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# Energy Efficiency in Green Building Certified Office Buildings: A Comparative Analysis

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**ABSTRACT**
Leed certificate, one of the assessment systems that comprise the necessary criteria for sustainable buildings, is an essential indicator for energy efficiency in buildings. Office buildings, where human activity is intense due to the high number of users and working function, play a critical role in energy consumption through heating, cooling, lighting, and hot water needs. This study examines the energy efficiency of office buildings with a Leed Certificate. The "Energy-efficient building design strategies" were classified under three central tenets: passive, active systems, and renewable energy sources. Besides, the office buildings with a Leed Certificate from various climatic regions and Turkey were examined through these criteria. The results show that passive systems were more preferred than active systems in these buildings, and the "building envelope" was the most significant parameter. Double-skin facade systems and solar control elements in passive heating and cooling while atrium and skylights were used as passive systems. Moreover, advanced lighting control and energy-efficient lighting were the most frequently used strategies for active systems. Besides, photovoltaic panels, observed in most examples, show that the most commonly used renewable energy source is solar energy.
**Keywords:** Office buildings, Green Building Certification Systems, Active Systems, Passive Systems, Renewable Energy Sources

## 1. INTRODUCTION

Built environments use a significant portion of energy use and cause substantial greenhouse gas emissions. The amount of greenhouse gas emissions is higher due to the increase in the global urban population (Lampropoulos, 2020). It is necessary to optimize the energy efficiency of buildings, minimize their energy need, and maximize renewable energy sources to design sustainable built environments. Moreover, developments such as minimizing primary water consumption and the volume of waste generated, optimizing the need for the vehicles used for transportation, reducing the immediate energy consumption of these vehicles, and maximizing the renewable energy resource usage in transportation should also be considered (Butera *et.al*, 2014).

The rapidly increasing global energy usage and resource depletion have raised global warming and climate change concerns. Residential and office buildings are now using between 20% and 40% of the consumable energy. It is predicted that the increase in energy demand will continue with the population growth and the increased accommodation requirements. Therefore, energy efficiency in buildings has become the focal point of energy policies at the regional, national, and international levels (Pérez-Lombard *et.al*, 2008).

One of the steps towards this goal is green building assessment systems. The Leed certificate, which a building must have to be considered sustainable, aims to keep the energy efficiency at the maximum level by minimizing the harmful impact of the buildings cause during their life cycle. The most common typologies, which account for more than 50% of non-residential energy consumption, comprise offices and commercial buildings. Besides, heating, cooling, lighting, and hot water usage are the primary factors behind energy consumption. Strategies developed in line with the needs of buildings are grouped under 3 main headings in this article: the passive, active systems, and renewable energy sources. Five examples, with the Leed certificate, from the world and Turkey were selected. These examples were assessed to better understand the energy efficiency strategies.

## 2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Energy consumption in buildings is categorized into the industry, transportation, and service sectors comprising offices, hospitals, and residences. The service sector includes several types of buildings with various use and energy services (HVAC, hot water usage). Economic and population growth simultaneously increase the demand for health, education, culture, entertainment services, and hence energy consumption (IEA, 2020).

The increase in energy consumption and $CO_2$ emissions in the built environments has crystallized the need to improve energy efficiency and saving strategies in most countries. The widespread demand for thermal comfort increased the energy consumption through HVAC systems. The need for heating, ventilation, and cooling causes energy usage in residential and non-residential sectors in the most extensive manner. HVAC use for residential buildings accounts for more than half of energy consumption, while this rate is around 48% for non-residential buildings. Overall, HVAC consumption in developed countries accounts for half of the energy use in buildings and 20% of national energy usage (Pérez-Lombard, 2004).

Offices and commercial buildings are the most common typologies, accounting for more than 50% of total non-residential energy consumption. Hotels, restaurants, hospitals, and schools complete the top-spenders list. HVAC constitutes the primary usage up to 50%, followed by lighting as 15% and the equipment by 10%. Furthermore, hot water, lighting, and kitchen utensils are among the other factors behind energy consumption (EIA, 2015).

The increase in energy consumption and $CO_2$ emissions in the built environments has become a priority for energy policies that design energy efficiency strategies, new building regulations, and certification programs for the certification requirements. Energy consumption in buildings is likely to increase even further in the short term due to resource depletion, the expansion of the built areas, and hence the continuation of energy demand. A future with sustainable energy seems likely with the proliferation of energy efficiency, new technologies for energy production, limiting energy consumption, and increasing social awareness about the proper energy usage (Pérez-Lombard *et.al,* 2008).

### 2.1. Energy-efficient Building Concept and Design Strategies

The energy-efficient building design is defined as an effort to use energy effectively through variable physical environment data such as prevailing wind direction and climate. It requires the implementation of active and passive system facilities suitable for the building to increase the performance of the building in heating-cooling-ventilation-lighting and to conserve energy (Özmehmet, 2007).

Heating, cooling, and lighting needs that cause energy consumption are based on specific criteria to ensure effective energy usage. These are the criteria examined in this study under passive, active systems and the use of renewable energy sources.

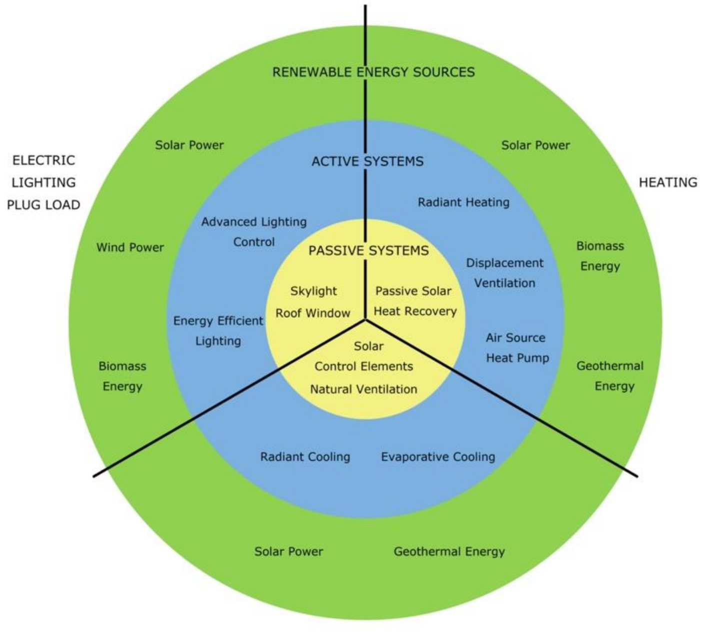



Figure 2.1. Classification of energy-efficient design strategies (Garde *et.al*, 2017).

Figure 2.1 illustrates that passive solar heat accumulation, double skin facade systems for the heating needs in buildings under the passive systems category. The radiant heating and air source heat pumps are classified as active heating systems. Solar, geothermal energy, and biomass-based systems are considered renewable energy sources. Shading systems and natural ventilation are the passive systems for the cooling requirements of buildings. Evaporative cooling and underfloor cooling are the active systems, while solar energy and geothermal energy are renewable energy sources. The atriums and solar chimneys are passive systems for the lighting needs in buildings. Advanced lighting control and energy-efficient lighting are active systems, while wind turbines and photovoltaic panels working with solar energy are considered renewable energy sources.

2.1.1. Passive Systems

Buildings with passive systems are also regarded as bioclimatic buildings. Ordinary buildings cannot effectively use the natural environment and energy resources, causing energy consumption and waste material generation. Thus, they are buildings with high costs and causing environmental pollution to emerge. Bioclimatic buildings are designed with completely natural cycles, do not harm the environment as they are designed to be integrated with water, air, soil, and energy (Butera *et.al*, 2014).

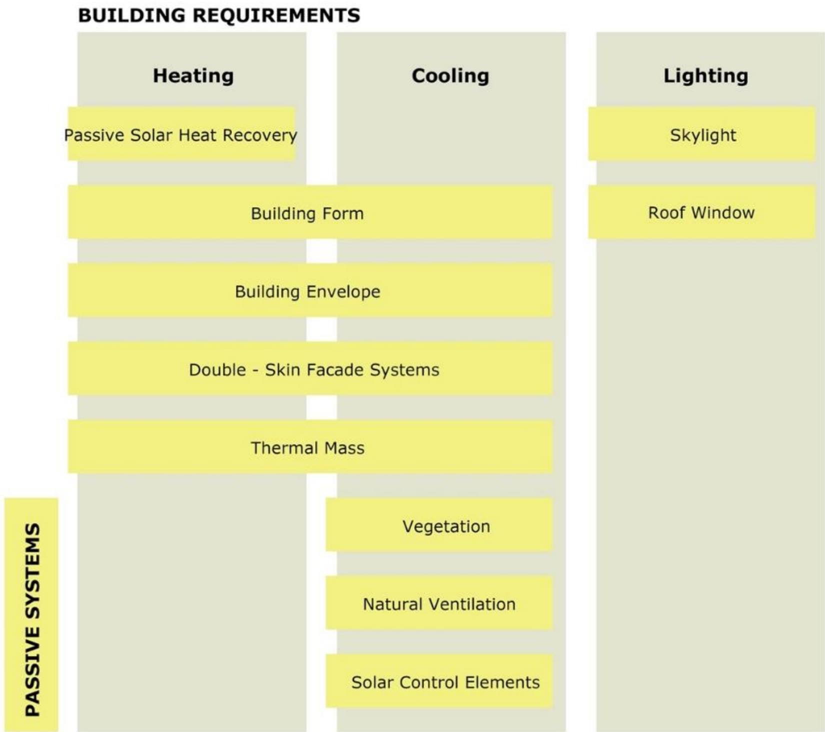



Figure 2.2. Passive systems used for building requirements (Garde *et.al*, 2017).

Figure 2.2 shows that passive solar energy systems are used for providing heating requirements energy-efficient in buildings. Building form and envelope properties play an essential role in heating and cooling, while thermal mass and advanced glass facade systems are also considered. Passive systems for cooling include vegetation, natural ventilation, and solar control elements, as the skylight and roof window are preferred for lighting.

Passive solar heat recovery for heating needs is classified into 5 applications: collectors, the transparent opening through which sunlight can penetrate, and absorbers that provide heat absorption by sunlight exposure on the wall or floors. This thermal mass ensures the storage of the resulting heat, scattering, the spreading of sunlight from collection and storage points to different areas of the house, and solar control provided with soffits. Three primary passive solar heat recoveries differ in how these five elements are incorporated as direct, indirect, and isolated recovery methods (Mazria, 1979).

Natural ventilation is based on replacing the air used indoors with fresh air (Berköz *et.al*, 1995). The air temperature is reduced thanks to evaporation on the surfaces of grass and leaves (Olgyay, 2015). Solar control elements, grouped into two categories as fixed and mobile systems, are placed according to the exposure and position of the sunlight, are other passive cooling strategies (Butera *et.al*, 2014).

Atrium and solar chimneys, which help buildings receive natural light and reduce energy consumption, are considered passive lighting systems.

### 2.1.2. Active Systems

Active systems, another method used to provide indoor comfort conditions, comprise systems with mechanical equipment, additional heat storage elements, or water-air collectors.

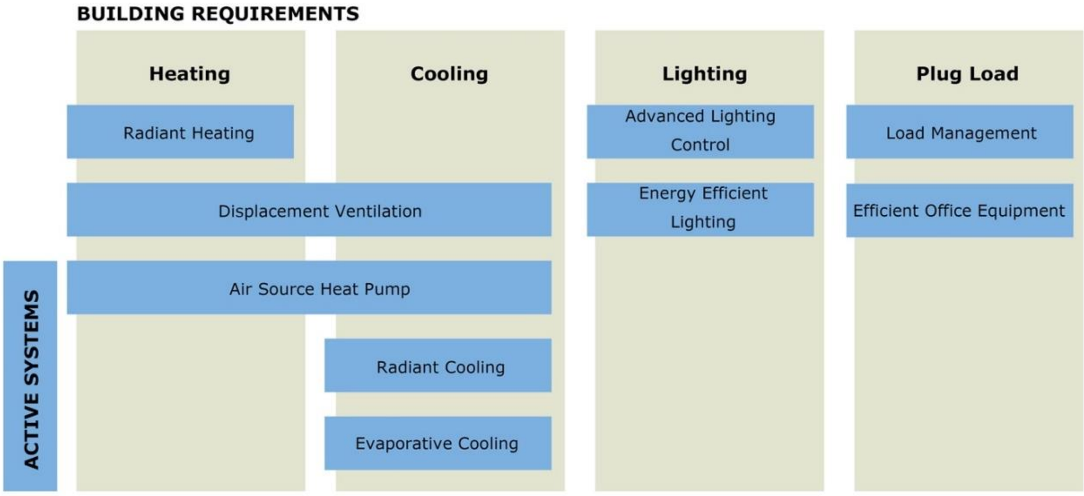



Figure 2.3. Active systems used for building requirements (Garde *et.al*, 2017).

Figure 2.3 illustrates that radiant heating – cooling, displacement ventilation, and air source heat pumps are utilized for both heating and cooling as active systems, while evaporative cooling, operating based on the water evaporation principle, is an active cooling system. The use of advanced lighting control and energy-efficient lighting, besides efficient office equipment and load management under the plug load category, are other strategies to conserve energy.

The circulation of fluids such as water through the panels or pipes placed inside the building components such as floors, ceilings, walls, and heating or cooling are defined as radiant systems. Air source heat pumps, devices that ingest the heat from the cold source and transfer it to the hot source, with displacement ventilation operating through the density difference, where the dirty and hot air is in the upper layer and the clean and cold air is in the lower layer is one of the active systems used for cooling.

A certain level of energy saving can be achieved using daylight-sensitive, motion-sensor control systems and energy-efficient LED lighting for lighting.

2.2.3. Renewable energy sources

Another design strategy used in energy-efficient building design is utilizing renewable energy sources.

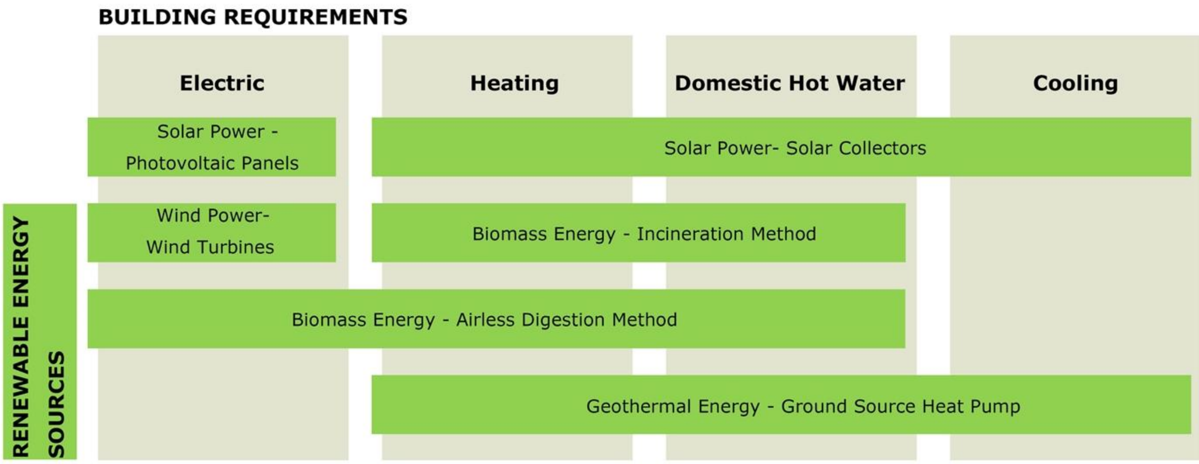



Figure 2.4. Renewable energy sources for building requirements (Garde *et.al*, 2017).

Figure 2.4 demonstrates that renewable energy sources applied for heating, cooling, and hot water in buildings are solar and geothermal energy. Electrical energy generation occurs with the solar energy recovery through the photovoltaic panels and the wind turbines integrated into the buildings. Gases obtained from biomass energy in various ways are also utilized for electricity generation, hot water use, and indoor heating.

The photovoltaic panels mounted to the structure in a way that they receive the sunlight at the required angle provide electricity production through solar energy to keep energy efficiency at a high level (Karakan *et al.,* 2015). The solar energy obtained through solar collectors is stored in the water tanks located at the lower level, adjacent to the building. This energy is then used for hot water, heating, or cooling. Wind turbines, which convert the kinetic energy in the air into electrical energy, provide a large amount of energy recovery, especially in high-rise buildings.

Biogas obtained from biomass sources, another renewable energy source, is used for electricity production by the airless digestion method. The ethanol obtained by the pyrolysis method is used for heating requirements, while the hydrogen obtained by the direct combustion method is used for water heating (Sakınç, 2006).

Geothermal energy occurs with the rising of the heat accumulated underground to the surface as water or water vapor. It is ensured that the temperature in the building is at the same level as the soil by transferring the air taken through the channels built at different levels of the soil into the building for heating in winter and cooling in summer.

## 3. FIELD STUDY: A COMPARATIVE ANALYSIS OF SAMPLED ENERGY-EFFICIENT OFFICE BUILDINGS

The need for energy in office buildings is higher due to user load and building function. Leed Certificate, which aims to minimize energy consumption and the negative impact of buildings on the environment by increasing energy efficiency to the highest level, is the green building certification system assessed in this study. 10 office buildings with a Leed Certificate from the world were sampled considering their sizes and analyzed through the aforementioned strategies.

### 3.1. Energy-efficient Office Buildings from the World

3.1.1. Quito Publishing House

Quito Publishing House received the first Leed Gold certificate in Ecuador (URL-1) for embodying environmental design principles in the tropical region.

Table 3.1. Specifications of Quito Publishing House

| | | |
|---|---|---|
| **Building Properties** | **Architect** | Estudio A0 |
| | **Location** | Quito, Ecuador |
| | **Function** | Office |
| | **Construction Year** | 2014 |
| | **Building Land** | 7589 $m^2$ |
| | **Certificate Level** | Leed Gold |
| | **Leed Consultancy** | SUMAC |

The building was constructed with bioclimatic design principles that minimize the need for mechanical ventilation, heating, and cooling systems. Since no shadows are falling on the building, the northeast and southeast facades are exposed to direct sunlight, especially in the morning. Sunshades, which regulate the incoming solar radiation and act as a filter and biological wall, are an interactive building component that can respond to changes in temperature and humidity. The movement of the orange louvers is user-bind as it is cost-effective to reduce energy consumption. The cross-section of the louvers is formed in such a way as to minimize the factors refracting the light and accelerate air transfer (URL-2).

The middle courtyard acts as a chimney that sucks the air towards the upper levels of the building, while it also acts as an atrium providing natural lighting on the lower floors. Besides, this system allows air to be conveyed to the car park under the floor. There are photovoltaic panels that provide electricity generation in the skylight located in the atrium. The vegetation layer on the roof deck acts as a filter to purify the air, provide airflow and shading. The rear facade acts as a thermal mass designed to absorb and radiate heat. The water element on the ground floor operates a cooling function. These systems were implemented to utilize natural resources such as sunlight and air to the optimum and minimize energy and water consumption.

The building has an integrated rainwater collection system that reduces the water consumption directed to wet areas, garden floors, and vertical flower beds. The vertical gardens, which consume a small amount of water, act as a thermal insulation layer just as the green roof. Maintenance racks along the building perimeter act as buffers for dust and provide corridors that make the garden area, windows, and blinds easy to clean. The building contains the elements necessary for the separation and collection of waste. Quito Publishing House also draws attention with its proximity to public transportation vehicles and its accessibility with bicycles (URL-2).

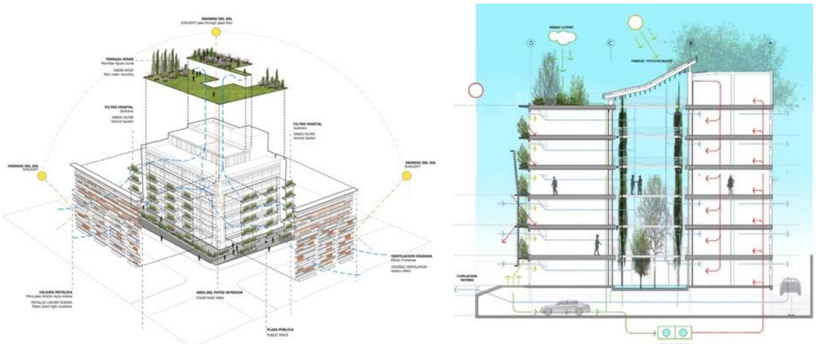


Figure 3.1. Schematic drawings (URL-2) displaying the energy efficiency of Quito Publishing House.

3.1.2. NASA Observatory

Nasa and William McDonough + Partners teamed up to create Earth’s first high-performance space station, a building that eventually earned Leed Platinum certification. This office building has an exoskeleton of approx. 5,000 m$^2$ inspired by images from NASA satellites. This design approach provides the building with structural performance for daylight and shading (URL-3).

Table 3.2 Specifications of the Nasa Observatory Building

| | | | |
|---|---|---|---|
| **Building Properties** | **Architect** | William McDonough |  |
| | **Location** | California, USA | |
| | **Function** | Office | |
| | **Construction Year** | 2012 | |
| | **Building Land** | 5000 m$^2$ | |
| | **Certificate Level** | Leed Platinum | |
| | **Leed Consultancy** | Loisos + Ubbelohde | |

The building applies two strategies to optimize energy needs and meet the demand with renewable energy sources. Natural daylight and natural are maximized, while active heating and cooling systems are also utilized to provide the desired comfort throughout the year.

A ground source heat pump, radiant cooling ceiling panels (40% less energy use than standard systems), hot water radiant wall heating panels, automatic window systems to provide natural ventilation, LED lighting to provide energy efficiency, advanced lighting control systems, building electrical photovoltaic panels, which will produce up to 30% of the requirements, and solar collectors to provide hot water are some exemplary systems utilized in the building. (URL-4).

The goal in saving water was to create a closed-loop system that will allow the water falling on the site to exit at the same rate, volume, and cleanliness as pre-improvement conditions. There is a facility near the building for pumping and cleaning groundwater. Native and drought-resistant plants were selected with a smart landscape design. Besides, there are water purification systems that reduce water demand.

Large wall-to-wall windows provide a high level of natural lighting for the interior. The simulations show that electric lighting is needed only 42 days of the year. The skylights on the second floor provide extra natural lighting, while the horizontal and vertical aluminum canopies with an integrated exterior reduce heat recovery and glare. The high-performance glasses, together with the insulated outer metal panel system, act as a warm shell. User-controllable windows provide cross ventilation when the interior gets too hot. The radiant panels in the building are another element that helps in heating and cooling. (URL-4).

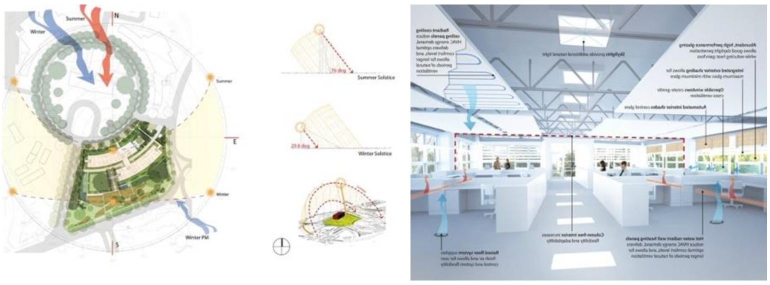


Figure 3.2. Schematic drawings displaying the energy efficiency of the NASA Observatory (URL-4).

3.1.3. Molymet Administration Building

The designers of the Molymet Administration Building had a vision that suggests they should be integrated into urban life to improve the life quality of employees and the environment. It is claimed that this is only possible with green concepts that provide energy efficiency. The designers suggested creating a thematic technology with high-tech office buildings built for sustainability in large green areas (URL-5).

Table 3.3 Specifications of the Molymet Administration Building

| | | | |
|---|---|---|---|
| **Building Properties** | **Architect** | David Rodriguez |  |
| | **Location** | San Bernardo, Chile | |
| | **Function** | Office | |
| | **Construction Year** | 2012 | |
| | **Building Land** | 4200 m$^2$ | |
| | **Certificate Level** | Leed Platinum | |
| | **Leed Consultancy** | Jimena Etchegaray | |

The administration building is designed by the green building concept, which incorporates all technological elements that contribute to energy control and minimizes its impact on the environment.

Reflective pools have been used as temperature regulators as part of the air conditioning system. The sunlight and natural lighting are controlled with the green roofs and double skin facade system. The gray water is reused with the recycling system, and the inner courtyard allows the temperature to be regulated naturally. The Molymet Administration Building was awarded Leed Platinum for the 'New Construction' category, a first in South America (URL-5).

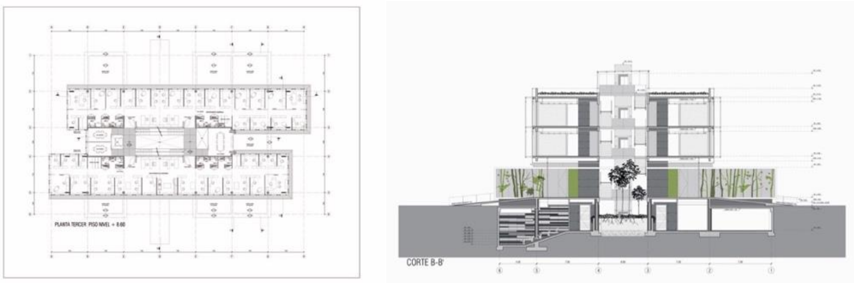


Figure 3.3. Molymet Administration Building plan and sections (URL-5).

3.1.4. Center for Urban Waters

Center for Urban Waters was designed as an exemplary building for sustainable strategies and was awarded the Leed Platinum certificate. Some of these strategies are natural ventilation of office spaces, shading of south and west facades with sunshades, vegetation-covered roofs, rainwater harvesting mechanism, and water recycling (URL-6).

Table 3.4. Tag of the Center for Urban Waters Building

| | | | |
|---|---|---|---|
| **Building Properties** | **Architect** | Perkins & Will |  |
| | **Location** | Tacoma, USA | |
| | **Function** | Office | |
| | **Construction Year** | 2010 | |
| | **Building Land** | 5100 $m^2$ | |
| | **Certificate Level** | Leed Platinum | |
| | **Leed Consultancy** | ATS | |

The materials used inside and outside the building were selected based on recycled content, volatile organic compounds, and product certifications. Responsible waste management before and during construction also played an active role in obtaining the certificate. Highly recycled aluminum sheet corrugated metal cladding was used on 3 facades of the building, and a glass curtain wall with fixed horizontal sunshades was applied on the south.

The Center for Urban Waters uses various strategies to reduce its energy needs. Sunshades and high-performance glasses on the exterior minimize unwanted heat recovery. Natural ventilation and ground source heat pump charging radiant paving slabs reduce the energy required for heating and cooling. Spaces that require minimum energy and receive good daylight were built through the lighting controls. Thanks to these strategies, the overall energy use of the building was 38% more efficient (URL-7).

Figure 3.4. Schematic drawings of Center for Urban Waters (URL-7) regarding energy efficiency.

3.1.5. Nexus Design Center

Passive and active systems were integrated into the building to minimize energy consumption in the Nexus Design Center. The glass materials used in the building envelope were used for high performance; tree shading was used on the east façade; planting was provided on the walls, and photovoltaic panels, which can produce more than 2 times the annual energy consumption of the building, were used on the roof (URL-8).

Table 3.5 Specifications of Nexus Design Center Building

| | | |
|---|---|---|
| Building Properties | **Architect** | Architectural Nexus |
| | **Location** | Utah, USA |
| | **Function** | Office |
| | **Construction Year** | 2010 |
| | **Building Land** | 2415 m$^2$ |
| | **Certificate Level** | Leed Platinum |
| | **Leed Consultancy** | Acutherm |

LEDs were used to provide energy efficiency in indoor lighting to benefit from daylight with skylights. All equipment in the project was Energy Star certified. There is an electric vehicle charging station for the users (URL-8).

Figure 3.5. Indoor and outdoor images of the Nexus Design Center (URL-9).

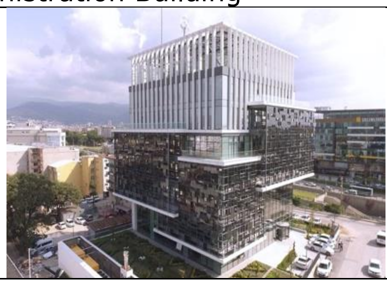
## 3.2. Energy Efficient Office Buildings in Turkey

3.2.1. The New Bursagaz Administration Building

The New Bursagaz Administrative Building, in Bursa, Turkey, in the gas distribution and trade services sector, received 83 points in 2017 and was awarded the Leed Platinum certificate. Automated systems provide the control of water and electricity consumption in this nature-friendly project (URL-10).

Table 3.6. Specifications of Bursagaz New Administration Building

| | | |
|---|---|---|
| Building Properties | **Architect** | Tago Architecture |
| | **Location** | Bursa, Turkey |
| | **Function** | Office |
| | **Construction Year** | 2016 |
| | **Building Land** | 7373 m$^2$ |
| | **Certificate Level** | Leed Platinum |
| | **Leed Consultancy** | Altensis |



The building, located in a dense residential area, is easily accessible with several public transportation lines. The use of individual vehicles was kept to a minimum, bicycle parking areas and charging stations were built for electric vehicles that will become widespread in the future to reduce carbon emissions. The rainwater is collected and utilized for landscape irrigation in wet areas where water consumption is kept to a minimum. Vegetation adapted to the region was preferred to reduce water use (URL-11).

ASHRAE 90.1-2007 criteria were followed while selecting the glass and insulation material for the project, and recyclable materials were used. Motion, daylight sensors, and energy-efficient lighting systems were implemented to prevent energy consumption. A particular share of the energy need is provided through the photovoltaic panels located on the roof level and wind turbines, hence utilizing solar and wind energy. (URL-11).

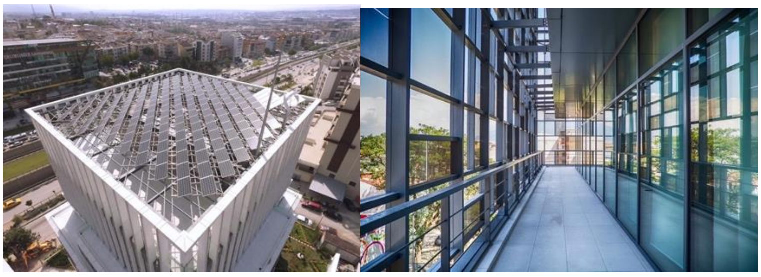


Figure 3.6. Indoor and outdoor images of The New Bursagaz Administration Building (URL-12).

3.2.2. Turkish Contractors Association Headquarters

The Turkish Contractors Association Headquarters, in Ankara/Turkish capital, was awarded the Leed Platinum certificate in 2014 with a score of 81. Numerous systems were applied to the building to ensure energy efficiency, such as the thermal labyrinth system. The Ankara climate, where the temperature difference between day and night is high, was turned into an advantage through this system. The heat stored in the summer nights was used for cooling during the day. Passive heating of the building was provided through the underground heat in the winter months (URL-13).

Table 3.7. Specifications of the Turkish Contractors Association Headquarters

| | | | |
|---|---|---|---|
| **Building Properties** | **Architect** | Avci Architects |  |
| | **Location** | Ankara, Turkey | |
| | **Function** | Office | |
| | **Construction Year** | 2013 | |
| | **Building Land** | 6900 m$^2$ | |
| | **Certificate Level** | Leed Platinum | |
| | **Leed Consultancy** | Turkeco | |

Rainwater was used for minimizing water usage in wet bulks, and solar collectors were used for hot water use. The mesh coating applied on the façade ensures a balanced daylight intake, and the cold beam system is used to provide comfortable indoor air conditions.

Photovoltaic panels on the roof meet approximately 5% of the energy requirement as the LED lightings were used with motion and daylight sensors to provide energy efficiency. Plants with low water consumption and a green roof system were used to save water in landscaped areas and reduce the need for cooling in the building during summer (URL-14).

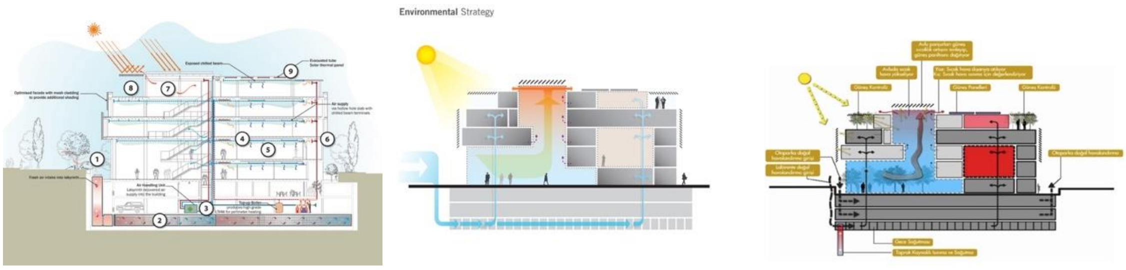



Figure 3.7. Schematic drawings of Turkish Contractors Association Headquarters (URL-14) regarding energy efficiency.

### 3.2.3. Eurogida Administration Building

Eurogida Administration Building, in Eskişehir, was awarded the Leed Gold certificate with 70 points in 2020. The building, which is planned to be an inward-looking structure, had an atrium where the spaces open this area for maximum lighting (URL-15).

Table 3.8. Specifications of Eurogida Administration Building

| | | | |
|---|---|---|---|
| **Building Properties** | **Architect** | Oney Architecture |  |
| | **Location** | Eskisehir, Turkey | |
| | **Function** | Office | |
| | **Construction Year** | 2015 | |
| | **Building Land** | 4400 $m^2$ | |
| | **Certificate Level** | Leed Gold | |
| | **Leed Consultant** | GBIG | |

The prevailing wind direction is South-West, temperatures remain high throughout the year, and the low percentage of precipitation provides arid conditions in the surrounding area. There are two wall barriers in the North-South axis of the building. The concave concrete form of the entrance facade protects the building and the terrace behind it from excessive heat. Besides, the second linear wall barrier provides the heat and daylight in the atrium in a controlled manner. The façade openings in the East allow sunlight into the building, while the impermeable West façade contributes to the cooling and shading. The vibrant colors used on the facades act as a reflector to control the heat emission and sunlight flow.

The automation system in the solar panels at the top of the atrium maximizes energy efficiency through natural light and ventilation. Furthermore, the wastewater from the factory facility and the rainwater collected naturally through the land slope are recycled for landscape irrigation. Eurogıda's multifunctional administrative building reflects the company's strong corporate identity via user-friendly and social spaces (URL-16).

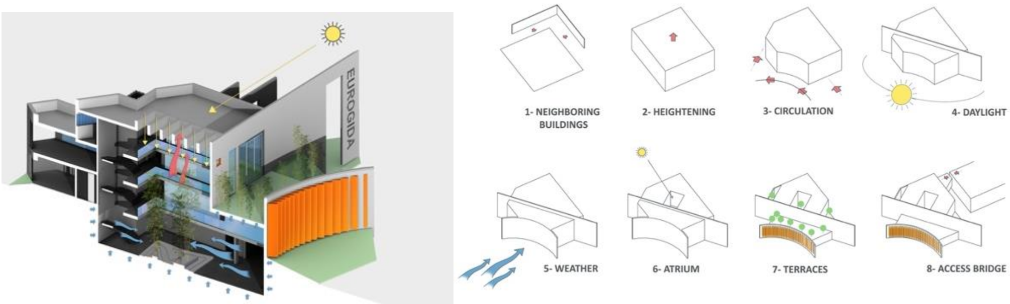



Figure 3.8. Schematic drawings of Eurogida Administration Building (URL-16) regarding energy efficiency.

### 3.2.4. Eser Holding Head Office

Eser Holding Head Office, designed for minimum energy consumption, was awarded a Leed Platinum certificate. Individual vehicle use was minimized together with bicycle parking areas and public transportation for sustainable environmental planning. 94% of the total parking area is located underground to keep the heat island effect to a minimum (URL-17).

Table 3.9. Specifications of Eser Holding Head Office

| | | | |
|---|---|---|---|
| **Building Properties** | **Architect** | Eser Holding |  |
| | **Location** | Ankara, Turkey | |
| | **Function** | Office | |
| | **Construction Year** | 2010 | |
| | **Building Land** | 7500 m$^2$ | |
| | **Certificate Level** | Leed Platinum | |
| | **Leed Consultancy** | Altensis | |

The collected rainwater irrigates landscaped areas as the water usage is kept to a minimum with the gray water treatment system. The materials used in the building do not harm the ozone layer, and most of the waste generated during the construction of the project was recycled (URL-17).

$CO_2$ sensors were used to ensure indoor air quality besides the VRV system, which provides the required air to the users with proper timing and measurements. The spaces with larger surfaces were designed to maximize daylight, besides the two daylight chimneys positioned on the roof level. Ground source heat pumps were used to convert the heat obtained from the soil to a higher temperature to heat the indoor air and water (URL-18).

A cogeneration unit, which recovers heat energy during electrical energy generation, and thermal energy storage tanks were used. These tanks ensure the cooling of the building during the days with high temperatures with the ice stored at night for minimizing energy consumption (URL-18).

Figure 3.9. Outdoor images of Eser Holding Head Office (URL-18).

### 3.2.5. Erke Green Academy

Erke Green Academy was awarded a Leed Platinum for emphasizing the use of renewable energy sources. High interior quality was provided with the automation systems used in the building to ensure user satisfaction (URL-19).

Table 3.10. Specifications of Erke Green Academy Building

| | | | |
|---|---|---|---|
| **Building Properties** | **Architect** | Deer Architects |  |
| | **Location** | Istanbul, Turkey | |
| | **Function** | Office | |
| | **Construction Year** | 2013 | |
| | **Building Land** | 400 m$^2$ | |
| | **Certificate Level** | Leed Platinum | |
| | **Leed Consultancy** | ERKE | |

No window space was left on the north façade in the ERKE project, while triple and double glazing, selected within the consideration of the heating and cooling loads on the other facades, as 41% compared to the walls. A ventilation system connected to $CO_2$ sensors was implemented to maintain indoor air quality. The water obtained from the gray water treatment system was used to irrigate the landscaped areas. Automation systems were used to deactivate the lighting when not needed to save energy, while LED lighting sensitive to daylight was preferred. 27% of the electricity consumption was met by the solar panels positioned in the east-west direction on the rooftop. Moreover, air source heat pumps achieved 75% energy efficiency in heating and 29% in cooling (URL-19).

The chimney effect strategy was used to prevent a potential greenhouse effect on the glass mass at the building entrance. The air is evacuated with the natural ventilation vents on three sides of the glass mass to prevent overheating. The fan positioned at the top of the volume ensures that the air descends homogeneously to the lower levels, preventing the heated air from rising to the upper levels in winter. Water-saving faucets, double-stage closet cisterns, and waterless urinals were used under the Environmental Protection Agency standards, and water consumption was reduced by 37%. Furthermore, the water from the gray water treatment system was used in wet and landscaped areas. Local plant selection was prioritized to reduce the amount of water needed for landscape irrigation (URL-19).

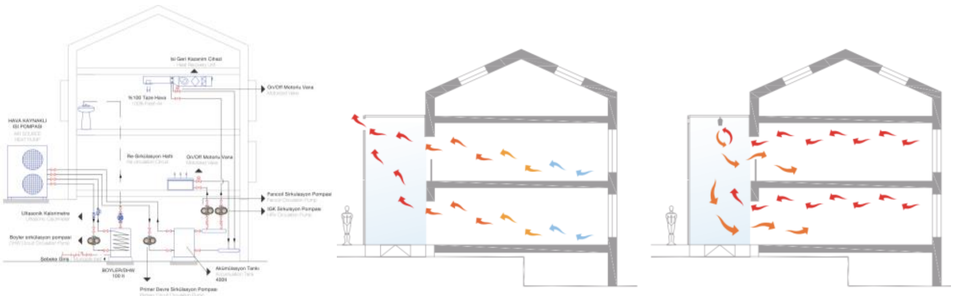


Figure 3.10. Schematic drawings of Erke Green Academy (URL-19) regarding energy efficiency.

The following inferences were obtained, in Table 3.11, after the analyses of sampled projects by Garde's active, passive systems and renewable energy resource strategies.

These buildings, from different climatic regions, have utilized passive systems more than active ones to make the best use of natural resources such as sunlight and air to minimize energy and water consumption for heating and cooling. It was observed that the building envelope, which separates the indoor and outdoor environments and covers the façade openings that allow the penetration of sunlight into the building and the impermeable façades that contribute to cooling and shading, is the most important parameter under passive systems for energy-efficient building design. High-performance double-skin facade systems, which are included in the building envelope and are preferred over traditional glass facades; Solar control elements, which are placed according to the angle of inclination and position of the sunlight, regulate the incoming solar radiation and act as a filter, are among the passive heating-cooling strategies frequently encountered in the examples. Atrium and solar chimneys, passive solar systems help to reduce lighting energy consumption by providing natural light to the screens. Daylight sensitive, motion sensor control systems and led lighting that turn off when not needed were the active systems grouped under advanced lighting control and energy-efficient lighting. The above-mentioned active and passive systems were used in almost all examples for the lighting requirement in buildings.

Photovoltaic panels receive the sun's rays at a right angle to keep energy efficiency at a high level, meet some of the building's electricity requirements. The sample units indicate that the most frequently used renewable energy source is solar energy.

Table 3.11. Strategies used by building requirements in office buildings with Leed certificate

| | Building Requirements | | Quito Publishing H. | NASA Sustainability | Molymet Administ. | The Urban Waters | Nexus Design C. | Bursagaz New Adm. | Turkish Contractors | Eurogida Administ. | Eser Holding HQ | Erke Green Ac. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Passive Systems | Heating | Passive Solar Heat Recovery | o | | | | | | o | | | o |
| | Heating-Cooling | Building Form | | o | | | | | | o | | |
| | | Building Envelope | o | o | o | o | o | o | o | o | o | o |
| | | Double Skin Facade Systems | o | o | o | o | o | o | o | o | o | o |
| | | Thermal Mass | o | | | | | | | o | o | |
| | Cooling | Vegetation | o | | o | o | o | | | o | | |
| | | Natural Ventilation | o | o | o | o | o | | o | | | o |
| | | Solar Control Elements | o | o | | o | o | o | o | o | | o |
| | Lighting | Skylight | o | | o | | | | o | o | | |
| | | Roof Window | | o | | | o | | | | o | o |
| Active Systems | Heating | Radiant Heating | | o | | o | | | o | | | |
| | Heating-Cooling | Displacement Ventilation | | | | | | | | | | |
| | | Air Source Heat Pump | | | | | | | | | | o |
| | Cooling | Radiant Cooling | | o | | o | | | o | | | |
| | | Evaporative Cooling | | | | | | | | | | |
| | Lighting | Advanced Lighting Control | | o | o | o | o | o | o | o | o | o |
| | | Energy Efficient Lighting | | o | o | o | o | o | o | | o | o |
| | Plug Loads | Load Management | | o | o | | | o | | | | |
| | | Efficient Office Equipment | | o | o | | | o | | | | |
| Renewable Energy Kaynakları | Electricity | Solar Power-Photovoltaic Panels | o | o | | | o | o | o | | | o |
| | | Wind Power-Wind Turbines | | | | | | o | | | | |
| | Electricity-Heating-Domestic Hot Water | Biomass Energy-Airless Digestion Method | | | | | | | | | | |
| | Heating-Domestic Hot Water | Biomass Energy-Incineration Method | | | | | | | | | | |
| | Heating-Cooling-Domestic Hot Water | Solar Power-Solar Collectors | | o | | | | | o | | | |
| | | Geothermal Energy-Ground Source Heat Pumps | | o | | o | | | o | | o | |

## 4. ASSESSMENT AND CONCLUSION

Today, it is known that half of the world's population lives in cities. Modern life in cities is entirely dependent on energy. Energy is required for almost every step in daily life, such as transportation, agriculture, telecommunications, the energy industry, heating, cooling, lighting buildings, powering electrical equipment. Considering the share of greenhouse gases caused by the energy consumption in climate change, the energy efficiency of built environments gains more importance with momentum.

Green building certification systems promote building design with various strategies for maximizing the energy efficiency of the built environment and minimizing the energy need in the buildings. The high number of users and serving function of office buildings compared to other facilities require higher energy in heating, cooling, lighting, and hot water. Thanks to the green building evaluation systems created, it became possible to design an energy-efficient building by reducing the energy needed. Leed Certificate, a green building evaluation system, is also an essential criterion in assessing the energy efficiency of buildings.

A total of 10 office buildings in different climatic regions were analyzed for their "passive, active systems and renewable energy source" strategies. It was found that the relevant systems are used according to the building requirements and energy efficiency is achievable. This comparative method discussed under these three strategies was applied to bring a different evaluation proposal to better understand how buildings can provide energy efficiency. The analysis showed that passive systems are more preferred than active systems in these buildings. It was also concluded that the "building envelope" is the most critical parameter. The most frequently applied renewable energy source is solar energy, which is used in photovoltaic panels integrated into buildings to provide electricity. Double skin facade systems, solar control elements, and atrium and skylights, which allow the spaces to receive natural light, were the most frequently used passive systems for heating and cooling. Energy-efficient lighting strategies, including advanced lighting control with motion sensor control systems and daylight-sensitive, led lighting, were among the most frequently applied active systems to reduce energy consumption in lighting.

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