficient Buildings in the Industrial Sector, 2009. Written by Aiming Zhou, Vestal Tutterow, Jeffrey Harris, Paul Bostrom. https://forum.cee1.org Accessed in: 19.12.2021)

3. Ansah, M.K. Chen, X., Yang, H., Lu, L. and Lam, P.T.I. (2019). "A review and outlook for integrated BIM application in green building assessment". *Sustainable Cities and Society,* 48, 101576. doi:10.1016/j.scs.2019.101576

4. Azhar, S. Carlton, W.A., Olsen, D. and Ahmad, I. (2010). "Building information modeling for sustainable design and LEED® rating analysis." *Automation in Construction*, 20(2), 217-224. doi: 10.1016/j.autcon.2010.09.019

5. Copenhagen Resource Institute, 2014. Resource efficiency in the building sector, http://ec.europa.eu/environment/eussd/pdf/Resource%20efficiency%20in%20the%20building%20sector.pdf (Accessed in: 19.12.2021)

6. Energy Star, (2022). Access address: https://www.energystar.gov/buildings/about-us/facts-and-stats (Accessed in: 12.01.2022)

7. European Commission, 2015. "Savings and benefits of global regulations for energy efficient products", https://ec.europa.eu/energy/sites/ener/files/documents/Cost%20of%20Non-World%20-%20Final%20Report.pdf (Accessed in: 12.01.2022)

8. Global Alliance for Buildings and Construction (2019). "2019 Global Status Report for Buildings and Construction: Towards a zero-emissions, efficient and resilient buildings and construction sector". https://wedocs.unep.org/bitstream/handle/20.500.11822/30950/2019GSR.pdf?sequence=1&isAllowed=y (Accessed in: 12.01.2022)

9. Greening America's Schools (2006). Written by Gregory Kats https://www.usgbc.org/resources/greening-america039s-schools-costs-and-benefits (Accessed in: 02.02.2022)

10. International Energy Agency (IEA) (2017). "IEA World Energy Statistics and Balances 2017: Energy Technology Perspectives 2017", IEA/OECD, Paris, www.iea.org/etp (Accessed in: 12.01.2022)

11. International Energy Agency (IEA) (2022). "World energy statistics and balances". https://www.iea.org/topics/energyefficiency/buildings/ (Accessed in: 12.01.2022)

12. Jalaei, F. and Jrade, A. (2015). " Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings." *Sustainable Cities and Society*, 18, 95-107. doi:10.1016/j.scs.2015.06.007

13. Kibert, C. (2016). *Sustainable Construction: Green Building Design and Delivery, 4th Edition*. ISBN: 978-1-119-05517-4, 2016

14. Kibert, J., 1994."Principles and a Model of Sustainable Construction". Proceedings of the First International Conference on Sustainable Construction, 1-9, Tampa, Florida, USA, 6-9 November 1994

life-cycle assessments". *Building and Environment,* 173 (2020), 106703. doi:10.1016/j.buildenv.2020.106703

15. Lu, Y. Wu, Z., Chang, R. and Li, Y. (2017). "Building Information Modeling (BIM) for green buildings: A critical review and future directions." *Automation in Construction*, 83, 137-144. doi: 10.1016/j.autcon.2017.08.024

16. North American Association for Environmental Education (NAAEE) (2016). "eeworks: From Anecdotes to Evidence: Demonstrating the power of environmental education", https://cdn.naaee.org/sites/default/files/eeworks/files/k-12_student_key_findings.pdf . (Accessed in: 12.01.2022)

17. Schwartz, Y. and Raslan, R. (2013). "Variations in results of building energy simulation tools, and their impact on BREEAM and LEED ratings: A case study." *Energy and Buildings*, 62, 350-359. doi: 10.1016/j.enbuild.2013.03.022

18. Seyis, S (2015). A decision making support model to determine appropriate credits for green building certification based on project delivery attributes. PhD Dissertation, Politecnico di Milano, Milan, Italy

19. Seyis, S. (2019). "Pros and Cons of Using Building Information Modeling in the AEC Industry". *Journal of Construction Engineering and Management,* 145(8), 04019046. doi:10.1061/(ASCE)CO.1943-7862.0001681

20. Seyis, S. 2022. "Case Study for Comparative Analysis of BIM-based LEED Building and Non-LEED Building" *Pamukkale University Journal of Engineering Sciences,* 28(3), 418 – 426. doi: 10.5505/pajes.2021.85668

21. Seyis, S. and Ergen, E. (2017). "A decision making support tool for selecting green building certification credits based on project delivery attributes". *Building and Environment,* 126(12), 107–118. doi: doi.org/10.1016/j.buildenv.2017.09.028

22. Seyis, S. Isin Guven, G. and Bayar, B. (2021). *"BIM-based energy analysis and design tools for LEED cerification*" *Uludağ University Journal of The Faculty of Engineering*, 26(3), 987- 1002. doi: 10.17482/uumfd.915932

23. Seyis, S.(2020). "Mixed method review for integrating building information modeling and

24. Singh, A., Syal, M., Grady, S.C., Korkmaz, S. 2009. "Effect of Green Buildings on Employee Health and Productivity", 100(9): 1665-1668, *American Journal of Public Health,* https://doi.org/10.2105/AJPH.2009.18068

25. Solla, M., Ismail, L.H. and Milad, A. (2019). "Measuring the feasibility of using of BIM application to facilitate GBI assessment process," *Journal of Building Engineering*, 25, 100821. doi: 10.1016/j.jobe.2019.100821

26. Statista, 2021. https://www.statista.com/statistics/323359/leed-registered-projects-in-the-united-states-by-type/ , (Accessed in 15.01.2022)

27. Sustainable buildings market study, 2019. https://ramboll.com/-/media/files/rgr/documents/markets/buildings/s/sustainable-buildings-market-study_2019_web.pdf?la=en (Accessed in 15.01.2022)

28. U.S. Dept. of Energy, Efficiency & Renewable Energy, 2014. Save (More) Energy Now with Intelligent Industrial Buildings, https://www.energy.gov/ (Accessed in: 19.12.2021)

29. U.S. DOE, Energy Information Administration, 2002. Manufacturing Energy Consumption Survey, https://www.eia.gov/consumption/manufacturing/index.php (Accessed in: 19.12.2021)

30. U.S. Environmental Protection Agency (EPA), 2016. "Green Building", https://archive.epa.gov/greenbuilding/web/html/about.html (Accessed in: 21.06.2022)

31. U.S. Green Building Council (USGBC), LEED v4.1 Building Design and Construction Guideline, 2021

32. UN Environment and International Energy Agency (2017). "Towards a zero-emission, efficient, and resilient buildings and construction sector. Global Status Report 2017". https://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf (Accessed in: 12.01.2022)

33. UN World Commission on Environment and Development. 1987. Our Common Future. Oxford: Oxford University Press

34. US Department of Energy, Energy Information Administration (EIA) 2019. International Energy Outlook 2019., Washington, DC, https://www.eia.gov/outlooks/ieo/pdf/ieo2019.pdf.

35. W. McDonough, The Hannover Principles: Design for Sustainability, William McDonough and Partners, Charlottesville, VA, 1992. www.mcdonough.com/wp-content/uploads/2013/03/Hannover-Principles-1992.pdf

36. Wang, Q,, H, Y., Hao, J., Lv, N., Li, T.Y. and Tang, B.J. (2019). "Exploring the influences of green industrial building on the energy consumption of industrial enterprises: A case study of Chinese cigarette manufactures" *Journal of Cleaner Production,* 231(5), doi: 10.1016/j.jclepro.2019.05.136

37. Worden, K. Hazer, M., Pyke, C. and Trowbridge, M. (2020). "Using LEED green rating systems to promote population health." *Building and Environment,* 172(4), 106550. doi:10.1016/j.buildenv.2019.106550

38. World Green Building Council (WGBC), 2013. "THE BUSINESS CASE FOR GREEN BUILDING, Review of the Costs and Benefits for Developers, Investors and Occupants", https://www.worldgbc.org/sites/default/files/Business_Case_For_Green_Building_Report_WEB_2013-04-11-2.pdf (Accessed in: 12.01.2022)

39. World Green Building Council (WGBC), 2016. "Building the business case: Health, Wellbeing and Productivity in Green Offices", https://www.worldgbc.org/sites/default/files/WGBC_BtBC_Dec2016_Digital_Low-MAY24_0.pdf (Accessed in: 12.01.2022)

40. Yin, RK. Case Study Research: Design and Methods, second ed., SAGE, Thousand Oaks, CA, 1994