



**FATİH SULTAN MEHMET VAKIF ÜNİVERSİTESİ  
LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ  
MİMARLIK ANABİLİM DALI  
MİMARLIK İNGİLİZCE YÜKSEK LİSANS PROGRAMI**

**AN EVALUATION OF SKYSCRAPER FACADES IN  
TERMS OF SUSTAINABILITY: IN CASE OF  
BUYUKDERE AVENUE**

**YÜKSEK LİSANS TEZİ**

**ELA AKTA**

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**İSTANBUL, 2020**

## LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜNE

Mimarlık Anabilim Dalı Mimarlık İngilizce Tezli Yüksek Lisans Programı'nda 180202034 numaralı ELA AKTA'nın hazırladığı "Analyzing The Usage of Eco-Materials of Istanbul Housing Project and Making a Design Proposal with Eco-Materials for prince Island (İstanbul Konut Projesinin Eko-Materyallerinin Kullanımını Analiz Etmek ve Büyükada İçin Eko-Materyaller İle Tasarım Önerisi Yapmak)" konulu Yüksek Lisans Tezi ile ilgili TEZ SAVUNMA SINAVI, 16/07/2020 Perşembe günü saat 11:00'da Çevrimiçi Video Görüşmesi ile yapılmış, sorulan sorulara alınan cevaplar sonunda adayın tezinin **KABULÜNE OYBİRLİĞİ** ile karar verilmiştir.

### **Düzeltilme verilmesi halinde:**

Adı geçen öğrencinin Tez Savunma Sınavı [..]/../20[.] tarihinde, saat da yapılacaktır.

### **Tez adı değişikliği yapılması halinde:**

Tez adının AN EVALUATION OF SKYSCRAPER FACADES IN TERMS OF SUSTAINABILITY: IN CASE OF BUYUKDERE AVENUE şeklinde değiştirilmesi uygundur.

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## **BEYAN/ ETİK BİLDİRİM**

Bu tezin yazılmasında bilimsel ahlak kurallarına uyulduğunu, başkalarının eserlerinden yararlanılması durumunda bilimsel normlara uygun olarak atıfta bulunulduğunu, kullanılan verilerde herhangi bir tahrifat yapılmadığını, tezin herhangi bir kısmının bağılı olduğum üniversite veya bir başka üniversitedeki başka bir çalışma olarak sunulmadığını beyan ederim.

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# SÜRDÜRÜLEBİLİRLİK KAPSAMINDA YÜKSEK YAPI CEPHELERİNİN DEĞERLENDİRMESİ: BÜYÜKDERE CADDESİ ÖRNEĞİ

ELA AKTA

## ÖZET

21. yüzyılda dünyanın pek çok şehrinde yüksek katlı yapılar inşa edilmektedir ve sayıları gün geçtikçe artmaktadır. Bu süreçte çözülmesi gereken bazı sorunlar ortaya çıkmaktadır. Yüksek katlı yapılar, az katlı yapılara göre çok daha fazla enerji tüketmektedir. Bu enerji tüketimi, sürdürülebilir cephe tasarım kriterlerine uyarak büyük ölçüde azaltılabilmektedir. Bu yapıların enerji tüketimini azaltıp verimini arttırmak için yüksek katlı bir yapı tasarlanırken sürdürülebilir cephe tasarım kriterleri dikkate alınmalıdır.

Bu tez çalışmasında, Büyükdere Caddesi'nde 2000'li yıllardan sonra inşa edilen ofis ve/veya konut fonksiyonlu gökdelenlerin cepheleri incelenecektir. Cepheler, tez kapsamında vurgulanacak olan sürdürülebilir gökdelen cephe tasarım parametrelerine göre incelenmiştir. Ayrıca, araştırma güneş-gün ışığı, doğal havalandırma ve malzeme kategorilerine odaklanmıştır. Kategorilere ait parametreler belirlenip bina cepheleri hakkında toplanan verilere, belirtilen parametreler kapsamında değerlendirme yapılmıştır. Bu sonuçlar neticesinde Büyükdere Caddesi için sürdürülebilir gökdelen cephe tasarımı için tasarım önerisinde bulunulmuştur. Son olarak, toplanan verilerden dikkate alınan parametrelerin yüzdelerle sonuçlarından değerlendirme çizelgeleri çıkartılıp çalışma sonuçlandırılmıştır.

**Anahtar kelimeler;** Sürdürülebilir cephe tasarımı, Sürdürülebilir gökdelen, Cephe, Enerji tasarruflu cephe, Gökdelen, Enerji tasarruflu gökdelen.

# **AN EVALUATION OF SKYSCRAPER FACADES IN TERMS OF SUSTAINABILITY: IN CASE OF BUYUKDERE AVENUE**

ELA AKTA

## **ABSTRACT**

The high-rise buildings are consuming much more energy compared to the low-rise buildings. This energy consumption can be reduced by following sustainable facade design criteria. Therefore, sustainable facade design parameters should be considered while designing a high-rise building in terms of reducing the building's energy consumption.

This thesis investigated the facades of the office and/or residential functioned skyscrapers built after the 2000s at Buyukdere Avenue. It studied the facades according to the sustainable skyscraper facade design parameters, which will be emphasized within the thesis content. Furthermore, the research focused on sunlight, natural ventilation, and material parameters. Determining a set of parameters and then evaluating the collected data of the buildings facades features within the stated parameters. Thereafter, an evaluation chart was constructed from the collected data having results with the consideration percentile of the parameters, ending up with a suggestion of sustainable skyscraper facade design for Buyukdere Avenue.

**Keywords;** Sustainable facade design, Sustainable skyscraper, Facade, Energy efficient facade, Skyscraper, Energy efficient skyscraper.

## **PREFACE**

The study investigated the facades of skyscrapers built in the 21<sup>st</sup> century at Buyukdere Avenue within the scope of the thesis, in terms of sustainable facade design parameters. Aiming to determine the sustainable parameters of the examined facades. Also, the high-rise buildings are consuming much more energy compared to the low-rise buildings. This energy consumption can be reduced by following sustainable facade design criteria.

In general, I was interested in concepts such as skyscrapers, sustainability, ecology, and eco-material. Thus, I chose this thesis topic to improve my knowledge, and I really gained very beneficial information while researching the thesis. During the research, I became more interested in skyscraper facade designs, and I also observed in detail how important the facade design is to the building. While writing the thesis, my aim was to raise awareness on this subject.

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## SYMBOLS

<b>ac/h</b>	: Air Changes Per Hour
<b>CO<sub>2</sub></b>	: Carbon dioxide
<b>°C</b>	: Degree Celsius
<b>kg/m</b>	: Kilo Gram Per Meter
<b>Km</b>	: Kilo Meter
<b>kWh/m<sup>2</sup></b>	: Kilowatt Hour Per Square Meter
<b>kWh/y</b>	: kWh Per Year
<b>kWs/m<sup>2</sup></b>	: Kilowatt Hour Per Square Meter
<b>M</b>	: Meter
<b>m<sup>2</sup></b>	: Square Meter
<b>mm</b>	: Millimeter
<b>m/s</b>	: Meter Per Second
<b>W/M<sup>3</sup>K</b>	: Watts Per Cubic Meter-Kelvin

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## ABBREVIATIONS

a.gr.	Above ground
Arch. height	Architectural height
ASHRAE	The American Society of Heating, Refrigerating and Air-Conditioning Engineers
BBVA	Banco Bilbao Vizcaya Argentaria
BD+C	Building Design+Construction
BRE	Building Research Establishment
BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CBD	Central Business District
Const. Date	Construction
CTBUH	Council on Tall Buildings and Urban Habitat
DSF	Double-Skin Facade
EE	Energy Emission
Ex.	Example
Func.	Function
HK-BEAM	Hong Kong-Building Environmental Assessment Method
HVAC	Heating, Ventilation and Air Conditioning
ISO	International Organization for Standardization
LEED	Leadership in Energy and Environmental Design
Low E	Low Emission
MIPIM	The World's Property Market
NFPA	National Fire Protection Association
NY	New York
PV	Photovoltaic

Ref. Page	Reference Page
RICS	Royal Institution of Chartered Surveyors
SHCA	Swanke Hayden Connell Architects
TEM	Transit European Motorway
UK	United Kingdom
UL	Underwriters Laboratories
USA	United States of America
USGBC	United State Green Building Council
UV	Ultraviolet
VAV	Variable Air Volume
VRV	Variable Refrigerant Volume
WGBC	World Green Building Council
WWI	World War One

## 1. INTRODUCTION

In the 21<sup>st</sup> century, the skyscraper construction which originated in the 1880s, increased rapidly in Turkey in general and in Istanbul especially. Therefore, the energy consumption of the building leads to environmental harm. According to Ayaz (2002), when we divide the environment into natural and built environments, it is seen that 50% of energy use, 40% of raw material use, 50% of the use of chemicals harmful to ozone are created by buildings located in built environments (Ayaz, 2002, cited by Kahraman, 2015).

The aim of the thesis is to examine the facades, which are one of the main elements of the buildings that make up the built environment and to propose approaches that are designed to cause the least harm to the environment. The first steps that will reduce the impact of a building on the environment and enable it to become a green building should be taken at the design stage. However, according to Tekeli and Atöv (2017), as they mentioned at their Sustainable Society and Built Environment (Sürdürülebilir Toplum ve Yapılı Çevre) book, people show the tendency to over-consumption mostly in buildings (Tekeli & Atöv, 2017, p.59).

According to Alakavuk et. al. (2015), approximately 33% of the energy consumed in buildings. 70% of the energy spent on buildings is spent on heating and cooling. However, according to the research done in the literature review, the well designed building facade has an important role at reducing the energy consumption of the building (Alakavuk et.al., 2015).

Buyukdere Avenue is located at the Levent district. Levent in the globalization process has been positioned as Istanbul's Central Business District and started to become a commercial and financial center. Due to its location and due to the density of the skyscrapers settlements in this area, it was deemed appropriate to be selected as a project investigation area.

Accordingly, this thesis will investigate the facades of the skyscrapers, built after the 2000s at Buyukdere Avenue, in terms of sun-daylight, natural ventilation and material categories, within the sustainable facade design parameters determined.

Resulting with the consideration percentile of the sustainable facade design criteria, which was explained within the thesis scope. Ending up with a suggestion of sustainable skyscraper facade design for Buyukdere Avenue.

### 1.1. LITERATURE REVIEW

In the 21<sup>st</sup> century, sustainability criteria gained huge importance in the construction industry. The foundation of sustainable development dates back to the 1970s. The Human and Environment Conference, which was established by the United Nations in Stockholm in 1972, is the first international organization in the field of environment. The usage of natural resources without wasting was emphasized at this conference (Karakurt, 2019).

The first official definition of the concept of sustainable development was made in Our Common Future Report published in 1987 by the World Environment and Development Commission, which operates within the United Nations. Sustainability is defined in the report as “Humanity can sustain development by providing daily needs without compromising the ability of nature to respond to the needs of future generations” (Brundtland, 1987).

Furthermore, the basis of human-induced climate change was developed by scientists from the 19<sup>th</sup> century. In 1896, according to the research conducted by the Swedish scientist Svante Arrhenius, who won the Nobel Prize in Chemistry, he found that doubling the density of CO<sub>2</sub> gas in the atmosphere would cause an increase in the average temperature of the planet by about 5°C, which is one of the main reasons that causes the global warming (Sachs, 2019, p.362). However, as a result of researches conducted by different independent organizations, it has been revealed that global warming is a reality and the environment is polluted in a way that will affect the living conditions of the next generations (Kahraman, 2015).

Thereupon, to improve the built environment, it is necessary to select the components of the built environment in a way that the building materials do not harm the environment (Kahraman, 2015).

Skyscraper terminology was first used in the 1880s with the construction of 10-20 storey buildings in the USA. The technological developments brought by the industrial revolution, which coincided towards the end of the 19<sup>th</sup> century, had an obvious effect on the construction of high-rise buildings. As well as advances in building design and the construction industry, enabled multi-storey buildings to be built. The production of modern steel, the invention of the elevator, reinforced concrete building material, the telephone, water pump, central heating systems are the most important of them (Hasol, 2014).

Modern skyscrapers began to be built in the United States in Chicago and New York cities in the late 19<sup>th</sup> century. For this reason, the names given to such buildings mostly originate from the American Architectural Literature. So, they used terms like Multistory Structure, High- Rise Building, Tall Building, Skyscraper, Supertall and Megatall Building (Sağlam, 2016).

According to (CTBUH) Council on Tall Buildings and Urban Habitat, high building lower limit is defined as a minimum of 14 storeys or 50m (165 feet) and buildings exceeding this limit are considered as high buildings (Url-1). Despite the diversity in the definition of a high-rise building in various references, according to the German standards, the building that exceeds 22m is classified as a high-rise building. 12<sup>th</sup> storey and above in the United States, while in Europe and Turkey 10<sup>th</sup> storey and above referred to be a high-rise building (Kıasif & Selçuk, 2016). Moreover, according to the criteria of CTBUH: Buildings exceeding 300m (984 feet) are defined as “supertall buildings” and buildings exceeding 600m (1.968 feet) as “Megatall Building” (Ur-1).

Norman Foster is a British architect who won the Pritzker Architecture Prize in 1999, has mentioned at, the Harvard Center for Green Buildings and Cities Inaugural Lecture, that there is a direct relationship between the pollution and the climate change, and he emphasized that it is the strongest threat to the global society and the planet. In 1997, he designed the world’s first breathable skyscraper, with a green landscape in the middle of the building which is providing natural ventilation by openable windows

into it. Additionally, by giving examples from his studies and projects it has been progressed within the thesis scope (Url-2).

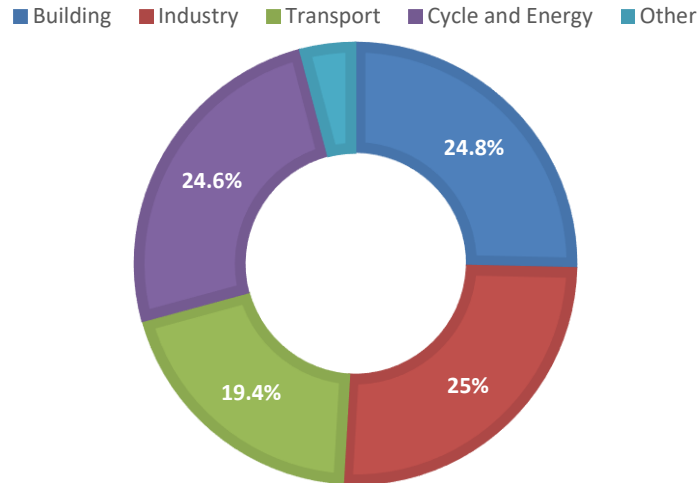
On the other hand, Elif Karakurt Tosun (2019) described green architecture in her book, Sustainable Urbanization (Sürdürülebilir Kentleşme), as a type of architecture that is sensitive to energy saving, effectively insulated, utilizing solar rays and using recyclable materials as much as possible (Karakurt, 2019).

In addition, for centuries, we see that climate is a dominant factor for architects and architecture all over the world. The shape of the structures has been substantially influenced by environmental requirements. The building shell defined at Sustainable building design guide (Sürdürülebilir yapı tasarımı kılavuzu) book by Alakavuk et.al. (2015) as, the building's main elements that distinguish the interior from the external environment and thus, are in direct contact with the external climate conditions, which is the main determinant of the indoor climate conditions. The elements that compose the building shell are the exterior facades and roof of the building (Alakavuk, et.al., 2015). This study will focus on the importance of the skyscraper building facade design, in Büyükdere Avenue, and discuss the appropriate criteria for skyscraper facade designing.

According to Alakavuk et.al. (2015) they mentioned that throughout the world in general and Turkey in particular, about 33% of the energy consumed in buildings, 30% in industry, 19% in transportation, and 18% are used in other areas. Besides, 70% of the energy consumed on buildings is spent on heating and cooling. In other words, it is used to keep the interior volume of the spaces in comfort conditions (Alakavuk, et.al., 2015).

On the other hand, according to the evaluation at the article (General Evaluation of Energy Outlook in Turkey and The World), 2016 year-end sectoral distribution of primary energy consumption in Turkey was shown with 24.8% consumed at buildings, 25% at energy, 24.6% at cycle and energy, and 19.4% consumed at transportation (Koç et. al., 2018).

## 2016 YEAR-END SECTORAL DISTRIBUTION OF PRIMARY ENERGY CONSUMPTION IN TURKEY



**Image 1.1:** 2016 Year-End Sectoral Distribution of Primary Energy Consumption in Turkey (Koç et. al., 2018).

Furthermore, the materials to be used in the project application phase have embedded energy. This embedded energy is the energy spent during the construction phase of the material. At the same time, the wastes and gases emitted by the material during the production process can be called as buried environmental performance (Kahraman, 2015). Accordingly, it is beneficial to examine the roof and exterior facade elements that form the building shell, where the heat conduction is the highest.

Ken Yeang, another architect, whose examples and design techniques were beneficial within the scope of the thesis. He is an architect, ecologist, planner and author from Malaysia, best known for his ecological architecture and ecomaster plans that have a distinctive green aesthetic. Talked about his practical work on the ecological design of facades and emphasized the importance of the design of the facade for human comfort and health, referring to it as the third skin of a human. He also mentioned that a well-designed building shell saves significant energy. He briefly introduced the facade as “An ideal exterior wall should act as an environmentally friendly filter” (Yeang, 2012).

He stated the main tasks of the facade as; providing natural ventilation, controlling cross-ventilation, presenting the exterior appearance of the building, protecting from the sun, arranging windy rain, draining heavy rainwater, providing insulation in cold

seasons, meeting the requirements arising between two seasons, summer and winter in temperate regions. In order to develop a more direct relationship with the natural environment, it should have interchangeable openings that function like sieve filters with various parts (Yeang, 2012).

## 1.2. AIM OF THE STUDY

This study aims to determine the sustainable parameters in the facades designs of the high-rise buildings examined within the scope of the thesis and then make suggestions to improve the design of the facades in terms of sustainability. The study will focus on sun-daylight, natural ventilation, and material parameters.

The high-rise buildings are consuming much more energy compared to the low-rise buildings. This energy consumption can be reduced by following sustainable facade design criteria.

Sustainable facade design parameters should be considered while designing a high-rise building in terms of reducing the building's energy consumption.

## 1.3. SCOPE AND METHODOLOGY

### **Scope:**

Among the study, the relationship between the high-rise building facade design and buildings energy consumption was emphasized. Sustainable facade design methods were discussed within the scope of the thesis, the importance of the sustainable facade design was emphasized and worldwide high-rise buildings that have considered the sustainable facade design were given as an example.

The high-rise buildings selected among the scope of the study were evaluated according to sustainable facade design criteria in terms of sun-daylight, natural ventilation, and material categories. Evaluation parameters had been determined for each category and buildings were evaluated within the scope of those parameters.

The main criteria used at the selection of high-rise buildings to be investigated were;

- High-rise buildings located at Buyukdere Avenue.
- Built or finished construction after the 2000s (21<sup>st</sup> century).
- High-rise buildings with office and/or residential functions.
- High-rise buildings of 22 floors and above and higher than 91m.

## **Methodology:**

Evaluation parameters were extracted according to sustainable facade design criteria which have been emphasized within the theoretical part of the thesis. As, 15 parameters for sun-daylight category, 12 parameters for the natural ventilation category, and 3 parameters for the material category. In total thirty evaluation parameters were chosen under the relevant categories. A mixed-method was used to determine the evaluation parameters. It was chosen according to the main requirements of sustainable facade design criteria which were used as evaluation parameters in other different sustainable facade design studies and extracted Also from the literature review that have been done through the thesis study.

In order to evaluate the buildings according to the parameters, necessary data about each building were collected. The data of the buildings was accomplished with mixed-method by contacting the building's relevant companies, scanning resources, and examining the buildings with bare eyes.

Resource scanning of the buildings was fulfilled by investigating the articles, magazines, newspapers, and research papers, etc. that provide information about the building. Also by reviewing the website of the building, and the authorized companies such as (The firm of the architectural offices that designed the building, the facade manufacturers company, etc.).

The weak and strong aspects of the examined high-rise buildings facades were discussed within the scope of the evaluation. Finally, it was achieved to a score for every building according to the scoring system which was created within the study.

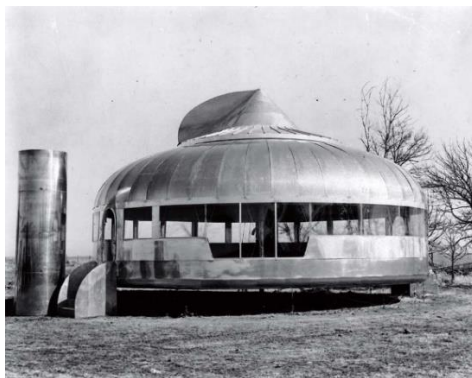
As a result, evaluation charts for each parameter were extracted from the collected data, founding out the consideration percent for each parameter. Consequently, the examined high-rise buildings were ordered according to their sustainability. Finally, taking into account the strong aspects of the evaluation results, a proposal has been made to create a substructure for future studies.

## 2. THE CONCEPT OF SUSTAINABILITY AND ITS HISTORICAL BACKGROUND

Through the history of human development, until the industrial revolution, manufacturing styles and quantities did not create negative effects on nature. However, after the industrial revolution in a capitalist order, the manufacturing and resource utilization approaches of the industry and the consumption forms, developed in parallel with this, have brought the negative effects of the human on the environment to an alarming level (Tekeli & Atöv, 2017). Therefore, it turns out that the lifestyle of consumers harms the balance of nature, as the amount of consumption has increased despite the decrease in production. Which led them to find a new system of life. So the term sustainability, which means continuity, appeared.

### 2.1. SUSTAINABILITY AND ITS APPEARANCE IN HISTORY

The origin of sustainability goes back to the 1940s. When Buckminster Fuller built the Dymaxion House and Cyclatron Geodesic Dome as a “self-sustaining” design call, in the 1940s and 1950s. Fuller is an American architect dealing with new forms of technology. His designs are based on the rule of doing more with less. According to Buckminster’s dictum, “The imperative is to do more in less”, in case of the demand of producing more energy, then, the cleanest way to produce that energy should be considered. Because there is a direct relationship between the pollution that occurred from producing energy and climate change (Mimarlıkta Malzeme, 2012).



**Image 2.1:** Dymaxion House (Url-3).



**Image 2.2:** Cyclatron Geodesic Dome (Url-4).

Subsequently, local and international organizations held by the United Nations play an important role in the formation of today’s definition of sustainability. The chronology of the building blocks related to the growth of the sustainable development approach is shown in the (Table 2.1) below;

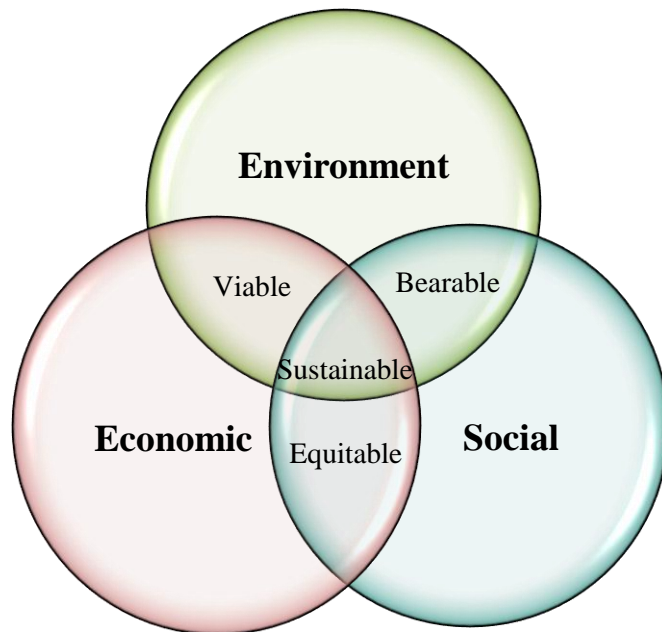
**Table 2.1:** Chronological Development of the Sustainable Development Approach (Karakurt, 2019).



However, the first definition of the concept of sustainable development, as used today, was made in the Common Future Report published in 1987 by the World Environment and Development Commission. Due to the Common Future Report, Sustainability is the maintenance of natural resources by controlling current resources usage to avoid the planet running out of them. So, it is important to mention that if the resources run out, the planet will corrupt in the future. Therefore, we have to control our usage in the present to save the planet for future generations.

There are more than 300 definitions for the term “Sustainability”, but the most accepted one is the definition of the Brundtland Report (1987), “Sustainable development means meeting presents requirements without compromising the needs of future generations” (Brundtland, 1987).

This report also mentioned the three dimensions of sustainability, social, environment and economy (Image 2.3). The sustainable part is where the three intersect. Therefore, the “Sustainability” term can not be mentioned without talking about the economy, social system and the environment (Sorguç, 2009, p. 39).



**Image 2.3:** The 3 Pillars of Sustainability (Von Keyserlingk, 2013).

## 2.2. ECOLOGY AND ITS APPEARANCE IN HISTORY

The term Ecology is defined for the first time by the German biologist Ernst Haeckel in his book (General Morphology), written in 1866 on philosophy and resurrection. This new term is derived from the Greek words “Oikos”, and “Logos”. Which means “Oikos” house, and “Logos” science. Then, it was translated to English as “Ecology”.

**Ecology:** (noun) used also as “Oecology” (eco+logy). “It is a living science that deals with the interrelationships between living things and their environment” (Sevgi, 2015).

Ecology is an approach that treats each entity with its environment and evaluates its relations with other living things. To indicate this approach, the ecological word or (eco) abbreviation, has been used in various research fields as a prefix. Accordingly, there are many physical problems experienced during the 20<sup>th</sup> century.

The rapidly expanding and strengthening technological advances and the widening of the activity area of the human have caused many negative consequences that threaten the living environment of human beings and other living creatures (Atıcı 2002).

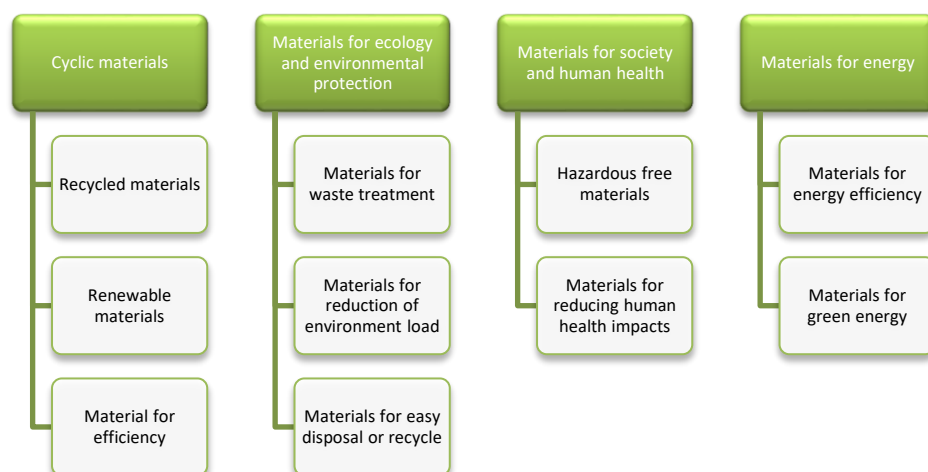
### 2.2.1. Eco-materials Definition and Classification

Eco-materials were defined by Halada and Yamamoto (2001) at (Modul H) book as, “Those materials that improve the environment’s perfection during the whole life cycle with preserving its responsible effectiveness” (Yamamoto et. al.). Furthermore, in North America and Europe, eco-materials are frequently called “environmentally-friendly materials” or “environmentally preferable materials”.

On the other hand, according to Professor Yagi, (2002), an eco-material should pass at least one of ten principal properties compared to traditional materials (Yamamoto et. al.). These properties are: 1- Energy saving ability, 2- Resource saving ability, 3- Reusability, 4- Recyclability, 5- Structural reliability, 6- Chemical stability, 7- Biological safety ability, 8- Substitutability, 9- Amenity, and 10- Cleanability.

Moreover, eco-materials were classified within the sustainability concept, following these four sustainable principles; 1- Cyclic materials, 2- Materials for ecology and environmental protection, 3- Materials for society and human health, and 4- Materials for energy (Yamamoto et. al.). After that, ten sub-categories were extracted from these four main categories. Sub-categories were like it is shown at (Table 2.2);

**Table 2.2:** Some Examples Of Eco-Materials Which Are Currently Commercialized In Japan) (Yamamoto et. al.).



Accordingly, ecological materials are mostly reusable, renewable, or recyclable/recycled materials. Examples of such materials can be shown like; sheep wool, paper panels, compacted soil, adobe, terracotta, clay, flax, hemp, seaweed, cork, wood, fiber, sandstone, rubble, timber, reusable brick, cut stones, volcanic pumice stone, linoleum, straw bales for insulation, polyurethane blocks.

Although bamboo is an environmentally friendly material growing quickly, it is not a material growing in Turkey. In this case, it is not considered as an eco-material in Turkey. Thus, it is only ecological in terms of the environment in which it grows. So, according to the geographical location of the buildings, their ecological meanings and the use of appropriate ecological materials also differ for each environment (Aytis & Polatkan, 2010).

### 2.3. SUSTAINABLE BUILDING MATERIALS

The sustainability of material is the main component of sustainable architecture. By adapting the concept of “sustainability”, which aims to protect the artificial and natural environment by ensuring the continuity of the resources, to the building materials, the concept of “sustainable building material” comes out.

Sustainable building materials are defined by Orhun (2012) as, “materials harmless to the environment and human health during their life cycle, which includes, consume minimal energy, obtain raw materials, process them, use them, maintain and repair and waste phases” (Orhun, 2012).

The energy used and the amount of CO<sub>2</sub> released into the atmosphere during the manufacture of a product or service are important indicators in terms of sustainability. These indicators are defined as follows:

**Embedded Energy:** It is the total amount of energy used during the production of the material.

**Embedded CO<sub>2</sub>:** Defines the amount of CO<sub>2</sub> (Carbon dioxide) released into the atmosphere during the production of the material. It is known also as (CO<sub>2</sub> emissions - Carbon emission - Carbon footprint) (Orhun, 2015).

The concept of sustainability in terms of materials can be divided into two groups:

- Direct acquisition approaches.
- Indirect acquisition approaches.

**Direct acquisition approaches:**

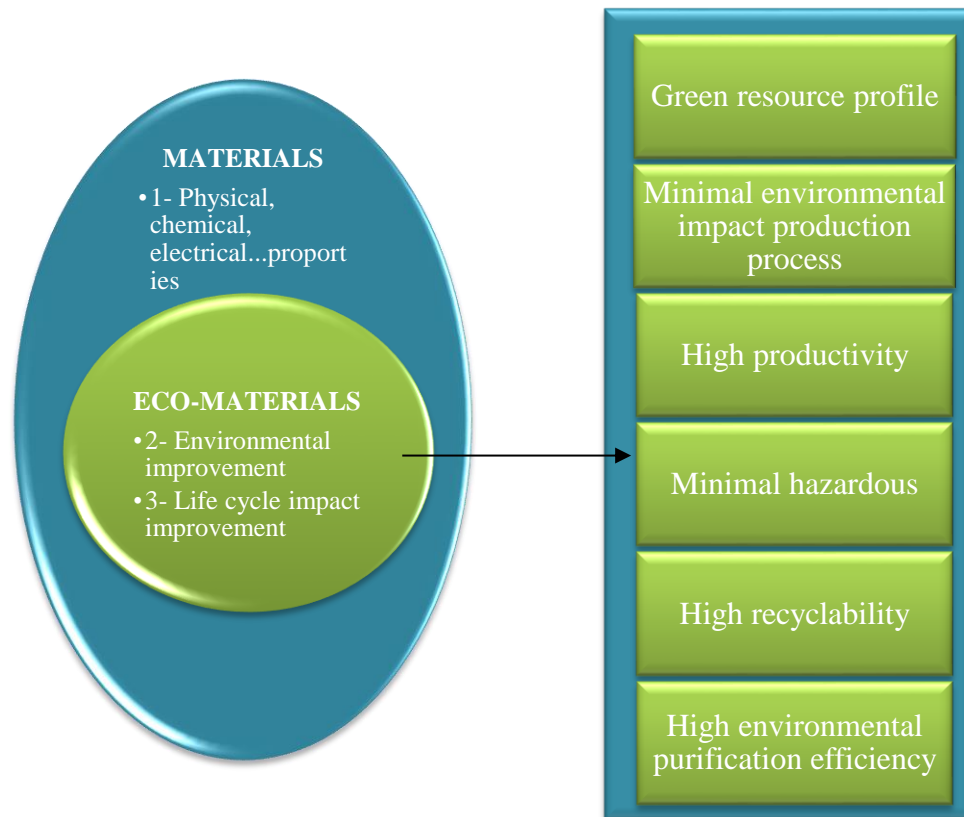
The approaches that aim to increase the sustainability of building material/components during the production processes. All sustainability approaches that reduce the embedded CO<sub>2</sub> (and hence embedded energy) value in the construction process of the material or component fall into this group.

**Indirect acquisition approaches:**

The approaches that aim to increase the sustainability of building in the usage process by using building material/components in accordance with its nature. All approaches that take into account the nature of the material to make buildings effective during the design process are included in this group (Orhun, 2015).

However, according to Shinohara (2004), if any material could fulfill the preconditions (1) and the required circumstances of eco-materials (1 and/or 2), then it could be an eco-material (Shinohara, 2004), as it is shown at the (Table 2.3) below;

**Table 2.3:** Conceptual Model Of Eco-Materials Within The Context Of Material Science (Nowosielski et. al., 2007).



However, in order to save energy spent between the production and the construction area, it is important to be noted whether the material used in the buildings is in the immediate vicinity. For example, traditional building techniques and vernacular structures that used local materials are natural and spontaneous sustainable structures, as they are completely a product of their environment (Aytis & Polatkan, 2010).

#### 2.4. SUSTAINABLE ARCHITECTURE AND CERTIFICATIONS

The methods of application of the sustainability concept, which is put forward as a solution proposal for human and environmental health problems, are discussed in the field of architecture as in many other disciplines.

Furthermore, Aysin Sev (2009) has defined sustainable architecture as;

“Sustainable architecture is to design buildings that protect the health and comfort of people, prioritizing the use of renewable energy sources, using energy, water, materials and the area where it is located, efficiently. Taking into consideration the future generations, in the conditions it is in and in every period of its existence” (Sev, 2009).

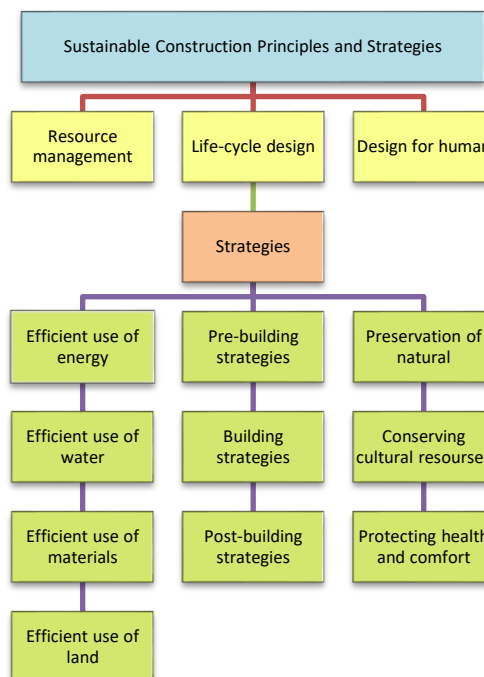
According to Sev (2009), we can gather the principles of sustainable architecture under three headings;

**Resource management principle;** It foresees reduction of resource use, reuse and recycling of resources.

**Life-cycle design principle;** It enables the analysis of the building’s effects on its existence and its surroundings.

**Design for human principle;** It focuses on the relationships between people and the natural world (Zinzade, 2010).

**Table 2.4:** Framework For Evaluating Sustainability Of The Construction Industry (Sev, 2009).



To design and operate a healthy building environment that holds on ecological resources, some principles should be considered during the construction and design process of the building aiming to achieve the basic target of sustainable architecture (Solmaz & Kaya, 2015).

These principles are:

- Effective use of building land and resources.
- Efficient use of energy.
- Efficient use of water.
- Efficient use of materials.
- Provide interior comfort and observance of human health.
- Waste management.

Sustainable architecture concept, including ecological environment, social and economic concepts, aiming to control the building's negative effects on the environment. Therefore, these concepts are used to measure and define the sustainability of the building.

In order to measure and evaluate the environmental impact of buildings, a wide range of certain evaluation criteria is used. These evaluation methods can be categorized in three ways;

- Tools and information sources to compare products and components used in building construction.
- Supporting databases used in the design and decision stages of the whole structure.
- Environmental assessment methods that take the structure as a whole (Solmaz & Kaya, 2015).

Furthermore, in different countries, organizations based on volunteering studies conducted, in order to measure and evaluate the environmental impacts of buildings, within the framework of certain criteria. As of 2012, there are 27 different methods developed in different countries.

Apart from sustainable building certification systems, BREEAM in the UK, and LEED in America, which are popularly used in the world, many sustainable building certification systems, such as SBTOOL, HK-BEAM and CEPAS used in Hong Kong, SBAT used in South Africa, GREEN STAR used in Australia, and CASBEE used in Japan, emerged in Canada but defined itself as an international system.

While the purpose of these certification systems is to create a unique system by considering each country's local standards, climatic data and living conditions. With the international identity of LEED and BREEAM evaluation systems, countries that do not have their own evaluation system have accepted these two certification systems as an evaluation system. Today, in many countries that are members of the World Green Building Council (WGBC), SBTool also has been adapted to the local standards in various countries as well as BREEAM, LEED, Green Star and CASBEE systems (Aytis & Polatkan, 2010).

The most popular evaluation organizations ( LEED - BREEAM – SB TOOL – CASBEE). These organizations are categorized under environmental assessment methods that take the structure as a whole evaluation method.

These methods, which consider the whole structure within the life processes it has undergone, assess within the framework of the determined criteria and present a certificate as a result. Because there is no local certification system in Turkey, the most accepted certification systems in the world LEED and BREEAM systems are used (Solmaz & Kaya, 2015).

## 2.5. SKYSCRAPER AND ITS APPEARANCE IN HISTORY

The skyscraper term is used for the giant size building or tower in terms of height. High-rise buildings have different definitions. According to the famous engineer Ali Armstrong, the multi-storey structure/high-rise building are buildings where, fast elevators are used, the carrier system is specially designed, the ones that reflect the urban physical economic and technological power

In the 21<sup>st</sup> century, buildings higher than 100 m are considered as skyscrapers. These kinds of structures appeared for the first time in the USA in the 1880s, in 1890 the Pulitzer building reached 26 floors and 94 meters. It was impossible to go beyond this with traditional building materials. Subsequent developments accelerated with the presenting of the steel structure system.

Next developments like materials (Steel, reinforced concrete), vehicles (elevator), new construction and lifting techniques, started from the end 19<sup>th</sup> century, facilitated the construction of higher buildings. The first tall structures were mostly symbolic.

For the history of skyscrapers, it is necessary to look at the USA, especially Chicago and New York City. In combination with the industrial production of steel, the development of glass and reinforced concrete, the development of elevators, other vehicles and water pumps, in addition to the fact that the land is less and expensive in urban centers, the passion of people to build high buildings for prestige, combined with the ambition of engineers, were main reasons that caused a skyscrapers race, started in USA, primarily in Chicago and NY Cities.

The tallest skyscraper before WWI is the C. Gilbert's Woolworth building (240 m) in New York. Later, in 1930-1931, the Empire State Building was built again in NY (380 m). The height of the sharp endpoint of this building reaches 449 m. Subsequently, buildings built through the later years, the Rockefeller Center (259 m, NY 1940), the 100-storey John Hancock-Center (344 m, Chicago, 1968), the 110-storey World Trade Center twin towers (417 and 415 m, NY, 1973, destroyed in 2001), Sears building (442 m, Chicago, 1974) and Petronas towers (452 m, 1998) in Kuala Lumpur are among the famous skyscrapers of the 20<sup>th</sup> century (Hasol, 2014, p. 188-190).

Burj Khalifa (828 m), which was completed in 2010, is at the top of this list. Skyland Office Tower in Istanbul (284 m) is the highest skyscraper in Turkey now (Url-5). Kizilay in Ankara Emek Building (24th floor, 76 m, 1959-1965) is considered as the first skyscraper in Turkey, therefore, in Ankara, it still named as “Skyscraper” (Hasol, 2014).

Recently, the number of skyscrapers primarily in Istanbul is increasing rapidly in Turkey. A density and highness contest continues with plot decisions based on parcels, far from holistic planning and urban planning.

In general, high-quality concrete and steel, post-stress, corrosion-resistant reinforcement, fire-resistant steels, cast parts, mixed systems and composite materials are technological determinants in today’s skyscraper designs.

From an architectural perspective, in the 21<sup>st</sup> century, performance-based design, delicacy, structural expression, advanced technology, free architectural form (sculptural appearance), green character and transparency are at the forefront (Hasol, 2014).

### **2.5.1. Skyscraper Classification Within Functionality and Height**

The Emporis site (Url-6), which analyzes tall buildings, defines 12-storey and 35m-high structures as multi-storey buildings. German Research Centers accept 22m and above as a high building. The Council on Tall Building and Urban Habitat (CTBUH) in America, states that 14-storey buildings do not count as high-rise in places such as Chicago and New York, where multi-storey buildings are dense, while it can be described as high-rise building in many cities of Europe. In addition, over than 300m high structures are described as “Super High” and over than 600m structures as “Mega High” structures (Eren, 2019).

#### **Building Use In Terms Of Function:**

If more than fifty percent of the building height is designed as a usage area, the building enters the skyscrapers category. If not, the building falls into the tower class (Such as a cruise tower or communications antenna).

Tall buildings are also classified according to their usage functions (Sağlam, 2016).

- **Single Function Buildings:**

At least 85% of the total floor area is designed for the same use function (Like an office).

- **Mixed Function Buildings:**

In the high building, if there are two or more different usage areas, the building has a mixed function. Sports areas with supportive areas, parking areas, and sanitary installation areas do not change this description.

## 2.6. SKYSCRAPER ARCHITECTURE WITHIN SUSTAINABILITY CONCEPT

In the 21<sup>st</sup> century, the concept of sustainability in architecture is often mentioned through skyscrapers. Especially since skyscrapers have larger scales and larger numbers of people than other buildings, the impact of them on the city and the environmental effects they create are higher.

Moreover, skyscrapers can create unhealthy conditions in the city by blocking the sunlight of the buildings and living organisms in their surroundings, bringing loads of traffic, installation and communication infrastructure to the city due to the large number of users, and may cause the formation of unpleasant strong winds for pedestrians by changing the wind movements of the region where they are built.

On the other hand, skyscrapers are also buildings in which the heating-cooling-ventilation, mechanical, circulation and lighting systems are required, and both the initial investment cost and the cost during the use of the building are higher than other buildings.

Internationally, there are two different views on the sustainability of skyscrapers (Begeç & Yalınar, 2017).

The first one as Wood (2014) stated is that the skyscrapers are naturally sustainable, prevent the urban sprawl and grow vertically by providing a high settlement density, which reduces the transportation costs and the economy of the building.

The second is that a large amount of energy is consumed during the construction of skyscrapers and is not sustainable because of its negative effects on the city's systems (Wood, 2014).

Within architecture, the necessity of three methods for low energy consumption is mentioned. These methods include; material and component selection, supplier economies (including a life cycle approach from the source to the waste water channel), and the basic design. As a non-traditional building type, the high-rise building needs its own design setup and principles based on the design of new service systems, based on the climatic data (Sarı, 2016).

From the second point of view, we may see that the image of the skyscrapers is not in the sense of sustainable architecture, even though we can see that the newly built skyscrapers use renewable energy sources with the help of the developing technology.

Briefly, sustainable high-rise building, is a structure that is sensitive to resource use in every period, observes the health and comfort of the user, does not create environmental pollution, does not impose an unnecessary burden on the infrastructure of its location and fulfills all these criteria economically (Kıasif & Selçuk, 2016).

## 2.7. SKYSCRAPER FACADE DESIGN WITHIN SUSTAINABILITY CONCEPT

Facade systems have a great role in creating healthy and comfortable use areas by protecting the interior from the negative effects of the external environment conditions as well as contributing aesthetically to the architectural forming of a building.

### **SKYSCRAPER FACADE SYSTEMS:**

- **Metal Facade Systems;**

The main reasons for the application of metal facade systems in multi-storey buildings are; easy to assemble, require low maintenance, and allow for individual design.

In case of the increase in the height of the building, due to the increase of the effect of the wind on the facade, the wind absorption level of the coating during the design, the

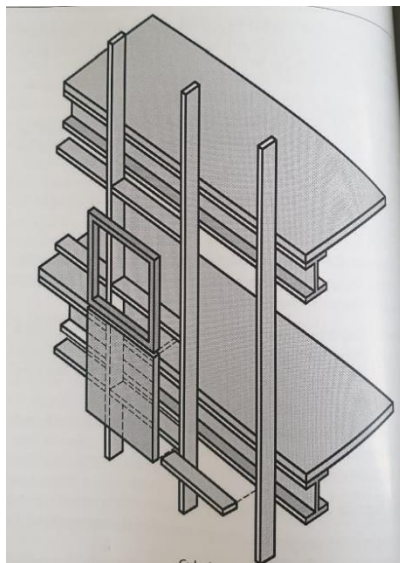
corrosion resistance due to the structure of the metal and elongation levels under the influence of heat, etc. should be taken into consideration (Eren, 2019).

**Metal facade elements consist of three main parts. These;**

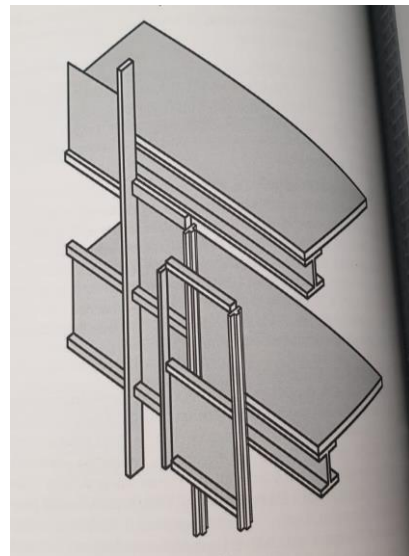
1. Panels
2. Carrier structure
3. The joints that connect the panels together.

- **Curtain Wall Systems:**

Curtain wall systems are made of a carrier skeleton. It is made of fasteners and facade panels used to fix the skeleton to the carrier system of the structure. Curtain walls can be produced in three different ways as strip systems, half panels, and panel systems. The most widely used system is the strip systems (Eren, 2019).



**Image 2.4:** Strip System (Eren, 2019).



**Image 2.5:** Panel System (Eren, 2019).

- **Glass Facades In Steel High-Rise Buildings:**

In steel structures, glass facade panels are used to take natural light into the interior, to hamper the system, etc. There is a common use area for reasons.

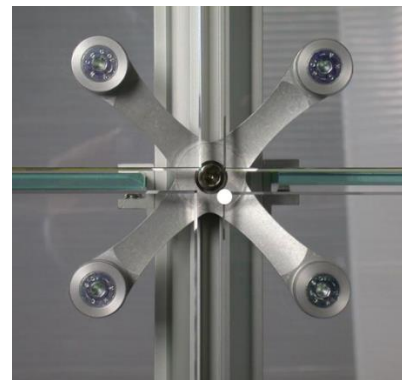
There is a widespread usage area of the glass facade because it allows the natural light penetration inside and it lightens the system, etc.

There are many different shapes of spider glass holders from point connection applications (Image 2.6-7).

Before the application starts, designs of anchorage elements should be made after the studies depending on the regional climate conditions and the direction of the building. It should not be forgotten that the use of sliding bearings against horizontal loads should be used in all facade applications, especially in multi-storey buildings (Eren, 2019).



**Image 2.6:** Spider Glass Facade (Url-7).



**Image 2.7:** Spider Glass Facade Detail (Url-8).

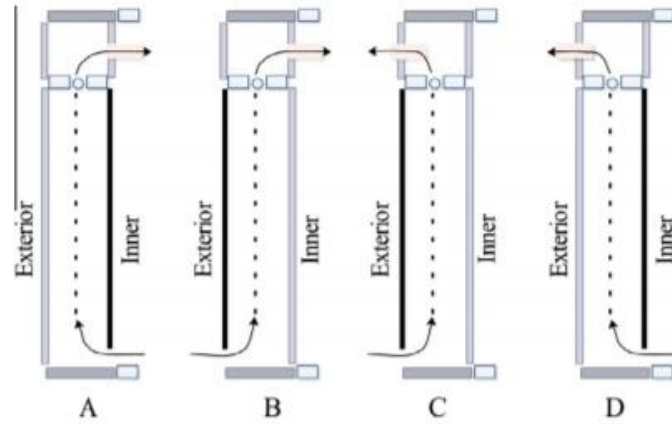
- **Double-Skin Facade-(DSF):**

The Double-skin facade systems, which gained common use in multi-storey buildings, are the energy-saving facade systems that are arranged in different ways by leaving a space called an air corridor between two facade shells between 20cm and 2m.

The control elements used to prevent the unwanted effect of the sun's rays are placed between the two shells and it is ensured that the use of the daylight is protected from the undesired effect.

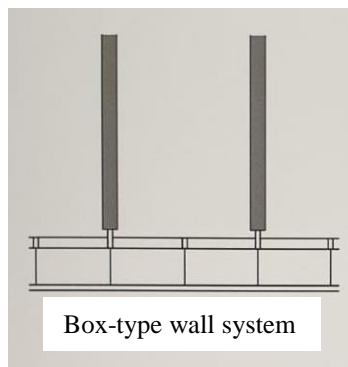
The second facade layer in the system allows windows to be opened on the upper floors, despite the strong wind pressure in high-rise buildings. Thus, natural ventilation (Image 2.8) of the office significantly contributes to saving the building user's energy consumption (Eren, 2019).

- **Box-Type Double-Skin Facade:**

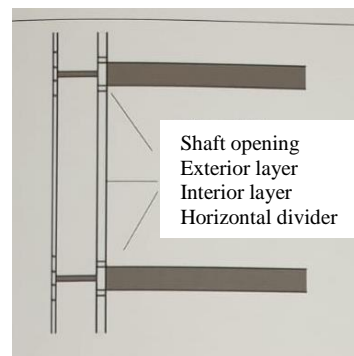


**Image 2.8:** Schematic Of The Working Modes Of Double-Skin Facade: A- Inner Circulation Mode, B- Supply Mode, C- Inner Circulation Mode, D- Exhaust Mode (Zhang et. al., 2016).

Box-type windows are the oldest form of Double-skin facades. It is the panel with vents that provide air inlet and outlet at the top and bottom of the panels consisting of double glass inside and single glass outside. In these floor-height systems, laminated single glass on the outside and double insulated glass on the inside are used. Between the two shells, there is 200-400 mm of space, which depends only on the size of the window. Shutter elements can also be placed in this section if desired. Each panel works on its own without being associated with windows on other floors (Eren, 2019).



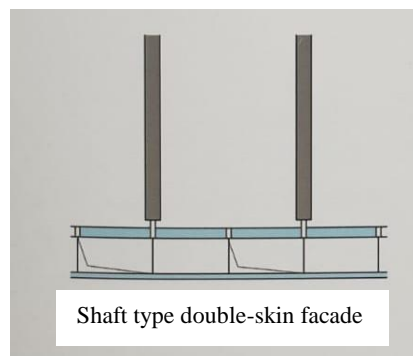
**Image 2.9:** Box-Type Wall System (Eren, 2019).



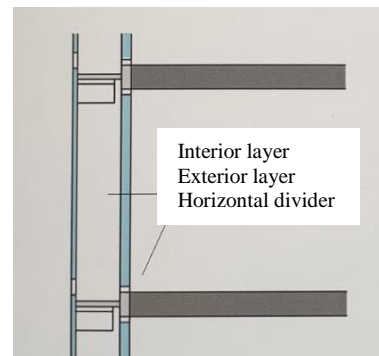
**Image 2.10:** Box-Type Wall System, Section (Eren, 2019).

- **Shaft Type Double-Skin Facades With Box Windows Proportional To The Floor Height:**

Chimney system works with box windows on shaft type box facades. The heated dirty air used in the spaces rises and is sent to the chimney from the outlets on the box windows, and thrown out of the exhaust vents at floor level inside the chimney. It takes the opposite of this process in the fresh air. The fresh air is taken from the lower part of the floor alignments to the chimney-shaft, and from there the box enters through the lower part of the window. At shaft type double-skin facades with box windows proportional to the floor height, the gap between two shell layers is interrupted at floor height. By placing grilles on each floor level, dirty air delivery and fresh air intake circulation is performed. Each floor is naturally ventilated by the operation of these grill systems within itself. Solar control elements are placed between the inner shell of the interior (Eren, 2019).



**Image 2.11:** Shaft Type Double-Skin Facade (Eren, 2019).



**Image 2.12:** Shaft Type Double-Skin Facade, Section (Eren, 2019).

- **Double-Skin Facades With Shutters Proportional To The Building Height:**

The double-skin facades with shutters proportional to the building height (Image 2.13-16) shows almost the same features as the multi-storey ventilated facades. While the outer shell is a louver system, the inner shell can be made from different systems.

Even when the louvered system in front of this facade is completely closed, there is no air impermeability (Eren, 2019).



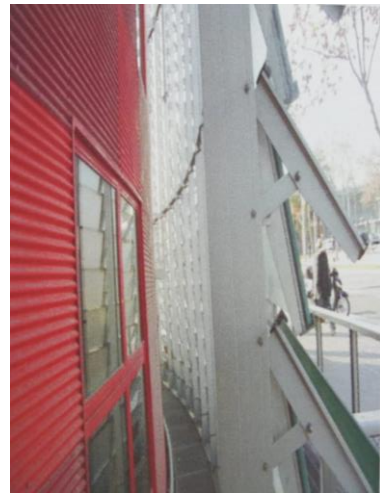
**Image 2.13:** Torre Agbar Tower's Double-Skin Facade Detail (Eren, 2019).



**Image 2.14:** Torre Agbar Tower's Double-Skin Facade Louvers (Eren, 2019).



**Image 2.15:** Torre Agbar Tower's Double-Skin Facade Shutters Detail (Eren, 2019).

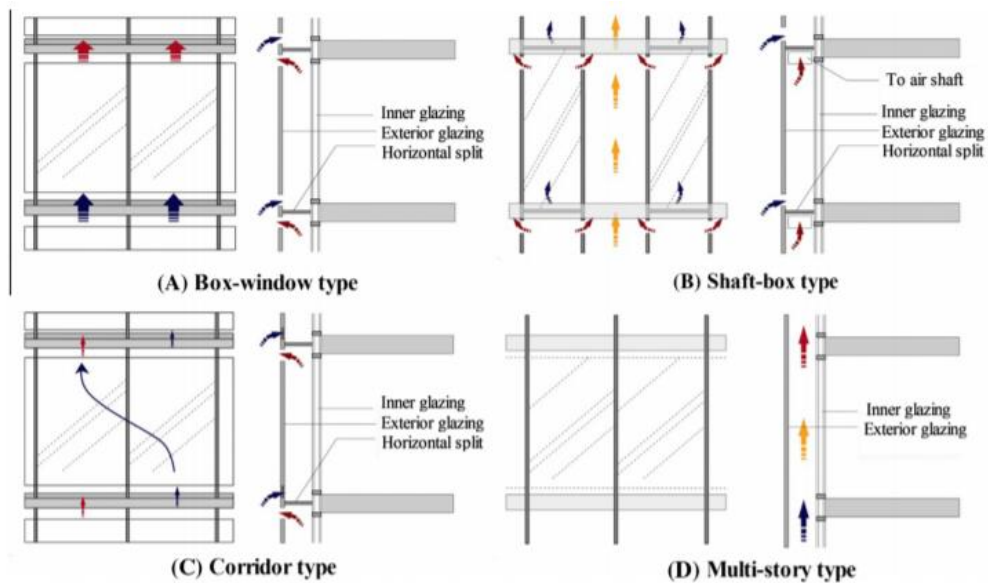


**Image 2.16:** Torre Agbar Tower's Double-Skin Facade, The Gap Between Inner And Outer Shells (Eren, 2019).

- **Corridor Type Double-Skin Facade:**

Corridor facade is the type of facade where two facade layers are divided by the floor alignments. Air exchange in the facade cavity can be done vertically and/or horizontally at the floor level from the corners of the building.

If the Double-skin facade is ventilated horizontally, the pressure in the facade cavity must be kept under control. In this way, the facade grilles are designed to be controlled according to the desired pressure level, wind direction, and speed. This reduces the energy cost required for ventilation by making it suitable for certain pressure conditions in the building (Eren, 2019).



**Image 2.17:** Different Connection Typed Of Double-Skin Facades (Zhang et. al., 2016).

**Performance criteria expected from all facade systems are as follows;**

- At the junction of the facade with spaces such as body and window-door, heat bridges should be designed to be minimized.
- The heat retention properties of the materials used in the construction of the facade elements should be high.
- Details should be designed to prevent metal facade panels from rubbing against each other and making noise.
- The performance of the joint panels arranged between the panel-panel, panel-carrier system, etc. of the facade panels should be high against water, sound, and heat.
- In order for the fire resistance of the facade panels to be high, special attention should be paid to choosing the insulation materials used behind the façade, which are highly fire-resistant (Eren, 2019).

Moreover, curtain walls, one of the most preferred facade systems in high-rise buildings, have ceased to be passive elements with the help of advancing technology. Furthermore, natural ventilation and natural lighting are provided with bioclimatic facade designs. Thus, large savings are obtained from the energy consumed in order to meet the building's transfer and lighting needs.

The control of the heat, light and sound transition between the indoor and outdoor environment is provided with the energy-efficient facade design, and the negative features of the outdoor environment are filtered like a strainer.

Energy-efficient facades are created with energy-producing facade systems such as the right glass selection, double-glazed facade systems, structural silicon facades, solar collectors and photovoltaic panels (Kıasif & Selçuk, 2016 ).

Therefore, functional, structural, aesthetic, cultural and environmental factors should be taken into consideration while designing the facade of the building. In terms of sustainability, environmental factors such as heat, light and sound are important factors in the design of the building facade (Alakavuk, et. al., 2015).

Depending on environmental factors, the main functions of the building facade are:

- Providing thermal comfort by controlling the effects of climatic elements.
- Providing visual comfort by controlling natural light.
- Providing auditory comfort by reducing the noise to an acceptable level (Oral et.al., 2004).

“Comfort can be defined as; achieve the highest level of satisfaction by consuming the least amount of energy physically, under the conditions facing the human being” (Sezer, 2004).

### **2.7.1. Bioclimatic Design:**

Bioclimatic Design is an effective approach that can provide the best way of climatic comfort of the people with minimum energy. While aiming to reduce energy consumption through passive methods, it also achieves important results in terms of sustainability by considering material selection and conservation of natural energy resources (Kıasif & Selçuk, 2016).

Ken Yeang, an English-based Malaysian architect, who is one of the most well-known names in bioclimatic architecture worldwide, defined the high bioclimatic structure as follows; “It is a type of structure that uses passive, low energy techniques, interacts with the natural environment, according to the meteorological and climatic data of the region, and uses less energy during its construction and operation.” (Yeang, 2012).

On the other hand, high building models, box-shaped have the same four-sided facade characteristics, regardless of the climate and region factors for long periods, were encountered. whereas buildings must have forms and facade systems adaptive with their different meteorological, physical and geographical conditions (Kıasif & Selçuk, 2016).

### **2.7.2. Passive Design Method**

The passive design method is actually bioclimatic design and it requires understanding the climate of the region in order to take advantage of the energies and climate features in the immediate surroundings. Passive design method systems

provide heat comfort by using natural energy sources and basins like solar radiation, indoor air humid surfaces, activation, internal gains, etc. The energy flow in these systems occurs by using natural tools such as radiation transmission and convection without using mechanical tools.

The human's demand for an external energy source is concentrated on fossil fuels today. Approximately 40-50% of the energy distribution is used in buildings and 50% of total carbon dioxide emissions are caused by buildings. 60% of carbon dioxide emissions associated with buildings can be attributed to the activities of the residential sector and about 30% to the service sector (public and commercial buildings) (Yeang, 2012).

**Table 2.5:** Energy Index (EE) And Carbon Dioxide (CO<sub>2</sub>) Emission Index For Residential Buildings (Yeang, 2012).

Design Features		Self-contained 100-150 m <sup>2</sup>
<b>Example case;</b> A "fictitious" building of randomly oriented compact form (in accordance with 1990's construction legislation)	EE kW/m <sup>2</sup> CO <sub>2</sub> kg/m <sup>2</sup>	100-115 25-29
<b>1. Step;</b> Most windows face south; no shading	EE kW/m <sup>2</sup> CO <sub>2</sub> kg/m <sup>2</sup>	85-100 25-30
<b>2. Step;</b> In addition to the above features, all windows are double glazed (0.75 ac/h).	EE kW/m <sup>2</sup> CO <sub>2</sub> kg/m <sup>2</sup>	55-65 17-20
<b>3. Step;</b> All windows have insulated night shutters or double glazing with heat control (Low E) coating; window area according to instructions	EE kW/m <sup>2</sup> CO <sub>2</sub> kg/m <sup>2</sup>	50-60 15-18
<b>4. Step;</b> In addition to the above features, external insulation (U-0.25)	EE kW/m <sup>2</sup> CO <sub>2</sub> kg/m <sup>2</sup>	35-40 11-12
<b>5. Step;</b> In addition to the above features, mechanical ventilation and heat recovery (0.5 ac/h)	EE kW/m <sup>2</sup> CO <sub>2</sub> kg/m <sup>2</sup>	<30 <9

However, Passive design method strategies require proper formatting in conjunction with the elements, the solar orbit of the building, usage of natural ventilation, planting - landscape, appropriate facade design, sun shading, etc. (Yeang, 2012).

Some passive methods that can be applied in buildings to meet the inner comfort requirement are listed below. These conditions can also be met by efficient or mixed-method systems powered by ecologically sustainable forms of energy:

- Building orientation (main facades, openings, etc.).
- Shell and facade design (window opening size, layout details).
- Solar control elements (Ex. shading for facades and windows).
- Passive daylight concepts.
- Wind and natural ventilation.
- Roof landscape.
- Building envelope color.
- Landscape arrangement (planting).
- Passive cooling systems.
- Building mass.

### **2.7.3. Energy Efficient Building Design**

The history of architecture has been referring to the connection between the building form and the climate. Tall buildings are buildings that are highly exposed to the sun and wind. Accordingly, it is argued that the most suitable climate for high-rise buildings is the temperate climate compared to the cold one. The high-rise building benefits from natural heating as well as the effect of a large solar collector. It is difficult to say that a high-rise building is energy-efficient in hot climates; The high-rise building acts like a permanent solar collector and therefore requires large quantities of air conditioning throughout the year. Climate issues that concern high-rise buildings are not only limited to the sun, but wind also appears to be an important factor. Many of the high-rise buildings built in temperate climates develop a design to take

advantage of the dominant winds. The main concept enables the use of wind energy as natural ventilation and cooling (Sari, 2016).

However, architects have to think about how building design can generate energy, how to manage it, how to consume it, and how to conserve it. Moreover, structures must acquire and process renewable energy, consume and conserve energy as efficiently as possible (Farrelly, 2017).

Ecologically sustainable design in high-rise buildings covers the designs that are; environmentally friendly, minimizing energy consumption, reducing the use of natural resources, using renewable and local resources, creating healthy interior spaces, using solar energy, using **natural ventilation** and **natural lighting**, using **reusable and recyclable materials**, that do not require frequent maintenance and repair (Sari, 2016).

The following principles are aim through energy-efficient building design to:

- Reducing unnecessary heat gains and losses by increasing energy conservation.
- Combination of passive and active air conditioning system.
- Preventing atmospheric pollution, climate imbalances, and ecological deterioration.
- Using more efficient and environmentally friendly renewable energy sources instead of expensive and scarce fossil-based resources.

Parameters that are effective in the energy-efficient building design process can be classified as the location of the building, building ranges, building orientation, building form, **building envelope**, **natural ventilation layout**. By making use of these parameters, it is possible to design buildings effectively, through passive and active systems (Demircan & Gültekin, 2015).

### 2.7.3.1. Facade Design Features Within Sun-Daylight Parameters

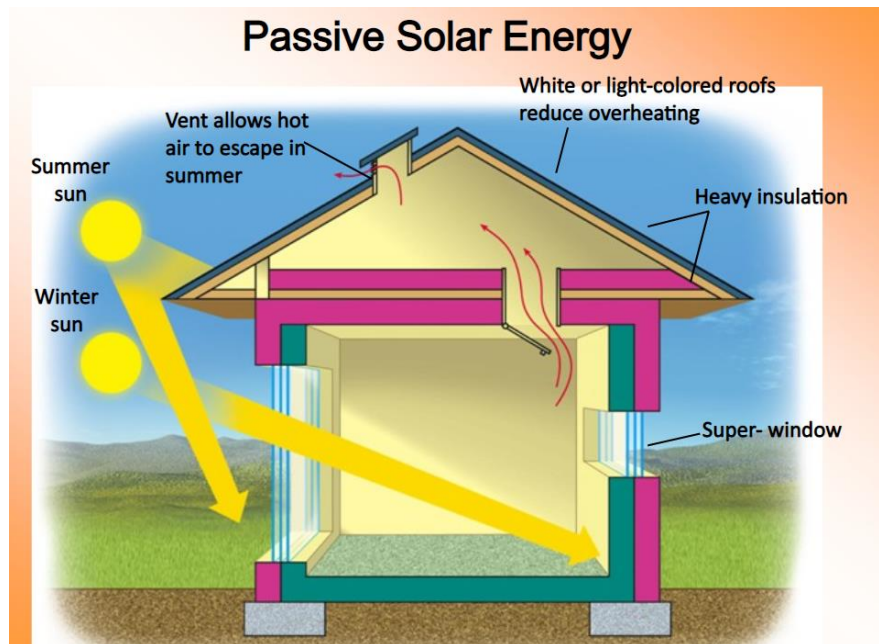
Solar energy is the most abundant among renewable resources. It can be said that solar energy is the most used renewable energy source for heating, cooling, lighting, and electricity generation in buildings. There are various alternatives for the use of solar energy in buildings. The most important of these alternatives are listed below (Demircan & Gültekin, 2015):

- Generating energy from the sun through passive solar systems (such as sunrooms and large glass surfaces designed in the south direction).
- Energy recovery from the sun (such as solar collectors and solar cells) and natural lighting through active solar systems.

As can be seen from the order above, the use of solar energy in buildings is classified as passive and active solar systems. The use of solar energy for heating the spaces during the design phase of the buildings is defined as “passive solar systems” and every technological product added to the design is defined as “active solar systems”.

- **Passive Sun Systems:**

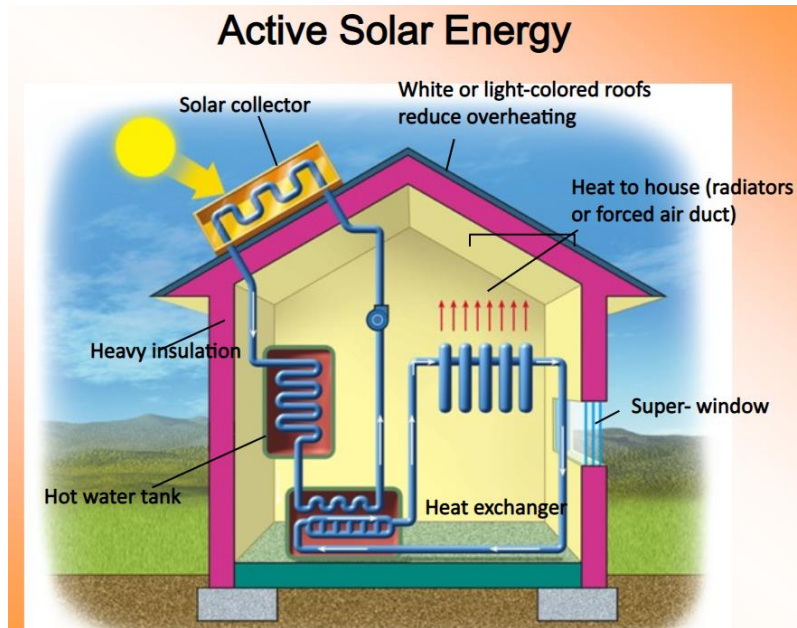
Since solar energy can be applied locally and does not require complex technology, it has been a preferred energy source in the construction industry in recent years. In addition to heating and cooling the building, solar energy is also used to obtain hot water and electrical energy. According to many countries, Turkey is in an advantageous position in terms of solar energy, the most common method of using solar energy in Turkey is through the solar collectors placed on the roof surface is obtaining hot water. Obtaining hot water from solar energy can be done by a decision made during the design phase of the building or it can be realized during the use of the building. By using solar energy, the heating and cooling costs of the building can be reduced significantly and energy conservation is provided.



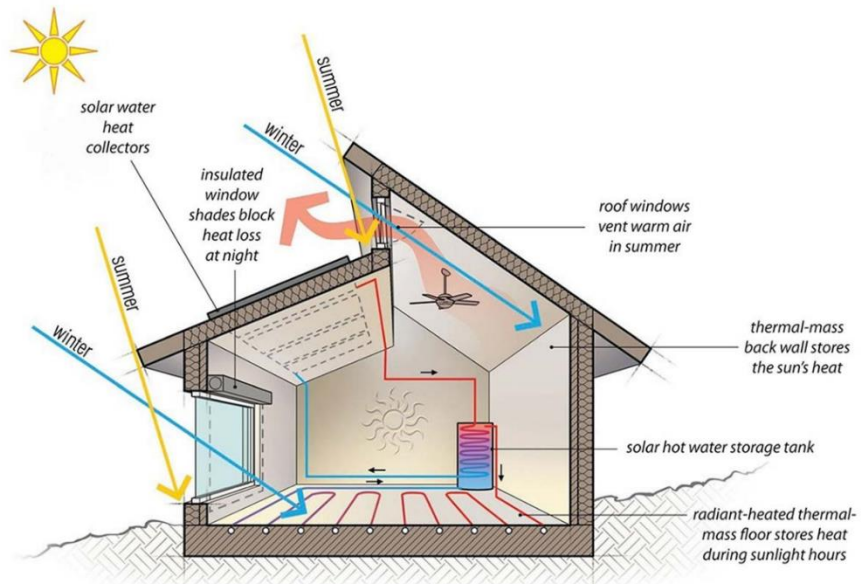
**Image 2.18:** Passive Solar Energy (Url-9).

- **Aktive Sun Systems:**

In order to utilize solar energy in buildings, supporting the applications with mechanical equipment and additional heat storage measures, controlling the heat distribution automatically, applying water-air collectors, and using high-efficiency collectors and solar cells are defined as “active solar systems”. In active systems that are not used directly for indoor heating purposes, solar energy is usually collected through collectors, the collected energy is stored adjacent to the building or at the lower elevations, and stored in pebbly areas, and the stored energy is distributed by means such as pumps and pipes, and the interiors are heated by hot water (Demircan & Gültekin, 2015).



**Image 2.19:** Active Solar Energy (Url-9).



**Image 2.20:** Active and Passive Solar Systems (Url-10).

- **Surface Color Of The Facade (Light-Dark):**

Building envelope (Facades - Roof) are exposed to the sunlight more than other building elements. Therefore, their sun-absorbing effects can be reduced by using light-colored material. The absorption and spreading properties of certain materials effectively protect the exterior wall from the radiation effect, especially in hot conditions. Materials that reflect the radiation instead of absorbing it and which release the absorbed heat more easily as heat radiation, allow the temperatures inside the building to decrease. The facade should be as light-colored as possible to alleviate overall air conditioning loads and reduce the heat island effect (Yeang, 2012).

- **Continuous Glass:**

The continuous panel system window, due to its large transparent surface, is better than the strip window in terms of daylight inlet. However, the architect should use a low emission coated glass to prevent the heat penetrating inside the building (Zeng et.al., 2012).



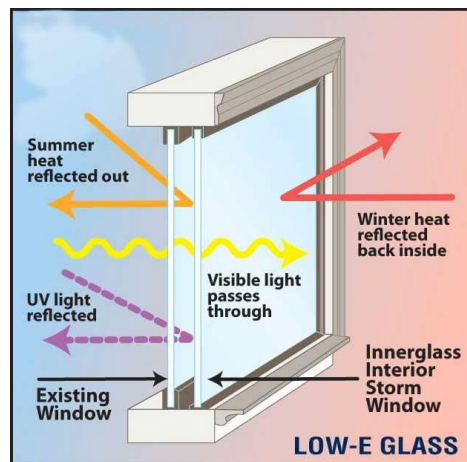
**Image 22:** Continuous Glass Facade (Url-11).

- **Double-Skin Facade:**

Double-skin facade (Image 2.8) formed by exterior and interior two facade types. The buffer zone formed between the interior and exterior shells is providing shading to the interior space of the building. Moreover, sun control elements can be placed within the buffer zone (K1as1f, 2015).

- **Low-E Coated Glass:**

Low emission glasses reduces the direct heat gain by allowing a greater ratio of the light pass compared to the heat pass, penetrating inside. It reflects heat back into space, reducing heat losses and looks the same as transparent glass. Therefore, it is useful in situations where sunlight is desired but solar heat gains are reduced. It also allows using slightly wider windows to allow daylight entry without having to pay a price for energy in winter (Yeang, 2012).



**Image 2.21:** Low-E Coated Glass (Url-12).

- **Reflective Glass:**

Sun reflective glass can reduce the sun inlet without affecting the appearance as much as heat-absorbing glass. Reflective glasses can be useful in situations where heat recovery is undesirable and external shading is not physically possible, especially on western facades (Yeang, 2012).

- **Insulation:**

Increased insulation is an effective and a passive method to reduce energy consumption in a building, especially in temperate climate it can reduce the heat bridges and leaks, and by increasing the external wall insulation we can reduce the ratio of solid surfaces to glass surfaces.

The current standard for external wall insulation nowadays for the temperate climate is  $0.45 \text{ W/M}^3\text{K}$ ,

So, the designer should aim while designing to reach lower insulation levels than this.

A single-glazed glass's heat loss rate is 10 times more than  $5.7 \text{ W/M}^3\text{K}$  which was recommended in building regulations. Thus, by using a double-glazed window this rate can be reduced to  $2.8 \text{ W/M}^3\text{K}$ , and a three-glazed window to  $2.0 \text{ W/M}^3\text{K}$ . However, by reducing the ratio of deaf surfaces to glass surfaces on the outer shell, the number given above could be decreased (Yeang, 2012).

- Skylight system to increase daylight:

- **Sky-Courtyards:**

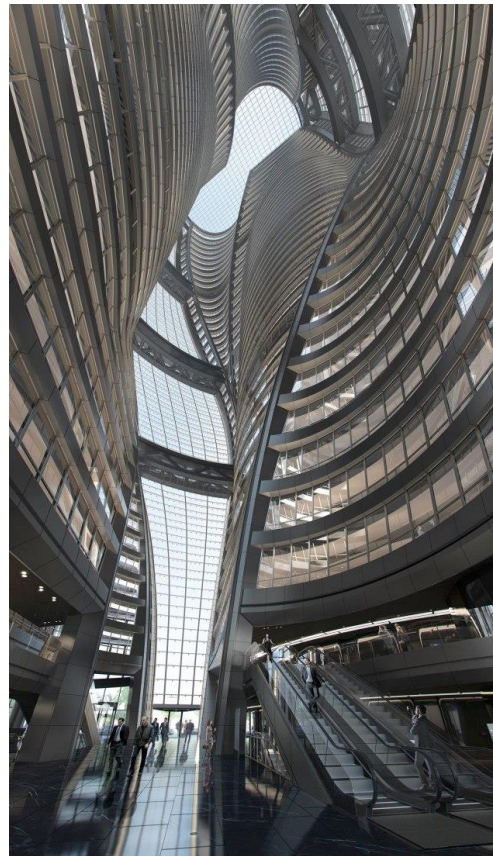
Sky-courtyards are formed by retracting on the facades, balconies, or withdrawing several floors together in order to protect against the undesired effects of the sun in high buildings. In addition to their bioclimatic functions, sky-courtyards create social spaces for users. Thus, a natural environment is created inside the building and comfort conditions are provided for the users (Kıasif & Selçuk, 2016).

- **Atriums:**

The atrium is the name given to the spaces inside the building. In inclined roofs, it provides shading and protection from rain, without preventing air from entering. In addition, the atriums provide natural daylight to workspaces. However, solar heat gains through windows in buildings can be reduced by blinds, balconies, deep recesses (such as retracted windows, etc.), or sky courtyards (Image 2.22,23) (Kıasif & Selçuk, 2016).



**Image 2.22:** Leeza SOHO Skyscraper, Zaha Hadid (Url-13).



**Image 2.23:** Leeza SOHO Skyscraper, Zaha Hadid, Atrium (Url-13).

- **Facade Shading Element:**

Shading should be designed to ensure both the passive passage of light reaches deeper parts of the floors and to reduce glare. This method allows the designer to use transparent glass and allows the daylight to enter the interior space better. Thus, lighting energy load is reduced and a better aesthetic relationship is established between the interior and exterior of the building.

However, the angle of the sun is different in summer and winter, so the designer should keep in mind these differences especially in temperate regions. Thus, in terms of ecologically efficient design, while designing a shading element, the region's solar path should be taken into consideration.

The external shading systems have many advantages such as:

- Can reduce the heat gain entering the space
- Can provide the space with fresh and clean air
- Can be used as a sound barrier
- Can contribute to the aesthetics of the building (Yeang, 2012).

Regardless of the location of the buildings, it is necessary to apply a number of vertical sun shading types, especially at the building's hot surfaces such as eastern and western facades, paying attention to the brightness and quality of the light entering the space.

The eastern facade must be shaded since it receives the morning sun.

However, the building that receives its sunlight from the western facade, has the maximum density at the hottest time of the day. In order to make optimum use of the facades, the angle control of the sun rays must be done correctly with computer-aided design programs (Yeang, 2012).

At high latitudes, fixed horizontal shading devices such as the console are very effective on southern facade windows. However, they have disadvantages because they work only depending on the height of the sun, regardless of the outside temperature. Hence, it can block beneficial sunlight in winter.

Fixed shading elements have been preferred mobile ones in the past, partly because of their simplicity, low cost, minimal maintenance, and limitation of human intervention in some respects. However, these are not as effective as moving canopy in shading buildings facing south.

Movable shading elements has two main advantages;

1. It provides maximum benefit from the sun and can be adapted to external conditions in order to protect it from glare and excessive heat gain.
2. Shading elements can be turned off in winter, in temperate areas, to reduce heat loss through radiation to the night sky in the building.

In temperate and cold regions, an adaptive facade is required, in residential buildings allowing the sun penetration through the windows to heat the interior space in winter, in offices reducing glare, and to reduce heat gain in the summer.

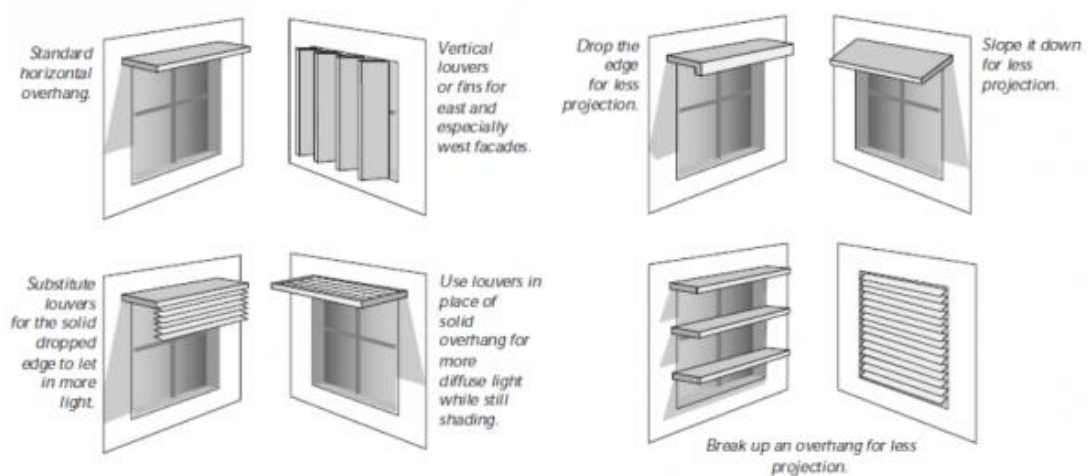
Furthermore, smart facades operate with automatic angle control, which is affected by the outside temperature value and the ray. In case of the occurrence of unwanted external heat gains, the shutters are positioned steeper than the periods when passive solar gains can be used to reduce energy costs in heating. Therefore, angle control is an important factor in terms of total solar energy transition. Another important factor is the type of glass used and the air gap between glass which is separating the interior space from the outside (Yeang, 2012).

**Table 2.6:** Facade Shading Element Per Orientation (Yeang, 2012).

Facade Orientation	Horizontal shading element	Vertical shading element
North	Not useful	Recommended
South	Recommended	Not useful
East	Possible	Recommended
West	Possible	Recommended

- **Self-Shading Glass:**

Fixed shading elements have been preferred over mobile ones in the past, partly because of their simplicity, low cost, minimal maintenance, and limitation of human intervention in some respects. However, these are not as effective as moving canopy in shading buildings facing south (Yeang, 2012).



**Image 2.24:** Window Shading Types (Url-14).

### 2.7.3.2. Facade Design Features Within Natural Ventilation Parameters

Natural ventilation is the replacement of used air with fresh air or outside air. The natural ventilation conditions occurring in the volumes are related to the features of the natural ventilation system and external climatic conditions. Air flows occur due to atmospheric pressure differences. Density differences lead to atmospheric pressure differences and temperature differences lead to density differences between air masses. The direction of the air flows determines the location of the pressure zones and the speed of the pressure difference amounts (Demircan & Gültekin, 2015).

Natural ventilation advantages are (General Directorate of Energy):

- Operation and maintenance costs are low.
  - Reduces environmental pollution and greenhouse effects because it reduces fossil-based energy consumption.
  - It requires less space in terms of installation place and energy distribution aspects.
  - It can be controlled by users.
- **Natural Ventilation, Wind Effect:**

Natural ventilation has a major impact on people's health and comfort. As a result of the pressure change created by the wind, without using any mechanical equipment, natural ventilation takes place when the air enters the openings of the building such as doors and windows, and provides fresh air to the indoor spaces. This method is mostly applied in countries with moderate climatic conditions. In countries with hot, cold and desert climate, natural ventilation is effective when applied together with mechanical systems.

How to provide natural ventilation in high-rise buildings should be handled at the design stage and it should be aimed to ventilate the building as a whole. Generally, the designs are naturally ventilated by using atriums, sky-courtyards, windows that can be opened and closed, ventilation chimneys, air inlet-outlet ducts and fans. The most important point to be considered when creating an air-permeable building shell is the control of the fresh air inlet.

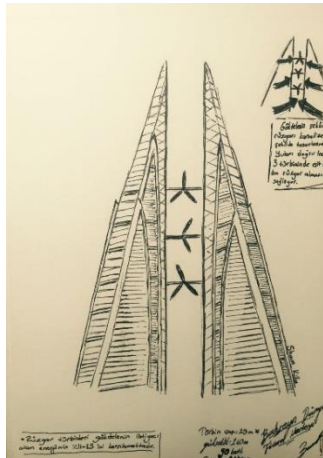
In case the wind flow is perpendicular to the facade, it has the effect of pushing the facade panels inward and in the case of parallel coming outwards. Therefore, when designing facade systems, it should be capable of balancing these internal and external pressures. Besides, variable wind loads such as cut winds and storms have compelling effects for structures and facade systems of buildings. The buzzing and noise sound caused by the wind have negative effects on the health and comfort of the users. Therefore, facade design should be considered in a way that prevents the entrance of external noise into the interior space (Kıasıf & Selçuk, 2016).

- **Wind Power:**

As a result of the integration of wind turbines into high structures, which convert the kinetic energy of the wind into mechanical energy and then into electrical energy, a significant amount of energy production is provided. Three wind turbines, 29 meters long, in the middle of the Bahrain World Trade Center in Manama (Image 2.25-27), were operated for the first time on April 8, 2008. 10-15% of the building's electricity needs are expected to be met by these turbines (Guthrie, 2008). this complex which Consists of a 240-meter high twin tower was designed by British architect Tim Wright, making it the world's first skyscraper with its own wind turbines (Kıasif & Selçuk, 2016).



**Image 2.25:** Bahrain World Trade Center, Tom Wright (Url-15).



**Image 2.26:** Bahrain World Trade Center, Tom Wright (Url-16).



**Image 2.27:** Bahrain World Trade Center, Wind Power (Url-17).

- Skylight system (Ventilation):

- **Sky-Courtyards:**

Sky-courtyards are formed by retracting on the facades, balconies, or withdrawing several floors together in order to protect against the undesired effects of the sun in high buildings. Sky-courtyards provide natural ventilation through the building. In the sky-courtyard design, the speed of the dominant wind should be kept at a level that will not impair the comfort of the user (Kıasif & Selçuk, 2016).

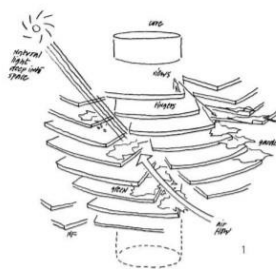
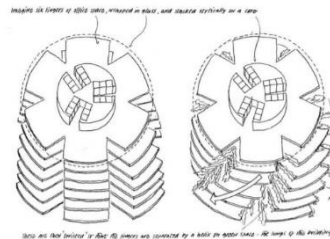
- **Atriums:**

The atrium is the name given to the spaces inside the building. In order to provide natural ventilation, the spaces are maintained along the height of the building and the upper part is not completely closed (Kıasif & Selçuk, 2016).

Swiss Re Headquarters (Image 2.28-29), designed by Norman Foster & Partners in London, can be given as an example for the atrium usage, its floor plans are placed on top of each other by rotating 5 degrees on each floor. Thus, 6 spaces were obtained on each floor and spiral-shaped atria were created throughout the building. These atriums direct the hot air inside the building upwards with the chimney effect in the summer months and reduce the heating load of the building by creating a greenhouse effect in the winter months. Besides, these atriums contribute to the natural light of the workplaces (Kıasif & Selçuk, 2016).



**Image 2.28:** Swiss Re Headquarters, Norman Foster (Url-18).



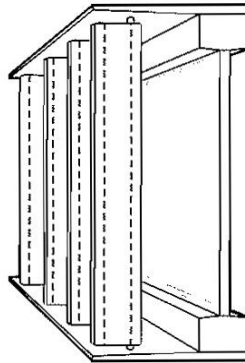
**Image 2.29:** Swiss Re Headquarters, Ventilation System (Url-19).

- **Ventilation At Double-Skin Facade System:**

Double-skin facade formed by exterior and interior two facade types (Image 2.8). The second facade layer in the system allows windows to be opened on the upper floors, despite the strong wind pressure in high-rise buildings. Thus, natural ventilation of the office significantly contributes to the savings of building user's energy consumption. Double skin facades are examined within three groups of ventilation; naturally ventilated, mechanically ventilated and mixed ventilated. Naturally ventilated facade systems are directed to the interior by taking advantage of the air pressure. Within naturally ventilated Double-skin facade systems, the air gap created between the two shells creates a chimney effect and natural ventilation of the interior is provided by designing openable windows in the inner shell. The vents in the outer shell are closed in winter and the interior space is insulated which contributes to the heating of the interior spaces, while the building can be passively cooled by leaving it open in the summer. On the other hand, mechanically ventilated Double-skin facade systems are provided with HVAC systems placed under the floor or ceiling, and fresh air and dirty air are absorbed. While the air taken from the inner shell to the intermediate space rises to the other floors of the mechanical vehicles, it is expelled through the grilles in the outer shell. In mixed systems, both natural and mechanical ventilation systems are used together. In cases where the natural ventilation system is not enough, the mechanical system is activated (Eren, 2019).

- **Vertical Shading Element:**

Vertical shading elements (Image 2.30) are not preferred for ventilation, it prevents the wind flow and causes an asymmetric ventilation schema due to its vertical orientation at the building facade. Thus increases the pressure on the facade.



**Image 2.30:** Vertical Shading Element (Url-20).

- **Wing Wall-Wind Scoop:**

Wing walls are low-energy vehicles designed to retain the wind through the interior of the building with the help of a fin on the front. Its purpose is to increase the airflow per hour, thereby creating comfortable indoor conditions similar to the effect of a ceiling fan. While the wind scoop is placed in the dominant wind direction and benefits from positive pressure, the wind tower air vent is placed in the opposite direction of the dominant wind, benefiting from negative pressure and the opposite airflow (Çavka, 2015).



**Image 2.31:** The Bioclimatic Tower of Singapore, Ken Yeang (Url-21).

- **Openable Windows:**

Windows that can be opened and closed at the high-rise buildings, providing natural ventilation to the building occupants. For example, in the case of Double-skin facade design, the interior shell may include openable windows even at high levels.

- **Natural Ventilation Grills:**

It is the last element of a ventilation system. They are the elements that ensure the supply of the incoming feed or the used air.

General expectations from culverts are (MEGEP, 2008):

- Providing the required airflow,
- Providing the spread of air in the place,
- No disturbing air currents
- Sending the air directly to the collecting grilles,
- No noise.
- Providing proper architectural design and aesthetics.



**Image 2.32:** Istanbul Sapphire Tower, Facade Natural Ventilation Grill (Url-22).

- **Vertical Landscape Elements In The Facade:**

Biologically, the leaf is an effective solar collector. The vertical landscape can shade the interior and exterior walls of the building and minimize external glare and glare within the building. Apart from the role of organic balancing, vertical landscaping also serves to reduce the urban heat island effect and to reduce the temperatures surrounding buildings as part of the passive design tools. Also, they provide natural ventilation through the building and support airflow within the building.



**Image 2.33:** Vertical Landscape Elements (Url-23).

### 2.7.3.3. Facade Design Features Within Material Parameters

Architects have a responsibility to use materials wisely and our future structures will need to be designed using as efficient, renewable resources as possible. In addition to taking care of the source from which the material is obtained, the architect is increasingly required to explore ways to handle the innovative architecture with the material to end up with sustainable architecture.

This ensures a building to be thermally efficient (it may mean combining materials, so less oil is required to heat the building) or ensures the consideration of materials and building structures in different contexts for recycling or reuse.

The emergence and development of “smart” materials that respond to different impulses also change the design possibilities of the architect (Farrelly, 2017).

- **Natural Materials:**

The sustainable approach in construction involves the use of natural materials, obtained from local sources, which can be easily reproduced (Ex. using reeds to cover the roof).

- **New Uses of Old Materials:**

Recycled materials are an important issue today. It is a contemporary architectural concept that includes artificial, protruding, or reused materials, from steel construction to brick walls.

- **Smart Materials:**

The properties of smart materials may vary in response to changes in external stimuli. For example, their form or color may change due to exposure to heat or light.

- **Luminescent Materials:**

These materials can emit lights of different colors pre programmed according to sound or other criteria as a result of electronic stimuli.

- **Biomimetic Materials:**

These materials have been developed for use in buildings, but they mimic the properties of the organic world or the plant world. As an example, it could be a material that changes its color (such as a chameleon) to suit its surroundings.

- **Nanomaterials:**

These human-made materials are available on a microscopic scale and have been developed to vary according to specific conditions. For example, a wall can become visible by reflecting light through the use of thousands of electrical circuits embedded in it.

- **Living Carriers:**

Living structures offer both the innovative and sustainable building options of the future. For example, a “living wall” may carry out the usual functions such as carrying a load of a multi-layered structure, as well as one of the layers that can support plant growth. that is, the structure will “live” and grow in time.

- **Local Material:**

The need to consider the sources of building materials is becoming more and more important. Materials must be obtained from sources close to the building site to reduce fuel use in transportation.

- **Recycling and Reuse:**

The most sustainable way of building construction is to reduce the amount of raw material usage, so recycled glass, steel and concrete are all practical options for the architect against the consumption of raw materials. For example, Japanese architect Shigeru Ban designed a grid shell carrier system using cardboard tubes as carriers (Farrelly, 2017).



**Image 2.34:** Paper Arbor, Nagoya, Japan, 1989, Shigeru Ban (Url-24).



**Image 2.35:** Apol Office Building - Jakarta, Indonesia, Shigeru Ban (Url-25).

#### **2.7.4. Examples of Energy Efficient Buildings**

Accordingly, optical and thermophysical properties of the building envelope are important for energy-efficient building design. Optical and thermophysical properties are the determinants of the amount of heat gained and lost from the unit area of the building envelope by the effects of outside temperature and solar radiation. The internal environmental climatic condition and making heating and air conditioning loads vary depending on the total amount of heat gained and lost from the building envelope (Demircan & Gültekin, 2015).

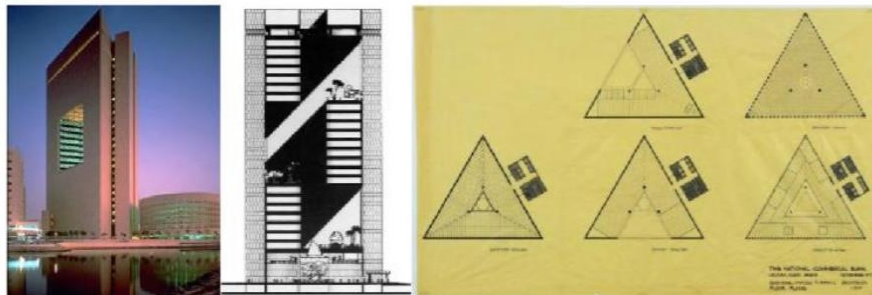
Moreover, Looking at today's global economy; Due to the increasing awareness of scarce energy resources, architects who take the principle of designing a sustainable future, which has become a clear necessity, draw attention. The famous Malaysian architect Ken Yeang has adopted the principle of creating a design input that will ensure the continuity between the architectural form and climate. He has signed many high-rise building projects in this direction (Sarı, 2016).

### **National Commercial Bank:**

Accordingly, the first skyscraper of Saudi Arabia, National Commercial Bank (Image 2.36-37), which was completed in 1983, designed by architect Gordon Bunshaft, a partner of SOM architecture firm, can be given as an example for high-rise buildings designed by adapting the climate of their environment.



**Image 2.36:** National Commercial Bank Jeddah (Url-26).

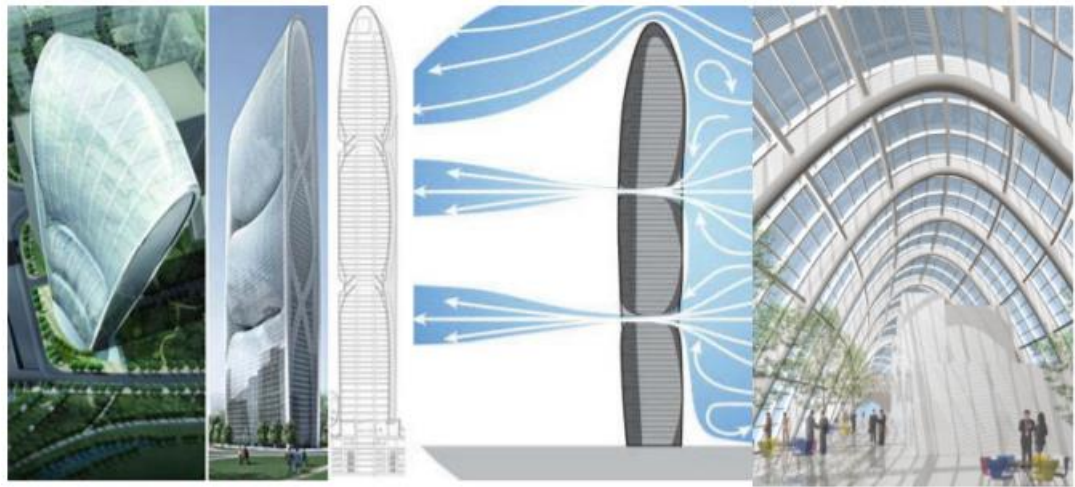


**Image 2.37:** National Commercial Bank, Jeddah (Mahmoud, Elbelkasy, 2016).

In this office building, the architect has applied a triangular plan scheme inspired by the courtyard houses of the Arabian Peninsula. He placed offices on both sides of the triangle and a sky-courtyard on the other. Office spaces change twice through height. The gaps in between are used as sky-courtyards and natural movement is provided with the effect of a chimney in the vertical. At the same time, it acts as a heat and solar buffer against the desert heat by placing the vertical structural elements (service core) on the facade of the building. Thus, a great reduction in ventilation costs can be achieved by reducing the heat in the interior (Kıasif & Selçuk, 2016).

- **Pearl River Tower:**

The 71-storey and 309.6 m high Pearl River Tower (2010) (Image 2.38) stands out among the most energy-efficient buildings in the world. The structure designed by Gordon Gill from Skidmore, Owings and Merrill, besides not only saving energy with passive methods but also actively generating energy are the outstanding features at first glance. It is expected to generate 1% of the electrical energy with 4 small scale, vertical axis wind turbines with 10000 kWh/y power placed in the crevices on the mass of the building. Since the wind speed in Guangzhou is an average of 4 m/s and it is not possible to operate the wind turbines effectively, the airflow is increased to 8 m/s with the negative pressure formed on the southern side parallel to the wind. According to the results of modeling and wind tunnel tests, this method will provide 15 times more electrical energy than a stand-alone, equivalent-sized conventional turbine.



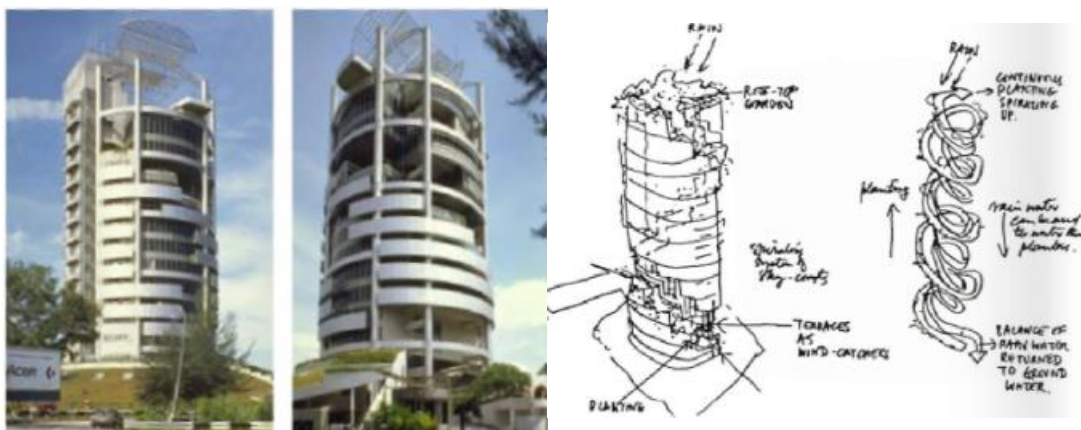
**Image 2.38:** Pearl River Kulesi, Guangzhou (Sev, Başarır, 2011).

In addition to wind power, a number of active energy strategies were also used in the building. In addition to the thin film PV cells integrated into the 1500 m<sup>2</sup> glass at the top of the mass, the 1500 m<sup>2</sup> PV cells placed on the fixed solar screen on the west facade will produce 2% of the required electrical energy with a total capacity of 300 000 kWh. In this office tower, which is exposed to the effects of the tropical sun, a double shell façade system is also designed to reduce the cooling load and energy consumption of mechanical systems. The outer layer is made of low-E coated and

insulated double glass, the inner layer is made of single glass, and when the air in the middle layer gets too hot with the effect of the sun, it is thrown out with fans from the spaces at each floor level without affecting the interior spaces. Under normal conditions, natural air taken into the intermediate space is directed to mechanical floors, where it is conditioned and delivered to the interior. In addition to utilizing natural light indoors, there are automatic shading elements integrated into the Double-skin facade and acting sensitive to sunlight in order to prevent solar heating effect and glare (Sev & Başarır, 2011).

- **Menara Mesiniaga Building:**

Menara Mesiniaga Building (Image 2.39) in Kuala Lumpur, Malaysia, the building designed by T.R. Hamzah and Ken Yeang; It is aimed to make maximum use of natural light and provide passive heating-cooling by directing it to the sun. The concept, which is based on the vertical landscape in the building design, starts from the ground floor of the building and continues up to the top level with the rotating sky-courtyards on the building facade (Begeç & Hamidabad, 2015)



**Image 2.39:** Menara Mesiniaga Building, Kuala Lumpur, Ken Yeang (Url-27).

### **3. CASE STUDY: EXAMINATION OF FACADE ELEMENTS OF SKYSCRAPERS BUILT AFTER 2000S IN BUYUKDERE AVENUE**

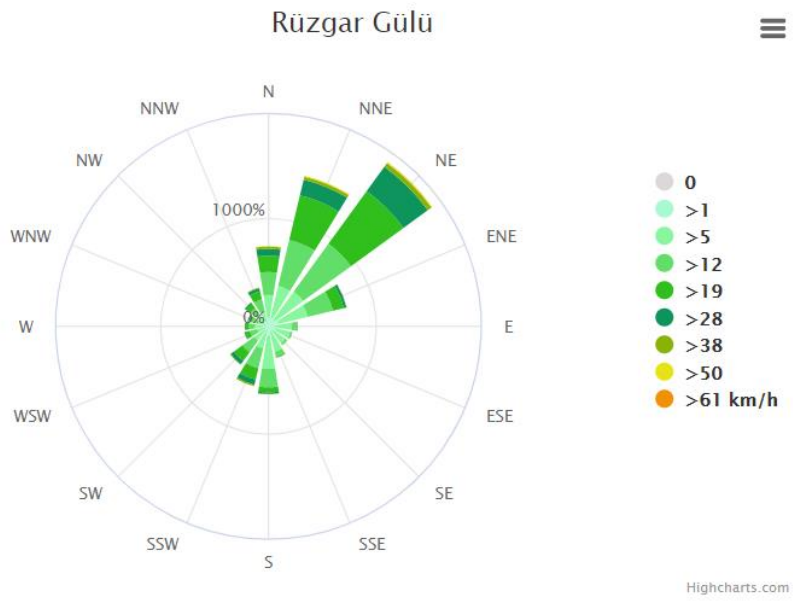
Within this chapter, facades of skyscrapers, built after the 2000s at Buyukdere Avenue will be investigated in terms of the three categories of sustainable facade design (sun-daylight, natural ventilation, and materials) that have been explained within the literature review done.

However, it was mentioned through the study, that sustainable building design should take into consideration its region's climate, sun path, dominant wind, and local materials, etc.

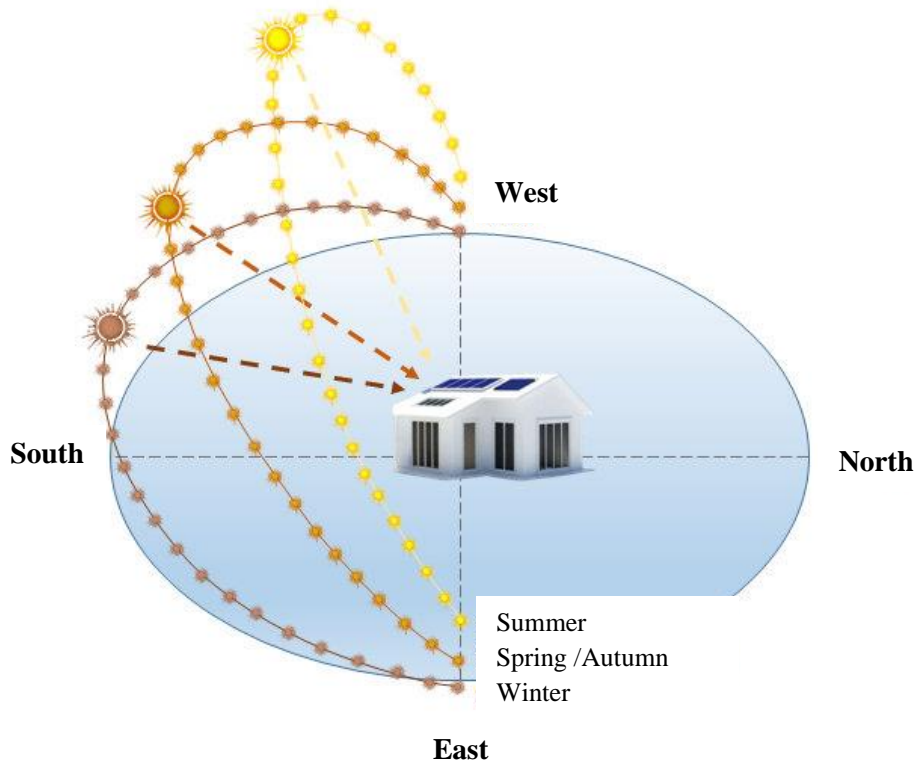
Istanbul is located at the northern half of the earth, 4.561.96 km north of the equator. The summers of Istanbul are generally hot and dry, and the winters are rainy and warm (Url-28).

It is affected by the Mediterranean, Black Sea, Balkan and Anatolian climates. In winter, it is influenced by warm lodos which come from the Mediterranean and the rainy weather from the Balkans or from the Black Sea (Url-29).

In general, there are two dominant wind directions in Istanbul. The first, one called Poyraz which comes from the North-east, and the second one called Lodos which comes from the South-west direction (Url-30).



**Image 3.1:** Istanbul's Wind Rose (Url-31).



**Image 3.2:** Istanbul's Solar Path (Url-32).

### 3.1. BUYUKDERE AVENUE AND ITS HISTORY OF SKYSCRAPERS

Buyukdere Avenue is located at 41.078487 latitudes and 29.012815 longitudes. It is connected to Levent as a Neighborhood and Besiktas as a district (Url-33).

Buyukdere Avenue is a major path that runs through the districts of Sariyer (Maslak quarter), Besiktas (Levent quarter), and Sisli (Esentepe quarter) on the European side of Istanbul, Turkey. The road passes through the following places, it starts at Sisli Mosque and flows in an eastward direction partially under the bridge of the inner-city motorway O-1 within Mecidiyekoy, Esentepe until entering Zincirlikuyu; where it meets with Barbaros Boulevard and turns northward passing into Maslak, Sanayi Mahallesi, Levent and by the Fatih Forest, closing at the Haciosman Slope on the Sariyer neighborhood border. The total length of this road is 14 km (8.7 mi). From Zincirlikuyu to Maslak, it creates a borderline between the regions of Besiktas in the west and Kagithane in the east. It is named after the Buyukdere area of Sariyer district, where it connects to. By the choice of Emlak Kredi Bank for a mass housing project in 1947, Levent has taken its current form. Many sites and housing projects were built in the region, after this project. After 1980, skyscrapers and business centers were built (Url-34 ).

After these developments, Levent in the globalization process has been positioned as Istanbul's Central Business District. Levent started to become a commercial and financial center instead of a residential settlement. While the value of the plots has been increasing, skyscrapers and business centers have been built on it (Geniş & Osmanoğlu, 2016). The definition of Central Business District, briefly called CBD, are the centers of big cities and places with high trade density. In zoning plans, they are defined as the area reserved for socio-cultural and commercial structures (Url-35).

Before being named as the Central Business District of Istanbul, Levent was an area with a population of about 2000, which was accepted outside of Istanbul in the 1950s, without a settlement around it (Geniş & Osmanoğlu, 2016).

In the 1960s, it was developed with 10-12-storey, multi-apartment luxury apartments and sites built by private individuals and cooperatives (Göksu & pilehvarian, 2019). With the increase in the presence of pharmaceutical factories, small-scale industrial

establishments and commercial communications in this region, accordingly, the number of slums increased, and Levent has become an urban settlement. In the 1970s, it was a place between slums and luxury buildings (Geniş & Osmanoğlu, 2016). It continued its development in 1980-1990 and started to take its current form (Göksu & pilehvarian, 2019).



**Image 3.3:** Buyukdere Avenue, 1966 (Url-36).



**Image 3.4:** Buyukdere Avenue, 1970 (Url-36).

There was a serious change in the Levent region in the 1980s. With the opening of Fatih Sultan Mehmet Bridge in 1983, the Central Business District shifted towards Levent districts, where the Bosphorus Bridge is located.



**Image 3.5:** Buyukdere Avenue, 1982 (Url-36).



**Image 3.6:** Buyukdere Avenue, 2006 (Url-36).



**Image 3.7:** Buyukdere Avenue, 2013 (Url-36).



**Image 3.8:** Buyukdere Avenue, 2018 (Url-36).

In the parts of the neighborhood overlooking Buyukdere Avenue, large conglomerates and skyscrapers have been built. Sabanci Center Towers, built in 1989-1993, and Is Bank Towers, built in 1996-2000, are among the first skyscrapers of the region. Büyükdere Avenue, which has turned into a Central Business Area, has changed the Istanbul silhouette with its skyscrapers (Geniş & Osmanoğlu, 2016). Another reason why these skyscrapers started to be built on Buyukdere Avenue is that the automotive and financial sector, which was on the rise in the 80s, was looking for an unlimited area for cheap and zoning rights.



**Image 3.9:** Istanbul's Silhouette (Url-37).

This region was determined as Buyukdere Axis and was used for many skyscrapers. Since it did not have an identity like the Historical Peninsula, it was not thought that it could affect the Istanbul silhouette as much as it is today. On the other hand, Some opinions argue that Istanbul's Business District should be built in another place that does not ruin the Istanbul silhouette. However, since Buyukdere Avenue is currently the Central business district of Istanbul, some skyscrapers can be built there. Therefore, this field has been chosen for the thesis study and a proposal has been presented in accordance with it. Companies that want to take part in developing sectors and international platforms have preferred modern multi-storey buildings, which are examples in the world, instead of the buildings in the old and inadequate Historical Peninsula (Url-38). Factories located in the region, which started to attract the attention of investors, have left their places to skyscrapers. As an example to these; Tekfen Bulb Factory has turned into Tekfen Tower, Philips TV Factory into Metrocity, Eczacıbaşı

Pharmaceutical Factory into Kanyon, Deva Pharmaceutical Factory into Zorlu Office and Roche Pharmaceutical Factory into Ozdilek Park. It was taken as the second center in the 1974 Master Plan. In this process, foreign bank branches, large conglomerates, international companies and many other companies took their place here. Other important decisions were taken in this master plan (Göksu & pilehvarian, 2019). Buyukdere Avenue, after the 1980s, has become the most important Secondary Business Center in Istanbul, as it connects Taksim, Sisli, Mecidiyekoy, Zincirlikuyu, Maslak, Levent and Esentepe, which are important centers of Istanbul. It is connected also to Kavacık and Altunizade, which are the lower centers on the Anatolian Side, by the bridges. Its connection with the world has been through London Asphalt / E5 highway / TEM, which provides connection to Ataturk Airport (Torcu, cited by Göksu & pilehvarian, 2019). Although the main use of the region was industrial until the 1990s, it became a trade management center with the fact that sixty-five percent of Istanbul offices were located in Taksim, Buyukdere-Maslak and Besiktas towards 2000s (Bayramoğlu, cited by Göksu & pilehvarian, 2019).

With the change of lifestyles, the existing settlements left their place to the new luxurious residential areas, residences, entertainment centers and shopping centers. The first residence in Turkey, which was constructed in 1993, is Akmerkez in Etiler. After the first example, many different shopping centers, shopping mall-residence projects were built in the region, such as Kanyon and Ozdilek projects. In the 1/5000 scale Besiktas back view and affected area plan, dated at 1991, it has been decided that Buyukdere Avenue is a residential settlement and can be used as a commercial trade area for tourism upon request. This decision has changed rapidly with the increasing business centers and structures in the Besiktas, Levent, Maslak-Buyukdere axis. It turned into a business and entertainment center instead of a residential area (Erdönmez, cited by Göksu & pilehvarian, 2019).

An important reason for the banking and financial sectors to switch to Maslak-Buyukdere-Zincirlikuyu axis is the move of the Istanbul Stock Exchange to Istinye in 1995. It has become a center of attraction with the request of many sectors that wanted to be in this region (Torcu, cited by Göksu & pilehvarian, 2019). In the 2000s, besides being a financial center, and with the developing world, it has become a center with

luxury residences, meets the changing demands of people, and helps them reach all they want. In the 1/100.000 Scale Istanbul Environmental Plan, completed in 2006, Buyukdere Avenue remained as CBD. It has been observed that in 2010 and afterwards, new shopping centers, plazas and residential areas have expanded with the expansion of transportation infrastructure (Göksu & pilehvarian, 2019).

### 3.2. EXAMINATION METHODOLOGY AND CLASSIFICATION

Within the theoretical part of the study, the role of the building facade design in reducing energy consumption by following the sustainable design criteria was emphasized.

The following criteria were taken into consideration while choosing the structures to be evaluated;

High-rise buildings located at Buyukdere Avenue, built or finished construction after the 2000s (21<sup>st</sup> century). High-rise buildings with office and/or residential functions. High-rise buildings of 22 floors and above and higher than 91m.

Furthermore, selected high-rise buildings were evaluated within sun-daylight, natural ventilation, and material categories, in terms of sustainable facade design systems. To make the evaluation, thirty parameters were selected under the relevant categories.

Data collecting was completed with mixed-method by contacting the building's relevant companies, scanning resources, and examining the buildings with bare eyes. Investigating the articles, magazines, newspapers, and research papers, etc. that provide information about the building. Also by reviewing the website of the building, and the authorized companies such as (The firm of the architectural offices that designed the building, the facade manufacturers company, etc.).

The evaluation will be done according to the scoring system shown at (Table 3.1), created by the researcher to extract the percentages and values that achieved in the buildings, it will proceed as follows;

Firstly, every building will be investigated separately within the selected parameters. Each parameter will be equalized to 2 points, thus each building will be evaluated within the related parameters total score. In case of the parameter completely occurred, the building score per parameter will be counted over 2. Otherwise, the score of the

parameter will be counted over 0. Besides, if the building fulfills half of the parameter condition/s it will get 1 point over 2.

**Table 3.1:** Evaluation Scoring System.

<b>SCORE</b>	<b>SCORING SYSTEM EXPLANATION</b>
<b>2</b>	In case of the parameter completely occurred, the building score per parameter will be counted over 2.
<b>1</b>	If the building fulfills half of the parameter condition/s it will get 1 point over 2.
<b>0</b>	In case of the parameter was not occurred, the building score per parameter will be counted over 0.

As a result of this scoring, evaluation tables and charts will be extracted. Finally, the evaluation will end with consideration percentage per each parameter and per each high-rise building. As a result, the sustainable facade design criteria consideration percentile, which was explained within the thesis scope will be obtained. Ending up with a suggestion of sustainable skyscraper facade design for Buyukdere Avenue.

### 3.3. EXAMINED HIGH-RISE BUILDINGS AT BUYUKDERE AVENUE

High-rise buildings facades will be evaluated within the parameters shown at the (Table 3.2-3) below:


**Table 3.2:** Evaluation Parameters Table.

Category	No	Parameter	Explanation	Ref. Page
Sun - Daylight Parameters	P1	<i>Surface color of the facade (Light-Dark)</i>	The facade should be as light-colored as possible to alleviate overall air conditioning loads and reduce the heat island effect. The effect of absorbing the sun on the light-colored surfaces is lower than the dark-colored surfaces, so light tones should be preferred on the facades.	38
	P2	<i>Self-Shading Glass</i>	Windows that have vertical or horizontal self-shading elements.	44
	P3	<i>Continuous Glass</i>	Due to its large transparent surface, is better than the strip window in terms of daylight inlet	38
	P4	<i>DSF</i>	Double-Skin Facade System are the energy-saving facade systems that are arranged in different ways by leaving a space called an air corridor between two facade shells between 20cm and 2m. Providing shading and natural ventilation	39
	P5	<i>Low-E coated Glass</i>	(Heat controlled glass) By using Low Emission Glass, which radiates heat, heat can be prevented from entering the building and absorbing it by the surface it hits on.	39
	P6	<i>Reflective glass</i>	The reflective glass does not absorb the sun's heating rays inside the buildings. Reflective glass can be particularly useful on western facades in case of heat recovery is undesirable and external shading use is not physically possible.	39
	P7	<i>Insulation</i>	Heat, water and noise insulations, etc.	40
	P8	<i>skylight system to increase daylight</i>	The usage of Sky-courtyards, Atriums, etc. increases the inlet of the daylight. Besides, provide shading for the relevant part of the building.	40-41
	P9	<i>West-East facade shading element</i>	It is necessary to apply a number of vertical sun shading types, especially at the building's hot surfaces such as eastern and western facades, paying attention to the brightness and quality of the light entering the space.	42-43-44
	P10	<i>Vertical shading element at the western facade</i>	At the western facade the usage of vertical shading elements is preferable than horizontal one	42-43-44
	P11	<i>Horizontal shading element at the southern facade</i>	At the southern facade the usage of horizontal shading elements is preferable than vertical one	42-43-44
	P12	<i>Sun consideration at the North (Vertical)</i>	Does the solar path taken into consideration in the north? (At the northern facade the usage of vertical shading elements is preferable than horizontal one).	42-43-44
	P13	<i>Sun consideration at the South (Horizontal)</i>	Does the solar path taken into consideration in the south? (At the southern facade the usage of horizontal shading elements is preferable than vertical one / Using a shading element inside, outside or in the middle / using a double facade system / Increase transparent surface).	42-43-44
	P14	<i>Sun consideration at the East (Vertical)</i>	Does the solar path taken into consideration in the east? (At the eastern facade the usage of vertical shading elements is preferable than horizontal one / Using a shading element inside, outside or in the middle / Using a double facade system). Shading is necessary on the eastern facade	42-43-44

**Table 3.3:** Evaluation Parameters Table (Continues).

	P15	<i>Sun consideration at the West (Vertical)</i>	Does the solar path taken into consideration in the west? (At the western facade the usage of vertical shading elements is preferable than horizontal one / Using a shading element inside, outside or in the middle). Shading should be provided on the western facade	42-43-44
Natural Ventilation Parameters	P16	<i>Natural Ventilation</i>	Natural ventilation allows fresh air to enter the interior spaces (Ex. air holes in double-skinned facades / fresh air entering the ground floor and evacuating from the roof when the air gets hot).	45
	P17	<i>Skylight system (Ventilation)</i>	Sky-courtyards, Atriums, etc. function as a wind bucket, which ventilates the interior of the building (Increases natural ventilation).	47
	P18	<i>Natural ventilation Grilles</i>	Allowing Fresh air to Penetrate inside, providing natural ventilation to the building.	50
	P19	<i>Wind Power</i>	Usage of wind turbines at high structures, which convert the kinetic energy of the wind into mechanical energy and then into electrical energy, providing energy to the building.	46
	P20	<i>No Vertical shading element</i>	Vertical shading element usage is not preferred for ventilation	49
	P21	<i>Wing Wall</i>	Wing wall that provides natural ventilation by detecting the wind and directing it into special balcony zones	49
	P22	<i>Openable Windows</i>	Allowing fresh air to get inside the high-rise building presenting natural ventilation and Fresh air to the occupants, reducing the sick building syndrome.	50
	P23	<i>Vertical landscape elements in the Facade</i>	The vertical landscape can shade the interior and exterior walls of the building and minimize external glare and glare within the building. Also serves to reduce the urban heat island effect and to reduce the temperatures surrounding buildings. Besides, providing natural ventilation.	51
	P24	<i>Wind consideration at the North</i>	Does the wind taken into consideration in the north? (Natural ventilation system, Double Skinned Facade, Wing Wall, Wind test, etc.)	45
	P25	<i>Wind consideration at the South</i>	Does the wind taken into consideration in the south? (Natural ventilation system, Double Skinned Facade, Wing Wall, Wind test, etc.)	45
	P26	<i>Wind consideration at the East</i>	Does the wind taken into consideration in the east? (Natural ventilation system, Double Skinned Facade, Wing Wall, Wind test, etc.)	45
	P27	<i>Wind consideration at the West</i>	Does the wind taken into consideration in the west? (Natural ventilation system, Double Skinned Facade, Wing Wall, Wind test, etc.)	45
Material Parameters		<i>Property of the facade material</i>	Property of the material used in the facade (Recyclable material, durable and low-maintenance material, fast renewable material, energy-efficient material, long-life material, local material, etc.)	52-53-54
	P28	<i>Local Material</i>	Materials must be obtained from sources close to the building site to reduce fuel use in transportation.	45
	P29	<i>Recyclable Materials</i>	The most sustainable way of building construction is to reduce the amount of raw material usage, so recyclable are all practical options for the architect against the consumption of raw materials	54
	P30	<i>Environmentally Friendly Materials</i>	Architects have a responsibility to use materials wisely and our future structures will need to be designed using as efficient, renewable resources as possible.	53

### 3.3.1. Istanbul Sapphire Tower

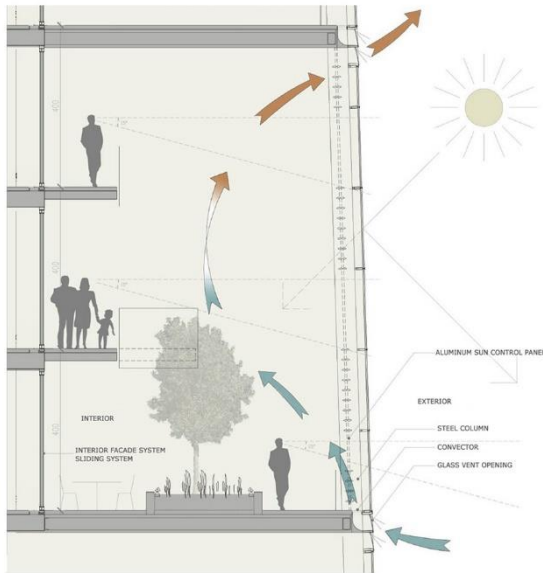
1.		ISTANBUL SAPPHIRE TOWER	
<b>Const. Date</b>	2006-2010		<p><b>Image 3.10:</b> Istanbul Sapphire (Url-59).</p>
<b>Architect</b>	Tabanlıoğlu Architecture		
<b>Building Func.</b>	Residential – Retail (Mixed-Use)		
<b>Facade Company</b>	Schüco		
<b>Certificates</b>	<ul style="list-style-type: none"> <li>• CTBUH Awards.</li> <li>• Best Tall Building Europe 2011 Award of Excellence.</li> </ul>		
<b>Arch. height</b>	261 M		
<b>Floors (a.gr.)</b>	55 Floor		
<b>Materials used (general)</b>	Reinforced Concrete + Steel		
<b>Facade Materials</b>	Glass- Curtain wall / Double Skinned Facade  Schüco - ASS 50 /ASS 70.HI -Automatic Series		
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• 4<sup>th</sup> tallest in Istanbul.</li> <li>• It is the country's first ecological skyscraper.</li> <li>• The building is especially focused on the height and bio-climatic structure as the main features of the project.</li> <li>• It was Istanbul's and Turkey's tallest skyscraper between 2010 and 2016, and the 4<sup>th</sup> tallest building in Europe when its construction was completed in 2010.</li> <li>• As of 2019, Istanbul Sapphire is the 4<sup>th</sup> tallest skyscraper in Istanbul and Turkey.</li> </ul>		



**Image 3.11:** Istanbul Sapphire's Facade (Url-24).



**Image 3.12:** Istanbul Sapphire Eastern Facade (Url-24).



**Image 3.13:** Istanbul Sapphire Double Skinned Facade System (Url-59).



**Image 3.14:** Istanbul Sapphire's Vertical Gardens (Url-24).




**Image 3.15:** Istanbul Sapphire Double Skinned Facade, Eastern Facade, (Url-24 ).

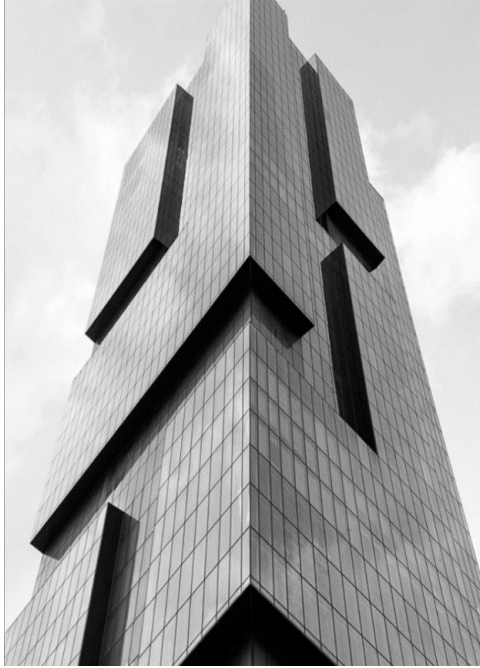


**Image 3.16:** Istanbul Sapphire's Curtain System (Url-59).

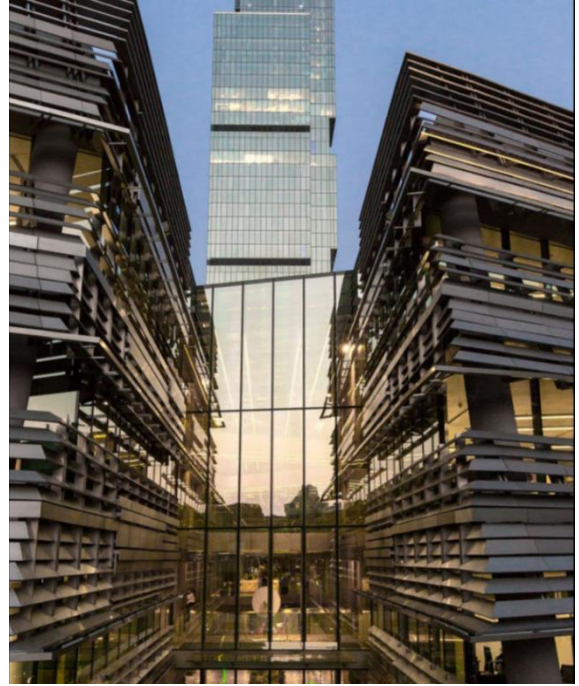
### 3.3.2. Levent 199

2.	LEVENT 199	
<b>Const. Date</b>	2011 - 2014	
<b>Architect</b>	Tabanlıoğlu Architecture	
<b>Building Func.</b>	Office	
<b>Facade Company</b>	Çuhadaroğlu Alüminyum Sanayi	
<b>Certificates</b>	<ul style="list-style-type: none"> <li>• LEED Gold BD+C: Core and Shell.</li> <li>• 2010 – Europe and Africa Property Awards 2010.</li> <li>• 2012 – Turkey's Most Successful Real Estate Investment Competition, in the office category, second prize.</li> </ul>	
<b>Arch. height</b>	170 M	
<b>Floors (a.gr.)</b>	43 Floor	
<b>Materials used (general)</b>	Concrete	
<b>Facade Materials</b>	Glass / Curtain Wall System ZRL 90 S Structural Silicone Modular Panel System with Heat Barrier	
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• 23<sup>rd</sup> tallest in Istanbul.</li> <li>• A<sup>+</sup> class Office Building.</li> <li>• Intelligent building automation and fiber-optic IT structure Energy Efficiency.</li> <li>• Material and resource management.</li> <li>• Indoor quality and user comfort.</li> <li>• Water efficiency.</li> <li>• Utilization of natural light.</li> <li>• Rain and gray water reuse.</li> <li>• Help protect the environment.</li> </ul>	

**Image 3.17:** Levent 199 (Url-60).



**Image 3.18:** Levent 199's Facade (Url-60).



**Image 3.19:** Levent 199's Western Facade (Url-60).




**Image 3.20:** Levent 199's Western Facade (Url-60 ).



**Image 3.21:** Levent 199 (Url-60).

### 3.3.3. Istanbul Tower 205

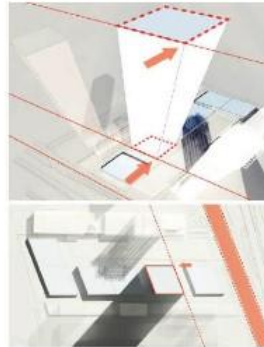
3.		ISTANBUL TOWER 205	
<b>Const. Date</b>	2015-2019		<p><b>Image 3.22:</b> Istanbul Tower 205 (Url-61).</p>
<b>Architect</b>	SOM - Skidmore, Owings & Merrill LLP		
<b>Building Func.</b>	Office		
<b>Facade Company</b>	Werner Sobek Stuttgart-Metal Yapı		
<b>Certificates</b>	LEED GOLD Certificate		
<b>Arch. height</b>	220 M (Turkey's highest office building)		
<b>Floors (a.gr.)</b>	54 KAT		
<b>Materials used (general)</b>	Reinforced Concrete + Steel Composite		
<b>Facade Materials</b>	Glass/ Cladding Company: Metal Yapı- Unitized Panel System		
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• 6<sup>th</sup> tallest in Istanbul.</li> <li>• A<sup>++</sup> Office Building.</li> <li>• inspired by the traditional layers found in Seljuk architecture.</li> <li>• Trickle Vent facade system.</li> <li>• User control feature and automation system.</li> <li>• Indoor air quality.</li> <li>• Prevent sick building syndrome.</li> <li>• Private aerodynamic and acoustic design.</li> <li>• Energy efficiency with lower ventilation costs.</li> <li>• Environmentally friendly.</li> <li>• Light pollution prevention.</li> <li>• Maximum use of daylight.</li> <li>• Use of recycled and certified materials.</li> <li>• Renewable energy.</li> <li>• Offers a large panoramic view.</li> </ul>		

## Main Design Elements

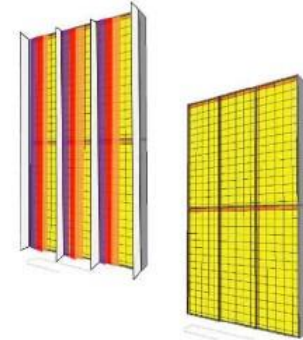
- 1 Inspired by historic texture:  
Seljuk



- 2 Positioning of the building  
maximize the view  
alternatives



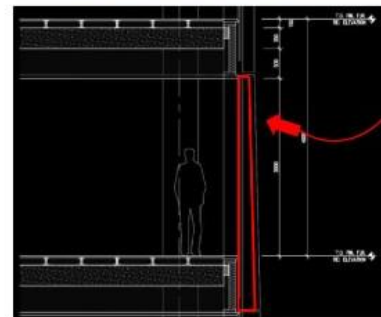
- 3 Facade design was  
developed by Solar  
Radiation Analysis



**Image 3.23:** Istanbul Tower 205 Facade's System (Url-56).

## Facade Design

- 4 3D facade design  
The facade offers a dynamic perception of building further  
emphasizing identity and timeless quality of tower



**Image 3.24:** Istanbul Tower 205 Facade's System (Url-56).

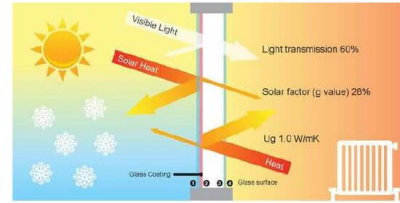
## Ultra-clear Glass & Triple Silver Coating

5

Ultra-clear glass and triple silver coating maximize daylight usage and provides energy saving



- Min. 60% light, 30% energy transmittance
- Ultra-clear glass with low iron content
- Triple silver coating technology

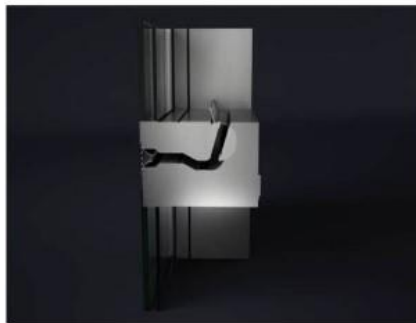


Pane 1		Pane 2	
6 mm	Float Glass Guardian UltraClear	8 mm	Float Glass Guardian UltraClear
1.52 mm	PFS Clear		
6 mm	Float Glass Guardian UltraClear		
	SaniGuard SW 6028		
Spacer 1 - 16 mm			
10%	Air		
90%	Argon		

Results		Solar energy (EN 410 - 2011)	
<b>Visible light (EN 410 - 2011)</b>		<b>Solar energy (EN 410 - 2011)</b>	
transmittance [%]	$\tau_v = 59.1$	solar factor [%]	$g = 27.2$
reflectance external [%]	$\rho_e = 12.0$	shading coefficient (g/0.87)	$sc = 0.31$
reflectance internal [%]	$\rho_i = 14.2$	direct transmittance [%]	$\tau_{d,v} = 25.1$
general colour rendering index [%]	$R_a = 92.9$	direct reflectance external [%]	$\rho_{e,d} = 36.6$
U-value [W/m <sup>2</sup> K]	$U_g = 1.0$	direct reflectance internal [%]	$\rho_{i,d} = 47.5$
	slip $\alpha = 90^\circ$	direct absorption [%]	$a_d = 38.3$
		UV transmittance [%]	$\tau_{uv} = 0.0$
		secondary internal heat transfer factor [%]	$q_s = 2.1$
		<b>Other data</b>	
		estimated sound reduction index [dB]	$R_w = \text{NPD}$
			$C_w = \text{NPD}$
			$C_p = \text{NPD}$

Image 3.25: Istanbul Tower 205 Facade's System (Url-56).

## Intelligent Naturally Ventilated Facade First in Turkey



100 Sqm Area Naturally Ventilated in 1 Hour with 100% Fresh Air



- Automated Facade Natural Ventilation System
- User Control Feature and Automation System in the Same Time
- Raised Indoor Air Quality
- Preventing Sick Building Syndrome
- Private Aerodynamic & Acoustic Design
- Energy Savings With Lower Ventilation Costs

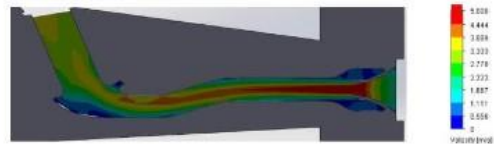


Image 3.26: Istanbul Tower 205 Facade's System (Url-56).

### 3.3.4. Kanyon


4.		KANYON	
<b>Const. Date</b>	2003 - 2006		
<b>Architect</b>	Tabanlıoğlu Architecture, Jerde Ve Arup Partnership		
<b>Building Func.</b>	Office		
<b>Facade Company</b>	Arup Türkiye + Ove Arup İngiltere & Los Angeles / Feniş Aluminum		
<b>Certificates</b>	<ul style="list-style-type: none"> <li>• ISO 14001 certificate of the standards of "Building, Settlement, Office Shopping Place and Entertainment Places".</li> <li>• Breeam Excellent certification in 2012.</li> <li>• Breeam Extraordinary Certificate in 2015.</li> <li>• "BREEAM Retail In-Use" at the "BEST OF BREEAM 2016" award ceremony.</li> </ul>		
<b>Arch. height</b>	118 M		
<b>Floors (a.gr.)</b>	25 Floor		
<b>Materials used (general)</b>	Reinforced Concrete - Glass - Steel		
<b>Facade Materials</b>	Glass - Stone - Painted copper metal bands - Aluminum		
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• Use of natural stones and original building materials.</li> <li>• It creates an urban effect with the connection corridors between the office, open mall and residences.</li> </ul>		

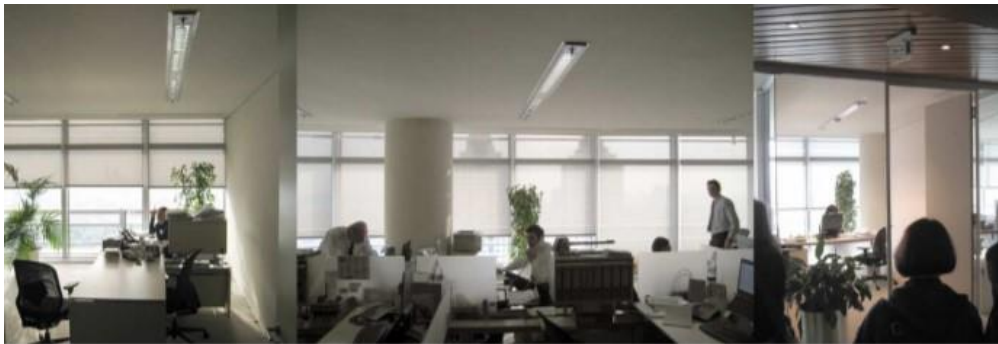
Image 3.27: Kanyon Office Tower (Url-62).



**Image 3.28:** Kanyon's Facade Shading Element From The Inside (Schulze, 2015).



**Image 3.29:** Kanyon's Facade (Url-63).




**Image 3.30:** Internal Vertical Blinds (Schulze, 2015).



**Image 3.31:** Kanyon Office Tower Eastern Facade (Url-63).

### 3.3.5. Tekfen Tower

5.	TEKFEN TOWER	
<b>Const. Date</b>	2003	
<b>Architect</b>	Swanke Hayden Connell Architects	
<b>Building Func.</b>	Business Center	
<b>Facade Company</b>	Schüco / Taş Proje	
<b>Certificates</b>	The materials used, have UL certification	
<b>Arch. height</b>	118M	
<b>Floors (a.gr.)</b>	28 Floor	
<b>Materials used (general)</b>	Reinforced Concrete Curtain Frame - Granite Blocks	
<b>Facade Materials</b>	Curtain glass- Granite stone- Aluminum curtain wall- Stone curtain wall	
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• It is a Class A Office building in SHCA International standards.</li> <li>• It is designed in accordance with NFPA and UL standards.</li> <li>• Granite and Aluminum coatings of the building have been subjected to earthquake resistance and filtration tests.</li> </ul>	

**Image 3.32:** Tekfen Tower (Url-64).




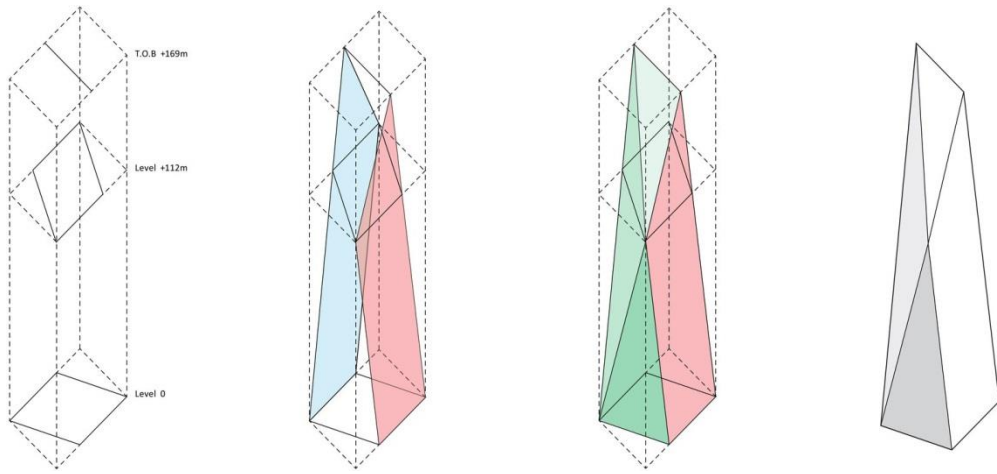
**Image 3.33:** Tekfen Tower's Northern and Western Facades (Url-64).



**Image 3.34:** Tekfen Tower's Eastern and Southern Facades (Url-65).

### 3.3.6. QNB Finance Bank Crystal Tower

6.	QNB FINANCE BANK CRYSTAL TOWER	
<b>Const. Date</b>	2011 - 2014	 <p><b>Image 3.35:</b> QNB Crystal Tower (Url-45).</p>
<b>Architect</b>	Pei Cobb Freed & Partners / Has Architects	
<b>Building Func.</b>	Office	
<b>Facade Company</b>	Pei Cobb Freed & Partners/ Permasteelisa Group/ Star Grup	
<b>Certificates</b>	<ul style="list-style-type: none"> <li>• LEED Silver Certificate</li> <li>• EMPORIS AWARD 2014 - 7th place.</li> <li>• International Architecture Award, 2016.</li> <li>• Design Award of Honor, 2015.</li> </ul>	
<b>Arch. height</b>	169 M	
<b>Floors (a.gr.)</b>	32 Floor	
<b>Materials used (general)</b>	Concret	
<b>Facade Materials</b>	Glass - Cladding: Haz Marble / Hilti AG	
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• A<sup>+</sup> Office Building.</li> <li>• 25<sup>th</sup> tallest in Istanbul.</li> <li>• It offers surprising and different views from different points of Istanbul with its dynamic form.</li> <li>• Henri Cobb found its shape with an identifiable geometry that he created on the millimetric paper with 7's multiples.</li> <li>• It forms a parallelogram in accordance with the boundaries of the plot.</li> <li>• Its symbolic form meets the design goal formed by its different facade surfaces obtained by transforming the parallelogram in accordance with the sensitive geometric parameters to a hexagon on the 14th floor and a parallelogram on the 28th floor, by offering surprising perspectives to the citizens from different points of view</li> <li>• The tower looks like a rectangular session from above, (Çatı ve cephe, 2016).</li> <li>• Soyak QNB was Turkey's first skyscraper that runs all integration systems together, internal monitoring, lighting, daylight sensors, automation, mechanical automation systems and low-voltage systems, (Candela, 2018, Url-42).</li> <li>• The architect used the form of Baklava at the building form, representing the region traditions at his design, (Çatı ve cephe, 2016).</li> </ul>	



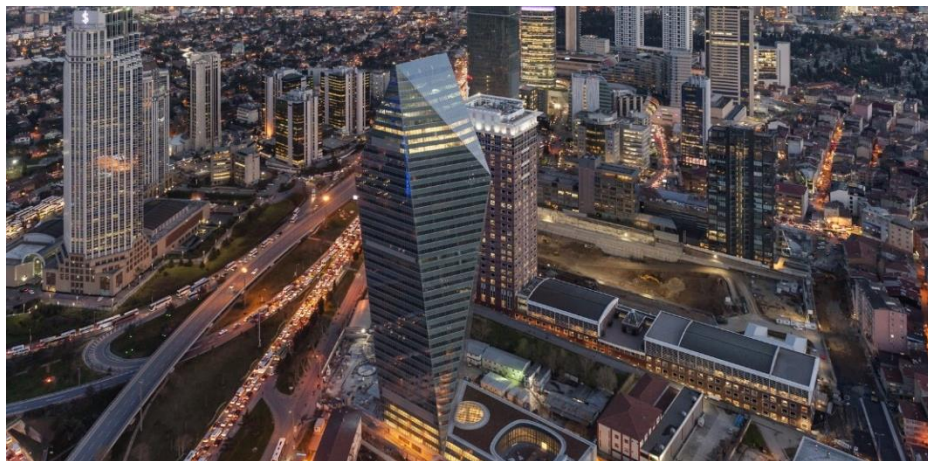
**Image 3.36:** Soyak QNB Crystal Tower's Facade Shape (Url-45).



**Image 3.37:** Soyak QNB Crystal Tower's Facade Detail (Url-45).



**Image 3.38:** Soyak QNB Crystal Tower's Facade From The Podium (Url-45).



**Image 3.39:** Soyak QNB Crystal Tower (Url-45).

### 3.3.7. Metrocity Office Tower

7.	METROCITY OFFICE TOWER	
<b>Const. Date</b>	2000	
<b>Architect</b>	Tekeli / Sisa Architecture	
<b>Building Func.</b>	Residential – Office	
<b>Facade Company</b>	Feniş Aluminum	
<b>Certificates</b>		
<b>Arch. height</b>	143 M	
<b>Floors (a.gr.)</b>	31 Floor	
<b>Materials used (general)</b>	Reinforced Concrete	
<b>Facade Materials</b>	Cladding glass, aluminum composite panels	
<b>Building Features</b>	<ul style="list-style-type: none"> <li>Turkey for the first time used in a structure of this size a Teflon coated fiberglass roofing to purify harmful ethics of direct sunlight during the day. Roofing material, Teflon, which is a self-cleaning material that can pass 10 - 12% light, has a minimum of 20 years of usability, was preferred. Besides, the other alternative, glass, was not preferred due to direct exposure to radiation (Sağlam, 2016).</li> </ul>	



**Image 3.40:** Metrocity Office Tower (Url-66).



**Image 3.41:** Metrocity Office Tower's Facade (Url-66).



**Image 3.42:** Metrocity Office Tower (Url-67).

### 3.3.8. Olive Grove Tower - Garanti Bank Headquarters (BBVA)


9.	OLIVE GROVE TOWER - GARANTI BANK HEADQUARTERS (BBVA)	
Const. Date	2002	
Architect	American Architects: Gerner, Kronick + Valcarcel	
Building Func.	Office	
Facade Company	Metal Yapı - Unitized Panel System/ Haz APAC - Stone	
Certificates	LEED Platinum Certificate 2019	
Arch. height	122 M	
Floors (a.gr.)	22 Kat	
Materials used (general)	Reinforced Concrete	
Facade Materials	Glass- Beige Stone / Cladding: Metal Yapı - Unitized Panel System. Haz APAC - Stone	
Building Features	<ul style="list-style-type: none"> <li>It is the only bank building in Turkey, having LEED certification.</li> </ul>	

Image 3.43: Olive Grove Tower (Url-53).

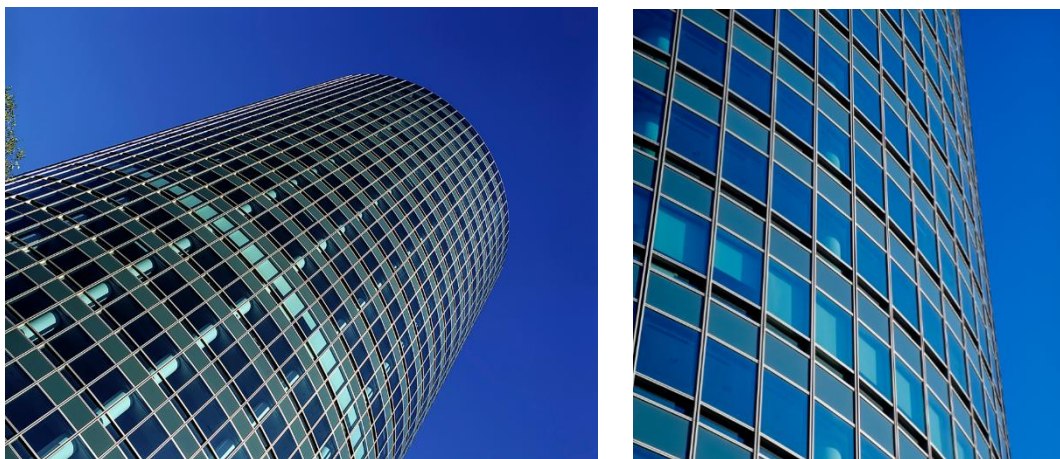


Image 3.44: Olive Grove Tower's Curtain Glass Facade System – Southern Facade (Url-68).



**Image 3.45:** Olive Grove Tower's Curtain Glass Facade System – Southern Facade, (Metal Yapı, Url-68).



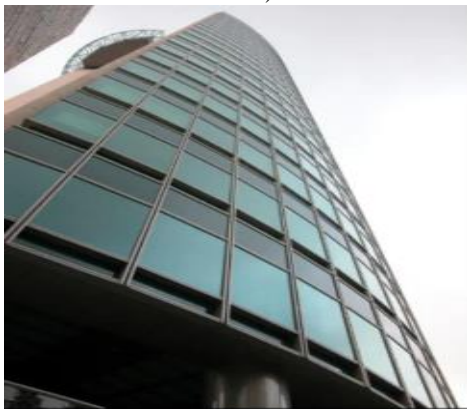
**Image 3.46:** Olive Grove Tower's Curtain Glass Facade System – Eastern Facade, (Antre Design, Url-69).



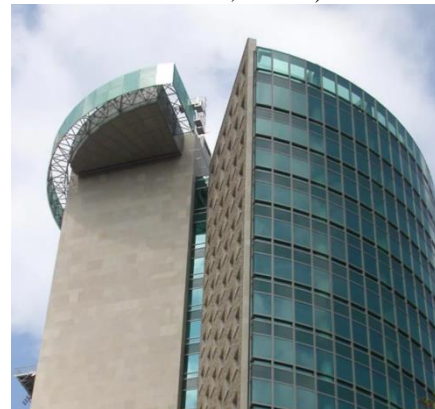
**Image 3.47:** Olive Grove Tower's Curtain Glass Facade System – Northern Facade (Architizer, Url-70).



**Image 3.48:** Olive Grove Tower's Curtain Glass Facade System – Western Facade (GKV Architects, Url-53).



**Image 3.49:** Olive Grove Tower's Curtain Glass Facade System – Southern Facade, Curtain Wall System, Ventilation Louvers (Url-53).



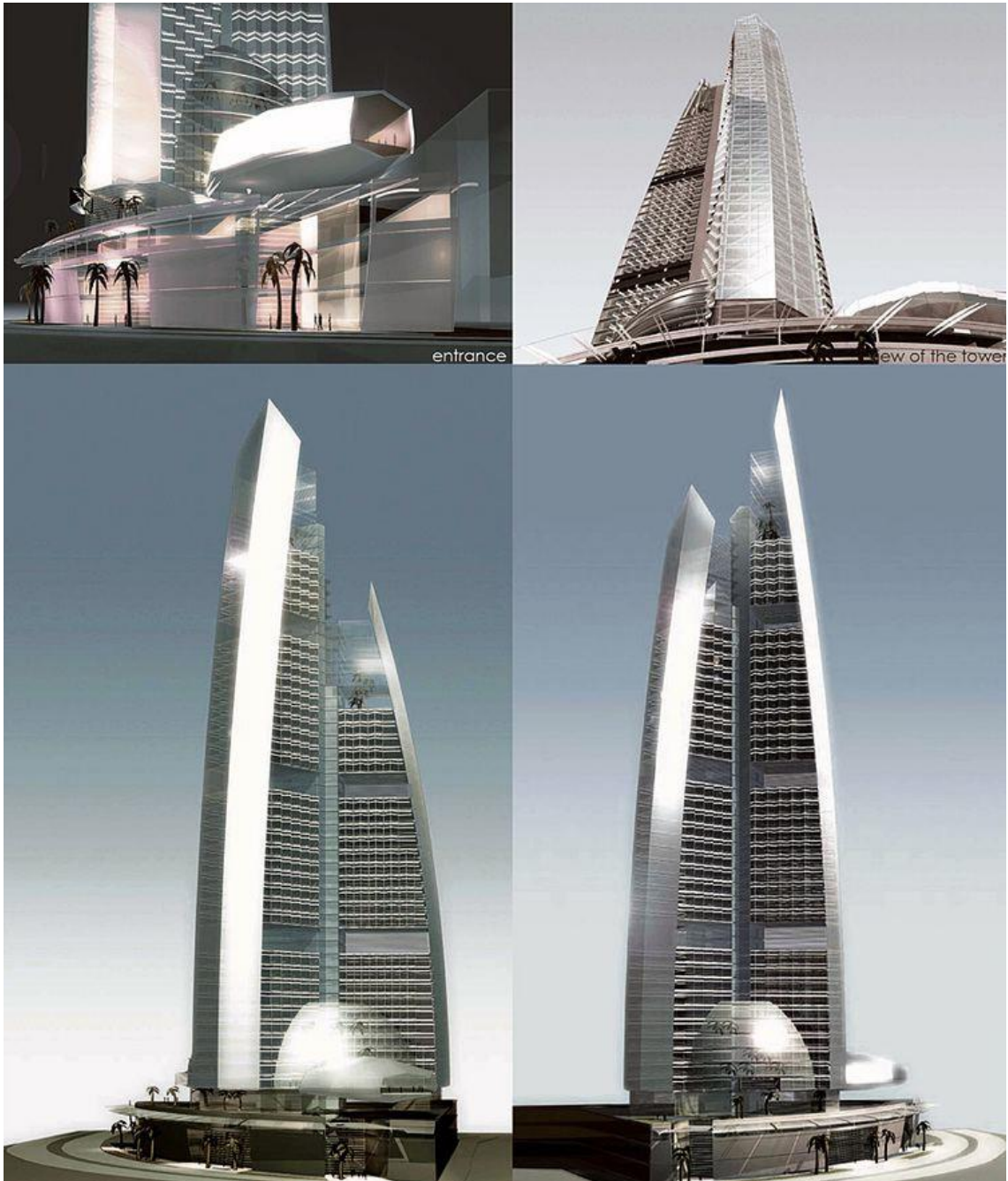
**Image 3.50:** Olive Grove Tower's Curtain Glass Facade System – Southern Western Facade (Architizer, Url-70).

### 3.3.9. Diamond of Istanbul

10.	DIAMOND OF ISTANBUL	
<b>Const. Date</b>	2004- On Hold	
<b>Architect</b>	Dome Architects; Murat YILMAZ	
<b>Building Func.</b>	Residential – Hotel – Office	
<b>Facade Company</b>	Ove Arup Partners / Arcelormittal	
<b>Certificates</b>		
<b>Arch. height</b>	268 M	
<b>Floors (a.gr.)</b>	53 Floor	
<b>Materials used (general)</b>	Reinforced Concrete + Steel + Composite	
<b>Facade Materials</b>	Glass / Double Skinned Facade	
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• Turkey's first steel-concrete composite skyscraper.</li> <li>• A-class offices.</li> </ul>	


**Image 3.51:** Diamond of Istanbul (Url-71).

\*Since the construction of the building is still on hold, some data could not be accessed.



**Image 3.52:** Diamond of Istanbul (Alchetron, Url-72).

### 3.3.10. Spine Tower

11.	SPINE TOWER	
<b>Const. Date</b>	2014	
<b>Architect</b>	2 Design Group	
<b>Building Func.</b>	Residential - Office	
<b>Facade Company</b>	Sapa Building System	
<b>Certificates</b>	<ul style="list-style-type: none"> <li>• LEED Gold Certificate-2014.</li> </ul> <p>By RICS:</p> <ul style="list-style-type: none"> <li>• Best Office Architecture Europe Certificate-2012.</li> <li>• Best Office Architecture Turkey Certificate-2012.</li> </ul> <p>By MIPIM:</p> <ul style="list-style-type: none"> <li>• Best Turkish Project Certificate - 2014.</li> </ul>	
<b>Arch. height</b>	202 M	
<b>Floors (a.gr.)</b>	47 Floor	
<b>Materials used (general)</b>	Concrete	
<b>Facade Materials</b>	Glass / Elegance 72 Panel Facade System	
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• A<sup>+</sup> class standards.</li> <li>• 7<sup>th</sup> tallest in Istanbul.</li> <li>• 360 degree view feature.</li> <li>• An exemplary project designed according to international sustainability standards.</li> <li>• It was designed to withstand an 8.5 magnitude earthquake.</li> <li>• It is a model project that is sustainable, energy-saving and 54% of it is green.</li> <li>• It was the first time in Turkey to use, C80 class of concrete material in this project.</li> </ul>	

**Image 3.53:** Spine Tower (Url-73).



**Image 3.54:** Spine Tower, Roof's Reflective Glass (Url-73).



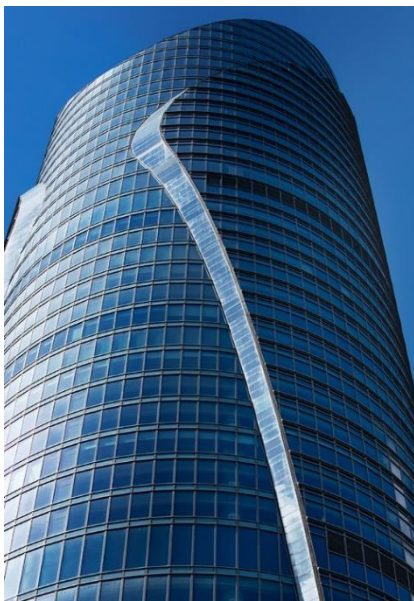
**Image 3.55:** Spine Tower, Elegance 72 Panel System (Url-75).



**Image 3.56:** Spine Tower, View From The Interior Facade (Url-73).



**Image 3.57:** Spine Tower, Western Facade, Horizontal Sunshade Elements (Url-73).



**Image 3.58:** Spine Tower's Facade (Url-73).



**Image 3.59:** Spine Tower (Url-74).

### 3.3.11. River Plaza - Ozdilek Plaza Tower A –B

12.	RIVER PLAZA - OZDILEK PLAZA TOWER A –B	
<b>Const. Date</b>	2011 - 2014	
<b>Architect</b>	B+H Architecture / Piramit Mimarlık	
<b>Building Func.</b>	B / Residential – A / Hotel – Office	
<b>Facade Company</b>	Erbay Aluminyum / Schüco	
<b>Certificates</b>	LEED Gold Certificate- 2016	
<b>Arch. height</b>	Tower A - 170 M / Tower B -148 M	
<b>Floors (a.gr.)</b>	Tower A - 38 Floor / Tower B -37 Floor	
<b>Materials used (general)</b>	Concrete	
<b>Facade Materials</b>	Glass- Unitised curtain wall system /Schüco Paint / Coating: Jotun	
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• 24<sup>th</sup> tallest in Istanbul.</li> <li>• A<sup>+</sup> energy saving building.</li> <li>• A Class Office Building.</li> </ul>	



**Image 3.60:** River Plaza (Url-49).



**Image 3.61:** River Plaza, Western Facade (Url-49).



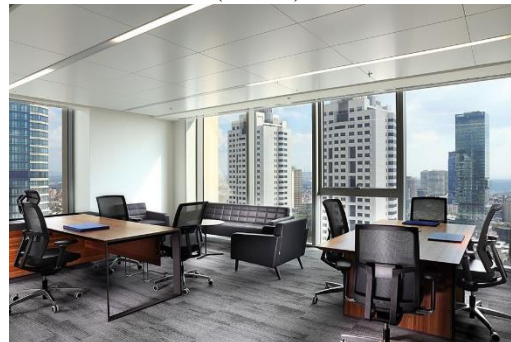
**Image 3.62:** River Plaza, Eastern Facade (Url-49).



**Image 3.63:** River Plaza, Northern Eastern Facade (Url-49).




**Image 3.64:** River Plaza, Northern Facade (Url-49).



**Image 3.65:** River Plaza, Interior Place (Url-49).

### 3.3.12. Is Bank Tower I

14.	IS BANK TOWER I	
<b>Const. Date</b>	1996 - 2000	 <p><b>Image 3.66:</b> Is Bank Tower I (Url-76).</p>
<b>Architect</b>	Tekeli Sisa Mimarlık / Swanke Hayden Connell International	
<b>Building Func.</b>	Office	
<b>Facade Company</b>	Heintges & Associates/ Şişecam	
<b>Certificates</b>	BREEAM In-Use (Very-Good) 2014	
<b>Arch. height</b>	181.2 M	
<b>Floors (a.gr.)</b>	52 Floor	
<b>Materials used (general)</b>	Concrete	
<b>Facade Materials</b>	Steel – Glass –Granite Paint / Coating: Jotun	
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• 14<sup>th</sup> tallest in Istanbul.</li> <li>• Uses "intelligent skyscraper" technologies, (Emporis- Url-22).</li> <li>• It became the first Turkish bank to receive the Green Building certificate, (Yeşil bina dergisi, Url-86).</li> <li>• This tower has maintained until 2011 the tallest building title structure in Turkey.</li> <li>• The total area of the various air ducts used in this project for heating, ventilation, air conditioning (HVAC) installation is 150,000 m<sup>2</sup>, which is equal to the surface of 26 football fields.</li> <li>• The total amount of pipes used in heating, cooling, wastewater, clean water, rainwater, fire extinguishing installations is 300 km which is equal to the distance between Istanbul and Bursa, (Wikipedia, Url-21).</li> </ul>	




**Image 3.67:** Is Bank Towers Eastern Facade (Url-76).



**Image 3.68:** Is Bank Towers Western Facade (Url-76).

### 3.3.13. Iz Plaza Giz

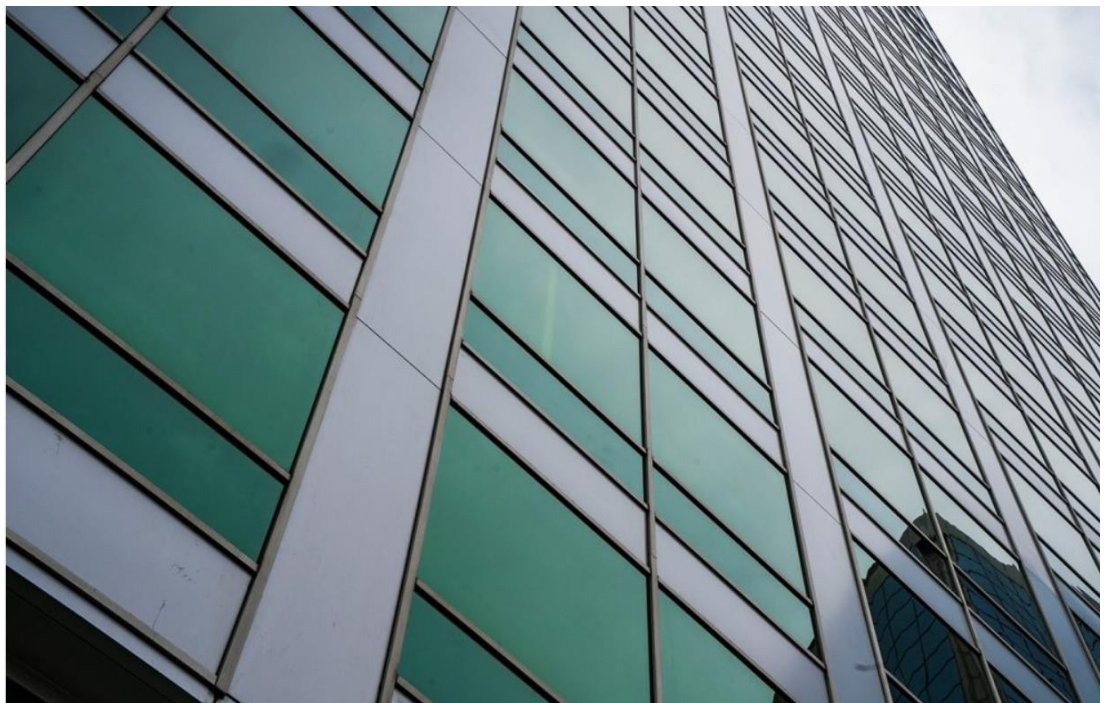
15.	IZ PLAZA GIZ	
<b>Const. Date</b>	2003	 <p><b>Image 3.69:</b> Iz Plaza Giz (Url-51).</p>
<b>Architect</b>	Giz İnşaat Mimari Grup	
<b>Building Func.</b>	Office	
<b>Facade Company</b>	Şişik Aluminium	
<b>Certificates</b>		
<b>Arch. height</b>	91 M	
<b>Floors (a.gr.)</b>	28 Floor	
<b>Materials used (general)</b>	Reinforced Concrete	
<b>Facade Materials</b>	Aluminium Curtain wall- Composite panels	
<b>Building Features</b>	<ul style="list-style-type: none"> <li>• A Class Office Building.</li> </ul>	



**Image 3.70:** Iz Plaza Giz (Url-51).



**Image 3.71:** Iz Plaza Giz Facade (Url-51).



**Image 3.72:** Iz Plaza Giz (Url-51).

### 3.4. EXAMINED HIGH-RISE BUILDINGS DATA

Buildings Facade evaluation data in term of sun-daylight, natural ventilation and material parameters are as follows:

• Sun-Daylight Parameters Evaluation Data are as follows at (Table 3.4-3.5):

Table 3.4: Sun-Daylight Parameters Data Table.

No	High-rise Buildings	Sun - Daylight Parameters															
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	
		Surface color of the facade (Light-Dark)	Self-Shading Glass	Continuous Glass	DSF	Low-E coated Glass	Reflective glass	Insulation	Skylight system to increase daylight	West-East facade shading element	Vertical shading element at the western facade	Horizontal shading element at the southern facade	Sun consideration at the North (Vertical)	Sun consideration at the South (Horizontal)	Sun consideration at the East (Vertical)	Sun consideration at the West (Vertical)	
1	Istanbul Sapphire	Blue glass facade	Aluminum sun control panels at the inner face of the outer skin (Çatı ve Cephe, 2010).	Existing	Existing	Special curtain system controlled automatically by PC depending on The season, day and hour (İnan, 2016).	Special curtain system controlled automatically by PC depending on The season, day and hour (İnan, 2016).	Schüco ASS 50/ ASS 70.HI-glasses are heat insulated (Url-39).	Sky-courtyard located on every three floors (Çatı ve Cephe, 2008).	Existing on the eastern facade (Çatı ve Cephe, 2010).	Not existing	Not existing	Deaf facade-cold facade system (Çakır Kıasif, 2015).	Deaf facade-cold facade system (Çakır Kıasif, 2015).	Double-skin facade, Aluminum sun control panels	Double-skin facade	
2	Levent 199	Transparent Glass	The modular panels in the plinth block designed and manufactured to carry horizontal band aluminum solar control elements (Yalıtım Dergisi, 2015).	Existing	Not existing	Special quality glasses and intermediate layers were used to reduce energy consumption (Url-52).	Special quality glasses and intermediate layers were used to reduce energy consumption (Url-52).	High heat-insulated - waterproof insulated noise insulated double glazed glass (Yalıtım Dergisi, 2015).	Smart building automation and fiber optic IT infrastructure (Url-40).	Not existing	Not existing	Not existing	Fully glass-clad facade, ZRL 90 S Structural Silicone Modular Panel System with Heat Barrier is used for facade cladding (Yalıtım Dergisi, 2015). A smart building automation and fiber optic IT infrastructure has been used (Url-40). There is no usage of shading element.				
3	Istanbul Tower 205	Transparent Glass (Ultra clear glass has low iron content to have natural silver tone) (Url-56).	Existing (Vertical shading)	Existing	Not existing	Triple silver coating maximize day light usage and provides energy saving (min. 60% light and max. 30% energy transmittance) (Url-56).	Triple silver coating maximize day light usage and provides energy saving (Url-56).	Trickle Vent System isolates the external noise (Url-56).	Not existing	Existing	Existing	Not existing	3D designed facade system with Vertical motives providing shading to the building and allowing maximum sunlight to penetrate inside, these motives of the tower give it a different look at every angle of the day (Url-56).				
4	Kanyon	Blue Glass - Beige/silver coloured stainless steel - Aluminum	Existing (Horizontal shading) Southern facade	Existing	Not existing	The tempered outer glazing coated by invisible silver low-emittance low E coating (Schulze 2015).	The partly tempered inner glazing is composed of two layers of polyvinyl (PVB) laminated glazing (Schulze, 2015).	Glazing system providing noise and heat insulation (Url-41).	Not existing	Not enough / South-eastern / South-western facades (Schulze, 2015).	Not existing	Existing	Glasses are designed from the ground up to allow the daylight passing inside (Url-78).	Horizontal sunshade elements are placed at the exterior facade face, so as not to obstruct the view for the office occupants. Semi-transparent rolled up Internal vertical blinds made of textile, automatically controlled by the solar intensity, control light, block glare and provide privacy (Schulze, 2015).	South-eastern / South-western facades, horizontal sunshade elements are placed so as not to obstruct the view. But due to the suns solar path the eastern and western facades are not shaded enough (Schulze, 2015). /North-eastern / North-western facades, Glasses are designed from the ground up to allow the daylight (Url-78).		
5	Tekfen Tower	Dark/ brick-color granite stones, grey-toned reflective glass.	Not existing	Partially (upper part of the building)	Not existing	Double-glazing system, allows maximum sunlight to penetrate, but leaves the minimum solar heat amount to get inside (Sağlam, 2016).	6 mm colored reflective glass - 12mm air gap - 6mm colored reflective glass (Sağlam, 2016).	Double-glazing system, leaves the minimum solar heat amount to get inside (Sağlam, 2016).	Not existing	Not existing	Not existing	Not existing	Less transparent surface	Less transparent surface. There is no shading element usage	The transparent surface increases at the eastern facade. There is no shading element usage	Less transparent surface. There is no shading element usage	
6	QNB Finance Bank Crystal Tower	Transparent Glass	Smart Facade/ Automatic shading is provided by the automation systems used, depending on the daylight sensors (Url-42).	Existing	Not existing	Sunguard S. Neutral 51/28, double-silver coated solar control glass is used (Url-43).	Automatic shading is provided by the automation systems used, depending on the daylight sensors (Url-42).	Excellent thermal insulation (Url-44).	There is a soaring sky garden at the upper level of the building (Url-45).	Existing	Interior shading element	Interior shading element	Due to curtain control system with NIAGARA / HELVAR, daylight is controlled by daylight sensors, providing an automatic shading, depending on latitude and longitude according to sunrise and sunset values, thus ensuring maximum efficiency. Due to the structure of the building, to provide the comfort of the building occupants, the curtain settings of the west side and the curtain settings of the east side are completely different. So the people working on the same floor can work comfortably and have the necessary amount of daylight (Url-42).				

**Table 3.5: Sun-Daylight Parameters Data Table (Continues).**

7	<b>Metrocity Office Tower</b>	White colored aluminum composite panel, dark colored reflective heat glass	Not existing	Existing	Not existing	Dark colored reflective heat glass is used, allowing maximum daylight inlet, leaving minimum solar heat inside (Sağlam, 2016).	Reflective heat glass is used	Heat insulated	Teflon coated fiberglass roofing is used to purify harmful effects of direct sunlight during the day. Roofing material, Teflon, which is a self-cleaning material that can pass 10 - 12% light (Sağlam, 2016).	Not existing	Not existing	Not existing	Facade designed to allow the maximum possible window view and daylight penetration, strip window provides a high-quality natural light is used (Wong, Yuen, 2011). There is no shading element usage	The circulation core is placed at the western facade (Sağlam, 2016).	
8	<b>Olive Grove Tower - Garanti Bank Headquarters (BBVA)</b>	Blue-colored Glass, Beige toned stone	Not existing	At the southern facade only	Not existing	Existing	Existing	Thermal insulation, Water penetrate insulation and noise insulation (Url-46).	Not existing	Not existing	Not existing	Not existing	On the northern facade the deaf part ratio increased clearly	The southern facade is covered with a completely transparent surface.	On the western and eastern facades, the ratio of transparent surfaces was reduced, and the deaf facade rates were increased.
9	<b>Diamond of Istanbul</b>	Transparent Glass	—	Existing	Existing	—	—	—	Existing	—	—	—	Double-skin glazed facade system is used, this facade type, allows the sunlight to penetrate inside, and separate the interior and exterior atmosphere, it also provides a shading to the interior place (Sağlam, 2016).		
10	<b>Spine Tower</b>	Transparent Glass	Existing, Horizontal shading at the western facade	Existing	Not existing	Existing	Diagonal curved area and glass selections on the top of the Spine Tower have been selected with reflective properties (Url-47).	Thermal insulation-Water insulation (Url-58).	Not existing	Existing on the western facade	Not existing	Not existing	Elegance 72 Panel Facade System has been specially designed for the project, in order to use uninterrupted windows at the floor-ceiling level to see the view uninterruptedly and to allow maximum daylight entrance (Url-48).	Horizontal shading existing at the western facade	
11	<b>River Plaza - Ozdilek Plaza Tower A - B</b>	Blue-colored Glass, Beige toned stone	Existing, Vertical shading at the eastern facade	Existing	Not existing	Existing	Existing	High heat and noise insulation (Url-49).	Not existing	Existing on the eastern facade	Not existing	Not existing	On the northern and southern facades, the ratio of transparent surfaces was reduced, and the deaf facade rates were increased. / Building facade system allows 50% of the sunlight to penetrate inside (Url-49).	Vertical shading elements are placed at the eastern facade	The western facade is covered with a completely transparent surface. Building facade system allows 50% of the sunlight to penetrate inside (Url-49).
12	<b>Is Bank Tower I</b>	Dark colored reflective heat glass	Not existing	Existing	Not existing	Building is surrounded by leak-proof glass. Heat-impermeable, light-permeable glass was produced especially by Şişecam (Sağlam, 2016).	Existing	Heat insulated	Not existing	Not existing	Not existing	Not existing	A wide window opening on the facade is providing a substantial amount of daylight into the building (Wong, Yuen, 2011). Blinds used to prevent reflection, glare and shine, can be controlled by users (Url-50).		
13	<b>Iz Plaza Giz</b>	Light composite boards + glass	Not existing	Existing	Not existing	Existing	High solar reflective glass (Url-80).	Water and sound insulation (Url-51).	Not existing	Not existing	Not existing	Not existing	All facades are designed with the same features, high solar reflective colored glass used at the curtain glass system.		

\*Since the construction of Diamond of Istanbul high-rise building is still on hold, some data could not be accessed.

- **Natural Ventilation Parameters Evaluation Data are as follows at (Table 3.6-3.7):**

**Table 3.6:** Natural Ventilation Parameters Data Table.

No	High-rise Buildings	Natural Ventilation Parameters											
		P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27
		<i>Natural Ventilation</i>	<i>Skylight system (Ventilation)</i>	<i>Natural ventilation Grilles</i>	<i>Wind Power</i>	<i>No Vertical shading element</i>	<i>Wing Wall</i>	<i>Openable Windows</i>	<i>Vertical landscape elements in the Facade</i>	<i>Wind consideration at the North</i>	<i>Wind consideration at the South</i>	<i>Wind consideration at the East</i>	<i>Wind consideration at the West</i>
1	<b>Istanbul Sapphire</b>	Existing (DSF, vertical gardens) (Çatı ve Cephe, 2008).	Sky-courtyard located on every three floors (Çatı ve Cephe, 2008).	Existing	—	Not existing	Not existing	Existing at the inner facade (Çatı ve Cephe, 2008).	Vertical gardens	Deaf facade-cold facade system		Considered /Double-skin Facade	
2	<b>Levent 199</b>	Adequate fresh air is supplied to all user areas / Filters used in ventilation system are selected at minimum F7 level (Url-52).	Cooling system and spacious green central courtyard (Url-40).	Not existing	Electricity is provided by the wind power station (Url-79).	Not existing	Not existing	Not existing	Existing	Double glazed facade. The building underwent wind tunnel tests, so it is providing the necessary resistance against high wind loads. Mechanical ventilation system (Url-40).			
3	<b>Istanbul Tower 205</b>	Intelligent naturally ventilated facade, Trickle Vent System (100% fresh air quality -Breathing Building) (Url-56).	Not existing	Trickle Vent System creates natural air circulation (Url-56).	—	Existing	Not existing	Not existing, Trickle Vent System existing	Not existing	Special Trickle vent system mounted to the facade system, allows natural air penetrating inside and providing 100% fresh air hourly (Url-56).			
4	<b>Kanyon</b>	Mechanical ventilation system, depends on taking fresh air from the exterior and extracting polluted air from the interior, at a rate of approximately two air changes per hour (Schulze, 2015).	Not existing	Not existing	Not existing	Not existing	Not existing	Not existing	Not existing	The building underwent wind tests so it is providing the necessary resistance against high wind loads and having a security system preventing any injuries that would occur in case of a window burst. But there is no natural ventilation (Schulze, 2015).			
5	<b>Tekfen Tower</b>	Before the working hours start, the building is provided with 100% cooldown outdoor air with Fan Powered Rehcat VAV air conditioning system (Sağlam, 2016).	Not existing	Existed at the circulation core, and openable window is used (Url-81).	—	Not existing	Not existing	Existing	Not existing	The building is using a mechanical ventilation system with openable windows. Schuco Unitized Curtain Wall system is used at the building facade, the curtain wall system has undergone weather tightness tests (Schuco brochure, 2019).			
6	<b>QNB Finance Bank Crystal Tower</b>	Ventilation works with an automation system. VAV Fan Power Box system is used (Url-54).	There is a soaring sky garden at the upper level of the building (Url-45).	Existing at the mechanical floors	—	Not existing	Not existing	Not existing	Existing	A detailed analysis has been made to the building in terms of wind loads (Url-55). Ventilation works with an automation system, with the mechanical automation, the amount of carbon inside is measured in air, if necessary, excess air is supplied or left airless, the system makes the quality measurements itself (Url-42).			

**Table 3.7:** Natural Ventilation Parameters Data Table (Continues).

7	<b>Metrocity Office Tower</b>	An openable windows is used for natural ventilation, and a VRV (Variable Refrigerant Volume) HVAC system connected to an automation system (Wong, Yuen, 2011).	Not existing	Openable windows is used (Wong, Yuen, 2011).	Not existing	Not existing	Not existing	Existing	Not existing	An openable windows is used for natural ventilation. The heat and light reflective dark-colored glass is used because of Istanbul's windy weather. It is storing storm water for garden watering (Wong, Yuen, 2011).
8	<b>Olive Grove Tower -Garanti Bank Headquarters (BBVA)</b>	The building is ventilated naturally with fresh air through the curtain wall system which is designed with louvers settled at the window sills (Url-53).	Not existing	Existing	—	Not existing	Not existing	Louvers settled at the window sills existing (Url-53).	Not existing	Building Curtain wall system underwent wind tests so it is providing the necessary resistance against high wind loads (Url-46). The curtain wall used at the building designed with louvers settled at the window sills, which allows the fresh air to penetrate inside the building (Url-53).
9	<b>Diamond of Istanbul</b>	Central big atrium (Url-83), Double skinned facade providing natural ventilation (Url-84).	Double-skin facade system (Sağlam, 2016).	—	—	Not existing	—	—	Inner gardens are existing (Url-84).	Double-skin facade / The exterior facade is designed to clean itself with rain and wind (Sağlam, 2016).
10	<b>Spine Tower</b>	The building is ventilated naturally with the fresh air provided by the openable windows, even at 191 m highness (Url-85).	Not existing	Openable windows is used (Url-47).	—	Not existing	Not existing	Existing	Existing	The building underwent wind tests so it is providing the necessary resistance against high wind loads. The window's vents are closed automatically in case of high wind pressures, due to engines included to windows, connected to the wind sensor (Çatı ve Cephe, 2014).
11	<b>River Plaza - Ozdilek Plaza Tower A -B</b>	The building is ventilated naturally with the fresh air provided by the openable windows, on every floor, there are 22 openable vents (Url-49).	Not existing	Existing	—	Existing	Not existing	Existing	Not existing	Building facade includes openable windows. Schuco Unitized Curtain Wall system is used at the building facade, the curtain wall system has undergone weather tightness tests (Schuco brochure).
12	<b>Is Bank Tower I</b>	No natural ventilation, VAV (Variable Air Volume) HVAC system connected to an automation system, a computer-controlled system, has been used to keep air quality and air conditioning at a high level of performance (Wong, Yuen, 2011).	Not existing	Not existing	—	Not existing	Not existing	Not existing	Not existing	No natural ventilation provided. The heat and light reflective dark-colored glass is used because of Istanbul's windy weather. It is storing storm water for garden watering (Wong, Yuen, 2011).
13	<b>Iz Plaza Giz</b>	Ventilated with conditioned fresh air supplied from the air stations (Url-80).	Not existing	Not existing	—	Not existing	Not existing	Not existing	Not existing	All facades are designed with the same features, the structural system of the building underwent wind tests (Url-51).

\*Since the construction of Diamond of Istanbul high-rise building is still on hold, some data could not be accessed.

- **Material Parameters Evaluation Data are as follows at (Table 3.8-3.9):**

**Table 3.8:** Material Parameters Data Table.

No	High-rise Buildings	General Information	Material Parameters		
			P28	P29	P30
		<i>Property of the facade material</i>	<i>Local Material</i>	<i>Recyclable Materials</i>	<i>Environmentally Friendly Materials</i>
1	<b>Istanbul Sapphire</b>	%90 of used facade materials local and natural (Çatı ve Cephe, 2008).	Existing	Existing	Existing
2	<b>Levent 199</b>	Building materials do not harm human health (Url-40). Over 20% of the materials used during construction have recycled content and over 40% were selected from local materials (Url-52).	Existing	Existing	Existing
3	<b>Istanbul Tower 205</b>	Eco-friendly building / Use of recycled and certified materials (Url-56).	Existing	Existing	Existing
4	<b>Kanyon</b>	Natural materials used (Url-78).	Existing	Existing	Existing
5	<b>Tekfen Tower</b>	Granite Blocks are imported from Africa, India, Finland and Italy (Url-82).	Not existing	Existing	Existing
6	<b>QNB Finance Bank Crystal Tower</b>	The project details and material selections in Finansbank Crystal Tower based on the principle of sustainable energy while projecting were created to receive LEED certification and to be registered as Green Building (Çatı ve cephe, 2016).	Not Existing	Existing	Existing
7	<b>Metrocity Office Tower</b>	Local materials were used, but no recycled materials were used (Wong, Yuen, 2011).	Existing	Existing	Existing
8	<b>Olive Grove Tower -Garanti Bank Headquarters (BBVA)</b>	The cladding company uses products with ISO 14000 Environmental system and ISO 18000 Health and Safety System Certificates (Url-46).	Existing	Existing	Existing

**Table 3.9: Material Parameters Data Table (Continues).**

9	<b>Diamond of Istanbul</b>	Durable, flexible and reusable and easily recycled steel material used (Url-57).	Not existing	Existing	Existing
10	<b>Spine Tower</b>	Lighting energy was saved by using special materials, the aluminum used at the facade is fully recyclable and supporting a zero-energy construction (Url-58).	Existing	Existing	Existing
11	<b>River Plaza - Ozdilek Plaza Tower A -B</b>	Local materials, environmentally friendly materials and recyclable material are used (Url-49).	Existing	Existing	Existing
12	<b>Is Bank Tower I</b>	Local materials and re-used materials were used, but no recycled materials were used (Wong, Yuen, 2011).	Existing	Existing	Existing
13	<b>Iz Plaza Giz</b>	Local materials, environmentally friendly materials are used (Url-51).	Existing	Existing	Existing

### 3.5. RESULTS

#### **1. Istanbul Sapphire:**

From the (Table 3.4-9) we can conclude that Istanbul Sapphire's facade system benefits from natural light at a maximum level, with the help of the glass which is covering the whole building. At the same time, green spaces are created on both sides of the building between the inner shell and the outer shell, arranged as inner gardens every three floors. These vertical garden spaces act like atriums that provide natural ventilation to the building through louvers which take the air from ground level and exhaust it through the top ensuring a natural and warm atmosphere which makes it a breathing building. Thus, it will consume less energy for air conditioning. On the other hand, due to the vertical gardening technique located on every three floors, it is protected from the direct sunlight. Also, it is designed with a special curtain system controlled automatically by computer depending on The season, day and hour. Besides, This Double-skin facade system that was used, especially the outer shell, provides the necessary protection against adverse meteorological conditions, air pollution and noise. On the other hand this skyscraper's occupants can open their windows and take fresh air through the buffer zone and the vertical gardens provided by the Double-skin facade. Moreover, %90 of used facade materials are local and natural materials.

#### **2. Levent 199:**

In accordance with the (Table 3.4-9), a fully glass-clad facade is used at Levent 199, so it is providing a good daylight ratio to the building occupants. The curtain wall type used is ZRL 90 S Structural Silicone Modular Panel System with Heat Barrier (Yalitim Dergisi). Special quality glasses and intermediate layers were used to reduce energy consumption. The building provides automation and fiber-optic IT infrastructure (Url-40). However, it is noticeable that there is no usage of shading elements at the exterior facade skin. On the other hand, the building is providing its fresh air with a mechanical system. A 4 Pipes Fan Coil Heating / Cooling system is used. According to Levent 199 (Url-40), adequate fresh air is supplied to all user areas / Filters used in the ventilation system are selected at minimum F7 level (Url-52). Additionally, the building underwent wind tunnel tests, so it is providing the necessary resistance against high

wind loads. Furthermore, the building includes green areas, spacious green central courtyard. In addition, building electricity is provided by the wind power station. On the other hand, the building is using materials that do not harm human health. Also, over 20% of the materials used during construction have recycled content and over 40% were selected from local materials. Thus, the carbon dioxide emission from transportation was reduced as the amount of raw materials required for construction and local resources were preferred (Url-52).

### **3. Istanbul Tower 205:**

As a result of the study done at the (Table 3.4-9), we can find that Istanbul Tower 205's facade system providing enough daylight, 60% light, 30% energy transmittance, to the interior places with the triple coated glass and the vertical motives settled on the facade which acting like sun shading elements. These motives of the tower give it a different look at every angle of the day. Also, this transparent facade design and the location of the tower gives the building a magnificent city and Bosphorus view. Besides that, as it is mentioned before, Istanbul Tower 205 is the first building in Turkey that used the Trickle Vent Technique at the facade, the technique that gives the building a breathing building feature, which allows the fresh air to penetrate inside and provides building occupants a fresh air hourly. Never forgets to mention that besides providing fresh air per hour, it isolates the building from the outside noise. One the other hand buildings facade does not include a vertical garden system but in this project, there is plenty of landscaping on the ground floor and outside courtyards. Besides, İstanbul Tower 205's materials are environmentally friendly. Thus, these are some of the reasons that led the building to obtain a LEED Gold Certificate.

### **4. Kanyon:**

According to (Table 3.4-9), Kanyon's facade has sun shading elements stretches from the south-eastern facade to the north-eastern facade, due to the investigation of various sources, we conclude that the design of the shading elements used in the facade does not consider the solar path. Therefore, it is not providing the required shading enough. It is also found that the internal sun shading elements were providing a good shading but it is not enough to prevent the heat entrance to the building. Which causes more

energy consumption for cooling the building. On the other hand, the building depends on a mechanical ventilation system, which takes the fresh air from the exterior and exhausts the polluted air to it. The air supplied mechanically, cooled and heated, then used to ventilate the interior space through the air conditioning systems. Besides, the building has durability against high wind loads because it was undergoing wind tests, and the laminated glazing system that used providing security by preventing the window from bursting into tiny pieces that cause injuries in case of a burst.

### **5. Tekfen Tower:**

Due to the information collected from the related sources and the (Table 3.4-9) for Tekfen tower's air conditioning system, the air-powered, Fan Powered Reheat VAV system has been preferred. which has been used in high-rise buildings in America since 1990. The entire system has been designed according to Turkish Standards, American BOCA codes and ASHRAE recommendations. Maximum indoor air quality and maximum oxygen content are provided by the stimulation received from indoor air quality sensors. The system has been designed so that the minimum amount of clean outdoor air per person is 50 m<sup>2</sup>/h. Before the working hours start, the building is provided with 100% cooldown outdoor air, allowing the day to start with fresh air. Besides, when the weather conditions are suitable, the amount of outdoor air is increased and natural cooling is performed, thus richer indoor air quality is provided (Sağlam, 2016). However, Tekfen tower's facade color is darker than the other selected building's facades. On the other hand, the facades of the building have been designed as, partly curtain glass and deaf parts which are partially covered with granite stone, according to architectural design rules. Besides, a Double-glazing system that allows maximum sunlight to penetrate, but leaves the minimum solar heat amount to get inside, was preferred. As well, the building's northern, southern and western facades transparent and deaf surfaces alike each other, when the eastern facade's transparent surface increases compared to them. So, it can be concluded that the sun path is not considered by the building facade. On the other hand, due to the collected data, materials used at the project are not local materials, building's granite blocks are imported from Africa, India, Finland and Italy.

## **6. QNB Finance Bank Crystal Tower:**

According to the (Table 3.4-9), QNB Finance Bank Crystal Tower's facade is acting as a smart facade because of the Sunguard S. Neutral 51/28, double-silver coated solar control glass that used (Url-43), its facade depended on an automation system, controls the curtains automatically due to the sun and the daylight directions, as the system is controlled automatically. According to the curtain control system with NIAGARA / HELVAR, daylight is controlled by daylight sensors, providing an automatic shading, depending on latitude and longitude according to sunrise and sunset values, thus ensuring maximum efficiency. Besides, due to the structure of the building, to provide the comfort of the building occupants, the curtain settings of the west side and the curtain settings of the east side are completely different. So the people working on the same floor can work comfortably and have the necessary amount of daylight (Url-42). On the other hand, the building's ventilation also is controlled by the automation system, which detects the air's carbon amount, and if it is necessary, excess air is supplied or left airless. So, the system makes the quality measurements itself. Also, a detailed analysis has been made to the building in terms of wind loads (Url-55).

As QNB Finance Bank Crystal Tower is based on the principle of sustainable energy it deserved to receive LEED certification and to be registered as a Green Building. Besides, the building, which was rated seventh in the Emporis Skyscraper Award 2014 ranking. It was the only project from Turkey to enter the Emporis rankings.

## **7. Metrocity Office Tower:**

In accordance with the (Table 3.4-9), the type of window used at Metrocity Office Tower is strip window, which allows a great amount of the daylight to penetrate inside, also it is providing a wide range of view to building occupants. Besides, the glass type used at these windows is a dark-colored reflective heat glass which is preventing the harmful UV beams inlet and allowing maximum daylight penetration. On the other hand, as a skylight system, Teflon coated fiberglass roofing is used to purify harmful ethics of direct sunlight during the day and provide daylight inlet. This Teflon roofing material is a self-cleaning material that can pass 10 - 12% light (Sağlam, 2016). As well, the aluminum composite used to cover the deaf parts of the facade is selected as

a light-colored so the sunlight absorbance of it is lower than the dark facade cladding materials. As a ventilation system, the building is designed with openable windows, so it can be ventilated naturally. Besides, a VRV (Variable Refrigerant Volume) HVAC system is used also, this system is connected to an automation system (Wong & Yuen, 2011). On the other hand, it is detected that local materials were used at the building, but no recyclable materials were used (Wong & Yuen, 2011).

#### **8. Olive Grove Tower - Garanti Bank Headquarters (BBVA):**

From the data collected at the (Table 3.4-9), The Olive Grove Tower, which is hosting Garanti Bank Headquarter is the first bank in Turkey having LEED Platinum Certificate. Thus, it is designed according to the green architecture criteria. However, the building facade cladding was done by Metal Yapı company, this company uses products with ISO 14000 Environmental system and ISO 18000 Health and Safety System Certificates (Url-46). On the other hand, it can be noticed that the building's southern facade is covered with a completely transparent surface, on the northern facade the deaf part ratio increased clearly and on the western and eastern facades, the ratio of transparent surfaces was reduced, and the deaf facade rates were increased. So, it can be concluded that the sun path is considered by the building facade. Besides, the building is naturally ventilated by the curtain wall system used, this wall system designed with louvers settled at the window sills, which allows the fresh air to penetrate inside the building (Url-53).

#### **9. Diamond of Istanbul:**

Due to the collected data at (Table 3.4-9), Diamond of Istanbul is Turkey's first steel-concrete composite skyscraper. The double-skin glazed facade system is used at Diamond of Istanbul, this facade type, allows the sunlight to penetrate inside, and separate the interior and exterior atmosphere, it also provides shading to the interior place (Sağlam, 2016). Besides, the building is providing natural ventilation by a central big atrium and double-skin facade. However, the exterior facade is designed to clean itself with rain and wind (Sağlam, 2016). Furthermore, the building contains vertical gardens that support natural ventilation through the building. On the other

hand, durable, flexible, reusable and easily recycled steel material used (Url-57).  
\*Since the construction of the building is still on hold, some data could not be accessed.

### **10. Spine Tower:**

In accordance with the data collected from (Table 3.4-9), the building is an exemplary project designed according to international sustainability standards. It is a model project that is sustainable, energy-saving and 54% of it is green. On the other hand, the diagonal sloping area and glass selections on the top of the Spine Tower have been selected to reflect the sun's rays. Furthermore, Elegance 72 Panel Facade System has been specially designed for the project, in order to use uninterrupted windows at the floor-ceiling level to see the view uninterruptedly and to allow maximum daylight entrance (Çatı ve Cephe, 2014). Additionally, the building is ventilated naturally with the fresh air provided by the openable windows, even at 191 m highness. Subsequently, the building's facade is providing the necessary existence against the wind pressure, and changeable weather conditions, in addition to thermal insulation, due to the Elegance 72 panel system used (Url-58). However, The building in general underwent wind tests so it is providing the necessary resistance against high wind loads. The window's vents are closed automatically in case of high wind pressures, due to engines included to windows, connected to the wind sensor (Çatı ve Cephe, 2014). On the other hand, the Elegance 72 facade system, is a panel system which is produced and becomes almost-finished at the factory, so that it is providing a faster construction and offering a better quality as it is produced at the factory. Besides, lighting energy was saved due to the special material used.

### **11. River Plaza - Ozdilek Plaza Tower A –B:**

From the data collected at the (Table 3.4-9), It is clearly noticeable that while the ratio of transparent surfaces was reduced and the deaf facade rates were increased on the northern and southern facades, the western facade is covered with a completely transparent surface without any usage of shading element. Vertical shading elements are placed at the eastern facade. Thus, it can be concluded that the sun path is not

considered by the building facade. However, the building facade system allows 50% of the sunlight to penetrate inside (Url-49). On the other hand, the building is ventilated naturally with the fresh air provided by the openable windows, on every floor, there are 22 openable vents (Url-49). The Schuco Unitised Curtain Wall system is used at the building facade, the curtain wall system has undergone weathertightness tests (Schuco brochure). Besides, local materials, environmentally friendly materials and recyclable material are used.

### **12. Is Bank Tower I:**

As a result of the study done at the (Table 3.4-9), dark colored reflective heat glass was used, the building is surrounded by leak-proof glass which is heat-impermeable, light-permeable glass, this glass was produced especially by Şişecam (Sağlam, 2016). Besides, it is detected that there is neither vertical nor horizontal exterior shading elements. However, there are interior shading blinds, these blinds are used to prevent reflection, glare and shine, and they can be controlled by users. Furthermore, a panel cladding system is used for the facade, this system is brought as almost-finished module-sized panels from the factory, and it is completed with the installation work at the construction site (Wong & Yuen, 2011). Thus, it is providing a faster construction and offering a better quality as it is produced at the factory. Besides, a wide window opening on the facade is providing a substantial amount of daylight into the building, according to Wong, Yuen, (2011), the percent of natural daylighting of the building is 85%. Additionally, there is no natural ventilation at the building, it is ventilated with the traditional VAV (Variable Air Volume) HVAC system, which is connected to an automation system, a computer-controlled system, to keep air quality and air conditioning at a high level of performance (Wong & Yuen, 2011). On the other hand, the heat and light reflective dark-colored glass is used because of Istanbul's windy weather. However, the building is storing storm water for garden watering (Wong & Yuen, 2011). Anyhow, it is detected that local materials and reused materials were used at the building, but no recyclable materials were used (Wong & Yuen, 2011).

### **13. Iz Plaza Giz:**

According to the (Table 3.4-9), All facades of Iz Plaza Giz are designed with the same features, a high solar reflective colored glass used at the curtain glass system. Besides, the building's facade is designed with a light color, so it does not absorb a big amount of sunlight.

On the other hand the building is ventilated mechanically with conditioned fresh air supplied from the air stations, according to the standards of ASHRAE (Giz İnşaat, Url-80). Besides, the structural system of the building underwent wind tests.

### 3.6. EXAMINED HIGH-RISE BUILDINGS EVALUATION SCORE

According to the data collected above, buildings evaluation scores are as follows:

- Sun-Daylight Parameters Evaluation score is as follows at (Table 3.10):

**Table 3.10:** Sun-Daylight Parameters Score.

No	Building	Parameter	Sun - Daylight Parameters														Total	%	
		Parameter Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14			P15
		Score per Parameter	2	2	2	2	2	2	2	2	2	2	2	2	2	2			2
1.	Istanbul Sapphire Tower		2	2	2	2	2	2	2	2	1	0	0	1	1	2	2	23	76.7%
2.	Levent 199		2	0	2	0	2	2	2	2	0	0	0	2	1	1	1	17	56.7%
3.	Istanbul Tower 205		2	2	2	0	2	2	2	0	2	2	0	2	2	2	2	24	80%
4.	Kanyon		2	2	2	0	2	2	2	0	1	0	2	2	2	1	1	21	70%
5.	Tekfen Tower		0	0	1	0	2	2	2	0	0	0	0	1	0	1	1	10	33.4%
6.	QNB Finance Bank Crystal Tower		2	2	2	0	2	2	2	2	2	2	2	2	2	2	2	28	93.4%
7.	Metrocity Office Tower		2	0	2	0	2	2	2	2	0	0	0	2	1	1	2	18	60%
8.	Olive Grove Tower - Garanti Bank Headquarters (BBVA)		2	0	1	0	2	2	2	0	0	0	0	0	1	2	2	14	46.7%
9.	Diamond of Istanbul		2	—	2	2	—	—	—	2	—	—	—	2	2	2	2	16	100%
10.	Spine Tower		2	1	2	0	2	2	2	0	1	0	0	2	1	1	2	18	60%
11.	River Plaza - Ozdilek Plaza Tower A –B		2	1	2	0	2	2	2	0	1	0	0	0	0	2	1	15	50%
12.	Is Bank Tower I		2	0	2	0	2	2	2	0	0	0	0	2	1	1	1	15	50%
13.	Iz Plaza Giz		2	0	2	0	2	2	2	0	0	0	0	2	1	1	1	15	50%
Total Score per Parameter			26	24	26	26	24	24	24	26	24	24	24	26	26	26	26	376	100%
Total Summation Per Parameter			24	10	24	4	24	24	24	10	8	4	4	20	15	19	20	234	62.3%
% Percent Per Parameter			92.3%	41.7%	92.3%	15.4%	100%	100%	100%	38.5%	33.4%	16.7%	16.7%	76.9%	57.7%	73%	76.9%	TOTAL SUMMATION	

\*Since the construction of Diamond of Istanbul high-rise building is still on hold, some data could not be accessed. Thus its evaluation has been done within the accessed data only.

- Natural Ventilation Parameters Evaluation score is as follows at (Table 3.11):

**Table 3.11:** Natural Ventilation Parameters Score.

No	Building	Parameter	Natural Ventilation Parameters											Total	%	
		Parameter Number	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26			P27
		Score per Parameter	2	2	2	2	2	2	2	2	2	2	2			2
1.	Istanbul Sapphire Tower		2	2	2	—	2	0	2	2	2	2	2	2	20	90.9%
2.	Levent 199		0	2	0	2	2	0	0	2	1	1	1	1	12	50%
3.	Istanbul Tower 205		2	2	2	—	0	0	2	0	2	2	2	2	16	72.8%
4.	Kanyon		0	0	0	0	2	0	0	0	1	1	1	1	6	25%
5.	Tekfen Tower		2	0	2	—	2	0	2	0	2	2	2	2	16	72.8%
6.	QNB Finance Bank Crystal Tower		0	2	2	—	2	0	0	2	2	2	2	2	16	72.3%
7.	Metrocity Office Tower		2	0	2	0	2	0	2	0	2	2	2	2	16	66.7%
8.	Olive Grove Tower - Garanti Bank Headquarters (BBVA)		2	0	2	—	2	0	2	0	2	2	2	2	16	72.8%
9.	Diamond of Istanbul		2	2	—	—	2	—	—	2	2	2	2	2	16	100%
10.	Spine Tower		2	0	2	—	2	0	2	2	2	2	2	2	18	81.9%
11.	River Plaza - Ozdilek Plaza Tower A –B		2	0	2	—	0	0	2	0	2	2	2	2	14	63.7%
12.	Is Bank Tower I		0	0	0	—	2	0	0	0	1	1	1	1	6	27.3%
13.	Iz Plaza Giz		0	0	0	—	2	0	0	0	1	1	1	1	6	27.3%
Total Score per Parameter			26	26	24	6	26	24	24	26	26	26	26	26	286	100%
Total Summation Per Parameter			16	10	16	2	22	0	14	10	22	22	22	22	178	62.3%
% Percent Per Parameter			61.5%	38.5%	66.7%	33.5%	85.5%	0%	58.4%	38.5%	85.5%	85.5%	85.5%	85.5%	TOTAL SUMMATION	

\*Since the construction of Diamond of Istanbul high-rise building is still on hold, some data could not be accessed. Thus its evaluation has been done within the accessed data only.

- **Material Parameters Evaluation score is as follows at (Table 3.12):**

**Table 3.12:** : Material Parameters Score.

No	Building	Parameter	Material Parameters			Total	%
		Parameter Number	P28	P29	P30		
		Score per Parameter	2	2	2		
1.	Istanbul Sapphire Tower		2	2	2	6	100%
2.	Levent 199		2	2	2	6	100%
3.	Istanbul Tower 205		2	2	2	6	100%
4.	Kanyon		2	2	2	6	100%
5.	Tekfen Tower		0	2	2	4	66.7%
6.	QNB Finance Bank Crystal Tower		0	2	2	4	66.7%
7.	Metrocity Office Tower		2	2	2	6	100%
8.	Olive Grove Tower - Garanti Bank Headquarters (BBVA)		2	2	2	6	100%
9.	Diamond of Istanbul		0	2	2	4	66.7%
10.	Spine Tower		2	2	2	6	100%
11.	River Plaza - Ozdilek Plaza Tower A –B		2	2	2	6	100%
12.	Is Bank Tower I		2	2	2	6	100%
13.	Iz Plaza Giz		2	2	2	6	100%
<b>Total Score per Parameter</b>			<b>26</b>	<b>26</b>	<b>26</b>	<b>78</b>	<b>100%</b>
<b>Total Summation Per Parameter</b>			<b>20</b>	<b>26</b>	<b>26</b>	<b>72</b>	<b>92.3%</b>
<b>% Percent Per Parameter</b>			<b>76.9%</b>	<b>100%</b>	<b>100%</b>	<b>TOTAL SUMMATION</b>	

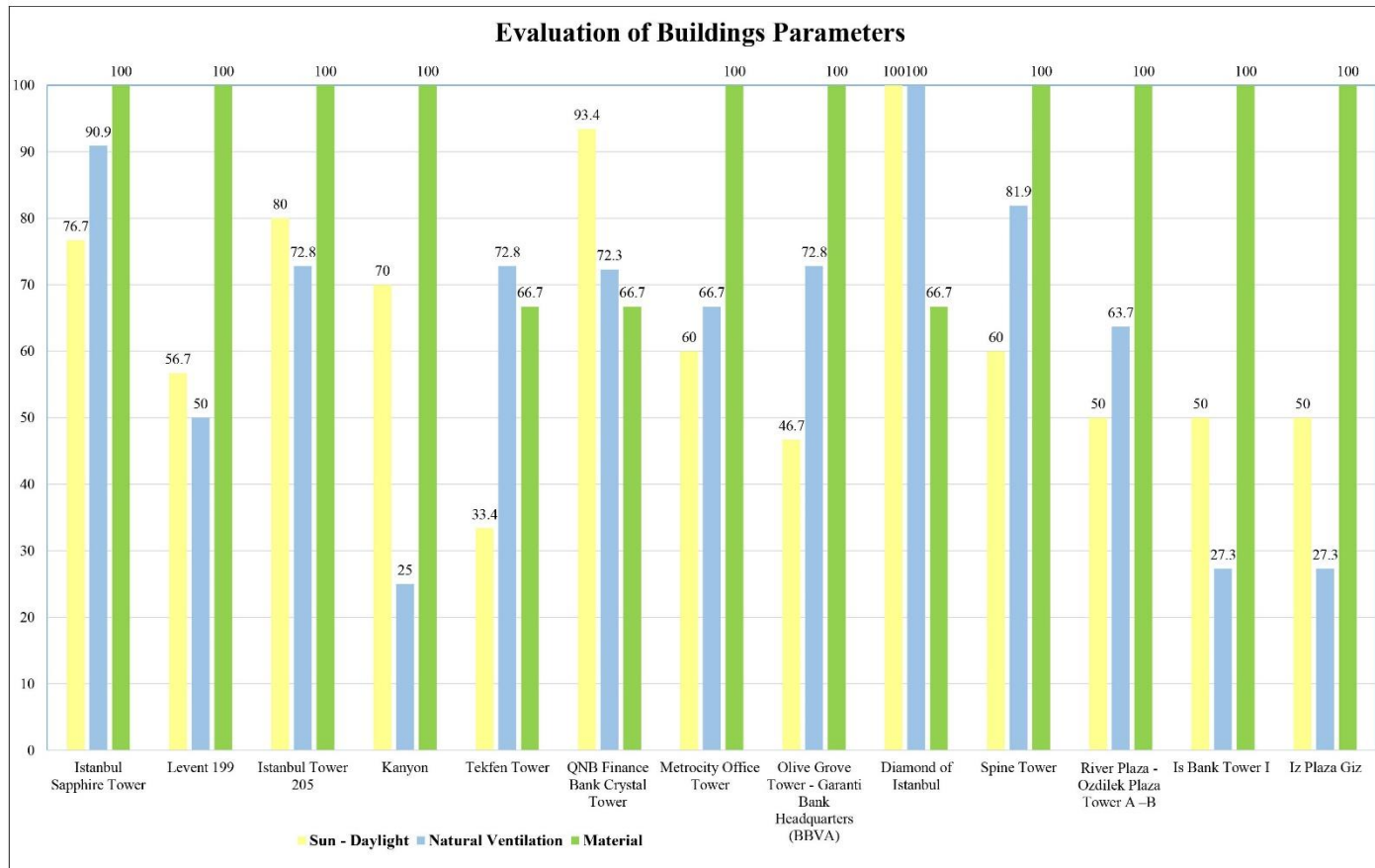
**Table 3.13:** Total Summation of Evaluated Parameter Scores.

No	Building	Parameter	Sun - Daylight Parameters		Natural Ventilation Parameters		Material Parameters		TOTAL SUMMATION		%
		Total Score per Parameter	Total	Parameter Score	Total	Parameter Score	Total	Parameter Score	Total	Score	100%
			30		24		6		60		
1.	Istanbul Sapphire Tower		30	23	22	20	6	6	58	49	84.5%
2.	Levent 199		30	17	24	12	6	6	60	35	58.4%
3.	Istanbul Tower 205		30	24	22	16	6	6	58	46	79.3%
4.	Kanyon		30	21	24	6	6	6	60	33	55%
5.	Tekfen Tower		30	10	22	16	6	4	58	30	51.8%
6.	QNB Finance Bank Crystal Tower		30	28	22	16	6	4	58	48	82.8%
7.	Metrocity Office Tower		30	18	24	16	6	6	60	40	66.7%
8.	Olive Grove Tower - Garanti Bank Headquarters (BBVA)		30	14	22	16	6	6	58	36	62.1%
9.	Diamond of Istanbul		16	16	16	16	6	4	38	36	94.8%
10.	Spine Tower		30	18	22	18	6	6	58	42	72.3%
11.	River Plaza - Ozdilek Plaza Tower A –B		30	15	22	14	6	6	58	35	60.4%
12.	Is Bank Tower I		30	15	22	6	6	6	58	27	46.6%
13.	Iz Plaza Giz		30	15	22	6	6	6	58	27	46.6%
<b>TOTAL SUMMATION</b>			<b>376</b>	<b>234</b>	<b>286</b>	<b>178</b>	<b>78</b>	<b>72</b>	<b>740</b>	<b>484</b>	<b>65.4%</b>
			<b>62.3%</b>		<b>62.3%</b>		<b>92.3%</b>				

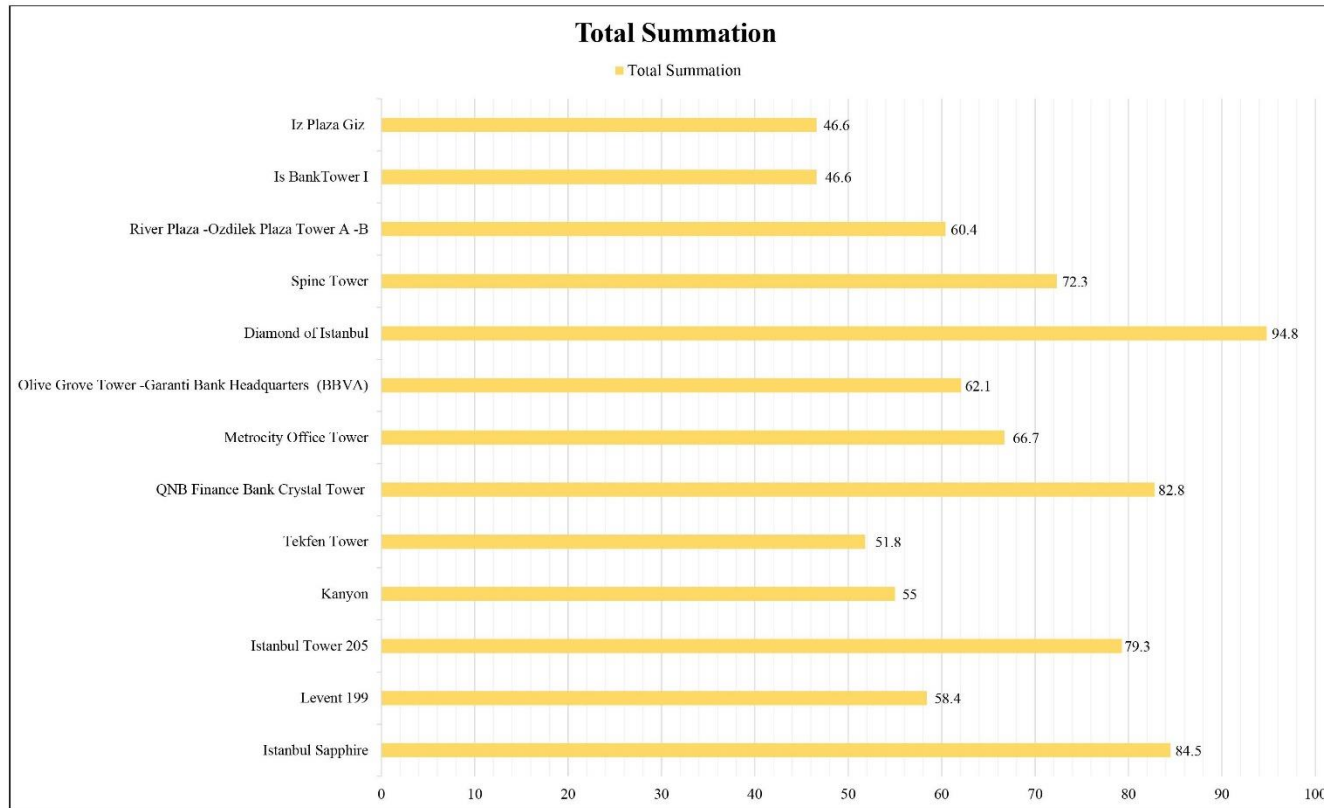
\*Since the construction of Diamond of Istanbul high-rise building is still on hold, some data could not be accessed. Thus its evaluation has been done within the accessed data only. Therefore, its evaluation score is shown as 36 over 38 – (94.8%). In case of including the missing data into the evaluation, the result may differ.

- Evaluation charts can be concluded from the evaluation parameters score tables above are as follows;

**Table 3.14:** Evaluation Chart of Buildings Parameters.

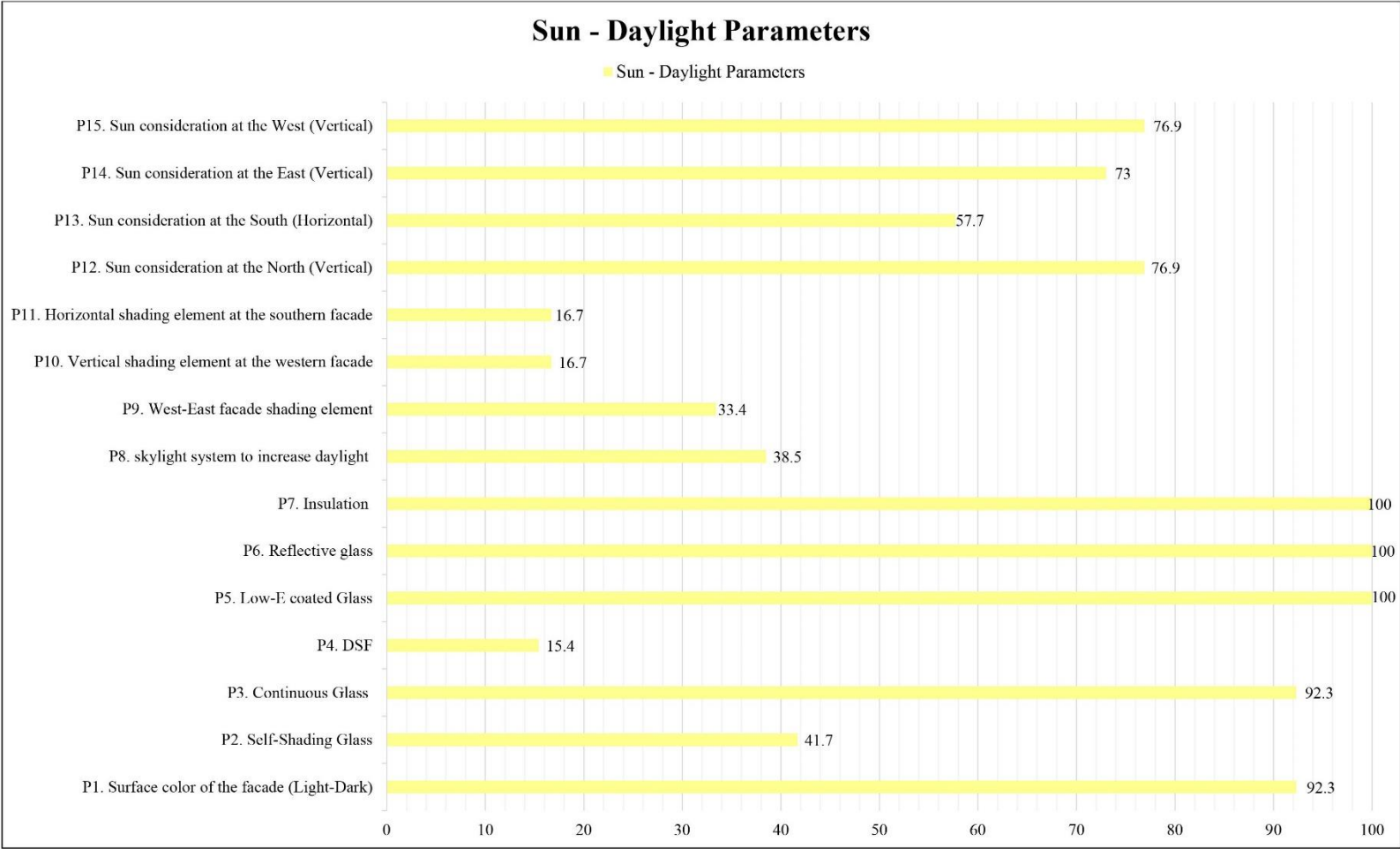


**Table 3.15:** Total Summation Evaluation Chart.

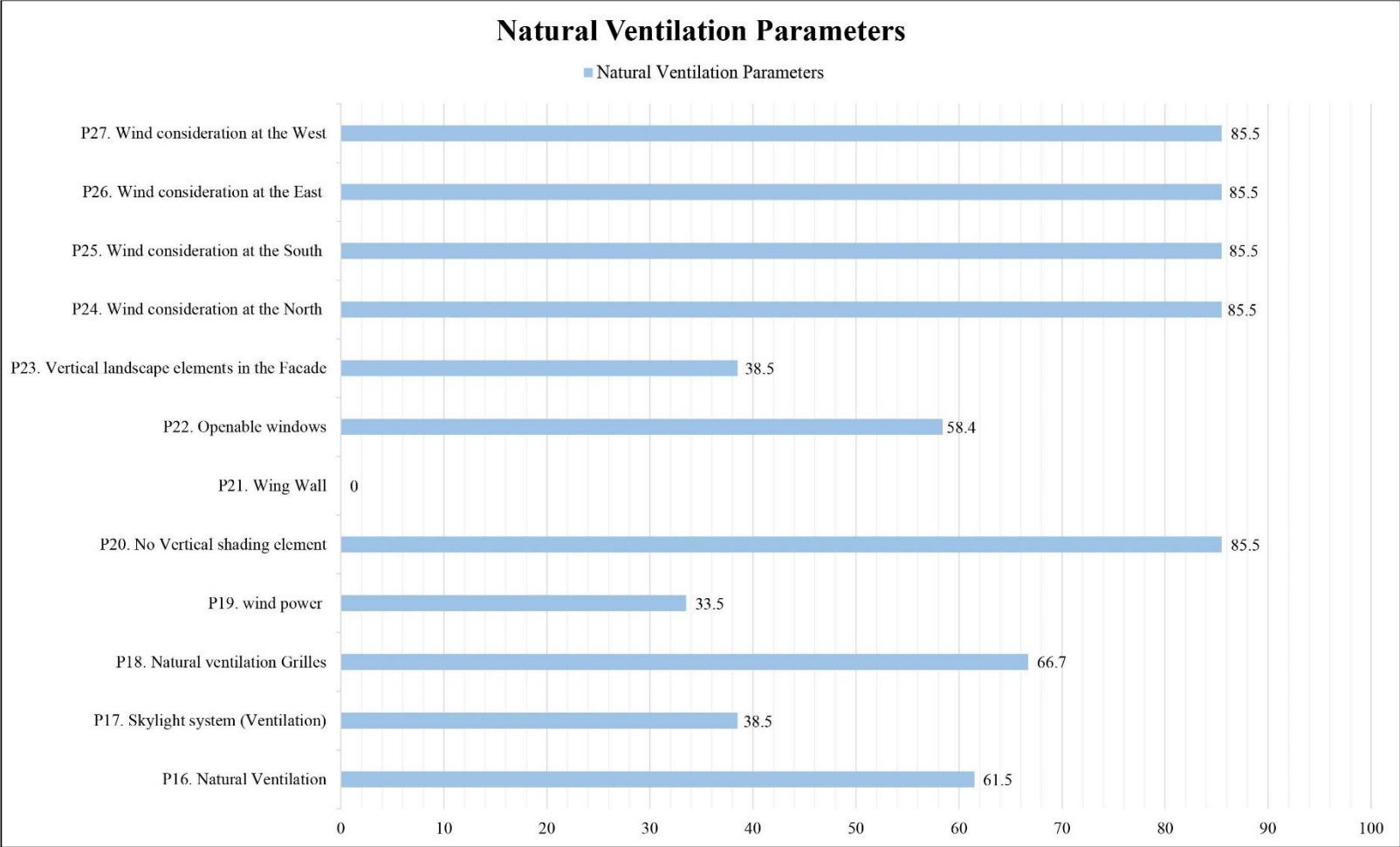


\*Since the construction of Diamond of Istanbul high-rise building is still on hold, some data could not be accessed. Thus its evaluation has been done within the accessed data only. Therefore, its evaluation score is shown as 36 over 38 – (94.8%). In case of including the missing data into the evaluation, the result may differ.

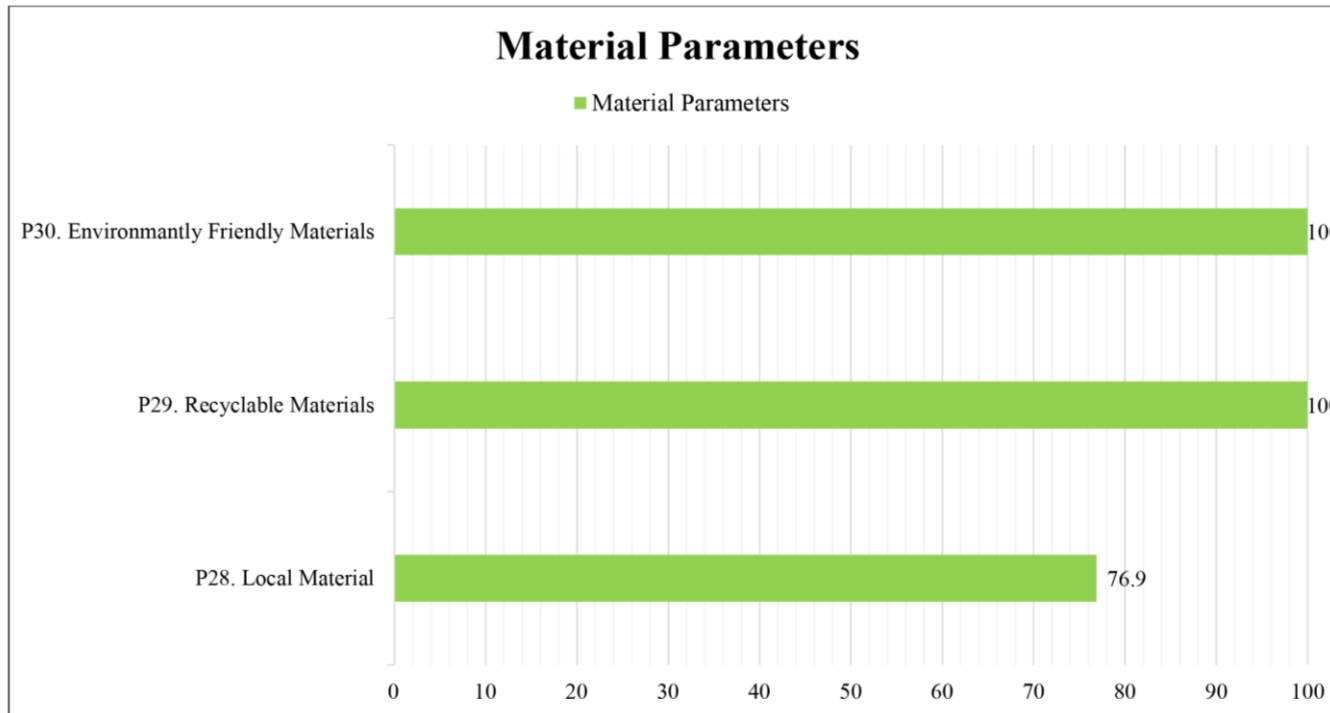
**Table 3.16: Sun-Daylight Parameters Evaluation Chart.**



**Table 3.17:** Natural Ventilation Parameters Evaluation Chart.



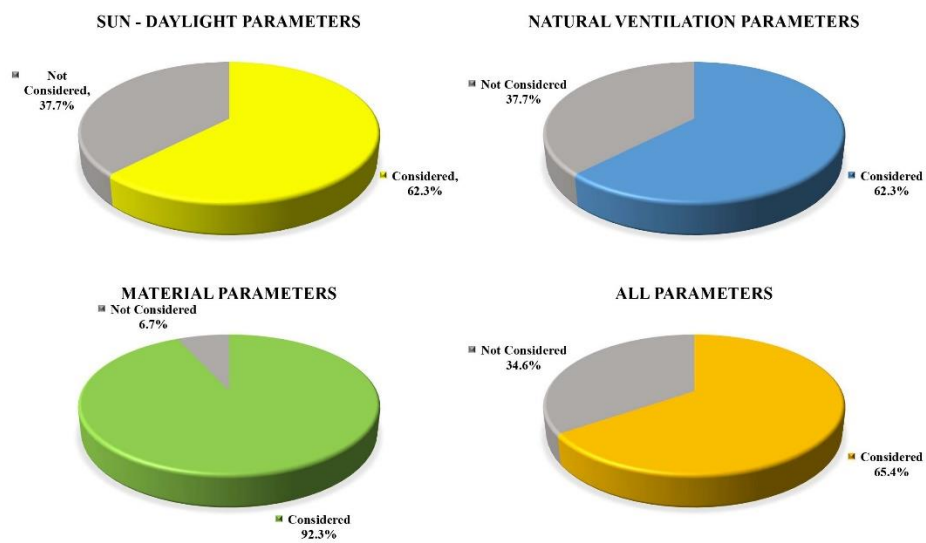
**Table 3.18:** Material Parameters Evaluation Chart.



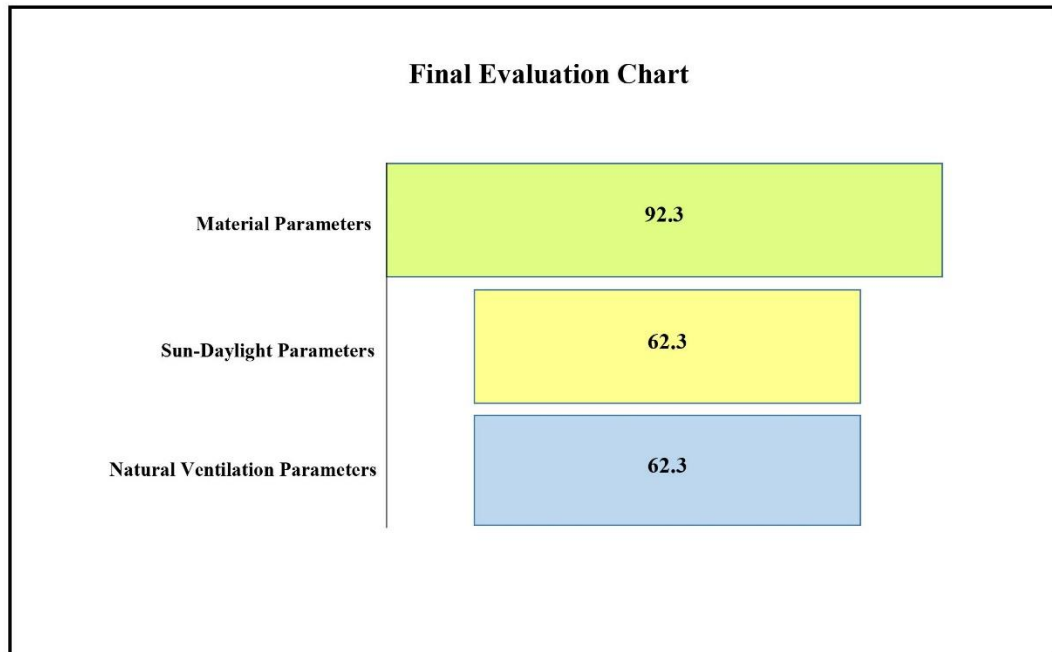
## 4. RESULTS OF STUDY AND SUGGESTIONS

According to the investigation done above, we can see that 62.3% of sun-daylight parameters, 62.3% of natural ventilation parameters, and 92.3% of material parameters were considered.

**Table 4.1:** Evaluation Parameters Consideration Percent.



**Table 4.2:** Final Evaluation Chart.



In terms of sun-daylight parameters;

In general, it has been observed that the usage of shading elements ratio, especially at the southern, eastern, and western facades, has not occurred properly with results under 50%, it was 16.7 % for horizontal south shadings, 33.4% for east and west shadings, and 16.7% as vertical west shadings. On the other hand, Low E coated glass, reflective glass, insulation, and facade surface color's parameters showed the highest consideration results, with a 100% ratio for each Low E coated glass, reflective glass, and insulation parameters, and with 92.3% for facade surface color parameter.

In addition, 38.5% of the investigated high-rise buildings facades have used skylight systems aiming to provide both of proper shading and daylight penetration. Moreover, 92.3% of the buildings used continuous glass intending to provide the proper natural daylighting. Furthermore, in general buildings' sun-daylight consideration within the northern, southern, eastern, and western facades was at a convenient ratio between 57.7% and 76.9%.

However, it is observed that some high-rise buildings such as Tekfen Tower and River Plaza's facade design have not considered the region's solar path. Therefore, the ratio of deaf and transparent surfaces distribution of their facade was not suitable according to their region's sun path. Besides that, some investigated high-rise buildings such as, Iz Plaza Giz Tower's facades were designed with the same features, regardless of the solar path, without providing any exterior shading elements.

On the other hand, high-rise buildings like, Istanbul Sapphire Tower has used a double-skin facade, which includes a buffer zone in between the exterior and interior facade skins, providing a lot of benefits to the building occupants, such as, allowing sun-daylight penetrating inside, besides providing an appropriate shading to the interior space.

In terms of natural ventilation parameters;

Generally, it has been noticed that the investigated high-rise buildings benefits from the wind flow in terms of providing natural ventilation with 61.5%. Furthermore, 58.4% of buildings have provided an openable window feature, and 66.7% of them have provided natural ventilation grills. However, in general, most of the investigated high-rise buildings were subjected to wind tests in order to face undesirable wind pressure occurrence. Whereas, the wing wall parameter was not found in any building. On the other hand, only 38.5% of the buildings have used skylight systems in order to increase and provide appropriate natural ventilation within the building.

Furthermore, vertical landscape element usage within investigated structures was shown with a low ratio of 38.5%. However, high-rise buildings such as Istanbul Sapphire Tower has used a double-skin facade, and a vertical garden within the buffer zone of the facade, which provides a lot of benefits to the building occupants, such as, providing natural ventilation to the interior spaces and giving the opportunity to use openable windows within the interior facade skin.

In terms of material parameters;

In general, within the investigation of high-rise buildings, it has been observed that the usage ratio of eco-materials was higher than 75 %. Thus, it could be counted as a nice ratio. However, some investigated high-rise buildings such as Tekfen Tower and QNB Finance Bank Crystal Tower did not use local materials.

As a result, the most sustainable buildings which recorded a score higher than 80% can be listed as, Istanbul Sapphire Tower at 84.5%, QNB Finance Bank Crystal Tower at 82.8%, and Diamond of Istanbul at 94.8% ratios. Whereas the less sustainable buildings which recorded a score lesser than 50% can be listed as, Tekfen Tower at 51.8%, Is Bank Tower at 46.6%, and Iz Plaza Giz at 46.6% ratios.

Accordingly, these results mentioned above, were concluded from the evaluation that has been done within the study's scope in accordance with the parameters that have been chosen. It is worthwhile to mention that the result of the evaluation made in this study is only the outcome of the evaluation made among the high-rise buildings

selected within the scope of this thesis. If any of the high-rise buildings under evaluation is compared with a building from abroad, different results may be obtained.

However, as a result of the study done, it can be concluded that a skyscraper would be built at Buyukdere Avenue should consider these criteria;

- 1.** Placing horizontal sunshade elements at the southern facade.
- 2.** Placing vertical sunshade elements at the eastern and western facades.
- 3.** Designing a building in a way to benefit from natural lighting as much as possible, to reduce energy consumed at lighting.
- 4.** Increasing Transparent surface at the southern facade.
- 5.** Reducing Transparent surface at the eastern and western facades.
- 6.** Do not use dark colors at building facades or roofs to reduce heat emission.
- 7.** Preferring low-E and reflective glasses to allow sunlight penetration and reflect heat beams.
- 8.** Using a continuous glass/window system to allow the largest amount of daylight penetration inside.
- 9.** Design the building with a natural ventilation system such as; double-skin facade, openable windows, vertical landscape elements, sky-courtyards, atriums, etc., to reduce energy consumption at cooling and reduce sick-building syndrome.
- 10.** Benefiting from wind by using a wing wall/ wind scoop to provide proper natural ventilation through high-rise buildings.
- 11.** Taking into consideration wind pressure, and applying wind tunnel tests before the construction stage.
- 12.** Use of vertical landscape elements which helps at natural ventilation through the building.
- 13.** Using eco-material at the building construction such as; recyclable, recycled and reused materials, etc. Which helps to reduce energy consumed at raw material production.
- 14.** Paying attention to the use of local materials to reduce fuel use in transportation.
- 15.** Insulating the building effectively in terms of; heat- noise- water- cold- etc.

16. Benefiting from renewable resources to generate buildings energy, such as generating electricity of the building, by emphasizing the function of daylight via photovoltaic panels placed within the facade skin, or placed on the roof.
17. Use systems to increase daylight penetration and natural ventilation through the building such as; sky-courtyards and atriums.
18. Take into consideration the solar path and the moderate wind of the building's region it is going to be built at, through the design phase.

Accordingly, as long as these parameters are taken into account, it can be helped to reduce the environmental damage that occurred from skyscrapers.

consequently, for high-rise buildings would be designed in the future at Buyukdere Avenue, it recommended to be designed in accordance with Buyukdere Avenue's weather, wind map, and solar path. However, they should also take into consideration within the designing phase the energy-efficient building facade parameters which were investigated within the thesis scope.

Besides taking into accordance the criteria mentioned above and in order to reduce the buildings' energy consumption, it is worthwhile to mention the smart facade systems, which protect the building from the sunlight heat by providing the proper shading to the interior space. In the case of smart facade system usage that follows the sun path automatically, more appropriate shading will be provided. It also allows the fresh air flow inside the building, benefiting from the wind, which participates in reducing the energy consumed at cooling or heating buildings. Also, it can be benefited from the transparent solar panels (Image 4.1) by using it at facade cladding. Besides allowing the light to illuminate the interior due to its transparent feature, it is generating electricity for the building by utilizing the heat spread by sunlight.



**Image 4.1:** Transparent Solar Panel (Url-77).

Subsequently, the difference between a skyscraper designed with a sustainable facade and a skyscraper designed without sustainable facade can be explained with the examples given at (Table 4.3).

In order to make a comparison between evaluated buildings facades, it has been tried to reach the annual energy expenditures of the buildings examined. It has been tried to contact the manufacturer's companies and the mechanical department of the high-rise buildings via e-mail and telephone, to provide the necessary information. Unfortunately, no positive response has been provided from the related departments except Tekfen tower. Most companies stated that they kept their information secretly and refused to share it. Mr. Ulas ISSI, the Technical Coordinator of Tekfen Tower, welcomed the request and shared the necessary information regarding the annual energy consumption of the building. However, to make the evaluation, the annual energy consumption of Istanbul Sapphire Tower and Kanyon high-rise buildings was obtained by scanning resources on the Internet. The energy consumption of Istanbul Sapphire Tower was obtained from the Architecture Civil Engineering Environment Journal (Aydın & Mihlayanlar, 2020), and the annual energy consumption of Kanyon was obtained from (Schulze, 2015) Doctoral dissertation.

**Table 4.3:** High-Rise Buildings Annual Heating Energy Consumption.

No	EVALUATED HIGH-RISE BUILDING DATA	HIGH-RISE BUILDINGS ANNUAL HEATING ENERGY CONSUMPTION			
		1	2	3	
		<i>Istanbul Sapphire</i>	<i>Kanyon</i>	<i>Tekfen Tower</i>	
1	Const. Date	2006-2010	2003 - 2006	2003	
2	Building Func.	Residential	Office	Business Center	
3	Arch. Height	261 M	118 M	118M	
4	Floors (a.gr.)	55 Floor	25 Floor	28 Floor	
5	Facade Company	Schüco	Arup Türkiye + Ove Arup İngiltere & Los Angeles / Fenış Aluminum	Schüco / Taş Proje	
6	Facade Materials	Glass- Curtain wall / Double Skinned Facade Schüco - ASS 50 /ASS 70.HI -Automatic Series	Glass - Stone - Painted copper metal bands -Aluminum	Curtain glass- Granite stone- Aluminum curtain wall- Stone curtain wall	
7	Self-Shading Glass	Existing	Existing	Not existing	
8	Continuous Glass	Existing	Existing	Partially (upper part of the building)	
9	DSF	Existing	Not existing	Not existing	
10	Low-E coated Glass	Existing	Existing	Existing	
11	Reflective glass	Existing	Existing	Existing	
12	Insulation	Schüco ASS 50/ ASS 70.HI-glasses are heat insulated.	Glazing system providing noise and heat insulation.	Double-glazing system, leaves the minimum solar heat amount to get inside.	
13	Skylight system to increase daylight	Existing	Not existing	Not existing	
14	West-East facade shading element	Existing on the eastern facade	Not enough / South-eastern / South-western facades	Not existing	
15	Vertical shading element at the western facade	Not existing	Not existing	Not existing	
16	Horizontal shading element at the southern facade	Not existing	Existing	Not existing	
17	Sun consideration at the North (Vertical)	Deaf facade-cold facade system	Glasses are designed from the ground up to allow the daylight passing inside	Less transparent surface	
18	Sun consideration at the South (Horizontal)	Deaf facade-cold facade system	Horizontal sunshade elements are placed at the exterior facade face, so as not to obstruct the view for the office occupants. Semi-transparent rolled up Internal vertical blinds made of textile, automatically controlled by the solar intensity, control light, block glare and provide privacy	Less transparent surface. There is no shading element usage	
19	Sun consideration at the East (Vertical)	Double-skin facade, Aluminum sun control panels	<b>South-eastern / South-western</b> facades, horizontal sunshade elements are placed so as not to obstruct the view. But due to the suns solar path the eastern and western facades are not shaded enough.	The transparent surface increases at the eastern facade. There is no shading element usage	
20	Sun consideration at the West (Vertical)	Double-skin facade	<b>North-eastern / North-western</b> facades, Glasses are designed from the ground up to allow the daylight.	Less transparent surface. There is no shading element usage	
Annual Heating Energy Consumption (kWh/m <sup>2</sup> )		Heating System	Natural Gas	Heating System	Hot Water System
		65.8 kWh/m <sup>2</sup>	68 kWh/m <sup>2</sup>	87.33 kWh/m <sup>2</sup>	4.75 kWh/m <sup>2</sup>

According to (Table 4.3), it has been shown that Istanbul Sapphire Tower is consuming 65.8 kWh/m<sup>2</sup> of energy for heating annually while Kanyon's annual heating energy consumption appears at 68 kWh/m<sup>2</sup>. On the other hand, Tekfen Tower is consuming 87.33 kWh/m<sup>2</sup> for heating system and 4.75 kWh/m<sup>2</sup> for the hot water system, which makes 92.08 kWh/m<sup>2</sup> of energy consumption for heating annually.

However, according to the evaluation done through the thesis the sustainable facade percent scores were 84.5% for Istanbul Sapphire Tower, 55% for Kanyon, and 51.8% for Tekfen Tower. According to the data showed at (Table 3.14), Tekfen Tower's sun-daylight parameters evaluation score was shown at a low rate as 33.4%, while Kanyon and Istanbul Sapphire Tower's rates were as high as 70% for Kanyon and 76.7% for Istanbul Sapphire Tower.

From the data shown in (Table 4.3), we can conclude that Istanbul Sapphire's facade system benefits from natural light at a maximum level, with the help of the glass which is covering the whole building, thus it consumes less energy to heat the building. It uses also a double-skin facade system, which includes sun control elements based on the region's sun path to provide shading to the interior space of the building, thus it consumes less energy for cooling the building.

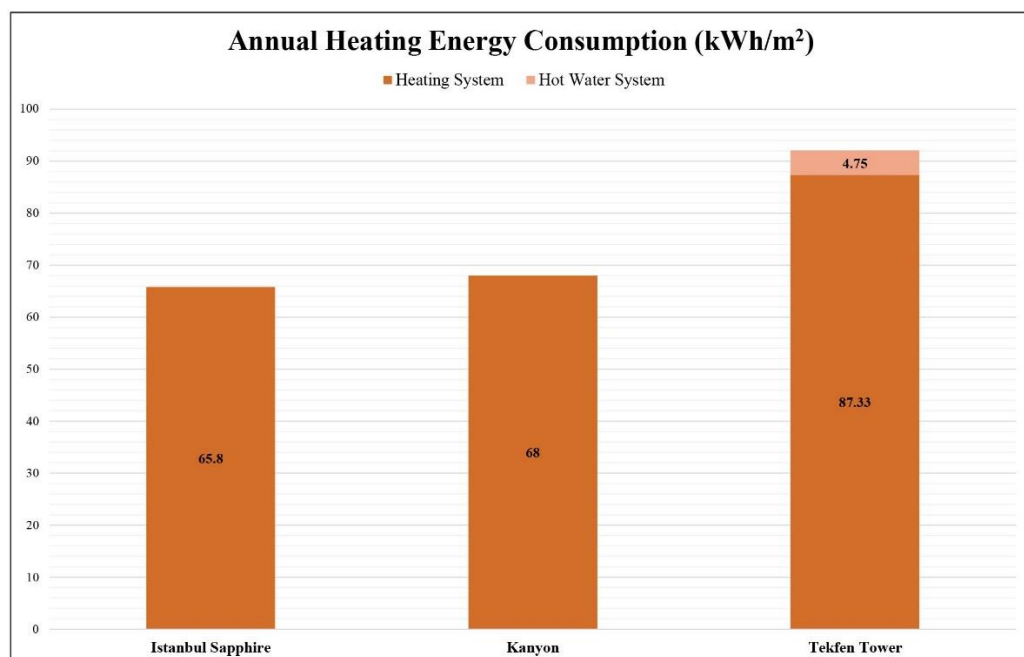
On the other hand, as it is shown above, Kanyon's annual heating energy consumption per square meter is higher than Istanbul Sapphire Tower's. Its facade has sun shading elements stretches from the south-eastern facade to the north-eastern facade. Therefore, according to data collected, it is clear that Kanyon's facade was not designed according to the region's sun path which occurred with higher energy consumption for heating. It is founded also that the internal sun shading elements, were providing a good shading but it is not enough to prevent the heat entrance to the building. Which causes more energy consumption for cooling the building.

On the other hand, Tekfen Tower used a Double-glazing system that allows maximum sunlight to penetrate but leaves the minimum solar heat amount to get inside. Nevertheless, the building's northern, southern, and western facades transparent and deaf surfaces alike each other, when the eastern facade's transparent surface increases compared to them. So, it can be concluded that the sun path is not considered by the building

facade. According to that, the building does not fulfill the required daylight penetration inside, which causes more energy consumption for heating compared to Istanbul Sapphire Tower and Kanyon.

Never forget to mention the functional difference between the high-rise buildings, while Istanbul Sapphire Tower has a residential function, Kanyon and Tekfen Tower have an office function. Since the residential building operates 24 hours a day compared to the office functioned building which operates within work hours. However, the annual heating energy consumption (kWh/m<sup>2</sup>) for Istanbul Sapphire Tower, Kanyon, and Tekfen Tower is listed below at (Table 4.4);

**Table 4.4:** Annual Heating Energy Consumption (kWh/m<sup>2</sup>).



On account of this, high-rise buildings designed within sustainable facade design features consumes less energy compared to high-rise buildings designed with an ordinary facade.

In conclusion, it should be mentioned that in case of appropriate design of sustainable facade in accordance with sustainable building facade design features that explained above, taking into consideration the buildings' regions' features, buildings energy consumption could be reduced and could be contributed to preserving the environment.

## REFERENCES

- Alakavuk, Ebru. Savaşır, Kutluğ. Tokuç, Ayça.** (2015). Yapı kabuğu In Kahraman, İlker (Eds) *Sürdürülebilir yapı tasarım kılavuzu*. (1st ed). İzmir: Mimarlar Odası İzmir Şubesi Publishing.
- Atıcı, Mustafa.** (2002). Ekolojik Mimari ve Felsefi Açılımları. Mimarlık ve Felsefe II Sempozyumu: Etik-Estetik, I.T.Ü. Mimarlık Fakültesi, İstanbul.
- Aydın, D., Mihlayanlar, E.** (2020). A Case Study on The Impact of Building Envelope on Energy Efficiency in High-rise Residential Buildings. *Architecture Civil Engineering Environment*. 13(01),5-18.
- Aytis, Saadet. Polatkan, Işıl.** (2010). *Sürdürülebilir Tasarım Kavramında Temel İlkelerin Yapı Ve Toplum Ölçeğinde Değerlendirilmesi*. Mimar Sinan, İstanbul.
- Begeç, Hasan. Darioush, Bashiri Hamidabad.** (2015). *Sustainable High-Rise Buildings and Application Examples*. In Conference: 3rd Annual International Conference on Architecture and Civil Engineering.
- Begeç, Hasan. Yalner, A.İlker.** (2017). *Gökdelenlerin Sürdürülebilirlik ve Sürdürülebilir Şehirler Bağlamında Yeniden Düşünülmesi-Yeni Tasarım İlkeleri*, Akademia Mühendislik ve Fen Bilimleri Dergisi,1(3), p. 57-68.
- Brundtland, Gro Harlem.** (1987). Report of the World Commission on Environment and Development: *Our common future*. Accessed Feb, 10.
- Cavka, Hasan Burak.** (2015). Bina Bilgi Modellemesi ve Kullanım Alanları In Kahraman, İlker (Eds) *Sürdürülebilir yapı tasarım kılavuzu*. (1st ed). İzmir: Mimarlar Odası İzmir Şubesi Publishing.
- Çakır Kıasif, Gözde.** (2015). *Enerji etkin çift kabuk cephe sistemlerinin İstanbul'a uygunluğunun analizi* (Doctoral dissertation), Fen Bilimleri Enstitüsü. haliç University, İstanbul.
- Çatı ve Cephe.** (2016, Feb). *Finansbank Kristal Kule*, (60). retrieved March, 21, 2020, from: <http://www.hasmimarlik.com.tr/tanitim/medya/160107-Kristalkule-Cati%20Cephe%20Dergisi.pdf>
- Çatı ve Cephe.** (2008, May-June). *İstanbul Sapphire*, (14). Retrieved May, 01, 2020, from: [http://www.cativecephe.com/yayin/640/istanbul-sapphire\\_18475.html#.Xquf62gzZPY](http://www.cativecephe.com/yayin/640/istanbul-sapphire_18475.html#.Xquf62gzZPY)

- Çatı ve Cephe.** (2010, july). *Schüco, Sapphire'de Çift Cephe Uygulaması Gerçekleştirdi*, (27). retrieved May, 01 ,2020, from [http://www.cativecephe.com/yayin/653/schuco-sapphire-de-cift-cephey-uygulamasi-gerceklestirdi\\_19342.html#.XysEtCgzZPb](http://www.cativecephe.com/yayin/653/schuco-sapphire-de-cift-cephey-uygulamasi-gerceklestirdi_19342.html#.XysEtCgzZPb)
- Çatı ve Cephe.** (2014, May). *Spine Tower*, (50). retrieved May, 25, 2020, from: [http://www.cativecephe.com/yayin/676/spine-tower\\_20178.html#.XuEzemgzZPZ](http://www.cativecephe.com/yayin/676/spine-tower_20178.html#.XuEzemgzZPZ)
- Demircan, Rüya Kılıç. and Gültekin, Aruzhan Burcu.** (2015). *Binalarda pasif ve aktif güneş sistemlerinin incelenmesi*. Ankara, Turkey.
- Eren, Özlem.** (2019). *Geçmişten Günümüze Çelik Yüksek Yapılar* (1st ed). İstanbul: Quientessence Publishing.
- Farrelly, Lorraine.** (2017) *Mimarlıkta yapım ve malzeme* (2nd ed) İstanbul: Literatür Yayıncılık Publishing.
- General Directorate of Energy.** (2016). *Bütünleşik Bina Tasarımı Yaklaşımının Türkiye Ortamı Ve Koşullarına Uyarlama Raporu*. Ankara: Uzerler Matbaası publishing.
- Geniş, Şerife. Osmanoğlu, Emir.** (2016, May 11-13). *Bildiriler Kitabı*. Paper presented at The Uluslararası Kent Araştırmaları Conference, İstanbul.
- Göksu, T. Pilehvarian, K.** (2019). Yüzyıldan 20. Yüzyıla Beşiktaş-Maslak-Büyükdere Aksı [Electronic Version]. *Yakin Mimarlik Dergisi*, 2K (2),118-137.
- Guthrie, Alistair.** (2008) *Tall buildings sustainability from the bottom up*, CTBUH 8th World Congress, Tall and Green: Typology for a Sustainable Urban Future, 3 - 5 March, Dubai, S. 95-101.
- Hasol, D.** (2014). *Ansiklopedik Mimarlık Sözlüğü* (13<sup>th</sup> ed). İstanbul: Yem Publishing.
- İnan, T.** (2016). *Experimental and numerical analysis of flow and heat transfer in double skin facade cavities*. (Doctoral dissertation). Izmir university- Izmir, Turkey.
- Kahraman, İlker.** (2015). *Sürdürülebilir yapı tasarım kılavuzu*. (1st ed). izmir: Mimarlar Odası İzmir Şubesi Publishing.
- Karakurt Tosun, Elif.** (2019). *Sürdürülebilir Kentleşme* (1st ed). Bursa: Dora Basım Publishing house.

- Kıasf, G. Ç., & Selçuk, E.** (2016). *Yüksek Yapı Tasarımında Sürdürülebilir Yapım Sistemlerinin İncelenmesi*. Paper presented at Proje ve Yapım Yönetimi Kongresi, Anadolu Üniversitesi, Mühendislik Fakültesi, İnşaat Mühendisliği Bölümü, Eskişehir.
- Koç, A., Yağlı, H., Koç, Y., & Uğurlu, İ.** (2018). *Dünyada ve türkiye’de enerji görünümünün genel değerlendirilmesi*. *Mühendis ve Makina*, 59(692), 86-114.
- Mahmoud, Mohamed Fekry. Elbelkasy, Mohamed Ibrahim.** (2016). *Islamic architecture: between moulding and flexibility*. *WIT Transactions on The Built Environment*, 159, 49-59.
- MEGEP, Mep.** (2008). *Büro Yönetimi ve Sekreterlik–Dş Mektubu*. Raporlama ve Yazı Metni Oluşturma Modülleri, Ankara.
- Nowosielski, Ryszard. Kania, Aneta. and Spilka, Monika.** (2007). Development of ecomaterials and materials technologies. *Journal of Achievements in Materials and Manufacturing Engineering*, 21(1), 27-30.
- Oral, Yener, Beyazit.** (2004). In Kahraman, İlker. (2015). *Sürdürülebilir yapı tasarım kılavuzu*. (1st ed). izmir: Mimarlar Odası İzmir Şubesi Publishing.
- Orhon, Vefa.** (2012, September). *Tasarımdan yapıma, sürdürülebilir beton yaklaşımları*. In Proceedings of 2nd project and construction management congress, Izmir Institute of Technology, Izmir (pp. 13-16).
- Orhon, Ahmet. Vefa.** (2015). Sürdürülebilir yapıım sistemlerine uygun malzeme seçimi In Kahraman, İlker (Eds) *Sürdürülebilir yapı tasarım kılavuzu*. (1st ed). izmir: Mimarlar Odası İzmir Şubesi Publishing.
- Özkaşıkçı, H.** (2004). *Elemanter ve Yüksek Teknolojili Mimari Tasarımda Ekoloji Düşüncesi ve Dönüşümü*, (Master thesis), MSGSÜ Fen Bilimleri Enstitüsü, İstanbul.
- Sachs, Jeffrey.** (2019). *Sürdürülebilir Kalkınma Çağı*, (Gönülşen, Barış Trans.). (1st ed). Istanbul: Yeditepe Üniversitesi Publishing house.
- Sarı, Tuba.** (Sep 2016). Yüksek Bina Tasarımında Katı Strüktürlerden Sürdürülebilir Yapılara: *İstanbul’da Üç Yapısal Yaklaşım Süreci*. Paper presented at The confarence of Türkiye Lisansüstü Çalışmalar Kongresi, Istanbul: ITU.
- Sağlam, Rifat.** (2016). *Yüksek Yapılar Kentleşme* (1st ed) İstanbul: Nobel Akademik Yayıncılık Publishing house.

- Schulze, Tobias.** (2015). *Natural Ventilation of High-Rise Buildings A Methodology for Planning with Different Analysis Tools and Case-Study Integration.* (Doctoral Dissertation), Fen Bilimleri Enstitüsü. ITU, Istanbul.
- Schüco International KG,** (2019, Ja). *Individual solutions and system-based innovations,* retrieved May, 25 ,2020, from: <https://www.schuco.com/web2/blob/26398770/808706e023b79ef9e5b6fdc805be0b90/corporate-brochure-data.pdf>.
- Sev, Aysin. Başarır, Bahar.** (April 2011). *Geçmişten Geleceğe Enerji Etkin Yüksek Yapılar Ve Uygulama Örnekleri.* Paper presented at The conference of X. Ulusal Tesisat Mühendisliği Kongresi, Istanbul: Mimar Sinan Fine Arts University.
- Sev, Aysin.** (2009). *Sürdürülebilir Mimarlık,* Yapı Endüstri Merkezi. YEM publishing, Istanbul, 138, 139-140.
- Sevgi, Orhan.** (2015). Ecology Teriminin Türkçe Karşılıkları Üzerine Bir Değerlendirme. *Avrasya Terim Dergisi,* 3(1), p27-46.
- Sezer, F. Ş.** (2004). In Kahraman, İlker. (2015). *Sürdürülebilir yapı tasarım kılavuzu.* (1st ed). izmir: Mimarlar Odası İzmir Şubesi Publishing.
- Shinohara, Y.** (2004). *Eco-materials guideline project in Japan.* In Proceedings of the 1st Japan-China Symposium on Eco-materials, Recycling-oriented Industry and Environmental Management, Suzhou, China.
- Solmaz, Aslıhan Şenel. Kaya, Hande.** (2015). Uluslararası Düzeyde kullanılan ölçütlere Dayalı değerlendirme ve Sertifika Programlarının Tanıtılması ve Değerlendirilmesi In Kahraman, İlker (Eds) *Sürdürülebilir yapı tasarım kılavuzu.* (1st ed). izmir: Mimarlar Odası İzmir Şubesi Publishing.
- Sorguç, Arzu Gönenç.** (2009). *Sürdürülebilirlik için Performatif Mimarlık.* Ekolojik Yapı Tasarımı, Malzeme, Teknoloji ve Çevre Sempozyumu, 7-8.
- Tekeli, İlhan. Ataöv, Anlı.** (2017). *Sürdürülebilir Toplum ve Yapılı Çevre Stratejiler Yelpazesi* (1st ed) İstanbul: : İstanbul Bilgi Üniv Publishing house.
- Üç aylık Mimarlık ve yapı Malzemeleri dergisi.** (2012). *Mimarlıkta Malzeme.* (21), p.14-39.
- Von Keyserlingk, M., Martin, N., Kebreab, E., Knowlton, K., Grant, R., Stephenson, M., Smith, S.** (2013). Invited review: Sustainability of the US dairy industry. *Journal of Dairy Science,* 96(9), p5405-5425.
- Wood, Antony.** (2014). *Rethinking the skyscraper in the ecological age: Design principles for a new high-rise vernacular.* Proceedings of the Council

on Tall Buildings and Urban Habitat (CTBUH), Shanghai, China, 16-19.

**Wong, Tai-Chee. Yuen, Belinda.** (2011). *Eco-City Planning. Policies, practice and design*: Springer Science+ Business Media BV.

**Yamamoto, R. Nguyen, XH. Honda, T. Wang, Y.** Eco-Materials In Crul, M.R.M. Diehl, J.C. Ryan, C. (Eds) *Design for Sustainability a Step-by-step approach*. Tokyo university, Tokyo.

**Yalitim Dergisi.** (2015, July). Zorlu Levent 199 Projesi'nin Tercihi, Çuhadaroğlu Oldu, (136). retrieved May 14,2020, from: [http://www.yalitim.net/yayin/496/zorlu-levent-199-projesi-nin-tercihi-cuhadaroglu-oldu\\_14673.html#.Xr0JjagzZPY](http://www.yalitim.net/yayin/496/zorlu-levent-199-projesi-nin-tercihi-cuhadaroglu-oldu_14673.html#.Xr0JjagzZPY)

**Yeang, Ken.** (2012). *Ekotasarım Ekolojik Tasarım Rehberi*, ( Eryıldız, Semih , Eryıldız Demet Trans.).İstanbul, YEM Publishing.

**Zeng, Zhen. Xiaofeng, Li. Cheng, Li. Yingxin, Zhu.** (2012). *Modeling ventilation in naturally ventilated double-skin façade with a venetian blind*. Building and environment, 57, 1-6.

**Zinzade, Deniz.** (2010). *Yüksek Yapı Tasarımında Sürdürülebilirlik Boyutunun İrdelenmesi* (Doctoral dissertation), Fen Bilimleri Enstitüsü. ITU, Istanbul.

**Zhang, Tiantian. Yufei, Tan. Hongxing, Yang. Xuedan, Zhang.** (2016) *The application of air layers in building envelopes: A review*. Applied Energy 165: 707-734.

**Url-1** <<https://www.ctbuh.org/>>, date retrieved 01.06.2020

**Url-2** <<https://www.youtube.com/watch?v=a1DOQSKmlnw>>, date retrieved 26.05.2020

**Url-3** < <https://tr.pinterest.com/pin/456482112221169680/>>, date retrieved 28.05.2020

**Url-4** <[https://cdn-0.enacademic.com/pictures/enwiki/67/Climatron%2C\\_Missouri\\_Botanical\\_Gardens.jpg](https://cdn-0.enacademic.com/pictures/enwiki/67/Climatron%2C_Missouri_Botanical_Gardens.jpg)>, date retrieved 28.05.2020

**Url-5** < <http://www.skyscrapercenter.com/>>, date retrieved 23.04.2020

**Url-6** <<https://www.emporis.com/>>, date retrieved 24.03.2020

**Url-7** < <https://www.pinterest.de/pin/422282902542256676/>>, date retrieved 11.06.2020

**Url-8** < <https://www.pinterest.de/pin/539165386613439864/>>, date retrieved 11.06.2020

**Url-9** < <https://slideplayer.com/slide/10265612/>>, date retrieved 11.06.2020

**Url-10** < <https://www.solarreviews.com/blog/active-passive-home-solar-heating-system>>, date retrieved 11.06.2020

**Url-11** < <https://www.navaltechllc.com/products/item/249-continuous-glass-walls.html>>, date retrieved 11.06.2020

**Url-12** < <https://www.apexwindowsandbath.com/products/glass-replacement/>>, date retrieved 11.06.2020

**Url-13** < <https://www.metalocus.es/en/news/zaha-hadid-architects-presents-leeza-soho-skyscraper-beijing>>, date retrieved 11.06.2020

**Url-14** < <https://autodesk.typepad.com/.a/6a00e5536ab23988330192ab529ce1970d-popup>>, date retrieved 11.06.2020

**Url-15** < <https://tr.pinterest.com/pin/470766967268813884/>>, date retrieved 28.04.2020

**Url-16** < <https://tr.pinterest.com/pin/314900198917725899/>>, date retrieved 28.04.2020

**Url-17** < <https://i.pinimg.com/originals/47/ef/31/47ef317fa76cda7bef0c151dbdf06b19.jpg>>, date retrieved 28.04.2020

**Url-18** < <https://www.swegonairacademy.com/wp-content/uploads/2014/10/Swiss-Re-by-Norman-Foster-part-1.pdf>>, date retrieved 28.04.2020

**Url-19** < <https://www.fosterandpartners.com/projects/30-st-mary-axe/>>, date retrieved 28.04.2020

**Url-20**  
< <https://www2.gov.scot/resource/buildingstandards/2013NonDomestic/chunks/ch08s03.html>>, date retrieved 11.06.2020

**Url-21**  
< <http://www.builtconstructions.in/OnlineMagazine/BuiltConstructions/Pages/The-Bioclimate-Tower-of-Singapore-0290.aspx>>, date retrieved 11.06.2020

- Url-22** < <http://www.arkiv.com.tr/proje/istanbul-sapphire/1223>>, date retrieved 06.04.2020
- Url-23** < <https://tr.pinterest.com/pin/484981453624575087/>>, date retrieved 11.06.2020
- Url-24** < [http://www.shigerubanarchitects.com/works/1989\\_paper-arbor/index.html](http://www.shigerubanarchitects.com/works/1989_paper-arbor/index.html)>, date retrieved 11.06.2020
- Url-25** < [http://www.shigerubanarchitects.com/works/p18\\_apol-office-building/index.html](http://www.shigerubanarchitects.com/works/p18_apol-office-building/index.html)>, date retrieved 11.06.2020
- Url-26** < <https://www.relbanks.com/asia/saudi-arabia/national-commercial-bank>>, date retrieved 26.04.2020
- Url-27** < <https://fliphtml5.com/cnvu/btpm/basic>>, date retrieved 11.06.2020
- Url-28** < <https://tr.distance.to/%C4%B0istanbul>>, date retrieved 14.04.2020
- Url-29** < <http://www.cografya.gen.tr/tr/istanbul/iklim.html>>, date retrieved 14.04.2020
- Url-30** < <https://www.hurriyet.com.tr/lodos-ve-poyrazin-yaptiklari-12472532>>, date retrieved 14.04.2020
- Url-31** < <https://www.iklim.istanbul/iklim/>>, date retrieved 14.04.2020
- Url-32** < <https://cbsakademi.ibb.istanbul/solar-enerji-potansiyeli-haritasi/>>, date retrieved 14.04.2020
- Url-33** < <https://www.haritamap.com/yer/buyukdere-caddesi-levent-besiktas> >, date retrieved 02.05.2020
- Url-34** < [https://tr.wikipedia.org/wiki/Levent,\\_Be%C5%9Fikta%C5%9F](https://tr.wikipedia.org/wiki/Levent,_Be%C5%9Fikta%C5%9F)>, date retrieved 29.05.2020
- Url-35** < <http://emlakansiklopedisi.com/wiki/merkezi-is-alani-mia>>, date retrieved 29.05.2020
- Url-36** < <https://sehirharitasi.ibb.gov.tr/>>, date retrieved 30.04.2020
- Url-37** < <https://panorama.istanbul/>>, date retrieved 30.04.2020
- Url-38** < <http://mimdap.org/2008/01/buyukdere-caddesi-ve-mimarlyk/>>, date retrieved 29.05.2020

- Url-39** <<https://www.schueco.com/de-en/architects/references/sapphire-istanbul-2975>>, date retrieved 12.05.2020
- Url-40** <<http://www.levent199.com.tr/tr/galeri.html>>, date retrieved 19.03.2020
- Url-41** <[http://www.yapi.com.tr/haberler/kanyon-projesini-fenis-giydirecek\\_19606.html](http://www.yapi.com.tr/haberler/kanyon-projesini-fenis-giydirecek_19606.html)>, date retrieved 31.05.2020
- Url-42** <<https://www.elekon-tr.com/medya/candela>>, date retrieved 18.05.2020
- Url-43** <<https://stargrup.com.tr/blog/projects-item/soyak-crystal-tower-istanbul/>>, date retrieved 31.05.2020
- Url-44** <<https://www.guardianglass.com/eu/en/products/brands/sunguard/super-neutral/51-28>>, date retrieved 31.05.2020
- Url-45** <<https://www.pcf-p.com/projects/soyak-kristalkule-finansbank-headquarters/>>, date retrieved 21.03.2020
- Url-46** <<http://www.metalyapi.com/projects/olive-grove-tower>>, date retrieved 23.05.2020
- Url-47** <<https://www.ekoyapidergisi.org/1036-omurga-formundan-esinlenen-feminen-bir-durus.html>>, date retrieved 25.05.2020
- Url-48** <[http://www.cativecephe.com/yayin/676/spine-tower\\_20178.html#.Xsvx8GgzZPY](http://www.cativecephe.com/yayin/676/spine-tower_20178.html#.Xsvx8GgzZPY)>, date retrieved 25.05.2020
- Url-49** <<http://www.riverplaza.com.tr/tr/leed/Sayfalar/2&kat=>>, date retrieved 26.05.2020
- Url-50** <[http://www.yesilbinadergisi.com/yayin/722/-yesil-bina-sertifikasi-alan-ilk-turk-bankasi-turkiye-is-bankasi\\_21909.html#.Xsa8vqgzZPY](http://www.yesilbinadergisi.com/yayin/722/-yesil-bina-sertifikasi-alan-ilk-turk-bankasi-turkiye-is-bankasi_21909.html#.Xsa8vqgzZPY)>, date retrieved 21.05.2020
- Url-51** <<https://www.sisikaluminyum.com.tr/en/project/giz-iz-plaza/>>, date retrieved 27.05.2020
- Url-52** <<https://www.milliyet.com.tr/konut/levent-199-a-leed-gold-sertifikasi-2021560>>, date retrieved 01.06.2020
- Url-53** <<https://www.gkvarchitects.com/projects/olive-grove-tower/>>, date retrieved 23.05.2020
- Url-54** <<https://pamirsoyuer.com.tr/content/finansbank-genel-mudurluk-bati/>>, date retrieved 14.04.2020

**Url-55** <[http://www.mimarizm.com/mimari-projeler/ofis/kristalkule\\_124786](http://www.mimarizm.com/mimari-projeler/ofis/kristalkule_124786)>, date retrieved 29.03.2020

**Url-56** <<https://www.theplan.it/eng/award-2018-officebusiness/istanbul-tower-205-4>>, date retrieved 17.03.2020

**Url-57** <<https://corporate.arcelormittal.com/sustainability>>, date retrieved 30.05.2020

**Url-58** <<https://www.sapabuildingsystem.com/en/tr/references/case-studies/spine-tower/>>, date retrieved 25.05.2020

**Url-59** <[https://www.archdaily.com/141615/istanbul-sapphire-tabanlioglu-architects/50149ab328ba0d395000085d-istanbul-sapphire-tabanlioglu-architects-photo?next\\_project=no](https://www.archdaily.com/141615/istanbul-sapphire-tabanlioglu-architects/50149ab328ba0d395000085d-istanbul-sapphire-tabanlioglu-architects-photo?next_project=no)>, date retrieved 07.05.2020

**Url-60** <<http://www.tabanlioglu.com/project/zorlu-levent-office/>>, date retrieved 20.03.2020

**Url-61** <<http://www.yesilgyo.com/istanbul-tower.php>>, date retrieved 19.03.2020

**Url-62** <<http://www.arkiv.com.tr/proje/levent-kanyon/1771>>, date retrieved 20.03.2020

**Url-63** <<https://www.jerde.com/places/detail/kanyon>>, date retrieved 20.03.2020

**Url-64** <[http://turkey.aukettswanke.com/projects/Tefken\\_tower\\_tr](http://turkey.aukettswanke.com/projects/Tefken_tower_tr)>, date retrieved 16.05.2020

**Url-65** <<https://www.tekfengayrimenkul.com/eng/tekfentower.aspx>>, date retrieved 17.05.2020

**Url-66**  
<[https://tr.wikipedia.org/wiki/Metrocity#/media/Dosya:Metrocity\\_Shopping\\_Center.jpg](https://tr.wikipedia.org/wiki/Metrocity#/media/Dosya:Metrocity_Shopping_Center.jpg)>, date retrieved 19.05.2020

**Url-67** <[http://tekelisisa.com/?portfolio\\_page=metrocity-konut-ve-alisveris-merkezi](http://tekelisisa.com/?portfolio_page=metrocity-konut-ve-alisveris-merkezi)>, date retrieved 04.04.2020

**Url-68** <<http://www.metalyapi.com/projects/olive-grove-tower>>, date retrieved 23.05.2020

**Url-69** <<http://www.antredesign.com/genel-mudurlukler>>, date retrieved 21.05.2020

**Url-70** <<https://architizer.com/projects/olive-grove-tower/>>, date retrieved 23.05.2020

- Url-71** <<https://3dkonut.com/diamond-of-istanbul/projesi/>>, date retrieved 23.05.2020
- Url-72** <<https://alchetron.com/Diamond-of-Istanbul>>, date retrieved 23.05.2020
- Url-73** <<http://www.aksoyaluminyum.com.tr/referans/428/spine-tower-istanbul.aspx>>, date retrieved 25.05.2020
- Url-74** <<https://archello.com/project/spine-tower>>, date retrieved 25.05.2020
- Url-75** <<https://www.sapabuildingsystem.com/en/tr/references/case-studies/spine-tower/>>, date retrieved 25.05.2020
- Url-76** <[http://tekelisisa.com/?portfolio\\_page=is-bankasi-genel-mudurlugu-kompleksi](http://tekelisisa.com/?portfolio_page=is-bankasi-genel-mudurlugu-kompleksi)>, date retrieved 04.04.2020
- Url-77** <<https://urnabios.com/transparent-solar-cells-solar-panels/>>, date retrieved 11.06.2020
- Url-78** <[http://www.yapi.com.tr/haberler/kanyon-mimaride-ve-yasam-tarzinda-yenilikci-bir-yaklasim\\_46416.html](http://www.yapi.com.tr/haberler/kanyon-mimaride-ve-yasam-tarzinda-yenilikci-bir-yaklasim_46416.html)>, date retrieved 20.03.2020
- Url-79** <[http://www.yapi.com.tr/Haberler/zorlu-levent-ofisin-insaat-sureci-basliyor\\_88352.html](http://www.yapi.com.tr/Haberler/zorlu-levent-ofisin-insaat-sureci-basliyor_88352.html)>, date retrieved 14.05.2020
- Url-80** <<http://giz.insaat.website/portfolio-item/iz-giz/>>, date retrieved 27.05.2020
- Url-81** <<http://ist.web.tr/finans/tekfen-tower>>, date retrieved 15.03.2020
- Url-82** <[http://www.tekfeninsaat.com.tr/TR/insaat\\_detay.asp?id=6](http://www.tekfeninsaat.com.tr/TR/insaat_detay.asp?id=6)>, date retrieved 15.03.2020
- Url-83** <<https://www.skyscrapercity.com/threads/istanbul-diamond-of-istanbul-203m-40-fl-u-c.172501/>>, date retrieved 28.05.2020
- Url-84** <<https://www.istanbulview.com/diamond-of-istanbul/>>, date retrieved 04.04.2020
- Url-85** <<https://www.ekoyapidergisi.org/1035-surdurulebilirlik-guvenlik-ve-konfor-bir-arada-spine-tower.html>>, date retrieved 25.05.2020
- Url-86** <[http://www.yesilbinadergisi.com/yayin/722/-yesil-bina-sertifikasi-alan-ilk-turk-bankasi-turkiye-is-bankasi\\_21909.html#.Xsa8vqgzZPY](http://www.yesilbinadergisi.com/yayin/722/-yesil-bina-sertifikasi-alan-ilk-turk-bankasi-turkiye-is-bankasi_21909.html#.Xsa8vqgzZPY)>, date retrieved 21.05.2020