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Study on Certification Criteria of Building Energy and Environmental Performance in the Context of Achieving Climate Neutrality

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Abstract: Increased greenhouse gas emissions have led to a global warming threat. As a result, countries have tended to focus their decision-making attention on energy-saving strategies. Specifically, the concept of green building has been developed for the construction sector. It aims to create energy-efficient structural activities (new constructions, repairs, or renovated constructions) that will be carried out in line with the determined criteria. With the concept of green building and the need to establish criteria and standards to ensure energy efficiency, green building certification systems have come to the fore. The Leadership in Energy and Environmental Design (LEED) and the Building Research Establishment Environmental Assessment Method (BREEAM) certification systems have been developed. This article investigates the achievements of the Indoor Environmental Quality (IEQ) category of LEED-certified projects in Türkiye and Europe. A comparison study of countries was carried out, based on the fourth version of the LEED BD+C framework that was developed for new green building projects. The study's primary goal is to show the linear correlation between market value and IEQ. It was revealed that the gross domestic product does not affect IEQ applications. Although Türkiye was ranked first in applying for IEQ credits, its economic development level is lower than that of other European countries.

Keywords: indoor environmental quality; building performance; Leadership in Energy and Environmental Design; sustainability determinants; Paris Agreement

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1. Introduction

The first industrial revolution, which started shortly after the middle of the 18th century and continued into the 19th century, was a period in which machine power began to be used in manufacturing, instead of human power. Since machine power requires fossil fuel consumption, this situation led to increased greenhouse gas emissions and global warming problems. Gases that trap heat in the atmosphere are greenhouse gases (GHGs), according to the United States Environmental Protection Agency (EPA) [1]. The primary greenhouse gases in Earth's atmosphere are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3) [2]. Human activities have been the primary cause of an increase in CO_2 in the atmosphere over the years. According to the Climate Change 2022 report of the Intergovernmental Panel on Climate Change (IPPC), total net anthropogenic GHG emissions continuously rose from 2010 to 2019, while net CO_2 emissions have cumulated since 1850. When mean greenhouse gas emissions were evaluated between 2010 and 2019, it was found that they reached higher levels than in previous years [3].

It has been observed that, due to fossil fuel consumption and increased manufacturing processes by machine power, carbon dioxide emissions increased by almost 90% from 1970 to 2011 [3]. The construction industry impacts greenhouse gas emissions massively, due to its manufacturing of building materials and its building processes. According to the Advancing Net Zero Status Report 2022 of the World Green Building Council (GBC), cement and steel manufacturers are responsible for 7–9% of global carbon emissions [4]. It is a fact that in the future, with the rise of the world's population and the need for new living spaces, emission rates caused by construction activities will increase.

At this point, the United Nations (UN) has taken action to prevent the harmful effects of GHGs and has established a series of conferences called Climate Change Conferences (COP). One of the most critical symposiums, called COP21, occurred in Paris in 2015. Within the scope of this conference, the decision-makers from countries participating in the meeting set long-term goals to reduce greenhouse gases by signing an international treaty on climate change [5]. During the conference, the participants agreed to reduce the global temperature rise or to limit it to 2 degrees (Celsius), compared to the global temperature before the industrial revolution [5]. As a result, it was decided that each party (country) must announce a five-year-long commitment to implementing an action plan to reduce greenhouse gases, and the countries signed the Paris Agreement. Following the meeting in 2015, every country took some actions, and most countries have established new codes to reduce their GHG emissions. On this point, green building (GB) certificates have become popular, as they require reductions in greenhouse gas emissions caused by construction activities. The requirements are related to different aspects of construction, such as the manufacturing of materials, the operation of construction machines, supply chain management, the water consumption of buildings, and other processes.

In 1993, a new certification type, called Leadership in Energy and Environmental Design (LEED), was developed by the United States Green Building Council (USGBC)). LEED helps to evaluate buildings in terms of their being "green" [6]. The LEED certification system has been improved over the years to meet the needs of both occupants of green buildings and GB contractors. A fourth version of the LEED certification system (LEED v4) was launched in 2015, the same year as the acceptance of the Paris Agreement. Thus, most countries' project owners have started to apply this new version of LEED certification to ensure that the requirements of the Paris Agreement and local policies are met.

According to the LEED processes, projects should earn points by achieving the prerequisites and credits. Such processes tend to consider current issues, such as carbon emissions, energy and water consumption, indoor environmental quality, and materials. GB projects can apply for LEED certification by earning points, and the certification type will be related to the earned points. LEED-certified projects must earn at least 40 to 49 points. Silver projects must earn 50–59 points. Gold projects must earn between 60 and 79 points, and Platinum projects must achieve at least 80 or more points [7].

The project types that apply in obtaining LEED certification have been divided into groups to develop related credits. Building design and construction projects, interior design projects, building operation and maintenance projects, and neighborhood development projects are the sub-certification types of LEED v4 [8]. In applying for the proper LEED certification types for a project, which are listed in Table 1, one should check categories and credits. The project owner and the contractor must develop the project's goals in relation to energy efficiency, the wellbeing of occupants, and water efficiency. At this stage, a green building consultant should also be involved.

Table 1. LEED v4. certification types [9].

LEED BD+C (Building Design and Construction)	LEED ID+C (Interior Design and Construction)	LEED O+M (Operation and Maintenance)	LEED ND (Neighborhood Development)
• New construction and major renovation • Core and shell • Development • Schools • Retail • Data centers • Warehouses and distribution centers • Hospitality • Healthcare • Homes and multifamily low-rise • Multifamily midrise	• Commercial • Interiors • Retail • Hospitality	• Existing buildings • Retail • Schools • Hospitality • Data centers • Warehouses and distribution centers • Multifamily	• Plan • Built project

In this study, LEED v4 certification for Building Design and Construction projects have been investigated in Europe and Türkiye by considering the "New Construction and Major Renovations" category. The reason for this focus is to investigate construction projects at the beginning of the design phase. For this reason, the category "New Construction and Major Renovations" has been used to search for projects from the design phase. In addition, the selected category contains residential homes and office buildings, residential buildings, schools, and commercial buildings (see Table 1). Thus, it has been applied to different types of certified construction projects.

Table 2 shows the credit categories and sub-credits of the LEED BD+C New Construction v4. In addition, achievable sub-credit points are presented. The LEED BD+C NC v4 has eight credit categories: Integrative Process, Location and Transformation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation.

Table 2. LEED BD+C NC v4 credit categories.

Credit Category	Credits	Points
Integrative Process	Integrative Process	1 point
	Total	1 Point
Location and Transformation	LEED for Neighborhood Development Location	Up to 16 points
	Sensitive Land Protection	1 point
	High Priority Site	2 points
	Surrounding Density and Diverse Uses	Up to 5 points
	Access to Quality Transit	Up to 5 points
	Bicycle Facilities	1 Point
	Reduced Parking Footprint	1 point
	Green Vehicles	1 point
	Total	16 Points
Sustainable Sites	Construction Activity Pollution Prevention	Prerequisite-Required
	Site Assessment	1 point
	Site Development-Protect or Restore Habitat	Up to 2 points
	Open Space	1 point
	Rainwater Management	Up to 3 points
	Heat Island Reduction	Up to 2 points
	Light Pollution Reduction	1 point
	Total	10 Points

Table 2. *Cont.*

Credit Category	Credits	Points
Water Efficiency	Outdoor Water Use Reduction	Prerequisite-Required
	Indoor Water Use Reduction	Prerequisite-Required
	Building-level Metering	Prerequisite-Required
	Outdoor Water Use Reduction	Up to 2 points
	Indoor Water Use Reduction	Up to 6 points
	Cooling Tower Water Use	Up to 2 points
	Water Metering	1 point
	Quality Views	1 point
	Total	12 Points
Energy and Atmosphere	Fundamental Commissioning and Verification	Prerequisite-Required
	Minimum Energy Performance	Prerequisite-Required
	Building-level Energy Metering	Prerequisite-Required
	Fundamental Refrigerant Management	Prerequisite-Required
	Enhanced Commissioning	Up to 6 points
	Optimize Energy Performance	Up to 18 points
	Advanced Energy Metering	1 point
	Demand Response	Up to 2 points
	Renewable Energy Production	Up to 3 points
	Enhanced Refrigerant Management	1 point
	Green Power and Carbon Offsets	Up to 2 points
	Total	33 Points
Materials and Resources	Storage and Collection of Recyclables	Prerequisite-Required
	Construction and Demolition Waste Management Planning	Prerequisite-Required
	Building Life-Cycle Impact Reduction	Up to 5 points
	Building Product Disclosure and Optimization-Environmental Product Declarations	Up to 2 points
	Building Product Disclosure and Optimization-Sourcing of Raw Materials	Up to 2 points
	Building Product Disclosure and Optimization-Material Ingredients	Up to 2 points
	Construction and Demolition Waste Management	Up to 2 points
	Total	13 Points
Indoor Environmental Quality	Minimum Indoor Air Quality Performance	Prerequisite-Required
	Environmental Tobacco Smoke Control	Prerequisite-Required
	Enhanced Indoor Air Quality Strategies	Up to 2 points
	Low Emitting Materials	Up to 3 points
	Construction Indoor Air Quality Management Plan	1 point
	Indoor air quality assessment	Up to 2 points
	Thermal Comfort	1 point
	Interior Lighting	Up to 2 points
	Daylight	Up to 3 points
	Quality Views	1 point
	Acoustic Performance	1 point
	Total	16 Points
Innovation	Innovation	Up to 5 points
	LEED Accredited Professional	1 point
	Total	6 Points
Regional Priority	Regional Priority	Up to 4 points
	Total	4 Points

Despite a rise in the number of green buildings, carbon dioxide emissions have increased. Building occupants, who have been negatively affected by GHGs, have paid increasing attention to their environmental conditions, comfort, and wellbeing. During the COVID-19 pandemic, building occupants' desire for indoor environmental quality has become a requirement for health. Thus, the importance of IEQ has increased. The quality of indoor air, the contaminant rates in exhaled air, and the wellbeing and comfort of building occupants have become more critical in the past three years, as occupants spend much more time in buildings. During the pandemic, it is commonly understood that GBs have less negative impact on indoor environment quality. At the same time, it is well known that GHG emissions negatively affect indoor environmental quality.

Table 3 presents all the certification types and sub-credits for the Indoor Environmental Quality category. In addition, the credit points and the prerequisite categories are shown. The prerequisite credits must be achieved to obtain points from the IEQ credit. The remaining credits can apply, but they are not mandatory; they are mostly related to the project's cost, technological potential, and location. Thus, the applicable credits and sub-credits should be determined during the design phase, before starting a project.

Table 3. The Indoor Environmental Quality credits and points of LEED BD+C v4 [10].

Certification Type	Credits	Points
New Construction and Major Renovation	Minimum Indoor Air Quality Performance	Prerequisite-Required
	Environmental Tobacco Smoke Control	Prerequisite-Required
	Enhanced Indoor Air Quality Strategies	Up to 2 points
	Low Emitting Materials	Up to 3 points
	Construction Indoor Air Quality Management Plan	1 point
	Indoor Air Quality Assessment	Up to 2 points
	Thermal Comfort	1 point
	Interior Lighting	Up to 2 points
	Daylight	Up to 3 points
	Quality Views	1 point
	Acoustic Performance	1 point
	Total	16 Points
Core and Shell Development	Minimum Indoor Air Quality Performance	Prerequisite-Required
	Environmental Tobacco Smoke Control	Prerequisite-Required
	Enhanced Indoor Air Quality Strategies	Up to 2 points
	Low Emitting Materials	Up to 3 points
	Construction Indoor Air Quality Management Plan	1 point
	Daylight	Up to 3 points
	Quality Views	1 point
	Total	10 Points
Schools	Minimum Indoor Air Quality Performance	Prerequisite-Required
	Environmental Tobacco Smoke Control	Prerequisite-Required
	Minimum Acoustic Performance	Prerequisite-Required
	Enhanced Indoor Air Quality Strategies	Up to 2 points
	Low Emitting Materials	Up to 3 points
	Construction Indoor Air Quality Management Plan	1 point
	Indoor air quality assessment	Up to 2 points
	Thermal Comfort	1 point
	Interior Lighting	Up to 2 points
	Daylight	Up to 3 points
	Quality Views	1 point
	Acoustic Performance	1 point
	Total	16 Points

Table 3. *Cont.*

Certification Type	Credits	Points
Retail	Minimum Indoor Air Quality Performance	Prerequisite-Required
	Environmental Tobacco Smoke Control	Prerequisite-Required
	Enhanced Indoor Air Quality Strategies	Up to 2 points
	Low Emitting Materials	Up to 3 points
	Construction Indoor Air Quality Management Plan	1 point
	Indoor Air Quality Assessment	Up to 2 points
	Thermal Comfort	1 point
	Interior Lighting	Up to 2 points
	Daylight	Up to 3 points
	Quality Views	1 point
	Total	15 Points
Healthcare	Minimum Indoor Air Quality Performance	Prerequisite-Required
	Environmental Tobacco Smoke Control	Prerequisite-Required
	Enhanced Indoor Air Quality Strategies	Up to 2 points
	Low Emitting Materials	Up to 3 points
	Construction Indoor Air Quality Management Plan	1 point
	Indoor Air Quality Assessment	Up to 2 points
	Thermal Comfort	1 point
	Interior Lighting	1 point
	Daylight	2 points
	Quality Views	2 points
	Acoustic Performance	Up to 2 points
	Total	16 Points
Data Centers	Minimum Indoor Air Quality Performance	Prerequisite-Required
	Environmental Tobacco Smoke Control	Prerequisite-Required
	Enhanced Indoor Air Quality Strategies	Up to 2 points
	Low Emitting Materials	Up to 3 points
	Construction Indoor Air Quality Management Plan	1 point
	Indoor Air Quality Assessment	Up to 2 points
	Thermal Comfort	1 point
	Interior Lighting	Up to 2 points
	Daylight	Up to 3 points
	Quality Views	1 point
	Acoustic Performance	1 point
	Total	16 Points
Hospitality	Minimum Indoor Air Quality Performance	Prerequisite-Required
	Environmental Tobacco Smoke Control	Prerequisite-Required
	Enhanced Indoor Air Quality Strategies	Up to 2 points
	Low Emitting Materials	Up to 3 points
	Construction Indoor Air Quality Management Plan	1 point
	Indoor Air Quality Assessment	Up to 2 points
	Thermal Comfort	1 point

Table 3. *Cont.*

Certification Type	Credits	Points
	Interior Lighting	Up to 2 points
	Daylight	Up to 3 points
	Quality Views	1 point
	Acoustic Performance	1 point
	Total	16 Points
Warehouses and Distribution Centers	Minimum Indoor Air Quality Performance	Prerequisite-Required
	Environmental Tobacco Smoke Control	Prerequisite-Required
	Enhanced Indoor Air Quality Strategies	Up to 2 points
	Low Emitting Materials	Up to 3 points
	Construction Indoor Air Quality Management Plan	1 point
	Indoor Air Quality Assessment	Up to 2 points
	Thermal Comfort	1 point
	Interior Lighting	Up to 2 points
	Daylight	Up to 3 points
	Quality Views	1 point
	Acoustic Performance	1 point
	Total	16 Points
Homes	Ventilation	Prerequisite-Required
	Combusting Venting	Prerequisite-Required
	Garage Pollutant Protection	Prerequisite-Required
	Radon-resistant Construction	Prerequisite-Required
	Air Filtering	Prerequisite-Required
	Environmental Tobacco Smoke	Prerequisite-Required
	Compartmentalization	Prerequisite-Required
	Enhanced Ventilation	Up to 3 points
	Contaminant Control	Up to 2 points
	Balancing of Heating and Cooling Distribution Systems	Up to 3 points
	Enhanced Compartmentalization	1 point
	Enhanced Combusting Venting	Up to 2 points
	Total	11 Points
Multifamily Midrise	Ventilation	Prerequisite-Required
	Combusting Venting	Prerequisite-Required
	Garage Pollutant Protection	Prerequisite-Required
	Radon-resistant Construction	Prerequisite-Required
	Air Filtering	Prerequisite-Required
	Environmental Tobacco Smoke	Prerequisite-Required
	Compartmentalization	Prerequisite-Required
	Enhanced Ventilation	Up to 3 points
	Contaminant Control	Up to 2 points
	Balancing of Heating and Cooling Distribution Systems	Up to 3 points
	Enhanced Compartmentalization	3 points
	Enhanced Combusting Venting	Up to 2 points
	Total	13 Points

In the Paris Agreement, it was decided that the developed countries should support the developing countries with financial sources to combat greenhouse gas emissions [5]. Because Türkiye has been defined as a developing country in the Paris Agreement, we have aimed to investigate, in this study, the relationship between the earned points of the IEQ categories that can be accepted as a performance to reduce GHG emissions. As a result, this research aims to verify the combination of the Agreement's requirements and the country's economic development level.

In the literature review, a knowledge gap was found, as development levels (economic) and IEQ were not previously compared. Previous studies focused on searching only for a relationship between climate change and economic development levels. However, no study showed the relationship between the LEED certification's IEQ credit and GDP values. The purpose and the importance of this study are to show that projects' applications for LEED certification were not determined by financial limitations, even if the economic development level of the country in which they were located was comparably lower than that of other countries. Investors want to show customers that their companies pay attention to building occupants' comfort and wellbeing by achieving high IEQ points.

On the other hand, the reason for selecting LEED version 4 (LEED v4) is the Paris Agreement, which was accepted in 2015. Projects certified before 2015 were not reviewed for IEQ criteria, because most countries did not start to apply the new requirements or develop new policies to reduce greenhouse gas emissions until after 2015.

2. Theoretical Background

2.1. Indoor Environmental Quality

Buildings that can reduce greenhouse gas emissions, energy usage, and water efficiency have great importance in maintaining the construction sector on a global scale. When considering the construction of buildings, especially during the material selection phase, the rough and fine construction stages are essential for the reduction of energy and water consumption and potential carbon emissions. When these stages are completed, inclusive of meeting green building certification targets, more comfortable and productive living spaces will be created for building occupants. When it comes to the comfort of building users, one of the first issues that comes to mind is indoor environmental quality [11,12].

To understand the importance and the effects of IEQ, a great deal of scientific research has been carried out in recent years. Most of these studies have investigated IEQ based on the effects of ventilation options and volatile organic compounds (VOCs). Ohura et al. conducted a study examining indoor air quality in China and Japan by focusing on the features of both indoor and outdoor residential VOCs. [13]. They examined indoor microenvironments, including living rooms, kitchens, and bedrooms, during the summer and winter. Shizuoka in Japan and Hangzhou in China were the two metropolitan centers in which their study primarily compared indoor and outdoor VOC levels to examine the possible impacts of such levels in each city and to calculate exposure risks. In Japan, samples from 30 and 27 homes in the summer and winter, respectively, were taken. Samples from seven of the 14 households in China were taken in summer, and seven were taken in winter. The cities' urban cores contained every house that was examined. A self-administrated survey of the residents provided data on the features of the houses. There were distinct disparities between Japan and China in the types of houses that were considered: in Japan, most of the homes were made of concrete, while the rest were built with steel (47%) and wood (53%). The outside samples were shielded from rain and bright sunlight and located away from the house's heat sources and exhaust vents. In order to avoid dust aspiration and adhesion brought on by human activity, most of the outdoor samples were situated in the backyards of the dwellings. The study found that indoor VOC concentrations tended to be much more significant in China than in Japan.

Lee et al. [14] studied the effects of both VOCs and air pollutants on indoor air quality by investigating residential homes in Hong Kong. Their study focused on observing IAQ rates specifically for residential flats. The air pollutants were measured and, according to the results, the kitchens' carbon dioxide and PM10 levels were higher than those of other areas.

In addition to residential homes, the indoor air quality of schools in Beijing was investigated by Cai et al. [15]. Their study compared the effectiveness of mechanical ventilation with fresh air ventilators to that of natural ventilation with air cleaners in

33 classrooms across 21 schools in Beijing. They measured indoor CO_2 and PM2.5 real-time concentrations, as well as the air temperature, humidity, and air-cleaning effectiveness of the mechanical ventilation system. In real time, continuous measurements were made of the ambient temperature, humidity, and indoor PM2.5 and CO_2 concentrations.

Babaoglu et al. conducted a similar study by assessing the indoor air quality in schools in Anatolia, Türkiye [16]. Thirty-four elementary schools in the Central Anatolia region were subjected to indoor air measurements as part of this investigation. Measurements were made on the levels of PM10, PM2.5, CO_2, CO, CH_2O, relative humidity, temperature, total bacteria, and total fungi. The measurements were compared with statistics from the World Health Organization. The findings showed a positive relationship between the number of students and the mean CO_2 concentration. Thus, schools must have proper ventilation procedures, such as opening windows during lunch or recess, to reduce the CO_2 concentration. Additionally, the lack of ventilation in the studied structures should be considered.

In addition to the indoor air quality of residential homes and schools, the indoor air quality of high-rise buildings has been investigated. A high-rise building's internal air quality was researched by Fu et al., taking into account variables such as the seasons and air infiltration [17]. In addition, atmospheric weather conditions have been considered to be a factor and have been analyzed in downtown Suzhou, China. According to the findings, winter had the most significant effect on indoor air quality, followed by spring, autumn, and summer, respectively. Stack impact, the wind effect, the infiltration rate, the outside air pollution rate, seasonal variations, and air filter effectiveness are other significant aspects. It has been confirmed that, with floor height changes, these parameters substantially impact indoor air quality levels. The investigation suggested using a high-efficiency filter to maintain healthy indoor air quality. The most significant influence of outside air pollutants on indoor air quality occurred in winter. Thus, a double-filter system was necessary if a structure was exposed to highly contaminated external air.

The investigation of the correlation between IEQ and GBs revealed some related studies in the literature. For instance, Xiong et al. compared five years of annual indoor air measurements of residential green high-rise buildings with those of conventional buildings in the northeastern United States. [18]. Persily and Emmerich searched the indoor air quality of sustainable, energy-efficient buildings [19]. Their study examined the correlation between a building's energy efficiency and indoor air quality. It was noted that various parameters, including improved envelope airtightness, heat recovery ventilation, or controlled ventilation on-demand, impact a building's energy efficiency.

Annaa et al. [20] considered three conventional and green buildings that had operated for at least one year and user perception regarding indoor environmental quality (IEQ) in São Paulo (Brazil). According to their study, employees of green buildings were satisfied with working in healthy environments; however, from the clients' perspective, there were no significant differences.

Another study about occupant satisfaction, in terms of Indoor Environmental Quality for LEED-certified projects, was carried out by Lee and Guerin [21]. In their study, the purpose was to determine occupants' satisfaction with their workspaces based on LEED IEQ design criteria. They listed the following design requirements: office layout, furnishings, thermal comfort, indoor air quality, lighting, acoustics, and cleanliness. Within this scope, fifteen LEED-certified projects were investigated and a questionnaire survey reviewed occupants' satisfaction. According to the results, office furnishing made occupants feel more comfortable and satisfied. Most of the occupants mentioned a low level of illuminance in their workspaces, which caused them to be affected by artificial lighting.

Lee and Kim [22] investigated LEED-certified projects' indoor environmental quality (IEQ) in the United States. Within the scope of their study, seven IEQ criteria were compared for LEED-certified and non-LEED-certified buildings. The seven IEQ criteria were the furnishing and layout of offices, thermal comfort, IAQ, lighting options, acoustic environment, cleanliness, and maintenance.

Using the importance–performance analysis, Lee [23] attempted to assess the success of IEQ in LEED-certified houses by comparing discrepancies between occupants' perceived importance and performance (IPA). A total of 235 completed questionnaires from a mail-in survey were examined, utilizing gap analysis and IPA. Thermal comfort, air quality, illumination, and acoustic comfort were the topics of the investigation. The results showed that three factors—air quality, temperature, and humidity—were the most crucial.

Most IEQ studies have focused on the scope of occupants' satisfaction. Many questionnaire-based survey studies have been carried out to understand occupants' expectations about IEQ for LEED-certified projects. Most of the existing studies have compared LEED-certified or green building projects' IEQ criteria with conventional buildings' IEQ circumstances. There is no existing study checking achieved IEQ points for LEED-certified projects and the affecting criteria for achieving or applying for IEQ credit. In addition, no existing study compares earned IEQ points for LEED projects by considering countries' wealth (GDP). The current study focused on showing the correlation between IEQ points and GDP values for countries that applied for LEED certification. Thus, the importance and the effect of GDP on green building projects is presented.

2.2. Factors Motivating Investors to Choose a Certification System

The reasons for applying for green building certifications could include offering attractive opportunities for investors and stakeholders. In particular, the USA has excellent offers for investors, such as tax reductions, discounts on fees (license, approval, permission), high precedent clearances, grants, and low-interest loans when applying for green building certificates. The types of incentives for green building certification applications, according to the USGBC, are shown in Figure 1.

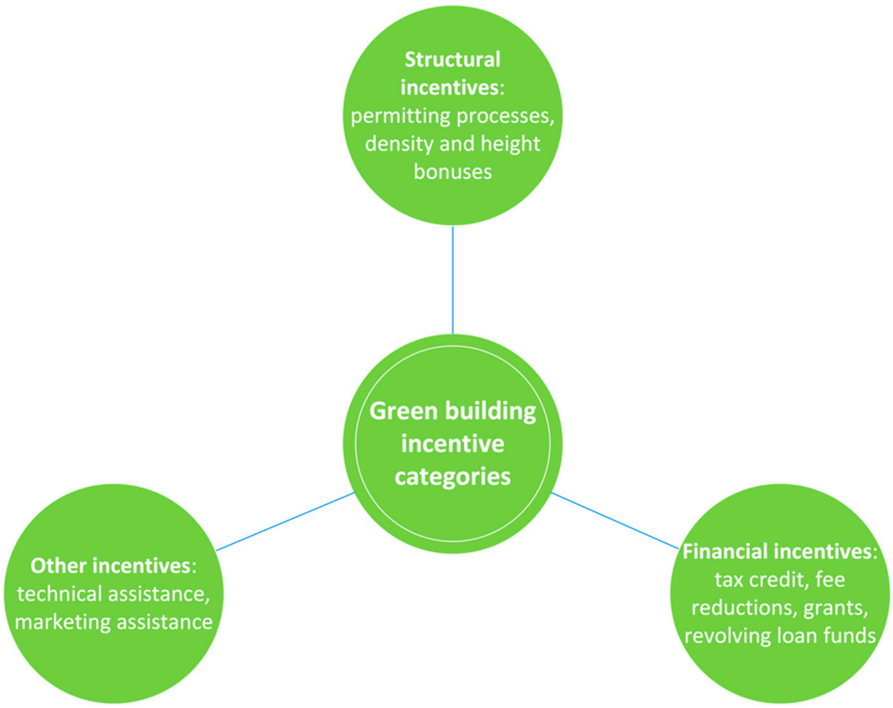

Figure 1. The green building incentive categories (USGBC).

Most European countries have developed some policies for reducing energy consumption and GHGs. The European Commission developed a set of recommendations to adapt Europe's taxing policies to reducing net greenhouse gas emissions, compared to 1990 levels, by a minimum of 55% by 2030. However, no specific codes encourage building investors to apply for green building certification programs. The European Commission has mentioned reducing energy consumption in the Energy Efficiency Directive [24]. In addition, in the case of applying for green building certification, most European countries prefer to use their own national green building certifications. For instance, Germany uses its national green building certification program, which is administrated by the German Sustainable Building Council (Deutsche Gesellschaft für Nachhaltiges Bauen—DGNB). Therefore, Germany does not require applications for other types of certifications. Additionally, applications to green building certification programs are in demand on voluntary systems, and there are no legal sanctions applicable to these systems.

3. Materials and Methods

3.1. Data Collection

The data consisted of LEED BD+C New Construction v4 projects certified up to 15 August 2022. Within the scope of the study, 44 European countries and Türkiye (a total of 45 countries) were investigated. Thirteen of these countries were not listed in USGBC's data, 12 are not certified projects, and 20 are certified projects by this date (Table 4). In addition, the numerical data distribution of LEED BD+C New Construction v4 projects is shown in Figure 2. Each of these records was gathered from USGBC's website.

Table 4. Current LEED BD+C New Construction v4 data information of European Countries.

Country↓	**Data Availability↓**	**Country↓**	**Data Availability↓**
France	Data Exist	Montenegro	No Data
Spain	Data Exist	Ukraine	No Data
Germany	Data Exist	Malta	No Data
Poland	Data Exist	Moldova	No Data
Netherlands	Data Exist	Liechtenstein	No Data
Finland	Data Exist	North Macedonia	No Data
Austria	Data Exist	Norway	Not Listed
Italy	Data Exist	Latvia	Not Listed
Denmark	Data Exist	Slovenia	Not Listed
Sweden	Data Exist	Albania	Not Listed
Lithuania	Data Exist	Belarus	Not Listed
Greece	Data Exist	United Kingdom	Not Listed
Portugal	Data Exist	Luxembourg	Not Listed
Switzerland	Data Exist	Monaco	Not Listed
Serbia	Data Exist	Iceland	Not Listed
Hungary	Data Exist	San Marino	Not Listed
Romania	Data Exist	Bosnia and Herzegovina	Not Listed
Russia	Data Exist	Holy See	Not Listed
Ireland	Data Exist	Andorra	Not Listed
Bulgaria	No Data		
Slovakia	No Data		
Czechia	No Data		
Croatia	No Data		
Estonia	No Data		
Belgium	No Data		

Table 5 lists the number of projects that have received LEED BD+C New Construction v4 certification.

Additionally, Figure 3 illustrates the numerical distribution of the LEED BD+C NC v4 certifications' certified project numbers graphically. The project numbers have been used as data input on IBM SPSS Statistics 24 software.

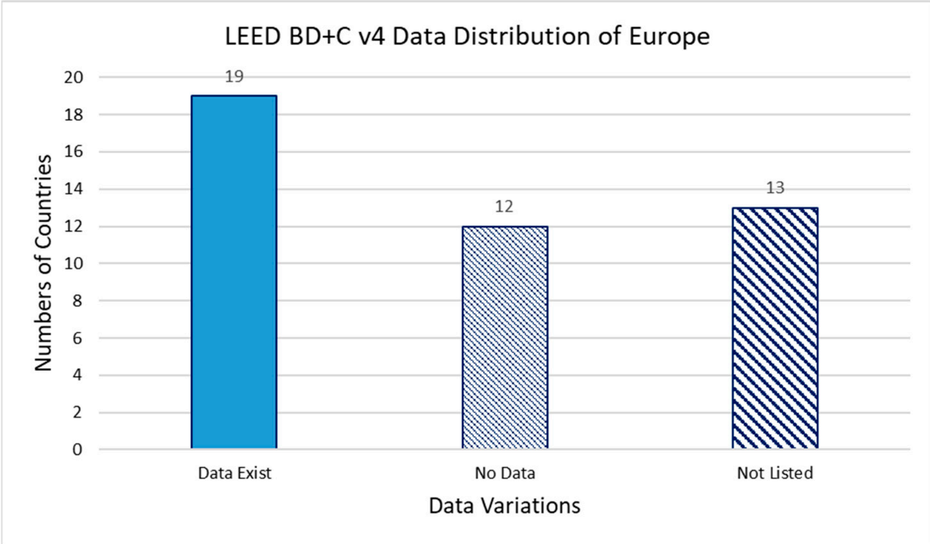

Figure 2. LEED BD+C New Construction v4 data distribution in Europe (without Türkiye).

Table 5. Number of the LEED BD+C New Construction v4 certified projects.

Country	Number of Certified Projects↓	Country	Number of Certified Projects↓
Türkiye	42	France	3
Germany	21	Greece	3
Italy	20	Portugal	3
Spain	13	Serbia	3
Sweden	9	Denmark	2
Finland	7	Lithuania	2
Ireland	6	Poland	1
Austria	5	Netherlands	1
Switzerland	5	Romania	1
Hungary	4	Russia	1

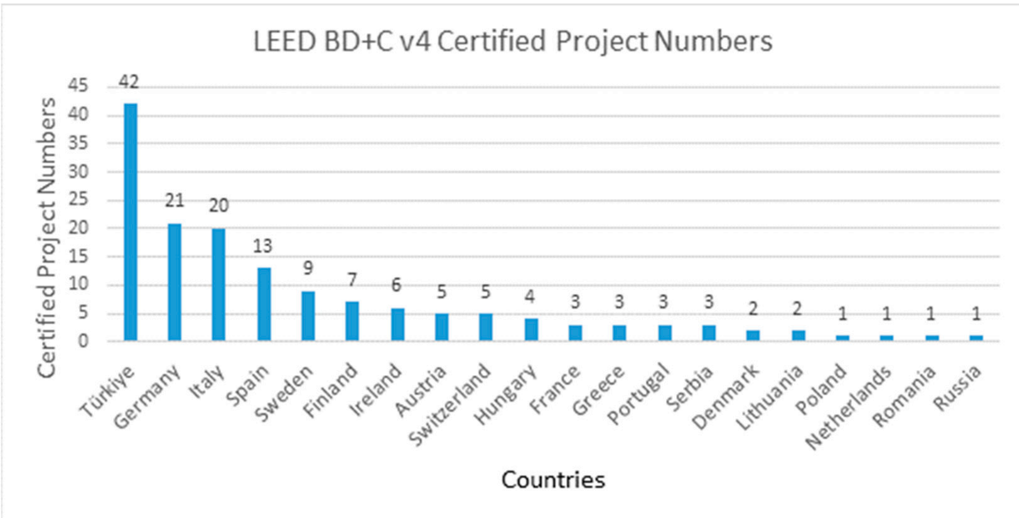

Figure 3. LEED BD+C New Construction v4-certified project numbers in Europe and Türkiye.

This study's primary goal was to determine the relationship between the IEQ points of LEED BD+C NC v4 projects and the economic development of Türkiye and countries in Europe. Thus, initially, the achieved IEQ points were investigated for each country. The USGBC states that the maximum number of points for IEQ credit that may be earned is 16, and Table 6 lists the total IEQ points that each country has earned. The collected data for IEQ consists of 9 credits and 2 prerequisite credits. In addition, the prerequisite credits do not contain any points, so we call them requirements. For this reason, two prerequisites were not added to the total achieved points. Only 7 out of the total credit points were examined.

Table 6. Achieved total points for IEQ credit for LEED BD+C New Construction v4 projects.

Countries	Number of Certified Projects	Achieved Total Points	Countries	Number of Certified Projects	Achieved Total Points
Türkiye	42	317	France	3	22
Germany	21	135	Greece	3	12
Italy	20	144	Portugal	3	27
Spain	13	89	Serbia	3	21
Sweden	9	43	Denmark	2	14
Finland	7	46	Lithuania	2	12
Ireland	6	46	Poland	1	6
Austria	5	28	Netherlands	1	12
Switzerland	5	31	Romania	1	9
Hungary	4	20	Russia	1	8

3.2. Data Analysis

The percentage of average scores (PAS) was calculated to compare the countries' total achieved points. The PAS for each country was calculated and the equation was as follows:

$$PAS = PO/TP \times 100 \tag{1}$$

PO means an obtained sum of the IEQ points of each country, and TP is the total IEQ points of the countries. In addition, the mean value and the standard deviation values were calculated, and the equation was:

$$\bar{x} = \frac{\Sigma f_x}{f} \tag{2}$$

$\bar{x}$ is the mean value, while Σf_x means achieved total points, and f is the number of certified projects. The mean value was calculated for each country. In addition, the standard deviation was calculated for each country. The formula of standard deviation (SD) is:

$$SD = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}} \tag{3}$$

$\bar{x}$ is the mean value, x is the achieved total points, and n is the number of certified projects. The calculated PAS values are shown in Table 7.

Table 7. PAS, mean, standard deviation values of the IEQ points of countries.

Countries	PAS (%)	Mean	SD	Countries	PAS (%)	Mean	SD
Türkiye	30.42	7.55	48.33	France	2.11	7.33	10.37
Germany	12.96	6.43	28.75	Greece	1.15	4	5.66
Italy	13.82	7.2	31.38	Portugal	2.59	9	12.73
Spain	8.54	6.85	23.72	Serbia	2.02	7	9.9
Sweden	4.13	4.78	13.51	Denmark	1.34	7	7
Finland	4.41	6.57	16.1	Lithuania	1.15	6	6
Ireland	4.41	7.67	17.14	Poland	0.58	6	-
Austria	2.69	5.6	11.2	Netherlands	1.15	12	-
Switzerland	2.98	6.2	12.4	Romania	0.86	9	-
Hungary	1.92	5	8.66	Russia	0.77	8	-

Afterwards, the collected data were analyzed using the IBM SPSS Statistics 24 software. Initially, the normal distribution of the values was investigated. The Shapiro–Wilk test was conducted to check the normality of the data, and the results are shown in Table 8. Because the p-value of 0.000 was lower than 0.05, the data were not distributed normally. Thus, one of the non-parametric analyses, Spearman's correlation analysis, was applied to the data set. The purpose of using Spearman's correlation analysis for this data set was to assess the null hypothesis that "there is a significant correlation between the number of LEED BD+C NC v4 projects and IEQ points of these projects". The results are listed in Table 9.

Table 8. The Shapiro–Wilk test results of both IEQ points and number of the projects.

Type of Data	df	Sig.
Number of the Projects	20	0.000
IEQ Points	20	0.000

Table 9. The Spearman correlation analysis results of both IEQ points and the constant mean values of GDPs.

Type of Data	Measure	IEQ Points	GDP
IEQ Points	Correlation Coefficient	1.000	0.356
	Sig. (2-tailed)		0.123
	N	0.20	20
GDP	Correlation Coefficient	0.356	1.000
	Sig. (2-tailed)	0.123	
	N	20	20

This study's primary purpose was to determine the relationship between the IEQ points of LEED BD+C NC v4 projects and the economic development of countries in Türkiye and Europe. With this purpose, the gross domestic product (GDP) constant values were investigated to determine the economic development levels of the countries. The GDP values and the IEQ points were analyzed to determine whether any relationship exists between the development levels of countries and the IEQ points of projects. The GDP value data collection was obtained by searching data held by the World Bank [25] and the Central Bank of the Turkish Republic (CBRT) [26]. The data covered the years from 2015 to 2021, ending on 31 December for each year. Because the financial year 2022 was not complete, it was not involved in the calculations. The reason for selecting the starting year of 2015 was that LEED BD+C NC v4 was released that year. Therefore, the data selection ranged from 2015 to 2021. IBM SPSS Statistics 24 software compared the correlation between IEQ points and GDP constant values. Initially, the GDP mean values were calculated for each country.

Moreover, the calculated values were compared using Spearman's correlation analysis. The null hypothesis was that "there is a significant correlation between the development level of countries and IEQ points of these projects". Constant mean GDP values determined the development levels of each of the countries.

4. Results

The PAS, means, and standard deviations are presented in Table 7. In addition, the obtained IEQ point's PAS values are shown in Figure 4.

The results of the normal distribution of the numbers of projects and IEQ projects were carried out by IBM SPSS Statistics 24 software, as shown in Table 8. The Shapiro–Wilk test was used to examine the data's normality because there were fewer than 30 projects (df). The null hypothesis stated that there was no noticeable deviation from the normal distribution of the data. The null hypothesis was rejected, and there was proof that the tested data respond to normal distribution if the p-value is smaller than the selected alpha level. The null hypothesis was rejected because the p-value was less than 0.05. It follows that the data were not distributed regularly.

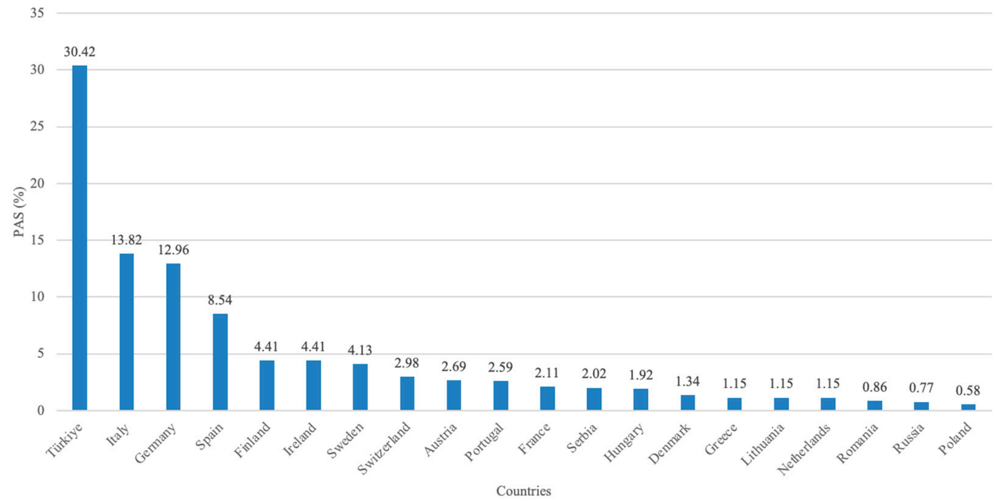

Figure 4. LEED BD+C New Construction v4 IEQ credit obtained points' PAS in Europe and Türkiye.

The constant GDP values were searched from 2015 to 2021 (Table 10) to investigate the economic development levels of the selected countries. Then, the mean GDP values for those years were calculated, as shown in Figure 5.

Table 10. The criteria may affect the achieved IEQ points.

Criteria.
• The constant GDP values of the countries • The green building incentives and policies developed by governments • The geographical locations of the countries • The climatic conditions of the countries • The application fees for green building certifications • Whether a country has a national green building certification system • Whether the applications to green building certification programs are voluntary

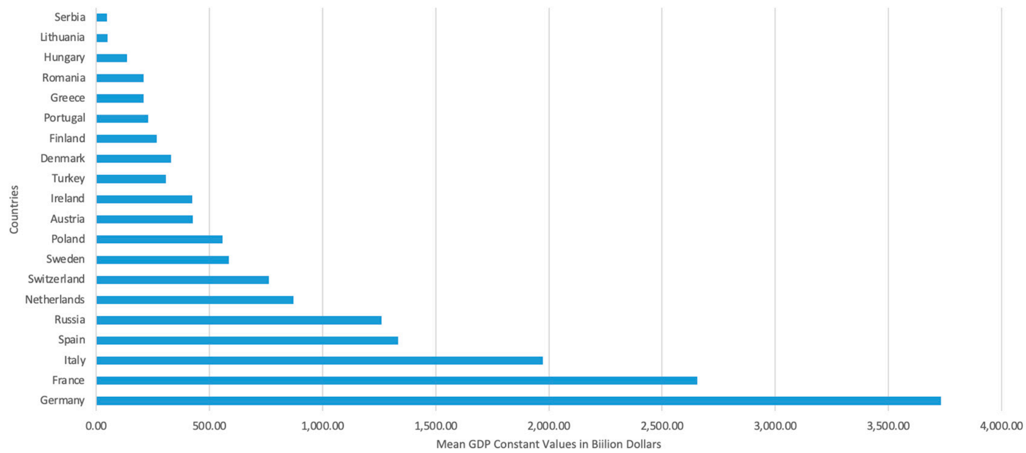

Figure 5. The constant mean GDP values of countries from 2015 to 2021.

The formulated null hypothesis that there is a significant correlation between achieved IEQ points and constant GDP values of the countries was analyzed via a Spearman's correlation test. The results of Spearman's correlation analysis are shown in Table 9.

Figure 5 shows that Germany had the highest constant mean GDP values from 2015 to 2021. It was followed by France, Italy, Spain, Russia, Netherlands, Switzerland, Sweden, Poland, Austria, Ireland, Turkey, Denmark, Finland, Portugal, Greece, Romania, Hungary, Lithuania, and Serbia. However, when the LEED BD+C v4-certified project numbers and the achieved IEQ points were checked, Türkiye was listed in the first row. On the other hand, Türkiye was ranked 12th in constant GDP value. In addition, France was listed as 11th for achieved IEQ points, but it was on the second line for GDP. According to the data set, it is clear that there is no correlation between achieved IEQ points and constant GDP values. In Table 9, the Spearman's correlation analysis results from the sig. (2-tailed) value was found to be 0.123, which is greater than 0.05, meaning there was no correlation between achieved IEQ points and constant GDP values.

In addition, the distribution of achieved IEQ points in Europe and Türkiye is shown in Figure 6, using Microsoft 3D maps based on the density of the achieved points by cities.

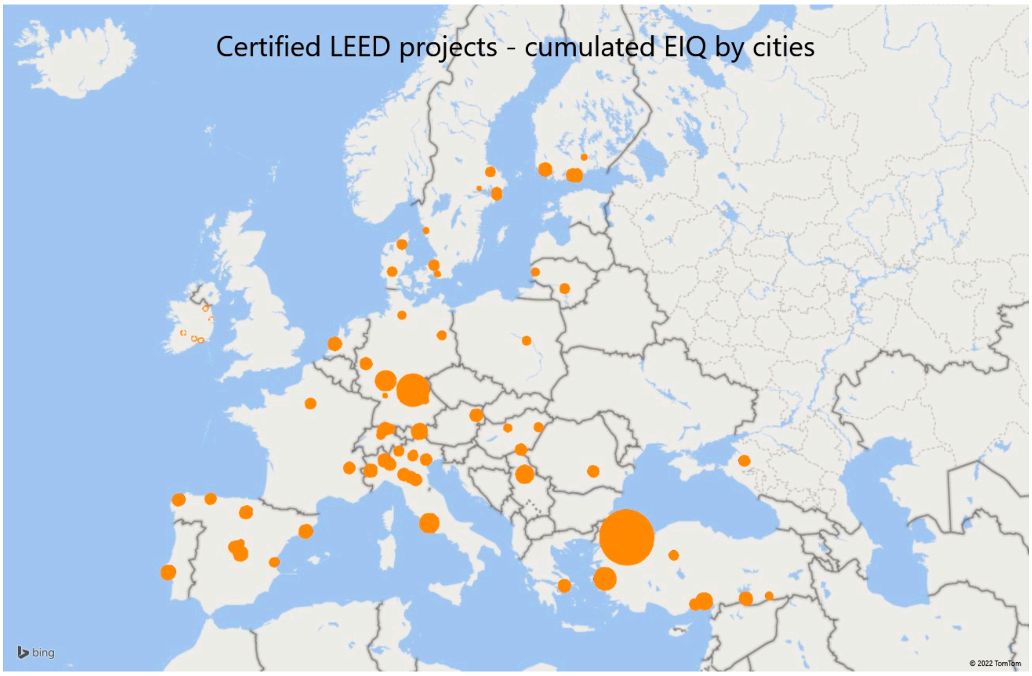

Figure 6. The achieved IEQ points' density of LEED BD+C New Construction v4-certified projects in Europe and Türkiye.

5. Discussion

In this study, the relationship between LEED BD+C v4 projects' IEQ points and GDP values in Europe and Türkiye was investigated. Only 19 of the 44 European countries have submitted applications for LEED BD+C v4 certification, according to data from the USGBC website. Twelve countries have not yet submitted applications, while thirteen were not found in the USGBC database. Therefore, 19 of the European countries and Türkiye (20 in total) were used as resources for this study.

According to the Paris Agreement, countries must reduce greenhouse gas emissions and increase environmental quality. Therefore, in this study, IEQ credit was selected as a parameter to search for achieved points for LEED BD+C v4 projects and to understand how much attention is given to achieving the Paris Agreement's goals.

The total project numbers that have earned the LEED BD+C v4 certification and the total amount of achieved points were investigated and listed. According to this analysis, the highest number of projects number to Türkiye, followed by Germany, Italy, Spain, Sweden, Finland, Ireland, Austria, Switzerland, France, Greece, Portugal, Serbia, Denmark, Lithuania, Poland, and the Netherlands, respectively.

To determine the relationship between the number of projects and the achieved total points, Spearman's correlation analysis was applied to the data set. The purpose of using Spearman's correlation analysis for this data set was to identify the null hypothesis, which formulated that "there is a significant correlation between the number of LEED BD+C NC v4 projects and IEQ points of these projects". According to the analysis's results, there was no significant correlation between the number of projects and the achieved total points

In addition, the achieved total points may vary even with the same certified project numbers. Accordingly, the sub-credits of IEQ must be considered because applying the sub credits (which have the highest points achievable) may result in more points when comparing countries with the same number of projects. There could be different factors that directly affect this situation, such as the constant GDPs of countries, the different incentive categories, the geographical location of the countries (which may affect international investors), the climatic conditions of each country, the various countries' green building policies, and whether countries have a national green building certification system (see Table 10).

The constant GDP value, one of the criteria that may affect the achieved IEQ points, was examined, as it impacts IEQ points earned. Due to the cost of each sub-credit, countries and investors may eliminate applying for more credits and obtain more points from IEQ credit. Thus, it was considered that countries with higher constant GDP values than other countries may have the advantage of applying and achieving IEQ credit. The constant GDP values were investigated by considering the years between 2015 and 2021 to explain this scenario. The starting year of 2015 was selected, as it was the signature date for the Paris Agreement. In addition, 2021 was selected as the final year because the financial year 2022 was not completed. According to the research results, Germany had the highest constant mean GDP values between those years. It was followed by France, Italy, Spain, Russia, Netherlands, Switzerland, Sweden, Poland, Austria, Ireland, Turkey, Denmark, Finland, Portugal, Greece, Romania, Hungary, Lithuania, and Serbia. When the LEED BD+C v4-certified project numbers and the achieved IEQ points were checked, Türkiye was in the first row. However, Türkiye ranked 12th in Europe's constant-GDP-value ranking. In addition, France was listed as 11th for achieved IEQ points, but it was on the second line for GDP. According to the data set, it is clear that there is no correlation between achieved IEQ points and constant GDP values. This relationship was also analyzed by applying Spearman's correlation analysis. According to the analysis's results, the sig. (2-tailed) value was found to be 0.123, which is greater than 0.05, meaning there is no correlation between achieved IEQ points and constant GDP values.

According to the analysis's results, the reasons for not correlating the achieved IEQ points and the constant GDP values must be considered. The reasons for this situation can be considered by examining Table 10.

When looking at national green building certification programs, we can see that most countries have their own systems, such as LEED in the USA, the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom, Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB)) in Germany, and the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan. National green building certification systems have been developed on the basis of countries' cultural values, climatic conditions, and geographical locations. Therefore, most countries apply their own certification programs. In addition to this, such an approach costs less than applying LEED.

Governmental policies and incentives may force inventors to apply sustainability criteria to construction projects, ensuring that the requirements of green building certifications are met.

Global climate change issues have forced countries to sign subject-related conventions. As part of such conventions, governments have had to take precautions to prevent increases in the causes of global warming.

Additionally, Figure 5 demonstrates that the density of certified LEED projects' density is mainly concentrated in areas of cities that have the most significant economic potential. In Türkiye, most LEED-certified projects are located around commercial areas. These areas have more potential for international investors who desire to invest in building and who have global green building certification under their home policies.

According to this study, Türkiye has the highest number of LEED BD+C v4-certified projects among the studied countries. However, Türkiye is listed as 12th when the mean constant GDP value is searched. When the reason behind this situation is examined, it is noted that although the country does not have economic power, its geopolitical position, the density of its trade centers, and its high potential for realizing investments encourage foreign investors. It has been observed that foreign investors' requests for LEED certification in Türkiye are at the forefront on a global scale. This has impacted the increased number of LEED-certified projects in the country.

Research Limitations and Future Research Lines

This study's main goal was to show the linear correlation between GDP values and IEQ points. The results show that GDP values have no effect on IEQ applications. Although Türkiye has been listed as the first country to apply for LEED projects' IEQ credits, its economic development level is lower than those of European countries. In this study, only GDP values have been considered as countries' economic development level parameters. In future studies, the authors will explore the factors affecting the economic development level and the correlations with LEED-certified projects.

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