World Journal of Environmental Research

Volume 11, Issue 2, (2021) 49-61

www.wjer.eu

# Integrated design approaches with photovoltaic panels and solar collectors in the building envelope

**Gevher Nesibe Kaya***[1], Faculty of Fine Arts and Design, City Regional Planning, Siirt University, Siirt, Turkey
**Figen Beyhan**, Faculty of Architecture, Architecture, Gazi University, Ankara, Turkey

**Suggested Citation:**
Kaya, G. N. & Beyhan, F. (2021). Integrated design approaches with photovoltaic panels and solar collectors in the building envelope. *World Journal of Environmental Research*. *11*(2), 46-61. https://doi.org/10.18844/wjer.v11i2.7232

Received from August 11, 2021; revised from October 15, 2021; accepted from December 01, 2021;
Selection and peer-review under responsibility of Murat Sonmez, Middle East Technical University, Northern Cyprus Campus, Cyprus


**Abstract**

Energy efficiency has been the main priority of the world countries because of increasing energy consumption, depleting resources, negative environmental effects, and incremental costs. Therefore, efforts to obtain energy from alternative energy sources have raised issues of safe energy supply and energy independence, as well as energy conservation. With an increasing tendency toward net-zero energy building designs in built environments belonging to a large share in terms of energy consumption, approaches to using solar energy in buildings have been developed. In this context, the study aims to examine the integrated design principles and application methods of active solar systems used in building envelope designs in recent years. These systems were examined in terms of system components, applicability, efficiency, and building integrated design approaches together with their advantages and disadvantages. Finally, integrated design approaches relating to solar system technologies were discussed in the context of energy efficiency.

**Keywords:** BIPV; BIST; energy efficiency; Renewable; integrated design.

* ADDRESS FOR CORRESPONDENCE: Gevher Nesibe Kaya, Faculty of Fine Arts and Design, City Regional Planning, Siirt University, Siirt, Turkey
*E-mail address*: nesibe.kaya97@gmail.com

## 1. Introduction

Serious concerns about the depletion of energy resources and environmental problems on a global scale have led societies to diversify energy resources and seek alternative energy resources (Gwesha, Alfulayyih, & Li, 2019). As a result of the joint work of architecture and engineering, methods for using renewable energy technologies in buildings have been developed for buildings responsible for 40% of energy consumption. Especially in recent years, the concept of using 100% renewable energy in the use of resources for one year in buildings, along with zero-energy buildings, has come to the fore. With the use of renewable energy technologies such as solar and wind energy resources in the building envelope, applications have become increasingly popular.

In this direction, the integrated design methods of solar technologies, which offer effective and efficient use potentials, and their application approaches in the building envelope constitute the subject of this study (Lippaiová & Reith, 2014). This context aims to discuss the optimum design systems and systems in the architecture of photovoltaic (PV) systems and solar collectors, which are active solar systems. In integrated building design, all systems, components, and technologies that make up the building should be integrated and involved in the process at the same time.

In addition to reducing the energy need of the building with integrated building designs, cost optimization is ensured throughout its life cycle (Saretta, Caputo & Frontini, 2019). In this way, adverse environmental conditions can also be controlled. For this reason, it is extremely important to design and construct high-performance buildings by considering how the technological systems integrated into the buildings at the design stage will be integrated and how to achieve maximum efficiency. For designers, the process of integrating active solar systems into the building together with the design phase is systematically expressed with literature studies and supported with an example in which integrated building design methods are applied in this direction.

### *1.1. Purpose of study*

The study aims to examine the integrated design principles and application methods of active solar systems used in building envelope designs in recent years. In this direction, the effective use potentials of active solar technologies in the building envelope were examined by considering integrated design methods.

## 2. Materials and Methods

The study examines the integrated design principles and application methods of active solar systems used in building envelope designs in recent years. These systems were examined in terms of system components, applicability, efficiency, and building integrated design approaches together with their advantages and disadvantages. Finally, integrated design approaches relating to solar system technologies were discussed in the context of energy efficiency. The study gathers secondary data through existing literature and a case study Bursagaz Office Building in Turkey.

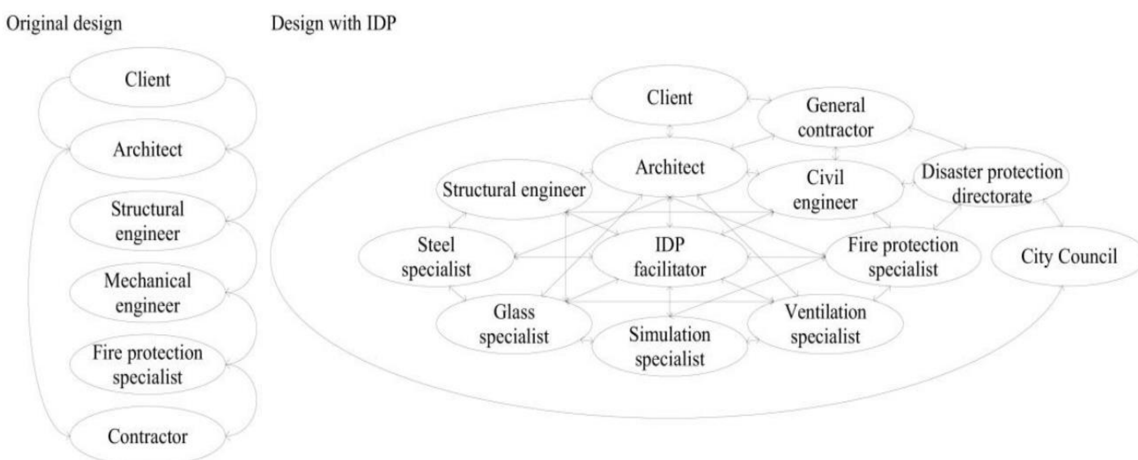
## 3. Results

For a building to be a sustainable building, it must meet certain criteria. According to these criteria, a sustainable building should provide performance improvement in various areas such as minimum use of space, minimum use of non-renewable resources, minimum emissions to water and air, and maximum indoor air quality (Zimmerman, 2006). In this direction, for a sustainable building, an integrated design method that requires different disciplines to work together should be applied.

There are different definitions of the integrated design process (IDP). One of the most comprehensive definitions is: "The integrated design process is an approach to building design that seeks to achieve high performance on a wide variety of well-defined environmental and social goals while staying within budgetary and scheduling constraints. It relies upon a multi-disciplinary and collaborative team whose members make decisions together based on a shared vision and a holistic understanding of the project." (Lippaiová & Reith, 2014).

**Figure 1**

*Traditional design and integrated design method (Lippaiová & Reith, 2014)*




In the integrated design method, unlike the traditional design process, the architect plays a key role in the integrated team to ensure optimization in building design (Figure 1). IDP not only optimizes projects but also increases project value and maximizes efficiency in the design, manufacturing, and construction phases (Kanters & Horvat, 2012). The building renewable energy integration design process, which is reflected in the architectural design according to the impact factor with the use of renewable energy technologies in the projects, integrates the architectural design with the renewable energy system design (Table 1) (Wei, 2018). In this direction, renewable energy technologies should be considered in the project from the pre-design stage to achieve high efficiency.

**Table 1**

*Stages of the integrated design process and renewable energy integration (Kanters & Horvat, 2012; authors)*

| Groups | Pre-Test | Post-Test Mean |
|---|---|---|
| Phase 1 | Pre-design | Integration of renewable energy |
| Phase 2 | Schematic design | into the design process |
| Phase 3 | Design development | |
| Phase 4 | Construction documentation | |
| Phase 5 | Bidding, construction, commissioning | Renewable energy integration |
| Phase 6 | Building operation | application |
| Phase 7 | Post-occupancy | |
| | | Recycle |

In the integrated design method, meeting the requirements of renewable energy systems in addition to the architectural design process (Wei, 2018) is carried out at an optimum level compared to the traditional design method. In this direction, solar energy, one of the renewable energy technologies, has an important place in terms of integrated design methods in buildings. Two active solar technologies are used in buildings, namely photovoltaic (PV) systems, and solar collectors.

Evaluating PV panels as a building element in the light of scientific findings and taking measures to increase system efficiency is an integrated engineering issue, and it is the basic duty of the building designer to recognize these systems (Çelebi, 2002). Thus, it is possible to keep the efficiency of PV systems and solar collectors, which are renewable energy systems, at the highest level in buildings. The economic benefits of the integrated design process of renewable energy and the that it maximizes energy efficiency is demonstrated by studies (Wei, 2018).

**Table 2**

*Architectural integration levels and forms of PV systems (Bachman, 2003)*

| Physical Integration | Visual Integration | Functional Integration |
|---|---|---|
|  |   |  |
| The systems share a common space and volume in the architectural space. | The system and the structure constitute an act of visual integration. | Functional integration occurs when the building system shares functional entitlements. |

The level of integration of active solar technologies, which will be used for the construction of an efficient and effective structure, should be determined at the pre-design stage. Integration of active solar systems into the structure takes place at different levels. Integration levels of PV systems and solar collectors into facades and roofs; It is realized in three ways as physical, visual, and functional integration (Table 2). In addition to integrations, dynamic integration, which has been popular in recent years, plays an important role in increasing the performance of active solar systems in interaction with structures.

### *3.1. Active solar systems*

By making use of solar energy, which is one of the renewable energy sources, by passive and active methods; it can be used to meet needs such as heating, cooling, lighting, and electricity (Saretta, Caputo & Frontini, 2019). The use of active solar systems, which is one of the leading renewable technologies for energy production, has gained great importance in recent years. Photovoltaic (PV) systems and solar collectors form the basis of active solar systems. In this respect, the best classification of these systems is of great importance to obtain optimum efficiency from system integrations.

### *3.1.1. Photovoltaic (PV) Systems*

The word photovoltaic (PV) consists of the combination of the Greek words "phōs" meaning "light" and "volt", the unit of voltage. "Daylight", which is a combination of sun and skylight, is transformed into electrical energy by means of photovoltaic cells. Photovoltaic cells are devices made of semiconductor materials that can convert the light incident on them into electric current (Ünver, 2013). The first appearance of PV systems took place in the 19th century. The first studies were used by America on spacecraft *(*Fraas, 2014). With the oil crisis after 1970, their use became widespread in architecture and different sectors due to the need for these systems.

PV system components in general;

- PV modules, systems made of semiconductor material that enables energy to be produced,
- Inverters, convert direct current to alternating current so that energy can be used,
- Batteries, allow energy to be stored when it is not consumed,
- Charge control units, prevent overloading and rapid discharging of energy,
- Other system components (Sayın & Koç, 2011).

Certain parameters affect the efficiency of PV cells. The type of PV cells, orientation and tilt angle, temperature factor, and shading parameters (Dabbagh, 2015) affect the optimum efficiency of PV systems. The type of PV cells (Table 3) is one of the most effective parameters in terms of energy production. Among these cells, the most efficient PV cell is the monocrystalline silicon type. However, since the cost of monocrystalline silicon cells is higher than polycrystalline silicon cells, the use of polycrystalline silicon cells is more common.

**Table 3**

*PV cell type and properties*

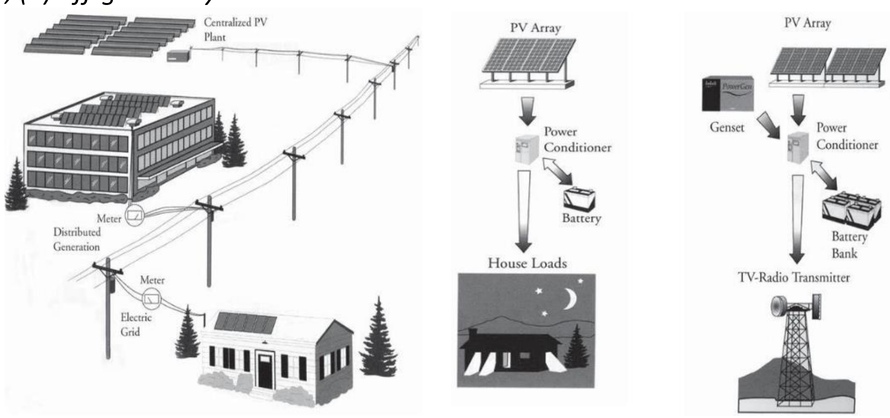
| PV Cell Type | | Main Material | Productivity |
|---|---|---|---|
| Thin film | A-Si | Silicon | %4- 12 |
| Crystal Silicon | Monocrystalline | | %17- 20 |
| | Polycrystalline | | %13- 16 |

The efficiency of PV systems is related to factors independent of the designers, such as the incidence angle of solar radiation, annual, monthly, and daily sunshine duration, and latitude angulation. However, besides this, the orientation or tilt angle, which is effective in the change of the amount of solar energy taken from the surface of the PV panels, can be controlled to capture the maximum radiation (Gwesha, Alfulayyih, & Li, 2019). The temperature factor has a great influence on the efficiency of PV cells. PV cells convert an average of 20% of the incoming solar radiation into energy and store the rest as heat. High temperature also creates a negative effect as it will increase the cooling loads inside the building (Dabbagh, 2015). In this direction, the amount of heat to be stored must be controlled in terms of the efficiency of the PV cells. Likewise, if any object shadows on PV systems, system efficiency is greatly affected. The shading situation should be minimized with the precautions taken during the design phase.

Classification of PV systems specific to the building is generally divided into two. These are on-grid and off-grid PV systems (Figure 2). In on-grid systems, the energy produced by PV panels is transferred to the city grid. However, energy losses occur during this transfer. In off-grid systems, the energy obtained from PV panels is consumed in the field.

**Figure 2**

*(a) on-grid PV, (b) off-grid PV systems*




**Source:** *Ofualagba, 2008*

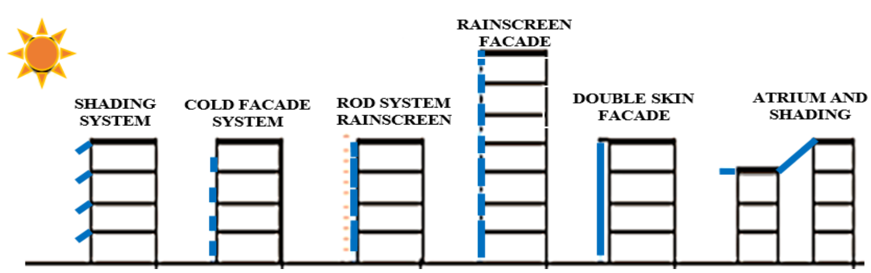
The use of photovoltaic technologies in buildings is provided by two different systems. These systems are building added photovoltaic systems (BAPV) and building integrated photovoltaic systems (BIPV). BAPV systems are installed in the building envelope after design. In these systems, they transfer a static load to the building as it is added later. BIPV systems, on the other hand, are systems that are integrated into the building envelope, considering during the design phase. Since they are integrated at the design stage, they have high-efficiency performance and aesthetics compared to BAPV systems. These systems are used as a whole on roofs and facades, as well as in building parts such as sunshades and balcony parapets.

3.1.1.1. Photovoltaic (PV) Systems Used as Facade and Roof Components

The presence of PV systems on the exterior of buildings occurs at two different levels, depending on the type of integration and design concepts. Classified according to their integration into the building envelope, PV panels are divided into five according to their use in shading, cold facade, warm facade, double-skin facade, and atrium and parapets (Figure 3). The most efficient system among PV integration types is the shading system. High-efficiency energy can be obtained from PV technologies integrated with an angle suitable for the sun. The disadvantage of the system is that the PV systems block each other's sunlight by shading. In this situation, certain intervals should be left. In other PV integration types, rainscreen PV facade applications work in curtain wall logic. There is a similarity between the cold front systems and the double skin PV facade system in terms of rear ventilation of PV systems.

**Figure 3**

*PV panels by type of integration*

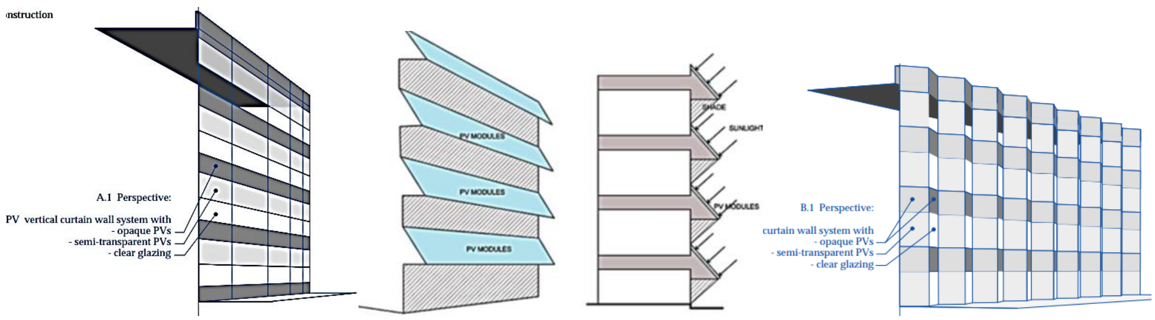


*Source: Tabakovic et al., 2016.*

PV systems on facades are classified according to different design concepts (Figure 4, 5). Among these systems, the most efficient one is inclined and stepped PV facade system, where energy production, appropriate angle, and orientation are made. However, since this system has an inclined orientation towards the sun, it causes high temperatures in space. Considering this situation, accordion PV facade systems (Figure 5a) are more advantageous despite their high cost and maintenance.

**Figure 4**

*PV system according to the design concept, (a) vertical PV facade, (b) horizontal saw-tooth PV facade (Basnet, 2012), (c) vertical saw-tooth PV facade system (Kiss, 1993)*

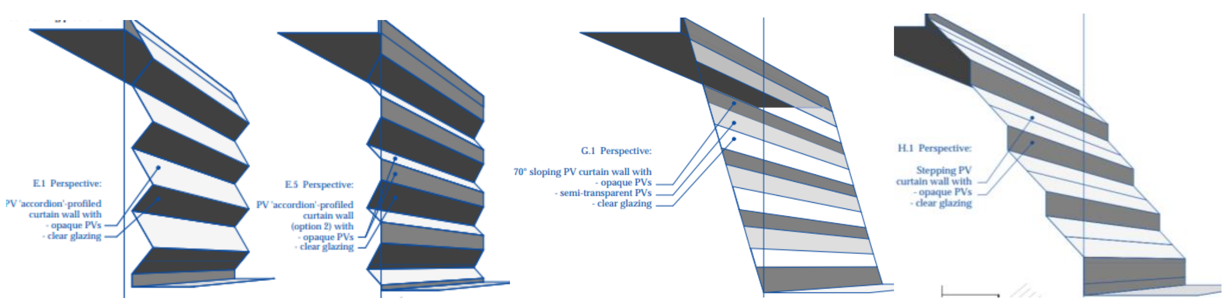



(a) (b) (c)

When other facade design concepts are examined, the working principle of horizontal saw-tooth PV facade systems is the same as shading PV facades and has high efficiency. The east-west orientation of vertical saw-tooth PV facades is particularly important for their efficiency. In sloped PV facade systems, high efficiency is achieved when the design is made considering the azimuth angle. When the necessary analyzes are made for the facade design concepts, the energy that the buildings will produce with the help of PV systems is maximized.

**Figure 5**

*PV system according to facade design concept, (a) accordeon PV facade, (b) sloped PV facade, (c) stepped PV facade system (Kiss, 1993)*




(a) (b) (c)

### *3.1.2. Solar Collector*

Another technology among active solar systems is solar collectors. Solar collectors are used to heat the space and water through the water in the system, using the heat they receive from solar radiation. In these systems, only heat is released and the energy production in PV systems is not realized in solar collectors. Solar collectors are classified as planar solar collectors and vacuum tube solar collectors (Altınöz & Mıhlayanlar, 2019). Considering the collector efficiency situation, vacuum solar collectors are more efficient than planar solar collectors as they reduce heat losses by vacuuming the pipes. The efficiency of the collectors is defined as the ratio of the amount of energy collected to the amount of energy falling on it (Demircan & Güntekin, 2017). The use of collectors in buildings is carried out by mounting them afterward or by integrating them into the system at the design stage, as in PV systems. Solar collectors are expected to play a leading role in providing thermal energy needs as they directly contribute to the building's heating, cooling, and hot water requirements (Aelenei, 2015).

**Figure 6**

*Solar collectors used on roofs and facades*

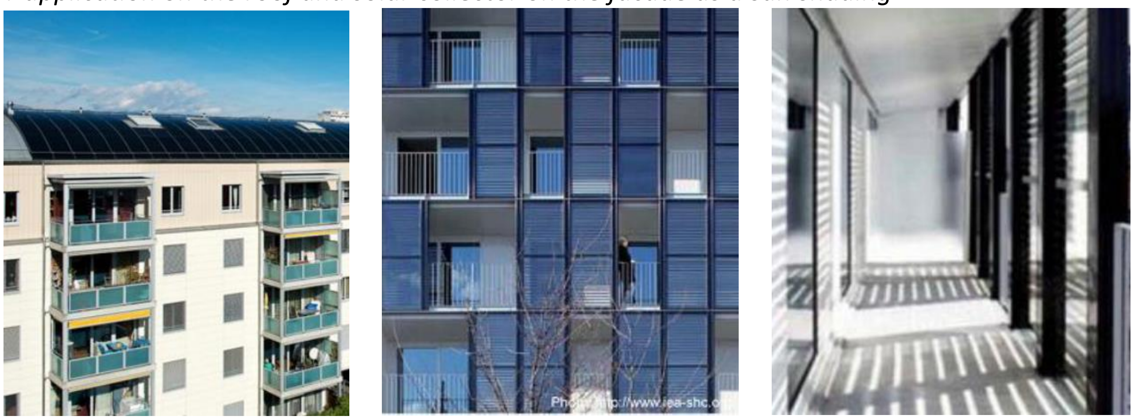

*Source:* Aelenei, 2015.

Building-integrated solar collectors (BIST), unlike traditional solar collectors, incorporate many functions (building envelope, insulation, heat generation, modern appearance) like BIPV systems (Figure 6). Integrating solar collectors on building facades increases the visual quality of the building (Baset, 2012). Likewise, with scientific and technical advances, the cost of energy obtained by the use of solar collectors is reduced (Zhelykh, Venhryn, Kozak, & Shapoval, 2020).

The roof has a high potential for the installation of BIST systems. BIST systems have many advantages such as high solar energy production and improving the thermal insulation quality of the roof (Qadourah, 2020). Integrating BIST systems on facades reduces efficiency on flat surfaces. As in BIPV systems, applications are made in different design concepts in BIST Technologies (Figure 7).

**Figure 7**

*BIST application on the roof and solar collector on the facade as a sun shading*



*Source:* Aelenei, 2015.

### *3.2. Methods - Integrated Design Case Study Bursagaz Office Building*

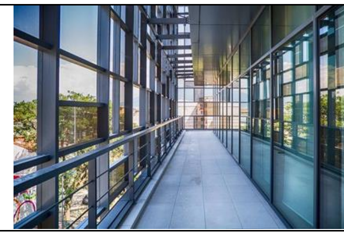
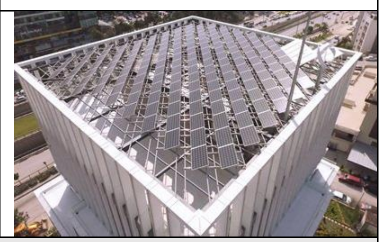
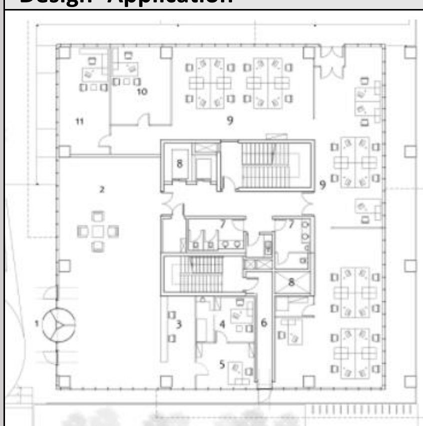
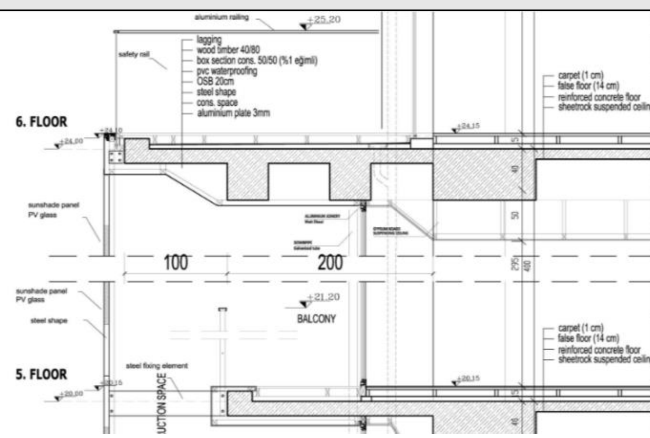
In this section, the analysis of the Bursagaz office building, which is a candidate for LEED Platinum in Turkey. The building is carried out to increase the energy efficiency of the building by integrating renewable solar energy systems into the roof and facade of the building by using the integrated design method. The project, which includes an integrated design process from the pre-design stage, it was aimed to establish a relationship between office life and energy efficiency (Table 4).

In the pre-design phase of the Bursagaz office building, it was aimed to create a sustainable and environmentally friendly architectural design concept by integrating architecture with renewable energy systems. With the integrated design method, a 28% reduction in the energy need of HVAC systems is achieved. At the same time, the reuse of rainwater and wastewater is provided by automatic systems. Thus, water-saving is achieved with mechanical systems in the building. The depreciation period of the translucent BIPV systems that create a rhythmic order on the façade and provides solar control and the PV systems on the roof is 6 years, meeting 3% of the annual energy need of the building.

**Table 4**

*Bursagaz office building integrated design and renewable energy integration analysis (URL 1; URL 2; URL 3)*

| BURSAGAZ OFFICE BUILDING | | | SAMPLE |
|---|---|---|---|
| BUILDING IDENTIFICATION | **Architecture** | TAGO Architects |  |
| | **Location** | Bursa, Turkey | |
| | **Climate** | Temperate climate | |
| | **Construction year** | 2013- 2016 | |
| | **Structure-function** | Office building | |
| | **Architecture concept** | Passive house design approach | |
| | **Floor area** | 820 m$^2$ | |
| | **Number of floors/ height** | 7 floor+ 3 floor basement | |
| | **Facade type** | Double skin PV facade | |
| | **Roof type** | Terrace roof | |
| INTEGRATED FACADE | **Design goal** | . Energy- saving<br>. Use of renewable energy sources (solar and wind energy)<br>. User comfort/ healthy | |

| | | | |
|---|---|---|---|
| | **BIPV Application** | Facade: Warm facade PV application |  |
| | **BIPV Application Type** | Facade: Double skin surface cladding material | |
| | **PV System Classification** | Off-grid |  |
| | **PV Installation area** | 315 number (50cm x70cm) | |
| | **PV Cell Type** | %20 transparent amorphous silicon glass | |
| | **Potential Power** | 4.1 kWp | |
| | **PV tilt angle** | 90° (facades) | |
| | **Payback period** | 6 year | |
| | **Annual energy production** | 3.400 kWh | |
| | **Efficiency rate** | It meets %3 of the energy needed from PV systems. | |
| **INTEGRATED DESIGN PROCESS** | **1. Renewable energy integration design** | BIPV, PV and wind turbine |  |
| | **2. Renewable energy integration application** | BIPV application on double skin facades and mounting PV and wind turbines on the roof | |
| | **3. After use** | - | |
| **DRAWINGS** | **Design- Application** | | |
| |  |  | |
| | Ground Floor Plan facades | BIPV section detail on the | |

## 4. Discussion

Within the scope of the study, investigations were made on buildings with high potential to prevent environmental degradation in the current situation and the future. In this direction, it has been concluded that the integration of renewable energy systems into the building with integrated design methods is more effective in terms of optimizing building energy efficiency and cost and reducing environmental impacts compared to the traditional design method (OnyxSolar, 2016). When integrating active solar systems (photovoltaic and solar collectors), which are the most widely and efficiently used among renewable energy technologies, into buildings, in this direction it is necessary to determine the techniques to be applied before the design phase and to design with the most optimum efficiency.

In particular, within the scope of the 20/20/20 targets of the European Union, with the requirement that existing and new buildings to be built should be at the level of approximately zero energy buildings, integrated design methods for optimum use of renewable energy in buildings and applications for renewable energy integration are increasing (Architizer, 2021; Arch20, 2021). In line with this target, the need for solar energy has increased with the use of renewable energy in buildings by 20%. As a result of energy production in buildings with the help of solar energy from renewable energy sources, carbon and greenhouse gas emissions from buildings can be prevented to a large extent.

## 5. Conclusions

In particular, after the data from the literature, it has been observed that a large part of the energy consumed in the built environment is met as renewable energy by the use of active solar technologies in the building envelope. In this direction, to benefit significantly from active solar systems used in the building envelope, primarily integrated design approaches and applications in architecture should be actively involved. Thus, the goal of a zero-energy, positive-energy building that can produce its energy can be achieved.

In this context, BIPV-BIST technologies, which are highly suitable for use in the building envelope within the integrated design process, with the evaluation of the results of the building analyzed in the study and the building analyses carried out in previous studies, both gave the building an innovative modern look and provided energy and heat. In the results of the analysis building, it has been seen that the PV systems used in the buildings generally meet the building energy needs at rates and reach 60- 70% after a payback period. By making use of solar technologies with integrated design approaches in the building envelope, the potential to perform many functions such as control of sunlight, sound insulation, building envelope function, and energy generation is emerging.

To disseminate active solar technologies with these potentials in buildings, regional and global incentives and certain obligations (standards and regulations) should be introduced. Developing countries, in particular, will ensure that solar technologies are spread at an optimum level in buildings by integrating the directives of advanced countries in solar energy into buildings, considering the climate and potential of their regions.

## References

Aelenei, L. (2015). Overview of Building Integrated Solar Thermal Systems State of the Art, Models, and Applications (C. TU1205 Ed.): Cyprus University Of Technology, Department Of Mechanical Engineering And Materials Sciences And Engineering. https://www.um.edu.mt/library/oar/handle/123456789/42536.

Altınöz, M., & Mıhlayanlar, E. (2019). Aktif Güneş Sistemlerinin Bina Enerji Verimliliği Üzerindeki Etkisinin İncelenmesi (The Influence of Active Solar Systems on Building Energy). Journal of Architecture and Life, 4(2), 323-335. https://dergipark.org.tr/en/pub/my/article/635052

Arch20. (2021). EWE and Bursagaz Headquarters. URL2:< https://www.arch2o.com/ewe-bursagaz-headquarters-tago-architects/> Last access: (30.05.2021)

Architizer, (2021). Ewe & Bursagaz Headquarters. URL 1:https://architizer.com/projects/ewe-bursagaz-headquarters/ Last access: (16.06.2021)

Bachman, L. R., (2003). “Integrated Buildings”, John Wiley&Sons, Inc., New York, 3-48.

Basnet, A. (2012). Architectural Integration of Photovoltaic and Solar Thermal Collector Systems into buildings. Master Thesis, Norwegian University of Science and Technology, Trondheim.

https://www.semanticscholar.org/paper/Architectural-Integration-of-Photovoltaic-and-Solar-Basnet/5243a137aa9c21d2d222d9650dd3f306b8a7dd2d#paper-header.

Çelebi, G. (2002). Bina Düşey Kabuğunda Fotovoltaik Panellerin Kullanım İlkeleri (Principles of Use of Photovoltaic Panels in the Vertical Envelope of the Building). Gazi University Journal of Engineering and Architecture, Vol 17(3), 17-33. https://dergipark.org.tr/en/pub/gazimmfd/issue/6653/89023

Dabbagh, N. (2015). Football Stadium: Solar Envelope As An Architectural Tool. Master Thesis. Delft University of Technology, Netherlands. https://repository.tudelft.nl/islandora/object/uuid%3A3a425d6e-70a7-4a7d-8b4e-8895a216c6f7

Demircan, R. K., & Güntekin, A. B. (2017). Binalarda Pasif Ve Aktif Güneş Sistemlerinin İncelenmesi (Investigation of Passive and Active Solar Systems in Buildings). TÜBAV Scientific Magazine, 1, 36-51. https://dergipark.org.tr/tr/pub/tubav/issue/27928/296689 .

Fraas, L. M. (2014). Chapter 1: History of Solar Cell Development. In Low-Cost Solar Electric Power. Switzerland. https://link.springer.com/content/pdf/10.1007/978-3-319-07530-3.pdf.

Gwesha, A. O., Alfulayyih, Y. M., and Li, P. (2019). Optimization of fixed PV panel "tilt" angles for maximal energy harvest considering year-around sky coverage conditions. ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE). https://asmedigitalcollection.asme.org/IMECE/proceedings-abstract/IMECE2019/V006T06A088/1073229

Kanters, J., & Horvat, M. (2012). The Design Process known as IDP: A Discussion. Energy Procedia, 30, 1153-1162. doi: https://doi.org/10.1016/j.egypro.2012.11.128.

Kiss, C. A. (1993). Building-Integrated Photovoltaics. NREL, Golden, Colorado. https://kisscathcart.com/pdf/BIPV1kc.pdf.

Lippaiová, R., and Reith, A. (2014). Reducing the costs of high-performance buildings – the integrated design process. Creative Construction Conference, Prague, Czech Republic. https://www.researchgate.net/publication/263848598_Reducing_the_costs_of_high-performance_buildings_-_the_integrated_design_process.

Ofualagba, G. (2008). Photovoltaic technology, applications, and market. 2008 IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, Pittsburgh, PA, USA. doi: 10.1109/PES.2008.4596218.

OnyxSolar. (2016). Bursagaz. URL3:https://www.onyxsolar.com/progetti/11-projects/103-bursagaz Last access: (30.05.2021)

Qadourah, J. (2020). Architectural integration of photovoltaic and solar thermal technologies in multi-family residential buildings in the Mediterranean area. Doctor of Philosophy. Berlin University of the Arts Berlin. https://www.researchgate.net/publication/343441117_Architectural_integration_of_photovoltaic_and_solar_thermal_technologies_in_multi-family_residential_buildings_in_the_Mediterranean_area.

Saretta, E., Caputo, P., and Frontini, F. (2019). A review study about energy renovation of building facades with BIPV in urban environment. Sustainable Cities and Society, 44, 343-355. doi: https://doi.org/10.1016/j.scs.2018.10.002.

Sayın, S., and Koç, İ. (2011). Güneş Enerjisinden Aktif Olarak Yararlanmada Kullanılan Fotovoltaik (PV) Sistemler Ve Yapılarda Kullanım Biçimleri (Photovoltaic (PV) Systems Used in Active Use of Solar Energy and Use in Buildings). S.Ü. Journal of the Faculty of Engineering and Architecture, c.26, s.3. https://dergipark.org.tr/en/pub/sujest/issue/23235/248069 .

Tabakovic, M., Fechner, H., and Knoebl, K. (2016). Framework and Requirements Analysis: Development of innovative educational material for Building-integrated PV. Utrecht University, The Netherlands. http://media.dem4bipv.eu/filer_public/31/b3/31b3cf4e-f391-402e-8d33-295475f308d3/del1_framework_and_requirements_analysis_november_2016.pdf.

Ünver, E. (2013). Binaya Entegre Fotovoltaik Sistemlerin Mimaride Kullanımı (Use of Building Integrated Photovoltaic System In Architecture). URL4: https://www.ekoyapidergisi.org/243-binaya-entegre-fotovoltaik-sistemlerin-mimaride-kullanimlari.html Last access: (04.09.2020)

Wei, S. (2018). Renewable Energy Technologies Applied in Architecture and Its Innovative Research. IOP Conference Series: Earth and Environmental Science. https://iopscience.iop.org/article/10.1088/1755-1315/186/4/012007/meta.

Zhelykh, V., Venhryn, I., Kozak, K., & Shapoval, S. (2020). Solar collectors are integrated into transparent facades. Production Engineering Archives, 26, 84-87. doi:10.30657/pea.2020.26.17.

Zimmerman, A. (2006). Integrated Design Process Guide. Canada. http://www.infrastructure.alberta.ca/content/doctype486/production/leed_pd_appendix_7a.pdf.