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# A Study on the BIPV System for Energy Saving According to the Passive Envelope Design

Kyungsoo Kim[1], Ri Ryu[2], Yongseong Kim[3*]

*[1]Graduate School of Techno Design Kookmin University, 77 Jeongneung-ro, Seongbuk-gu, Seoul, Korea*
*[2]Graduate School of Techno Design Kookmin University, 77 Jeongneung-ro, Seongbuk-gu, Seoul, Korea*
*[3]Graduate School of Techno Design Kookmin University, 77 Jeongneung-ro, Seongbuk-gu, Seoul, Korea*
*[1]k.kyungs216@gmail.com, [2]ri23414@hanmail.net, [3]yongkim@kookmin.ac.kr*

***Abstract***

*The BIPV system among the envelope technology elements of passive design has the advantage of utilizing solar photovoltaic energy and enhancing the design, so relevant studies are being carried out continuously as part of a complex system. Therefore, the purpose of this study is to review the façade design of the BIPV system through the current application cases by considering the BIPV system that can be applied to the building envelope in terms of energy saving through the analysis of passive design applied element technologies as an envelope technology for energy saving.*

***Keywords:*** *Passive Design, Building Envelop Design, Eco- System, BIPV System*

## 1. Introduction

The building envelope in the pre-modern period existed for different characteristics according to the weather conditions to prevent the indoor space from being affected by external environmental elements and it played a simple role in distinguishing between indoor and outdoor spaces. After the industrial revolution, significant technical developments were achieved and the architecture established new paradigms due to the development of materials so that various designs and architectural forms of envelope appeared. Modern architecture avoids the functionalistic elements of the past and develops eco-friendly technology elements for energy saving, examining areas such as passive design. Especially, the envelope field in passive design is receiving a lot of attention because of its energy saving potential and its main role is to realize significant indoor energy saving rather than simply separating indoor and outdoor spaces as it did in the past. The BIPV system among the envelope technology elements has the advantage of utilizing solar photovoltaic energy and enhancing the design so relevant studies are being carried out continuously as part of a complex system. [1]

Therefore, the purpose of this study is to review the façade design of the BIPV system through the current application cases by considering the BIPV system that can be applied to the building envelope in terms of energy saving through the analysis of passive design applied element technologies as an envelope technology for energy saving.

[1] Yongseong Kim is the corresponding author.

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# 2. Passive Design

## 2.1. The Definition of Passive Design

The dictionary meaning of passive design states that it is a design for cooling and heating that saves energy by controlling the flow of heat through the structure by means of radiation, convec-tion and conduction without using a separate mechanical device at the design stage [1]. Also, the passive design is defined in the Passive Design toolkit (2009) in Vancouver of Canada as the method to design a building by using architectural methods to minimize energy consumption and improve thermal comfort [2]. According to the definition mentioned earlier, the passive design has the characteristics shown in Table 1.

**Table 1. Characteristics of Passive Design**

| Classification | Characteristics |
|---|---|
| Avoided | Mechanical facilities |
| Oriented | Aims for thermal comfort of user |
| Minimization | Minimize energy consumption |
| Effect | Cooling and heating effects due to the flow of heat |
| Energy source | Utilize natural elements as the energy source |

## 2.2 Technology Elements of Passive Design

The environmental elements in each site should be considered in the passive design since natural energy is utilized. The passive design elements are applied while going through appropriate design steps. Normal planning process consists of 5 steps as shown in Table 2. and these steps should be applied by considering each planning order. Since the passive design is an eco-friendly element obtained by utilizing natural energy, it is intended to find the elements of passive design from natural energy. Sun, wind, water, plant and temperature were defined as the elements of natural energy and the elements of passive design were applied as the Table 3 [3,4].

**Table 2. Passive Design Planning for the Order**

| Order plan | Considerations |
|---|---|
| 1. Arrangement and land utilization plan | Optimal direction, Solar radiation&Sunshine, Ground heat, Climate |
| 2. Building type and cross-section plan | Use of the building, Size, User, Load characteristic |
| 3. Space program and indoor plan | Program placement, Load control |
| 4. Façade plan | Insulation facade |
| 5. Landscape plan | · |

**Table 3. Passive Design of Natural Elements[3]**

| Elements of natural | Elements of passive design |
|---|---|
| Sun | Lignting, Awaning |
| Wind | Ventilation, Cooling, Heating |
| Water | Rain water, Water resources |
| Plant | Green roof, Green wall |
| Temperature | Heat storage, Insulation |

### 2.3 Passive Design Applied Envelope Technology Elements

The envelope where the passive design is applied is the most important element for reducing energy consumption in the internal space [4]. The envelope is composed of an opening, wall and roof. The passive technology elements of each component are summarized and shown in Table 4.

| Classification | | Elements |
|---|---|---|
| Opening | Windows | BIPV system, Double envelope, Light-shelf, Daylight duct, Prism glass |
| | Awaning | Luver, Blind, Awning |
| | High insulation | High insulation double glazing glass, High insulation window system |
| Wall | High performance | High insulation outer wall |
| | Heat storing reagent | Thermal storage wall |
| | Green system | Green wall system, Projecting roof |
| Roof | Heat storing reagent | Heat storing slab |
| | Ventilation | Protrusion roof, Solar Chimney |
| | Green system | Green roof system |

**Table 4. Based Planning of Passive Design**

## 3. BIPV System of Building Envelope where the Passive Design is Applied

### 3.1. Concept of BIPV System

European countries are making efforts to achieve the goal of 31% for the usage of new renewable energy by 2020, and solar photovoltaic energy use is being supported by the government so that the solar photovoltaic energy business is growing rapidly [5]. The utilization value of solar photovoltaic energy among natural energy fields that come into contact with buildings frequently has been judged high so that the relevant studies are being carried out continuously. Unlike previous normal PV modules, the BIPV system is a multi-functional system which applies the technologies to the envelope, replaces the finishing material and produces electricity using solar photovoltaic energy. Since the BIPV system is integrated with the building, this system should satisfy the performance of envelopes and the complex function as a facility system; this system can be summarized as shown in Fig 1 [4].

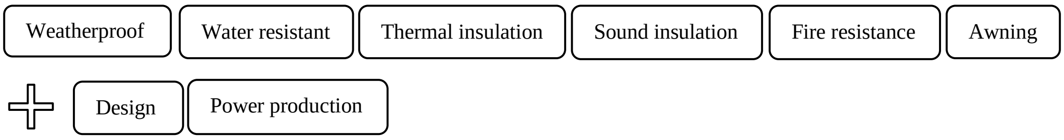
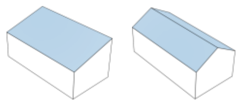
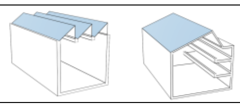
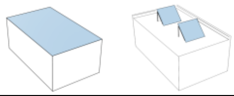
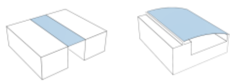
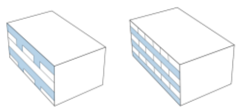
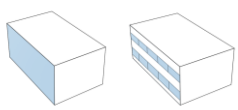


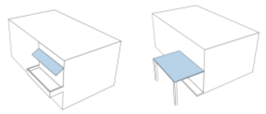
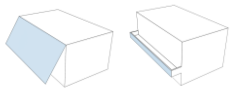
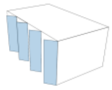

**Figure 1. Performance Requirements of BIPV System**

### 3.2. Application Area of BIPV System

The BIPV system is a facility which receives solar photovoltaic energy and produces electricity, and it can be installed on any spot in the envelope where solar photovoltaic energy reaches. However, it is most important to apply such a system in an efficient position according to the weather conditions and condition for installation [4]. The BIPV system can be applied on the building as shown in Table 5. For the morphological application according to each area, it is most advisable to decide the direction according to the orbit of sun and the weather conditions at each site.

**Table 5. Facade Application Method of BIPV System [4]**

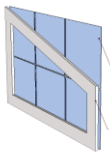
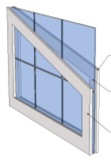
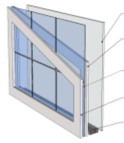
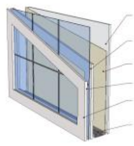
| Classfication | Type | | Contents | Position |
|---|---|---|---|---|
| Roof | Slope | Roof | -Easy to install it at the optimal angle<br>-Easy to install it to the existing buildings |  |
| | | Lighting | -Lighting available from the roof<br>-Easy to use it as a design element |  |
| | Flat | Roof | -Lighting available from the roof |  |
| | | Lighting | -Easy to apply it as an atrium |  |
| Wall | Wall attachment | | -Possible to utilize it as building exterior material<br>-Possible to utilize it aesthetically (shape, pattern, color)<br>-Possible to utilize the PV module for various functions |  |
| | Skylight | | -Possible to replace it with the curtain wall<br>-Possible to utilize the translucent module and cell arrangement change<br>-Possible to utilize it as building exterior material |  |

| | | | |
|---|---|---|---|
| | Awning | -Possible to utilize it as building awning material<br>-Possible to utilize it at various angles<br>-Possible to utilize it as a design element |  |
| Facade | | -Possible to apply it to the balcony<br>-Possible to apply it to vertical and<br>gradient curtain walls |  |
| Combination | | -Possible to use it with other facilities<br>such as a louver |  |

### 3.3. Affiliations

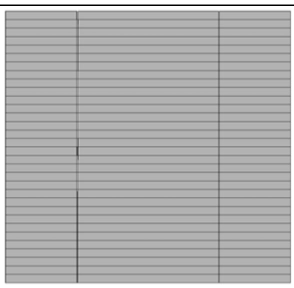
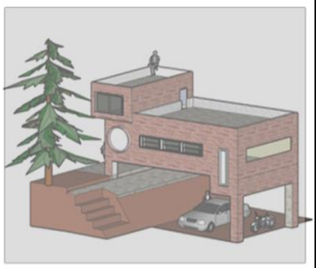
The BIPV system is classified into two types including the classification according to the glass sealing method as shown in Table 6 such as the G-G type which is most widely used and the arrangement density of cells for each unit area as shown in Table7.

**Table 6. Classification of BIPV According to the Glass Sealing Method**

| Type | Single layor glass Black-sheet Type | Double glazing G-G Type, | Sealing double glazing G-G Type | Safety film applied sealing double glazing G-G Type |
|---|---|---|---|---|
| Contents |   |   |   |   |
| Position | wall of non air-conditioned section | Canopy, Sun Shade | wall of air-conditioned section | Ceiling |

The single plate sealing method has better energy creation efficiency than the double-layer sealing method but the double-layer sealing method has better heat insulation properties so that it is more advantageous in term of energy efficiency than the single plate sealing method[4].

**Table 7. Arrangement Density of Cells**

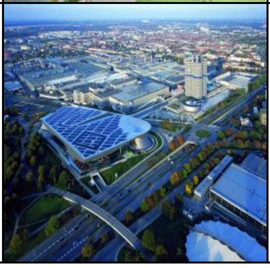
| Type | Crystalline | Thin film type (Permeability 20%) | Thin film type (Permeability 40%) |
|---|---|---|---|
| Contents |  |  |  |

The transparency and efficiency of glass are determined according to the arrangement density of cells. If the number of cells for each unit area increases, glass becomes more efficient and opaque, and if the number of cells for each unit area decreases, glass becomes less efficient and more transparent, so it is necessary to decide the arrangement density of cells efficiently for different situations.

## 3. Domestic and International BIPV System Cases

The result of analyzing the BIPV system application cases shows that this method can improve efficiency by considering natural environments and that an external design can be applied. When applying the BIPV system to facade, the façade method which can improve energy saving performance should be considered.

**Table 8. Domestic and International BIPV System Cases**

| Building name | Photo | Contents |
|---|---|---|
| Yeouido FKI Tower |  | - Sunlight generation: 255 kWh<br>- Installation position: Rooftop and outer walls<br>- Accounts for 4~7% of building electricity consump-tion |
| Songdo SC Hotel |  | - Installation position: Outer walls<br>- Sunlight generation: 38.4 kWp<br>- Produce and apply the module in a complete form<br>- Large scale see-through amorphous module |
| Seoul Government building |  | -Installation position: Roof<br>- Sunlight generation:: 200 kW<br>-Use for cooling, heating and hot-water supply |
| BMW World |  | -Installation position: Roof<br>- Sunlight generation: 824 kWp<br>- BIPV consisting of PV modules |

| | | |
|---|---|---|
| PTM Zero Energy Office |  | - Installation position: Roof<br>- Sunlight generation:: 92KWP<br>-amorphous module (roof), polycrystal module (main roof), translucent PV (atrium), monocrystal (roof on the parking lot) |
| Sanitary complex of the Alzheimer Project |  | -Installation position: Outer walls<br>-Sunlight generation: 19.92 kWp<br>-pv + thermal protective skin applied<br>-3 types (sunlight generation, shading, transparent module) |

**Table 9. Domestic and International BIPV System cases on the Theorem**

| Type / Building | Roof type | | | | Wall type | | |
|---|---|---|---|---|---|---|---|
| | Slope type | | Flat type | | Wall attachment | Skylight | Awning |
| | Roof | Lighting | Roof | Lighting | | | |
| Yeouido FKI Tower | ○ | x | x | x | ○ | x | x |
| Songdo SC Hotel | x | x | x | x | x | ○ | x |
| Seoul Government building | x | x | x | x | x | x | x |
| BMW World | x | x | ○ | x | x | x | x |
| PTM Zero Energy Office | x | x | ○ | ○ | x | x | x |
| Sanitary complex of the Alzheimer Project | x | x | x | x | x | ○ | x |

Use : ○ Non use : x

## 4. Conclusion

Passive design which is a part of sustainable architecture is being implemented for the purpose of saving energy by extracting natural elements, and the envelope technology elements in the passive design are acting as essential elements for utilizing natural energy. Studies on the envelope should be carried out with the aim of saving energy so that a sustainable type of architecture can be achieved rather than being simply a method to distinguish between indoor and outdoor spaces or to produce aesthetic qualities. The BIPV system among the building envelope technology elements plays the role of converting solar photovoltaic energy as an energy source into electricity and it is a complex system which integrates the PV system with the building envelope to act as an external material. Efficiency is prioritized with regard to the BIPV system as a passive system. However, the combination with other design elements as a design element is most important. Also, it should be arranged by considering shading, angle and building elements that meet the weather conditions for each installation site in order to improve its efficiency. The advantages of the BIPV system are as follows. Since it is integrated with external materials, it can save on material expenses, serve as an advertisement billboard, help reduce power consumption and electricity peaks and enhance the eco-friendly design elements of the building and the value of the building as an exterior design element.

Therefore, the various advantages of the BIPV system among the passive design envelope technologies for saving building energy use should be utilized efficiently in the solar photovoltaic energy field and various studies on the BIPV system in the context of envelope technologies should be carried out with a focus on multi-functional complex systems by applying it to other facility systems to combine the advantages of both systems, not as a single application of the BIPV system.

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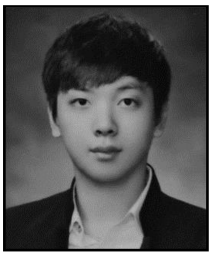
## Authors



**Kyungsoo Kim**
Graduate School of Techno Design Kookmin University, 77 Jeongneung-ro, Seongbuk-gu, Seoul, Korea
E-mail: k.kyungs216@gmail.com

**Ri Ryu**
Graduate School of Techno Design Kookmin University, 77 Jeongneung-ro, Seongbuk-gu, Seoul, Korea
E-mail: ri23414@hanmail.net

**Yongseong Kim (**Corresponding Author)
Graduate School of Techno Design Kookmin University, 77 Jeongneung-ro, Seongbuk-gu, Seoul, Korea
E-mail: yongkim@kookmin.ac.kr