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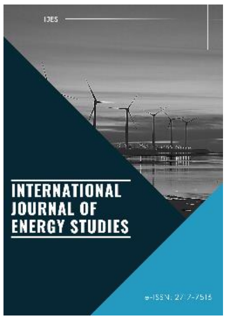

Research Article

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Evaluation of facade features in green building certified office buildings in terms of energy efficiency

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Highlights

- Office buildings are among the buildings where energy conservation should be ensured.
- Practices that emphasize the use of renewable energy sources are carried out on sustainable office facades.
- Active and passive energy systems are used in energy efficient office buildings.

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ABSTRACT

The energy crisis in the world and reaching the point of depletion of resources have pushed the construction industry to seek the use of renewable energy resources. The sustainability approach that comes to the fore with this has gained an important place in the construction sector as well as in all other sectors. The construction of office buildings, which have a high energy consumption rate among the building groups, within the framework of sustainability principles is a result of this search. From this point of view, the aim of this study is to evaluate the facade features of sustainable office buildings with green building certificate within the scope of energy efficiency and to reveal the current practices. Within the scope of the study, 20 office buildings located in the world and in the literature were analyzed in detail in terms of their facade features. These analyzes are grouped under the titles of building envelope, facade material, integration of active and passive systems. In the light of the data obtained, it has been revealed that sustainable office buildings have facade applications for the use of renewable energy sources.

Keywords: Building office, Certification systems, Sustainability, Energy efficiency

1. INTRODUCTION

The world has faced a serious climate crisis and environmental problems due to factors such as human beings' uncontrolled use of nature and natural resources, changing living conditions, increasing demands and needs, and the development of industry and technology. The environmental problems experienced as a result of the unconscious use of non-renewable energy sources are increasing day by day. In order to combat these problems, it is necessary to reduce fossil-based energy consumption and to use renewable energy sources effectively. In line with these requirements, the development of ecological methods and the dissemination of the sustainability movement have gained importance. While the sustainability approach aims to protect natural resources and energy, it also prioritizes human health and comfort.

Due to the uncontrolled growth of the building sector and the increase in the rate of building production, a significant portion of energy consumption is seen in this sector worldwide. Therefore, one of the areas where energy conservation should be taken into consideration is the building sector. Sustainable architecture, which is discussed throughout the life cycle of the building starting from the selection of the land, includes the adaptation of the building to the environment, climate and topography, prevention of waste generation, use of renewable energy sources, integration of passive systems that will reduce energy consumption, etc. shaped by the applications. Although the initial construction cost of sustainable architectural systems is considered to be high, it provides economic savings as it will reduce energy costs in the building use process [1]. Therefore, sustainable architectural practices bring both ecological and economic benefits in the long run.

With the increase in sustainable architectural practices, green building evaluation programs have emerged in order to realize and control these practices within the scope of certain standards. Certification systems allow investors to choose and offer insight into how to meet a certain sustainability criterion. Although there are many certification systems around the world, many of the developed countries have developed certification systems in line with their own building standards [2,3,4]. The first of these certification systems is the BREEAM certificate created by the Building Research Institute (BRE) in 1990. It can be taken during the design, construction or use phase of the project. Certification levels are considered as pass, good, very good, excellent and outstanding [5,6]. In addition, since it is the first developed certificate system in the world, it formed the basis of other certificate systems.

LEED (Leadership in Energy and Environmental Design), developed by the American Green Building Council (USGBC), established in 1993, is the first certification system developed after the BREEAM certificate. LEED, which emerged in 1998 and plays an important role in the worldwide spread of green building certification systems, aims to reduce the negative environmental effects of buildings and to ensure energy efficiency [7]. LEED certification evaluates under the headings of new buildings, new interiors, existing buildings and spaces, neighborhood development, cities and communities, residential, recertification and retail. The sustainability criteria determined for the LEED certification system correspond to a certain score. The total scores obtained from these criteria determine the level of certification that buildings will receive. In case of getting a full score, a maximum of 110 points can be obtained, while 80-110 points are considered Platinum, 60-79 points are Gold, 50-59 points are Silver, and 40-49 points are Certified [8].

Although BREEAM and LEED certificates are the most widely used green building assessment systems around the world, there are also certificate systems developed by many countries. Examples of these systems are GREEN STAR in Australia, SBTool in Canada, CASBEE in Japan, HK-BEAM in Hong Kong, DGNB in Germany, LIVING BUILDING CHALLENGE in the USA. These certification systems have been accepted by many countries that are members of the World Green Building Council (WGBC) and are used in accordance with the national standards of each country [3,9,10].

In addition to the high energy costs in the construction sector, this rate is higher in some building groups than in others. When is considered in terms of the equipment used, heating-cooling, ventilation costs and user density, it is seen that the amount of energy consumed in office buildings cannot be ignored. Therefore, it is extremely important for office buildings to have sustainable features both in terms of energy efficiency and comfort and health of users. Achieving these qualities is possible by shaping within the framework of the sustainability approach the building envelope, which provides the circulation of physical variables such as heat, humidity and sound between the indoor and outdoor spaces and where energy costs are the highest. From this point of view, the aim of this study is to evaluate the facade features of sustainable office buildings with green building certificate in the perspective of energy efficiency. In this direction, it is aimed to carry out investigations specific to the samples determined.

2. MATERIAL AND METHOD

In the study, literature review and analysis method was used. After reviewing the literature on the subject, the theoretical framework of the study was drawn. In order to limit the sample of the study, office buildings built abroad in 2000 and later were included in the study. Since the basic criteria for sustainability of certificate types are common, there is no restriction on certificate type and countries. In line with these limitations for the sample, 20 office buildings with green building certificates and sufficient information on energy efficient design practices were identified. Since the analysis of the whole building requires a very comprehensive study, the analysis study was only considered within the scope of the facade features. In terms of determining the sub-parameters for the analysis, these structures are analyzed in perspective of building envelope, facade material, integration of active and passive systems. In Table 1, the imprint information of the examined buildings is given.

Table 1. Information on the examined office buildings

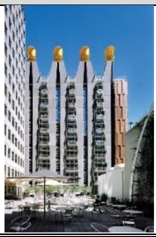
No	Building Name	Location	Year of construction	Architect	Certificate
1	Genzyme Center [11]	ABD	2004	Behnisch Architekten	Leed/Platinum
2	Counsil House 2 [12]	Avustralya	2006	DesignInc	Green Star
3	Manitoba Hydro Place [13]	Kanada	2008	KPMB Architects	Leed/Platinum
4	Bank of America Tower [14]	ABD	2010	Cook + Fox Architects	Leed/Platinum
5	Pixel [15]	Avustralya	2010	Studio 505	Leed/Platinum Green Star
6	Angel Square [16]	İngiltere	2012	3D Reid	Breeam/Outstanding
7	Bullitt Center [17]	ABD	2013	Miller Hull Partnership	Living Building Challenge
8	Turkish Contractors Association Headquarters [18]	Turkish	2013	Avcı Architects	Leed/Platinum
9	Shanghai Tower [19]	China	2015	Gensler	Leed/Platinum
10	The Edge [20]	Hollanda	2015	PLP Architecture	Breeam/Outstanding
11	Bursagaz Administration Building [21]	Turkish	2016	Tago Architects	Leed/Platinum
12	Prokon-Ekon Administration Building [22]	Turkish	2016	Prokon-Ekon	Leed/Platinum
13	Bloomberg [23]	İngiltere	2017	Foster + Partners	Breeam/Outstanding
14	Budynek Biurowy Komandorska [24]	Poland	2017	Grupa 5 Architects	Leed/Gold
15	Hoho Wien [25]	Avusturya	2019	RLP Rüdiger Lainer + Partner	Leed/Gold
16	M-NCPPC Wheaton Headquarters [26]	ABD	2020	Gensler Architects	Leed/Platinum
17	The City of Hope Administration Office Building [27]	ABD	2020	Daniel Traub, Principal	Leed/Gold

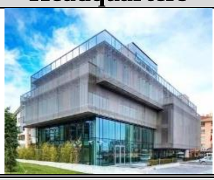
18	The Soto [28]	ABD	2020	BOKA Powell, Lake|Flato Architects	Leed/Certified
19	SporX [29]	Norway	2021	Dark Architects	Breeam/Outstanding
20	The Helix [30]	ABD	2022	NBBJ Architects	Leed/Platinum

3. FINDINGS

In the study where sustainable building practices are examined in the perspective of facade features, office buildings with green building certificates and their facade features for the efficient use of energy are given in Table 2.

Table 2. Facade features of examined office buildings

No	Genzyme Center	Building Shell	Facade Material	Integration of Active and Passive Systems
1		• Double facade application	• Glass	• Mechanically controllable blinds between double facades • Roof mounted heliostats • Use of photovoltaic panels on the roof
2	**Counsil House 2**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Thermal mass	• Wood • ETFE • Glass	• 10 wind turbines on the north facade • Rain tower • Wooden shutters that move according to the position of the sun • Use of photovoltaic panels
3	**Manitoba Hydro Place**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Double facade application	• Low iron content glass	• Solar chimney • Automatic sunshades
4	**Bank of Amerika Tower**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Glass curtain-wall	• Low iron content glass • Steel	• Daylight control with paint chips placed between double glazing with steam
5	**Pixel**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**

		• Reversible panel curtain-wall	• Double glass • Low carbon concrete	• Fixed shading louvers • Wind turbines • Use of photovoltaic panels
6	**Angel Square**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Double facade application • Thermal mass	• Thermal mass concrete • Glass • Steel	• Thermal chimney • Atrium
7	**Bullitt Center**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Wooden structure • Panel curtain-wall	• Glass • Composite panel	• Use of photovoltaic panels on the roof • Integrated window system with temperature, air and daylight control
8	**Contractors Assoc. Headquarters**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Double facade application	• Glass • Stainless steel mesh	• Use of photovoltaic panels and solar collectors on the roof • Mesh facade and sunshades • Atrium
9	**Shanghai Tower**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Double facade application	• Glass • Steel	• 270 wind turbines integrated into the facade
10	**The Edge**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Glass curtain-wall	• Glass	• Atrium
11	**Bursagaz Admin. Building**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Curtain-wall	• Self cleaning glass • Steel	• Use of photovoltaic panels on facade and roof • Wind turbines

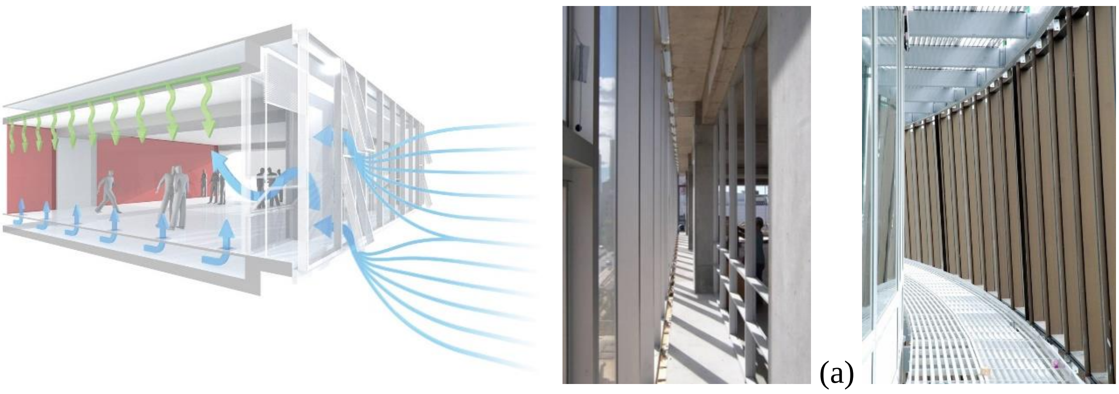
12	**Prokon-Ekon Admin. Building**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Glass and panel curtain-wall	• Concrete • Steel • Acoustic and heat insulating glass	• Use of sunshades on the south-west facade • Use of sun wall on the south-west facade • Use of photovoltaic panels on the roof
13	**Bloomberg**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Glass curtain-wall	• Glass • Steel	• Sunshades that change in angle and intensity according to the facade
14	**Budynek Biurowy Komandorska**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Glass curtain-wall	• Aluminum • Glass	• Aluminum sunshades
15	**Hoho Wien**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Wooden prefab	• Wood	-
16	**M-NCPPC Wheaton Headquarters**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Rain curtain	• Glass • Metal composite panel	• Use of photovoltaic panels on the roof • Sunshades
17	**The City of Hope Office**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Glass and steel curtain-wall	• Concrete • Glass • Steel	• Use of photovoltaic panels on the roof • Steel sunshades
18	**The Soto**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Wooden prefab • Glass curtain-wall	• Glass • Brick	-
19	**SporX**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**

		• Wooden structure	• Wood • Glass • Composite panel	-
20	**The Helix**	**Building Shell**	**Facade Material**	**Integration of Active and Passive Systems**
		• Glass curtain-wall	• Glass	-

The office buildings analysed within the scope of the study were built between 2004 and 2022 and are mostly located in the USA (7 units), Turkey, Australia, Canada, the Netherlands, the UK, Austria, China, Poland and Norway. The buildings, which are determined to be high-rise, show diversity in terms of building form.

Building Shell properties

It has been determined that glass or panel curtain walls are used intensively in terms of building envelope properties in the examined office buildings. Examples where the panels used on the facade are thermal or recyclable are seen in Council House 2, Pixel, Angel Square buildings. In addition, it has been observed that the double shell facade application, which allows passive heating-cooling and ventilation, is widely used in buildings such as Genzyme Centre, Manitoba Hydro Place, Angel Square, Turkey Contractors Association Headquarters, Shanghai Tower. (Figure 1). Double skin facade applications act as a buffer zone between the exterior and interior in order to prevent unwanted heat losses and gains in buildings, to provide natural ventilation and to prevent noise pollution from the outside environment.



(a) (b)

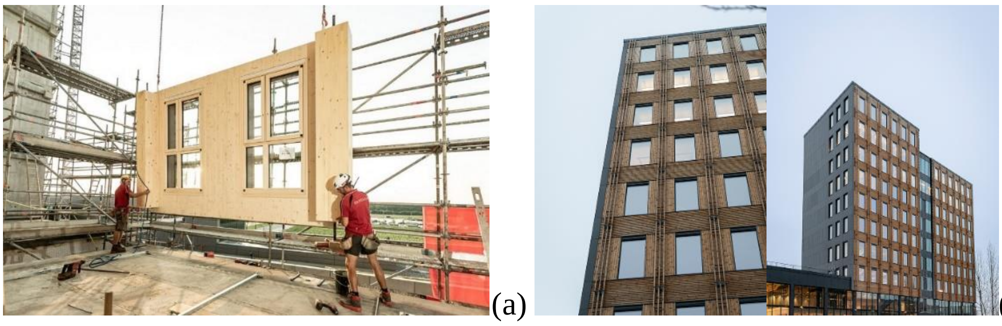
Figure 1. Double skin facade applications, (a)Manitoba Hydro Place [13]; (b) Angel Sguare [16]

In order to increase the effectiveness of natural lighting in sustainable construction practices, it is seen that transparent materials are used in the design of the building envelope. However, it was determined that wood, which is a sustainable material, was used as a structural material in the building envelope in Bullitt Centre and Spor X buildings. It is seen that the rain screen system, which is applied to prevent the penetration of external weather conditions into the interior space through building facades, is applied in the M-NCPPC Wheaton Headquarters building. In the rain curtain system, the rain that touches the facade is provided to slide down the facade panels without penetrating the building through the slits and cracks here. Thus, measures are taken to protect the indoor climate.

Facade Material

In almost all of the examined office buildings, it was observed that glass material was preferred in order to increase the efficiency of natural lighting and to provide visual communication with the outdoors. The use of glass not only creates a transparent image in buildings, but also allows daylight to penetrate interiors more effectively. At the same time, glass materials with certain properties in terms of energy efficiency are also preferred. For example, in the Prokon-Ekon Administration Building, glass with very low reflection, high light transmission, acoustic and thermal insulation properties was used. The double glazing used in the Pixel building provides energy efficiency in terms of heat and sound insulation. The use of self-cleaning glass in the Bursagaz Administration Building saves energy consumed for cleaning costs.

As another material, wood is frequently used both as a structure and cladding material as in the facades of Hoho Wien and Spor X buildings. Since it is an environmentally friendly, recyclable and ecological material, wood is a frequently preferred material in today's modern buildings (Figure 2).



(a) (b)

Figure 2. Wooden facade, (a) Hoho Wien [25]; (b) SporX [29]

In addition to wood, composite facade cladding panels, which have been widely used in recent years, have been used on the facades of Bullitt Centre, M-NCPPC Wheaten Headquarters and Spor X buildings. In some office buildings such as Pixel, Angel Square, which were examined within the scope of the study, the use of concrete materials with sustainable features was found. We see that a traditional material with low carbon content and thermal properties is applied in an ecologically improved way. Apart from these materials, building materials such as brick and steel are also encountered in office facades.

Integration of Active and Passive Systems

As in all buildings built with a sustainable feature, there are applications in which active and passive energy systems are integrated into the structure in office buildings. The most widely used among these applications is the use of photovoltaic panels, which is an active system. Examples where this system, which provides electricity generation with the energy from the sun, is applied on the roof and/or facade such as Genzyme Centre, Council Kouse 2, Pixel, Bullitt Centre, Turkish Contractors Association Headquarters, Bursagaz Administration Building, Prokon-Ekon Administration Building, M-NCPPC Wheaten Headquarters, The City of Hope Office buildings were identified (Figure 3). Another active system applied in the analysed buildings is the automatically controlled blinds and sun shades in the Manitoba Hydro Place building. Apart from this, shading blinds, which are used as fixed in some buildings, are also preferred.

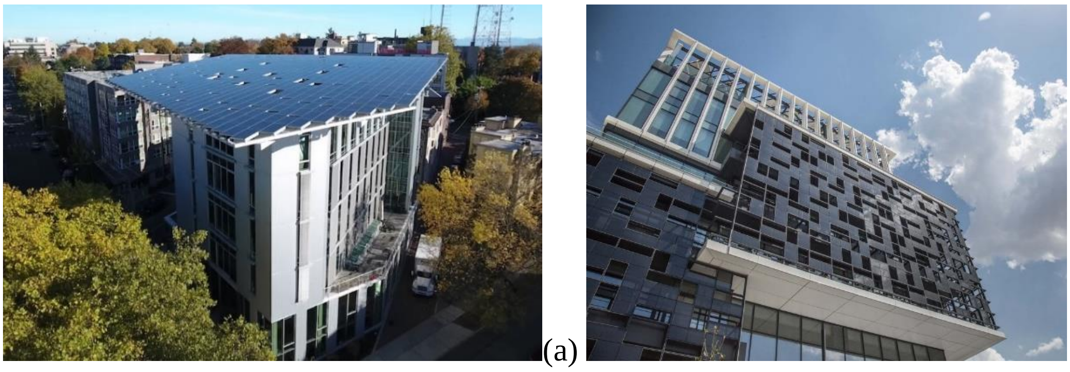

(a) (b)

Figure 3. Use of photovoltaic panels on the roof and facade, (a) Bullitt Center [17]; (b) Bursagaz Administration Building [21]

Heliostats, which are placed on the roof or south facade of buildings and consist of mirrors and lenses that automatically follow the sun, are passive energy systems that collect daylight and distribute it indoors. In Genzyme Centre, which was examined within the scope of the study, it was determined that heliostat application was made to increase daylight efficiency (Figure 4). With this application, more than 75% of employees can work without the need for artificial lighting and electricity costs are saved by 42%.

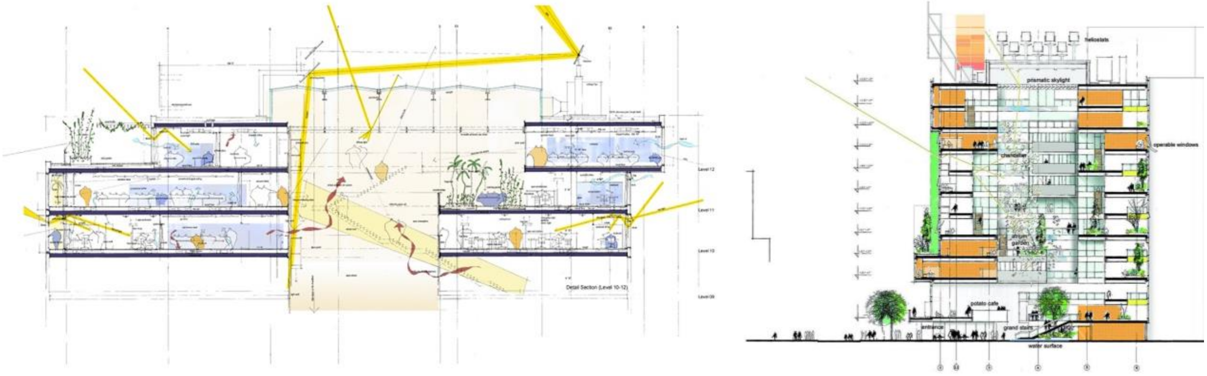


Figure 4. Roof mounted heliostats and section, Genzyme Center [11]

In high-rise buildings, wind turbine applications that provide natural ventilation by taking advantage of the positive and negative pressure of the wind by drawing in fresh air and expelling dirty air are seen in Council House 2, Pixel, Shanghai Tower, Bursagaz Administration buildings. (Figure 5) . In Shanghai Tower, the carbon footprint of the building has been reduced by 34% through increasing daylight efficiency with a transparent facade, landscaping applications covering one third of the building, water saving applications and highly efficient mechanical systems.

Figure 5. Section, plans and wind turbines, Shangai Tower [19]

Similarly, it was determined that the rain tower system, which significantly reduces the indoor air temperature, was also applied in the Council House 2 building (Figure 6). According to this system, the air coming down from the rain tower is cooled by evaporation at the points where the water flows. The west facade of Council House 2, which aims to minimise energy costs, is inspired by the epidermis structure of the tree. The wind pipes used on the north and south facades refer to the bronchi of the tree. The purpose of placing the ventilation shafts on the north facade is that it is the facade most exposed to the sun due to Australia's location. In this way, the warm air coming into the northern vents exits more easily and quickly and is replaced by cold air coming from the southern vents [31]. Thanks to the active and passive systems implemented in the Council House 2 building, 85% savings were achieved in electricity consumption.

Figure 6. Use of rain tower, Council House 2 [12]

In addition to these systems, passive systems have been developed for the natural ventilation of buildings with structural elements such as solar chimney, thermal chimney, and atrium in the examined structures. In the chimney ventilation, air circulation is provided by taking the cold air into the building from the lower openings and raising the heated air and expelling it from the upper openings.

The common features of the buildings examined within the scope of the study under the headings of building envelope, facade material, active and passive system integration were determined and tabulated (Table 3). The frequency of application of the features described above under these headings is given in the table.

When the building envelope features are examined, it has been determined that in sustainable office buildings, double facade application generally contributes to the natural ventilation system of the building. In addition, it has been observed that materials such as glass, composite panels and curtain wall systems are frequently preferred. It has been observed that the use of both traditional and modern materials in sustainable office facades comes to the fore. In addition to building materials such as wood, brick, concrete, composite panel, it has been determined that the use of sustainable materials such as thermally enhanced concrete, low carbon concrete, low iron content glass has gained importance. It is seen that the most used material in office facades is glass, especially in terms of increasing daylight efficiency. It has been determined that natural ventilation and daylight control are provided to a large extent by the integration of active and passive energy systems into sustainable building facades. In addition, generating electricity from solar energy through photovoltaic panels is a frequently used system. It is important that these systems become functional in buildings in order to increase the indoor comfort and air quality of office buildings where users spend most of the day.

Table 3. General facade characteristics of the examined buildings

No	Building Shell					Facade Material							Active / Passive Systems	
	Double facade	Thermal mass	Curtain wall	Wooden structure	Rain curtain	Glass	Wood	Steel	Concrete	PVC based panel	Alüminyum	Brick	Active system	Passive system
1	■					■							■	■
2		■				■	■			■			■	■
3	■					■							■	■
4			■			■		■						■
5			■			■			■				■	■
6	■	■				■		■	■					■
7			■	■		■				■			■	■
8	■					■		■					■	■
9	■					■		■					■	
10			■			■								■
11			■			■		■					■	
12			■			■		■	■				■	■
13			■			■		■						■
14			■			■					■			■
15				■			■							
16					■	■				■			■	■
17			■			■		■	■				■	■
18			■	■		■						■		
19				■		■	■			■				
20			■			■								

In the facade applications of the buildings subject to the study, it is seen that strategies have been developed to save energy in heating, cooling, ventilation and lighting. These strategies are summarised in Table 4 as active and passive energy applications. When the green building certificate score points of the buildings were analysed, it was found that they scored above the average under the title of "energy". Accordingly, among the buildings whose scorecards can be accessed; Council House 2 achieved an energy score of over 60%, Bank of America Tower approximately 70%, Pixel 100%, Turkiye Contractors Association Headquarters approximately 54%, Bursagaz Administration Building 80%, Prokon-Ekon Administration Building approximately 88%, Hoho Wien approximately 57%, M-NCPPC Wheaton Headquarters approximately 52%. These scores show that active and passive system applications in buildings are closely related to energy gain and conservation.

Table 4. Active and passive energy protection systems

	Strategies for Heating/Cooling	**Strategies for Ventilation**	**Strategies for Lighting**
Active Systems	• Mechanically controllable blinds • Rain tower • Automatic sunshades • Solar collectors • Photovoltaic panels	• Wind turbines	• Photovoltaic panels • Roof mounted heliostats
Passive Systems	• Fixed sunshades • Sun wall on the south-west facade • Double facade • Use of thermal glass	• Solar chimney • Thermal chimney • Atrium • Double facade	• Glass facade • Use of low iron content glass • Atrium

4. CONCLUSION

In recent years, the increase in energy needs and the depletion of fossil resources have made it necessary to implement practices for the effective use of renewable energy resources and energy. At this point, the sustainable architecture approach has gained importance. Green building certification systems, developed to guide sustainable construction practices and inspect the works done, reveal the necessary sustainability criteria for almost every building group. It is important that office buildings, which have a significant share in energy costs among the building groups, gain a sustainable quality through passive system elements that will save energy. With this study, it is aimed to examine the facade features of office buildings that have received green building certificate and to reveal practices that will set an example for new office buildings in the context of sustainability. Office buildings examined in this direction are discussed in terms of building envelope, facade material, integration of active and passive energy systems.

As a result of the determinations made, it was revealed that solutions were developed to increase energy efficiency by providing the use of renewable energy sources in sustainable office facades. These solutions are exemplary not only for office buildings but also for all building groups. Therefore, both new buildings should be constructed with energy efficient solutions and existing buildings should be improved in this direction in order to prevent the energy crisis, which is becoming more noticeable day by day, and to ensure the conservation of sufficient resources for future generations.

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DECLARATION OF ETHICAL STANDARDS

The author of the paper submitted declares that nothing which is necessary for achieving the paper requires ethical committee and legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Zeynep Yanılmaz: Conducting research and analyses. Writing the text.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

REFERENCES

[1] Feige A, Wallbaum H, Jancer M, Windlinger L. Impact of sustainable Office buildings on occupant's comfort and productivity. Journal of Corporate Real Estate 2013; 15 (1): 7-34.

[2] Lavasani H. Impact of green building certifications on the economıc performance of real estate office assets: net operating income, and market value. PhD Thesis, University of Maryland, 2018.

[3] Tuna R. Bina sertifika sistemleri. Ege Mimarlık 2013; 20-23.

[4] Kibert C. Sustainable construction: green building design and delivery. Hoboken, John Wiley & Sons, New Jersey, 2013.

[5] Cole JR, Valdebenito MJ. The importation of building environmental certification systems: international usages of BREEAM and LEED. Building Research & Information 2013; 41(6): 662-676.

[6] Gültekin AB, Bulut B. Yeşil bina sertifika sistemleri: Turkish için bir sistem önerisi. 2nd International Sustainable Buildings Symposium Ankara, Turkish, 2015.

[7] Kubba S. Handbook of green building design and construction: LEEDS, breeam, and green globes Butterworth-Heinemann, Virginia, USA, 2012.

[8] USGBC. LEED V4 User Guide, USA, 2014.

[9] Sev A, Canbay N. Dünya Genelinde Uygulanan Yeşil Bina Değerlendirme ve Sertifika Sistemleri. Yapı Dergisi Yapıda Ekoloji Eki 2009; 329: 42-47.

[10]Yanılmaz Z. Sürdürülebilir Temel Eğitim Yapılarında İç Mekân Konfor Koşullarının Değerlendirilmesi. Master Thesis, Karadeniz Techical University, 2020.

[11] https://archello.com/project/genzyme-center, [Accessed 06.09.2022]

[12]https://www.archdaily.com/395131/ch2-melbourne-city-council-house-2-designinc, [Accessed 06.09.2022[

[13] https://www.hydro.mb.ca/corporate/history/mh_place_design_and_construction/, [Accessed 06.09.2022]

[14]https://www.archdaily.com/247880/bank-of-america-tower-at-one-bryant-park-cook-fox-architects, [Accessed 01.10.2022]

[15] http://mimdap.org/2011/12/pixel-studio505/, [Accessed 06.09.2022]

[16] https://www.arch2o.com/sustainable-office-buildings-worldwide/, [Accessed 06.09.2022]

[17] https://www.arch2o.com/sustainable-office-buildings-worldwide/#!, [Accessed 07.09.2022]

[18] https://www.arkiv.com.tr/proje/turkiye-muteahhitler-birligi-merkez-binasi/2851, [Accessed 12.09.2022]

[19] https://www.archdaily.com/783216/shanghai-tower-gensler, [Accessed 11.09.2022]

[20] https://www.archdaily.com/785967/the-edge-plp-architecture, [Accessed 11.09.2022]

[21] http://www.arkiv.com.tr/proje/bursagaz-yonetim-binasi/11715, [Accessed 12.09.2022]

[22]https://www.yesilbinadergisi.com/yayin/730/prokon-ekon-sirketler-grubu-yonetim-binasi_22247.html#.Yz1--3ZBxPY, [Accessed 02.09.2022]

[23]https://www.archdaily.com/882263/bloombergs-european-hq-foster-plus-partners, [Accessed 05.09.2022]

[24] https://www.usgbc.org/projects/budynek-biurowy-komandorska, [Accessed04.09.2022

[25] https://www.hoho-wien.at/, [Accessed 05.09.2022]

[26]https://montgomeryplanning.org/m-ncppc-wheaton-headquarters-becomes-first-government-owned-office-building-to-achieve-leed-platinum-status-in-maryland/, [Accessed 07.09.2022]

[27] https://www.architectmagazine.com/project-gallery/the-city-of-hope-administration-office-building, [Accessed 05.09.2022]

[28]https://www.archdaily.com/963688/the-soto-office-building-boka-powell, [Accessed06.09.2022

[29] https://dofengineers.com/portfolio/sporx/, [Accessed 08.09.2022]

[30]https://www.dezeen.com/2021/02/03/amazon-hq2-headquarters-nbbj-glass-tower-usa/, [Accessed 08.09.2022]

[31] Radwan GAN, Osama N. Biomimicry, an approach, for energy effecient building skin design. Procedia Environmental Sciences 2016; 34: 178-189.