# Analyzing Energy and Biomimesis Concepts in the Context of Sustainability on Building Envelope



Meryem Altınöz, Esma Mıhlayanlar, Seyhan Yardımlı*
Institute of Science Master of Architecture
Trakya University, Edirne / Turkey
* Istanbul Aydın University, Faculty of Architecture and Design
merymaltinoz@gmail.com,
emihlayanlar@trakya.edu.tr
seyhanyardimli@aydin.edu.tr

***Abstract:*** *Humans have learned to mimic nature by observing and interpreting it to put outcomes to use in architectural design for centuries. In the 19th century, nature, imitated only in aesthetically architectural style, is now being used in architecture with the production of building shells and skeletons from biological information sources. Every work done so far has revealed how important the concept of biomimesis is and cannot be ignored. It can be said that the energy consumption of existing buildings around the world is about 40% of the whole consumption rate and that the energy resources are being depleted rapidly, the biomimesis approach should be more utilized in architectural designs.*

*Accordingly, in this study, the studies on biomimesis and energy consumptions of structures adopting the biomimesis concept were examined. Two of the buildings examined were offices; Al Bahar Tower, Aldar Skyscraper, three housing functions; Tao Zhu Yin Yuan, Central Park I, II. The benefits in terms of energy consumption in buildings surveyed biomimesis concept is supported with certificates. Today, the importance of energy consumption is important to design sustainable constructions and to minimize the energy consumption of the buildings. The biomimesis approach shows that designs made with nature inspiration will reduce energy consumption in harmony with nature.*

***Keywords:*** *Biomimesis, energy, building envelope, sustainability.*

## *Sürdürülebilirlik Bağlamında Enerji ve Biyomimesis Kavramının Bina Kabuğunda İncelenmesi*

***Özet:*** *İnsanlar yüzyıllardır doğayı gözlemleyerek, öğrendiklerini taklit ederek ve yorumlayarak bunları mimari tasarımlarında kullanmışlardır. 19.yy da sadece estetik açıdan mimaride taklit edilen doğa, günümüzde biyolojik bilgi kaynaklı yapı kabukları ve iskeletlerin üretimi ile mimaride kullanılmaktadır. Biyomimesis olarak bilinen bu kavram ile ilgili yapılan çalışmalar giderek artmaktadır. Bugüne kadar yapılmış her çalışma biyomimesis kavramının ne kadar önemli olduğunu ve göz ardı edilemeyeceğini ortaya koymuştur. Dünya üzerindeki mevcut binaların enerji tüketiminin, tüm tüketime oranının yaklaşık %40 olduğu ve enerji kaynaklarının hızla tükendiği düşünüldüğünde, mimari tasarımlarda biyomimesis yaklaşımından daha fazla yararlanılması gerektiği söylenebilir. Bu çalışmada biyomimesis kavramı ve bu yaklaşımla yapılan örnekler incelenmiştir. Bu kavramı benimseyen binaların enerji tüketimleri incelenerek sağlanan kazançlar araştırılmıştır. İncelenen binalardan ikisi; Al Bahar Tower, Aldar Skyscraper ofis; Tao Zhu Yin Yuan, Central Park I, Central Park II ise konut fonksiyonundadır. Binalarda biyomimesis kavramının enerji tüketimi açısından sağladığı yarar sertifikalarla desteklenmiştir. Günümüzde enerji tüketimi ne kadar önemli ise sürdürülebilir yapılar tasarlamak, binaların enerji tüketimlerini en aza indirmek bu konuda çalışmaları yürütmek de o kadar önemlidir. Biyomimesis yaklaşımı doğadan ilham alınarak yapılan tasarımların doğa ile uyum içerisinde enerji tüketimini azaltacağını göstermektedir.*

***Anahtar Kelimeler:*** *Biyomimesis, enerji, bina kabuğu, sürdürülebilirlik.*

## 1.INTRODUCTION

Since the first years of its existence, architecture has been of great importance in human life. People have developed architectural design to find effective solutions to their needs and problems, and have tried different way sover time. At this point, architects and engineers have turned to nature in creative and innovative solutions. Human has used metaphorical and analogy in architectural design by imitating, interpreting, and learning from nature. This metaphorical relationship, obtained using nature and scientific knowledge, has continued till day by day, with different focuses on different periods of architectural history. Nature with its revolutionary, innovative, universal, objective qualities; scientific concepts, theories, methods, architects have been seen as potential sources for finding solutions to the problems of their own knowledge domain [1].

In the 19th century, the nature imitated only in aesthetically architecturally is changing and transforming the approach of nature to architecture by the production of building shells and skeletons originating from biological information, not only from metaphorical and analogical aspects.

Today, rapid developments in computer hard ware and soft ware enable digital technology to be included in the design process, and computation is effectively used with all kinds of modeling and preliminary production. The development of this digital technology has revealed computer methods and design tools to better under stand and interpret the “emergence” process integrated with design approaches.

Many vital mechanisms in the nature can be used as a form of thought and design in which aesthetic, function, form – material and structure are considered together in a sustainable architectural approach. Thus, a new sustainable environment that is compatible with the eco system in the field of architecture, and new, feasible long-lived solutions inspired by biological systems are targeted [2].

## 2.PURPOSE AND METHOD

The use of a large portion of the energy by the buildings has brought the energy effiency concept to the forefront. This is especially important in higher buildings. In this study, architectural formation of buildings was examined through the biomimesis approach and evaluated in terms of energy consumption and sustainability.

The study of researches on the biomimesis and the study of five samples houses and ofice buildings selected from different geographical areas were examined within the scope of the study. The information about the examined samples was edited by cataloging method.

## 3.BIOMIMESIS/BIOMIMICRY

Biomimesis as a term has been derived from the Greek word “bios” (life) and mimesis (imitation), which was coined by Benyus towards the end of the 1990s. It is the study of nature by studying the architectural form of buildings through biomimesis approach and examining the models, systems, formation processes and elements, it is expressed as a new science for problem solving which utilizes, by imitating information or by taking creative inspiration.

Biomimesis aims to develop creative solutions by incorporating designs and designers into the process through inspiration from nature [3]. It has increased our ability to study Nature’s 3.8 billion years of experience with existing tools and abilities [4].The importance given to concepts such as energy efficiency and sustainability is explaining the return to nature in this day.

Benyus lists nine (9) basic features in nature's designs in this direction:

- It benefits from sunlight,
- It uses the necessary energy,
- It creates the appropriate form,
- It provides the recycling of every thing,
- It supports rewarding of cooperation,
- It invests into diversity,
- It benefits from local elements,
- It keeps the excesses away,
- It forces the limits.

Within the principle, it is important that not only the products but also the infrastructures and processes can follow this way of natural design. Benyus (1997) expresses nature seeing as a model, criterion and mentor [5].

In addition to the basic work of Benyus (1997), Primlani (2013) lists the design principles of the biomimicry institute as follows:

- Adapt to changing conditions,
- Develop to survive,
- Harmonize growth with developments,
- Creating awareness and responsibility in local needs,
- Using chemistry compatible with nature,
- Be fruitful at sources.

In all these design principles, system emphasis is actually being made. As systems evolve over time to show adaptation, harmonize sub-structures within local constraints and conditions, create sustainable and always-new designs using less resources and without damaging the environment [6].

Biomimicry, biomimesis, biomimetic, biognostic, and bionic, which are meant to imitate nature, are commonly referred to. Biology has been used in architecture since ancient times. Through the definition of biomimicry cooperation in biology and architecture,

- Biomorphic design
- Biomimicry
- Biodesign

are addressed under three different design approaches. Logistic imitation of nature with the metaphor effect is called "biomorphic" architecture. Biodesign aiims at direct use of nature as a benefit [2] .

The summary of the literature summarizing the works to be examined in the study and the studies on the subject are given below.

Radwan and Osama's biomimicry research focuses on the effect of this approach on energy efficient building facade design. Eiffel Tower, National Aquatics Center, Beijing National Stadium, Eastgate Center, HOK, Lavasa structures examining with biyomimesis approach, it is noted that how it is implemented in design and which problem of design is resolved [7].

The researches of Özdemir and Cengizoğlu focuses on the use of natural scientific knowledge in architecture (in the context of visual impact) through examples of architectural facades. Explained through examples of the architectural facades, nature-architecture interaction, comparative studies are set forth with similarities and differences. The approach is seen to be important in terms of its

contribution to the architectural process and its visual impact. For this purpose, emphasis of this study is to make the complex features of nature by analyzing their visual impact in an architectural environment more understandable by using the knowledge of biology and to solve problems. It also focuses on studying nature as a beneficial area rather than a consumption field.

The systematic approach called biomimesis in the study of Selçuk and Sorguç; it is emphasized that the issues of minimizing the use of materials and sustainability will affect the cities of the coming centuries, the physical conditions of the places and the way people live, just as in nature. It is stated that "biomimesis" as a scientific and technical discipline could also be a candidate in the field of architecture to produce new solutions inspired by biological systems in order to live harmoniously with the answers of these questions in the world and create a sustainable environment [9].

Rajshekharise aims to demonstrate how the radical increase in resource efficiency can be achieved by utilizing the inspiration nature of biomimesis in his work. The Gherkin Tower, Watercube, Bird's Nest Stadium were examined from nature-inspired projects in the study. Architects and designers are contribute to the development of eco performance principles that can be used by industry professionals worldwide to create biomimic solutions for their designs [4].

Buildings are using natural energy sources throughout their lives, affecting the water, air, and soil that are necessary for the life of man and all living species, affecting the natural cycle in the ecosystem in an irreversible manner and damaging the environment. The globally accepted concept of sustainability deals with the ecological, economic, social and cultural dimensions of the building. In this sense, ecological sustainability is defined in a wide range of resources and ecosystem conservation, long-term use of economic sustainability resources and minimization of usage costs, and social and cultural sustainability in a wide range covering the protection of human health and comfort, social and cultural values. The concept of sustainability necessitated reviewing architectural design criteria with environmental and energy issues.

The building industry uses a significant portion of natural resources which causes to deteriorate ecological balance, create threatening environments for human health, and adversely affect human-nature-environment interaction. 90% of the energy consumed in the world and 75% of the energy consumed in Turkey are supplied from fossil fuels such as coal, oil and natural gas [10]. In addition, 50% of the energy consumed worldwide and 42% of the water are spent in building construction or in usage of process [11]. 50% of the greenhouse gases that cause global warming, 40% of the contamination of drinking water, 24% of air pollution is caused by the activities associated with the structure [12].

Sustainability refers to the necessity of preserving nature and natural resources for future generations while supplying today's needs. For this reason, the design of the building, which has a negative impact on the environment and which is largely responsible for energy consumption, should be reconsidered in the context of sustainability. Sustainability should be assessed in a long-term process, including the entire planning, programming, preliminary design, design, application, usage, demolition and re-planning phases of the architectural design process.

The sustainability approach has led to the redefinition of building design, which has a significant share in energy consumption, as architectural design criteria, defined as technology-functionality-aesthetics and economy, expanding and becoming widespread the conservation and comfort of nature-environment energy.

The fact that sustainability is a very broad concept has led to the emergence of applications in this context at different scales and in different concepts. Sustainability is being moved to a new level where buildings are indispensable for nature, rather than intervening in the sustainable ecosystems of nature and supporting nature's work.

In his work, Yanping and his colleagues point out that the bionic green architecture means the harmony obtains between the buildings and the natural environment. Building functions, structures and materials constitute the bases of bionic technologies. The buildings utilize the wisdom of nature and use it with architectural innovations through examples such as the convenient natural ventilation systems built on the termites. In the study, it is also stated that passive construction technologies with solar energy sources both improved the indoor thermal environment and provided low energy consumption in the buildings. Used solar energy, natural ventilation, water condensation, natural lighting and metabolism technologies in Bionic architecture are given to provide energy efficiency in the buildings. It is stated how bionic architectural structures use cables, thin crust, membrane and cavity structures and apply bionic architectural materials [13].

Lopez and his colleagues have investigated facade design solutions developed with new technological solutions, which are possible in particularly changing environmental conditions, by examining the relationship between biology and architecture [14].

Aziz and his colleagues demonstrate how designers and architects learn from nature and how optimizing solutions are achieved in multifunctional structures. It is also stated that biomimicry will be a good solution to problems related to buildings by improving ecological approaches [15].

## 4. EXAMPLES

In the scope of the study, the design and construction of buildings inspired from different countries (houses, offices) through selected examples of buildings (houses, offices) were examined through the catalogs on how the concept of biomimesis was used in terms of energy efficiency and sustainability.

Information on the properties of the buildings (location, year of construction, construction system, architecture, if there is any award) and their contribution to energy efficiency and the use of the concept of biomimesis are given in photographs, figures and details.

Five sample buildings surveyed in turn:

- Aldar Skyscraper
- Central Park I
- Central Park II
- Al Bahar Towers
- Tao Zhu Yin Yuan Tower.

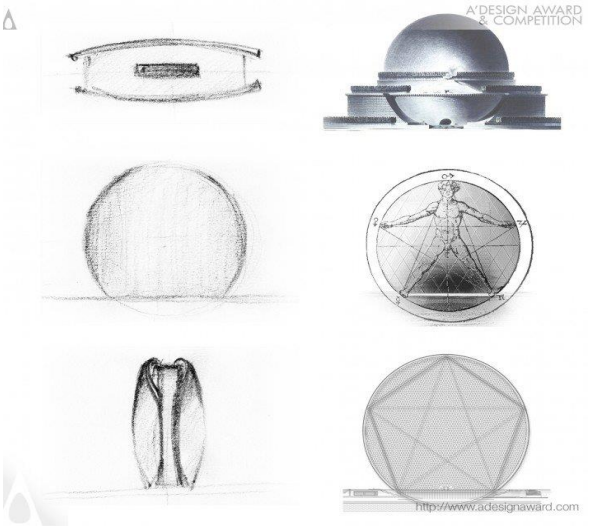
Different inspiration sources such as sea shells, waves, DNA spiral and cellular structures which exist in nature in the design and application of buildings are used. The buildings examined as an example are the tall building features built between 2007 and 2017 with a floor number between 20-50. Inspiration resources are combined with design and technology, which is provided energy efficient buildings, and with these properties, they are also entitled to receive certificates or awards at different levels. Figures 1-5 show catalogs prepared for sample buildings.

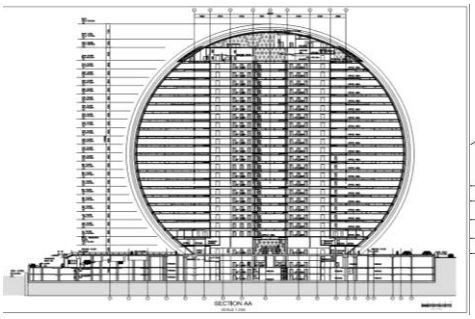
| | | | | | |
|---|---|---|---|---|---|
| Building Name: | Aldar Skyscraper | Location: | Al Raha Beach-Abu Dhabi | | |
| | | Stories: | 23+3 | Height: | 121 m |
| Function: | Office | Architect: | Adeas Architects (AHR) | | |
| Construction System: | Concrete,Steel, Glazing, | Engineer: | Al-Futtaim Carillion | | |
| Inspiration: | Sea Shell/ Mussel | Year of Construction: | 2007-2010 | | |

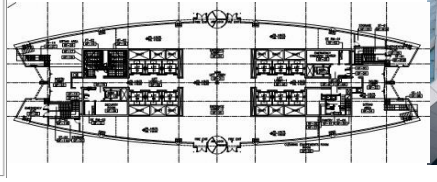
The facade of the building is inspired by the shell of the mussel. diagrid exterior side has been developed With Abu Dhabi's maritime legacy and a geometric rounded symbolic. The load on the structure is evenly distributed with the diagrid design on the facade. Depending on the Diagrid system, although 10,000 pieces of different glass fragments were needed, it could be reduced to eight different forms [16,17].

The building is mostly illuminated with natural lighting. All waste products from the building are transferred to the local waste station for recycling and compaction with an automatic vacuum waste system in underground. This system was used for the first time in Abu Dhabi [17,18].

The project was developed in accordance with the LEED rating system of the US Green Building Council. The efficiency of the building being classified as 82%, was made it the most efficient as a safe area [18,19].





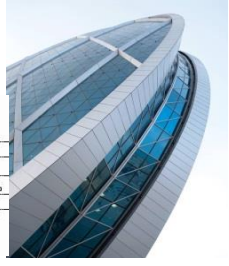
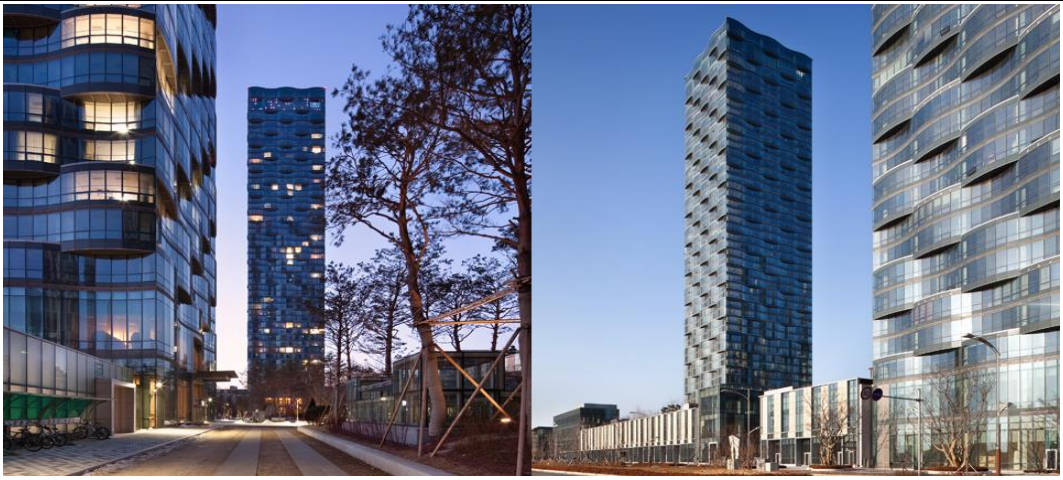


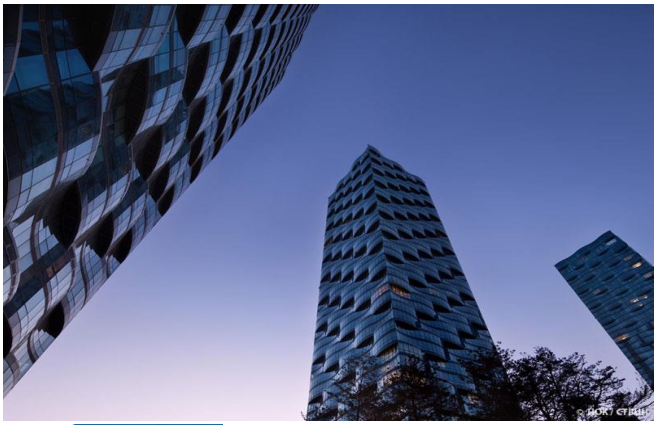
*Figure 1. Aldar Skyscraper catalog*

| | | | | | |
|---|---|---|---|---|---|
| Building Name: | Central Park I | Location: | New Songdo - South Korea | | |
| | | Stories: | 50+2 | Height: | 163 m |
| Function: | Residence | Architect: | HOK | | |
| Construction System: | Concrete | Engineer: | Midas IT,Arup | | |
| Inspiration: | Waves | Year of Construction: | 2007-2010 | | |



It was inspired by the waves in the facade design of the building. The fine fluctuation in the front was created by balancing the two layers [20].

The housing-towers ,which made from glass and aluminum, residence benefited from facade in the south with cage-like facades and unique interiors and scenes for each unit. Landscaped roof gardens were constructed in low-rise buildings as accessible areas around residential buildings. The building is illuminated with 95% natural daylight. Additional sustainable design features on site include recycling of 75% of the waste generated during construction, water use reduction, lighting system controllability and energy reduction [21]. The building is a candidate for LEED silver energy certificate [21,22].



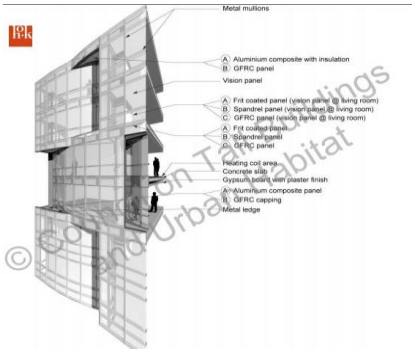
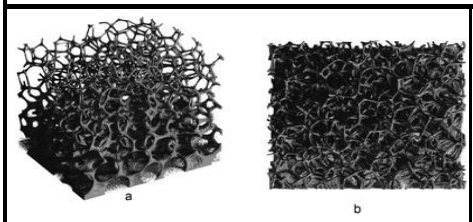



*Figure 2. Central Park I catalog*

| | | | | | |
|---|---|---|---|---|---|
| Building Name: | Central Park II | Location: | New Songdo - South Korea | | |
| | | Stories: | 45+2 | Height: | 180 m |
| Function: | Residence | Architect: | HOK | | |
| Construction System: | Concrete | Engineer: | Midas IT,Arup | | |
| Inspiration: | Cellular Structure | Year of Construction: | 2008-2011 | | |




The facade design of the building is inspired by the cellular structure. There are 632 luxurious residences in the vertically constructed building [21].

The design of the towers was developed by applying glass to the front of the concrete and aluminum skeleton facing south and north. It provides the appearance of a glass sliding tower reinforced with diagrid in the house.
To maximize sunlight in the project, a 10% improvement was achieved compared to ASHRAE 90.1 by keeping the glass area at the highest level. More than 95% of the areas designed in this way can provide access to natural light [21,23].

The building, which has a high performance facade and many sustainable design features, is candidate for the Silver LEED certificate [21,22].

*Figure 3. Central Park II catalog*

| | | | | | |
|---|---|---|---|---|---|
| Building Name: | Al Bahar Towers | Location: | Abu Dhabi | | |
| | | Stories: | 29+2 | Height: | 121 m |
| Function: | Office | Architect: | Adeas Architects (AHR) | | |
| Construction System: | Concrete, Steel, Glazing. | Engineer: | Al-Futtaim Carillion | | |
| Inspiration: | Mashrabiya | Year of Construction: | 2009-2012 | | |

The design of the building was inspired by mashrabiya, which was used as a secrecy element in arabic architecture, shading, ventilation. This structure of Mashrabiya was applied to the structure with strengthened by technology and controlled by the sunlight [24,25].

The facade panels were built in an independent frame two meters away from the structure. The active facades were formed from a large number of side transparent PTFE panels. With the building management system, panels that open and close according to sunshine conditions have reduced heating by 50% and carbon dioxide emissions by 1,750 tons per year. The need for 2098 units of dynamic unit coatings was removed and thanks to that it reduced the need for artificial lighting and mechanical air conditioning [24].

According to the US Green Building Council, LEED is candidate for Silver [24]. It was given 2012 Tall Building Innovation Award [25].

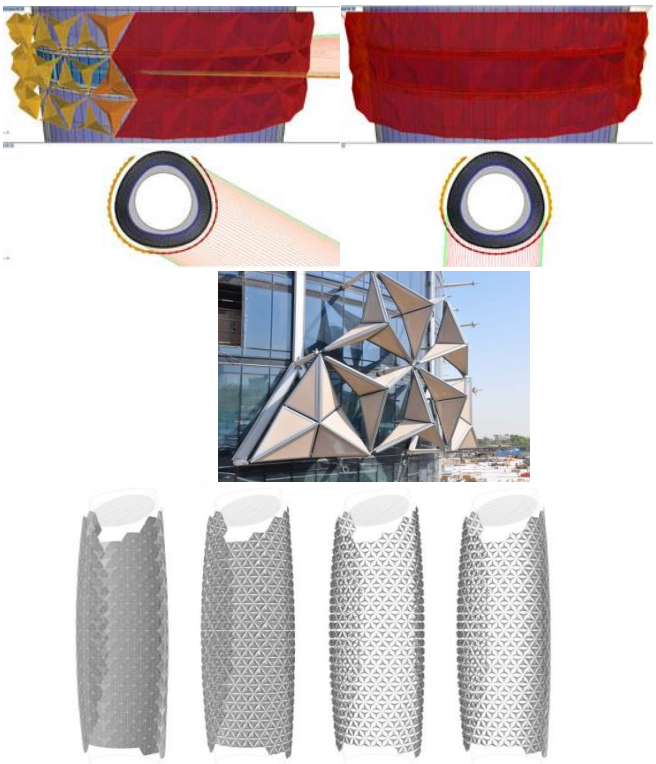
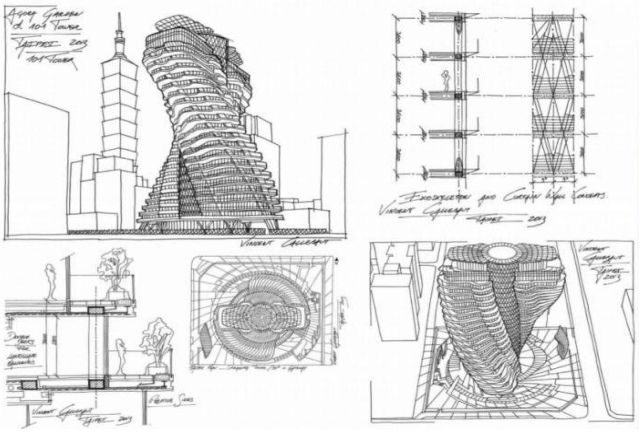


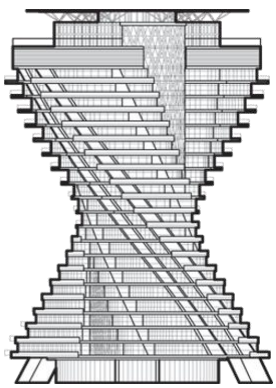
*Figure 4. Albahar Towers catalog*

| | | | | | |
|---|---|---|---|---|---|
| Building Name: | Tao Zhu Yin Yuan Tower | Location: | Taipei - Taiwan | | |
| | | Stories: | 21 | Height: | 93 m |
| Function: | Residence | Architect: | Vincent Callebaut | | |
| Construction System: | Concrete, Steel, Glazing. | Engineer: | King-Le Chang & Associates | | |
| Inspiration: | DNA Spiral | Year of Construction: | 2013-2017 | | |

The design of the building was inspired by the DNA spiral. The DNA spiral building was rotated at an angle of about 4.5 degrees on each floor and the building was rotated 90 degrees in total. This method avoided visual axes and gave privacy to each apartment unit [26,27].

The building was designed as a green icon. In the ground-floor and residential-level balconies will be planted with over 40,000 trees and the public space ventilation system managed by solar energy on the roof, the self-balancing design of the towel is just one of many features of the green housing project. When the building is completed, it is estimated that it can absorb around 130 tons plants of carbon dioxide emissions. In addition to the moving geometry of the building, the project represents an ecosystem built by bringing back fauna and flora in the heart of the city and creating a new environment for a single subtropical biodiversity [26,27,28].





It was finalist in the Innovation Award 2015 [29].
It is candidate for USA Green Building Council, LEED Gold certification, Low Carbon Building, and Diamond Level.[27,29].

Figure 5. Tao Zhu Yin Yuan Tower catalog

## 5. CONCLUSION

The biomimesis approach investigated in this study seems to have been used by architects for many years. Every work done so far has revealed how important the concept of biomimesis is and can not be ignored. When the energy consumption of existing buildings around the world is approaching 40% and energy resources are thought to be consumed rapidly, the biomimesis approach needs to be reflected more in designs and applications. Because the biomimesis approach does not harm nature, it is an approach that can reduce the environmental damage when various regulations in the nature are applied to the buildings as a design criterion. Samples examined in this study, two of them are offices and three of them are residential. The importance of designs for energy consumption and sustainability have increased since 2007 and this issue has begun to be supported by certifications. Considering the office buildings, Al Bahar Tower received the 2012 Tall Building Innovation Award and came to the fore with a reduction of 1,750 tons / year of carbon dioxide (CO2) emissions. In addition, it provided a 50% reduction in the heating of the panel construction. Aldar Skyscraper was developed in accordance with the US Green Building Council (USGBC) rating system. Building efficiency classified as 82%, was emphasized that it was the most efficient design for floor space. When the residential buildings are dealt with, The Tao Zhu Yin Yuan residential bulding which is a candidate for LEED Gold certification also has the 2015 Innovation Award. It is expected to reduce carbon dioxide (CO2) emissions by around 130 tonnes per year. This reduction will be provided by planting over 40.000 trees on the balconies. In Central Park I and Central Park II residential buildings, natural lighting and lighting expenses are reduced using glass. Central Park I is among the other sustainable design features of recycling 75% of the wastes generated during construction and reducing the use of water. At the same time Central Park I and Central Park II are candidate for the USGBC LEED Silver Certificate. This study demonstrates again that biomimesis approach which is inspired by nature will reduce energy consumption in harmony with nature. Nowadays, it is very important to design sustainable constructions and to work towards reducing the energy consumption of the buildings. By studying and learning the existing systems in the nature and combined their utilization with today's developing technologies, it is easy to produce healthy, non-polluting and efficient products in every aspect.

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**MERYEM ALTINÖZ,** Arch.
Graduated from Balıkesir University at 2016. She worked for a while in a private company in Balikesir. Graduated from Trakya University Graduate School of Natural and Applied Sciences Department of Architecture in 2016 and continues her education.
**ESMA MIHLAYANLAR, Asst.Prof.Dr.,** Arch.
She graduated in 1992 from Trakya University Faculty of Engineering and Architecture Department of Architecture as a Research Assistant to the Department of Structural Informatics in 1993. She became an Instructor in the same department in March 2003 and Assistant Professor in 2005. She still continues to serve in the same department. Her professional interests are energy efficiency, building materials and building physics issues.
**SEYHAN YARDIMLI, Asst.Prof.Dr.,** Arch.
In 1984 she graduated from Mimar Sinan University Faculty of Architecture. In 1984-1990, 53 architectural projects of her were realized. In 1990, she entered the Architecture Department of the Faculty of Engineering and Architecture of Trakya University as a research assistant to the Department of Architecture. In 1993, she completed his master degree in Architecture and Construction, and in 2001 she completed his PhD in Building Physics and Materials. In 2005 she became Assistant Professor. Since 2013, she has been a lecturer in the Department of Architecture at Istanbul Aydın University Faculty of Architecture and Design.