THE FUTURE LOOKS PROMISING WITH BIPV

ABSTRACT:

The market size of Building Integrated Photovoltaic (BIPV) is projected to increase from USD 5.51 billion in 2023 to USD 10.98 billion by 2028, with a compound annual growth rate (CAGR) of 14.79% during the forecast period (2023-2028). BIPV is an effective way to utilize solar power, which is the most abundant, inexhaustible, and clean source of energy. In India, there is a growing trend of applying PV on buildings due to the country's solar mission target for 2022. The design of BIPV systems is gaining popularity among architects and design engineers, while green, zero-energy and sustainable buildings are becoming increasingly significant in India due to rapid urbanization. This paper provides an overview of BIPV and the associated technology, showcasing the various functions and aesthetics of BIPV systems. Additionally, the paper discusses the opportunities related to BIPV systems and presents the conclusion and future approaches associated with BIPV.

Keywords: Building Integrated Photovoltaic (BIPV), Solar Energy, Net Zero Energy Building (NZEB), BIPV Categories.

I. INTRODUCTION

BIPV, which stands for Building Integrated Photovoltaics, is a cutting-edge solar technology that enables buildings to produce their electricity rather than just relying on consumption (Hagemann, 2004). A BIPV product is a small photovoltaic component that cannot be divided electrically and mechanically and serves as a building component in a BIPV system. BIPV is a technique that optimizes a building's solar energy generation by integrating PV panels into its roof, windows, facades, and shading devices. By replacing parts of the building with BIPV modules, integrated photovoltaics can reduce construction costs, thus making the building more eco-friendly and economical. But if in the future BIPV product gets dismantled only a piece of competent equipment would reinstate it.

BIPV is gaining more attention as a result of numerous countries setting particular goals for the construction of NZEBs, and they can be employed as an alternative in both residential as well as commercial markets. Numerous aspects, including the temperature of the solar module, shade, installation angle, and orientation, must be considered for BIPV systems to fulfill multifaceted functions (Quesada, 2012). The irradiance and photovoltaic module temperature are crucial elements that impact the electrical efficiency of the BIPV system and the energy performance of buildings where these systems are installed. Below is the schematic diagram representing the working of BIPV (Fig. 1).

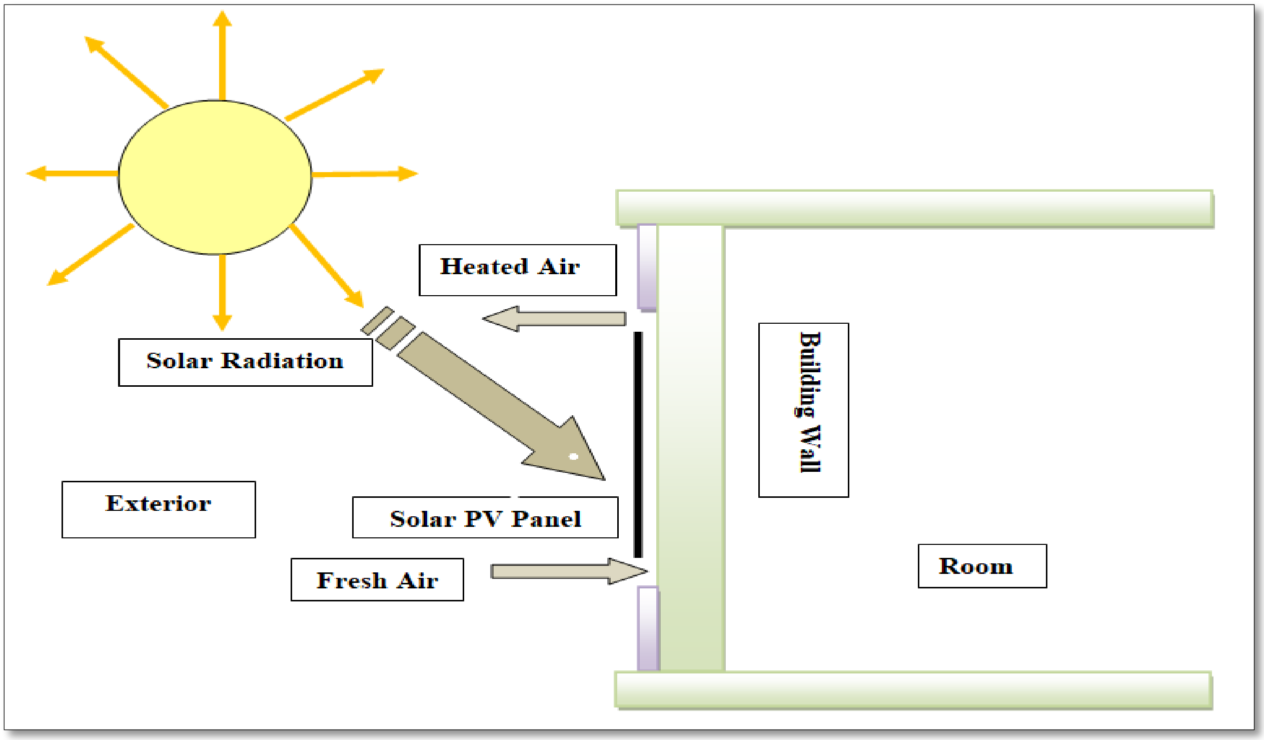


Fig.1 *Schematic diagram of BIPV (Adapted from Debbarma, et. al., 2017).*

II. REVIEW OF LITERATURE

Reddy, et al., 2020 states that BIPV is an instance demonstrating the idea of using PV to replace the conventional building envelope, such as the window, walls, and roofs, and is one of the comprehensive strategies that lessen the need for such enormous land expanses is the integration of PV inside buildings. The inclusion of PV into a building is one of the holistic approaches that reduce the necessity for such large land areas.

Debbarma, et al., 2017 suggest that BIPV is a technique that uses PV panels in place of conventional roof shingles or wall cladding. Compared to the typical "add-on" strategy, this method has numerous benefits. Firstly, It lessens the amount of penetrations required to attach the panel to the existing envelope and secondly, it reduces the number of penetrations necessary to attach the panel to the existing envelope These benefits result in improved efficiency and more long-term reliability.

Penga, et al., 2011 describe that BIPVs are solar-powered materials that have been utilized to replace traditional construction materials in building envelope components including roofs, skylights, and facades. BIPV modules may also be integrated into existing buildings, but they are increasingly being included in the development of new structures as a primary or secondary source of energy.

III. OBJECTIVES OF THE STUDY

1. To comprehend BIPV's basic principles.

2. To understand the numerous BIPV categories in India.

3. To unfold the various market opportunities associated with BIPV.

IV. RESEARCH METHODOLOGY

Research for this paper was based on secondary sources including articles published in the ABDC journal, reports published by Mordor Intelligence, government websites such as MNRE, and e-journals, as well as papers.

1. CATEGORIES OF BIPV SYSTEM AVAILABLE IN INDIA

There are three categories of BIPV systems available in India which are described below:

1.a. System Categories: As stated in the report (SUPSI, 2022) Classification of building skin systems is based on technology systems that are offered for building envelopes, and the categorization is based on the specialized construction units in each class. Various system categories are described below in Table 1, and their diagrammatic representation in Fig. 2.

Table 1: *BIPV System categories*

Categories	Description
1. Skylight	Architectural features that allow light to pass through and cover all or part of the roof are known as skylights. They are often designed with additional thermal, acoustic, and waterproofing properties to safeguard the interior environment while also being (semi)transparent to natural sunlight.
2. Dicontinous Roof	A sloping area of the opaque building's outer shell is known as the "discontinuous roof" which is composed of tiny components like tiles, slates, or shingles. Its main use is to drain water. Due to the benefits of ideal pitch orientation and simple installation, this area has witnessed early achievements with PV transmission.
3. Continous Roof	Continuous roofs have a large uninterrupted layer designed to be water-resistant and can be either flat or curved. As a water barrier, these roofs frequently utilize membranes. Lightweight and self-supporting systems are used in the second generation of PV applications, referred to as BIPV. These technologies include solar

	flooring, flexible membranes, and other options that enable PV to be incorporated as a multipurpose component of the building environment.
4. Curtain Wall	When discussing a building's exterior, a continuous fenestration system known as a curtain wall refers to panels that are supported by a foundation and have no structural elements on the exterior. These panels may be completely or partially coated.
5. RainSreen	This type of facade, also called a "cold" or ventilated facade, consists of a load-bearing foundation, an air gap, and cladding. During summer, the cavity is naturally ventilated to dissipate heat from the sun through top and bottom holes that allow for natural airflow. Installing a rain screen can further enhance rear ventilation
6. Double Skin Facade	It is composed of two layers, generally two glazing pieces, through which air flows. The distance between structures (which can range from 20 cm to a few meters) works as insulation against severe temperatures, winds, and noises, boosting the heating capacity of the structure for extremes of temperature.
7. Window	A window is a glass wall aperture that allows light and wind into the structure along with glimpses of the outside world. Windows, a very old innovation that most likely coincided with the creation of permanent and enclosed buildings, is also closely tied to building architecture, spaces architecture, temperatures, operations, techniques, execution, and beyond.
8. Masonry Wall	An exterior wall assembly made of bricks, stones, or concrete, called a "barrier wall" or "mass wall," depends on the tightness of the outermost surfaces and construction joints to prevent water penetration and moisture ingress. This can include precast concrete walls, EIFS, and other materials. In masonry construction, the thickness of the wall, its storage capacity, and the bond between the masonry units are also factors in preventing bulk rainwater infiltration.
9. External integrated device	Building shading devices may be classified into three kinds. The first form of solar shading device is multi-functional and photovoltaic, such as louvers or incorporated Venetian blinds that may be transparent or opaque. These devices are used for façades or balustrades and aid in "fall protection" for buildings. They are crucial for balconies, loggias, and parapets. The second category is roof shading devices, which can be transparent or opaque and are used to limit how much solar radiation enters the structure. Finally, integrated canopies, greenhouses, and verandas are kind.
10. Canopy	A canopy is an open roof or building with a covering connected to it. It provides weather and shadow protection. These canopies are supported by the building to which they are attached as well as a separate structure, such as a fabric-covered gazebo.

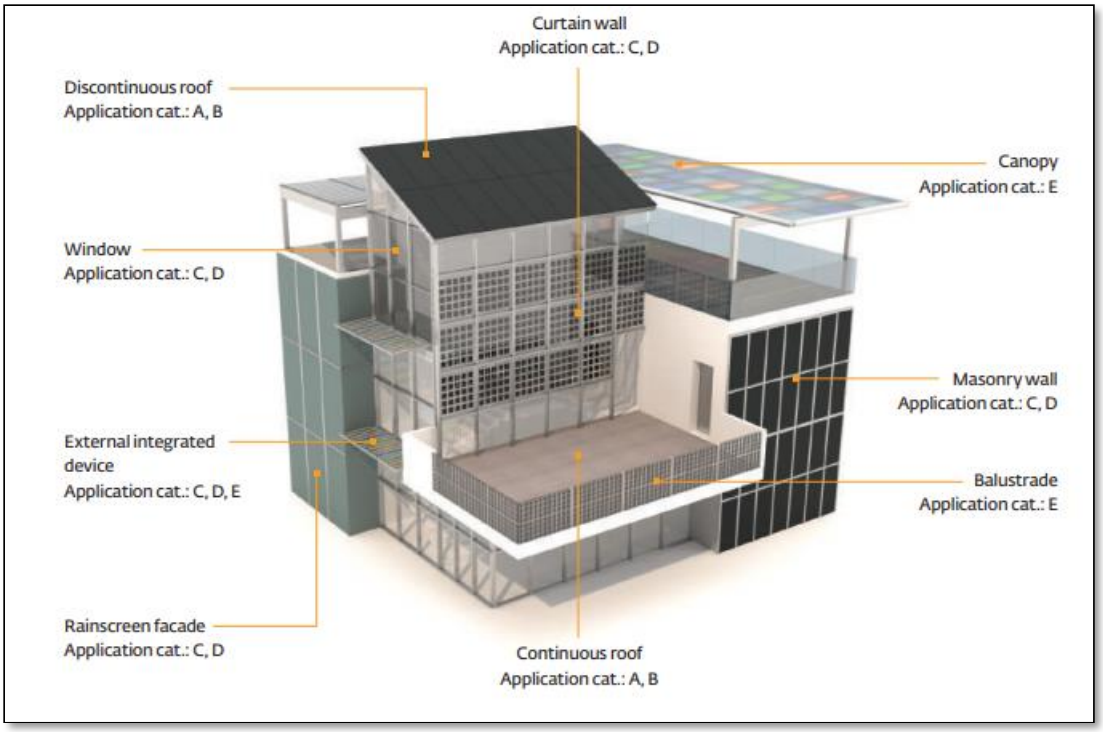
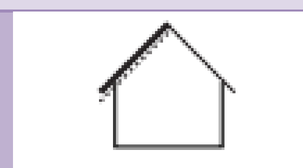
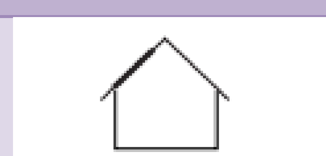
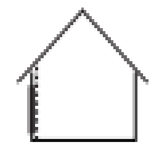
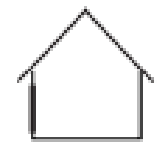
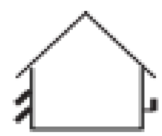


Fig.2. *System categories. Source: SUPSI.*

1.b. Application Categories: Applications were divided into five primary categories by Application Categories for BIPV. It is essential to many BIPV module types and is categorized following several factors, including the integration style, slope, and accessibility (Frontini, et al., 2022).

Table 2: *BIPV System categories*

Categories	Description	Digramatic Representaion
1. Category A	Roof-integrated, sloping, and inaccessible through the interior of the structure itself The BIPV modules are mounted at an angle ranging from 0° to 75° from the level of the horizontal [0°, 75°], with a separate product placed beneath.	
2. Category B	Slanted, roof-integrated, and easily accessed through the interior of the structure BIPV modules are mounted at various angles ranging from 0° to 75° from the level of the horizontal [0°, 75°].	

3. Category C	The envelope is non-sloping (vertically) and is not approachable through the interior of the structure. The BIPV modules are mounted at an angle ranging from 75° to 90° from the level horizontally [75°, 90°], with another construction product fitted behind them.	
4. Category D	The BIPV modules are mounted within the structure, integrated into the envelope, and accessible. They are mounted at a tilt inclination of 75° to 90° from the horizontal plane, without any slope in the vertical direction [75°, 90°].	
5. Category E	BIPV modules can be integrated into the structure of a building or added as an extra functional layer. They can be used for various purposes such as balconies, blinds, awnings, louvers, brise soleil, and more.	

1.c. Cladding Categories: The term "cladding" refers to the layering of the technical system's exterior components (such as façade cladding or roof tiling) and the corresponding technological needs (such as building covering, weatherproofing, safety, etc.) as shown in Table 3. BIPV claddings, specifically BIPV modules, may now be customized for practically any type of building envelope, creating a functional and very attractive solution. Color, size, form, thermal characteristics, material, and other customization options are included.

Table 3: *BIPV Cladding categories*

Categories	Description
1. Material	It denotes the primary material(s) in which the solar cells are incorporated to generate the final BIPV product. Glass is now the most often utilized substance as a component's back sheet and/or front sheet. Glazed applications are appropriate for both translucent and impermeable solutions. Polymer, metal, and cement-based materials are also used as supporting materials for BIPV systems. The qualities of the material determine the thermal, architectural, and technical characteristics of the structure's environment.
2. Transparency	Differentiating between semi-transparent and opaque solutions is important. Semi-transparent solutions like curtain walls, double skin facades, warm facades, skylights, canopies, and others are suitable for enhancing the building's user comfort and energy performance. Modifying the transparency performance of semi-transparent surfaces can

	also change factors such as daylighting, glare, and view out. On the other hand, opaque solutions prevent light from passing through the building envelope and are appropriate for rain-screen, prefabricated roofs/facades, railings, louvers, curtain walls, and flat or pitched roof solutions. Architects and designers can use the transparency value of BIPV modules to improve building performance.
3. Thermal Insulation	It is expressed as the thermal transmittance (U value) of the module. The materials that comprise the building shell provide thermal protection. The minimal value needed to meet the energy standard is determined by local legislation. The methods listed below provide the claddings with thermal insulation: • Insulated glazed unit: A glazed solution that is typically employed when thermal insulation within two spaces is needed (such as insulated glass unit, curtain walls, or skylights,); • Prefab solution: A composite solution in which the cladding is one single element composed of a front sheet, a photovoltaic layer, and a substrate. The front sheet might be glazed or not. Various functional materials, such as thermal/acoustic or fire protective layers, might be used to make up the substrate.
4. Colouring	There are now several vendors who offer colored options for solar panels, and the use of colored modules is becoming more and more popular. This technique allows for the complete integration of the original visual appearance of the PV cells while hiding them behind colored patterns. Some of the available coloring options on the market include products with patterned or colored interlayers, unique sun filters, colored anti-reflective coatings on solar cells (c-Si), and colored and/or semi-transparent PV-active layers (thin film, OPV). Other options include products with colored polymer films, coated, printed, specially finished, or colored front glass covers.
5. Size	Substantial amounts of modules are those that are more than 2.6 meters in any dimension or 2.1 meters in both dimensions. Shingle modules are those that are less than 0.9 meters in both dimensions. Regular modules are those that do not fall into the big or shingle categories.

2. MARKET OPPORTUNITIES

The integration of solar energy infrastructure into commercial buildings for energy-saving and architectural optimization has led to a rise in demand for BIPV materials. This demand is driven by increasing environmental concerns about the depletion of non-renewable energy sources like coal and oil, and a growing desire for green and emission-free structures. The construction and building sector's rapid modernization and increased focus on clean energy have also contributed to this surge in demand. Additionally, the market for BIPV components is being driven by increased grid-parity of photovoltaic systems, as well as financial incentives from local governments. Developed countries like North America and Europe are particularly affected by these factors. However, due to lower solar installation prices and the widespread availability of BIPV materials in these rising economies, like India, China, and Vietnam, product demand is substantial. As a result, this field is a promising area to focus on. The next section list includes some of the sector's opportunities:

There are four potential opportunities to look out for in India. Firstly, the building construction industry is expected to expand significantly, with an estimated increase of 45 billion square meters of floor space by 2060. This makes it an ideal area to explore building-integrated photovoltaic (BIPV) modules. Secondly, the Indian Government is aiming to electrify the transportation sector. By 2030, they hope to have 30% of private vehicles, 70% of commercial vehicles, and 80% of two- and three-wheelers running on electric power. Although this may only account for approximately 2% of the country's electricity demand, electric vehicle (EV) distribution and charging may contribute more to building energy than public distribution networks (Barbar, et al., 2021). Thirdly, the increase in construction energy consumption is an opportunity. It is predicted that with constant GDP growth, baseline cooling, and home EV charging, the demand for building energy is anticipated to increase ten times from that of 2020 by 2050. Additionally, when combined with prefabricated modular construction, BIPV installation might have a significant economic impact and implementation potential. Lastly, take into account BIPV as an innovative technology. A key selling feature of BIPV is that it is a versatile renewable energy technology that may take the place of traditional building components. However, in the context of India, the industry has not yet matured. BIPV technology may expand rapidly and have a disruptive impact on the building construction industry through product and construction standardization, improved economic awareness, and economic viability in the coming era (IEA, 2018).

V. CONCLUSION

The installation of photovoltaics into the building framework on a fundamental, architectural, and aesthetic dimension is known as BIPV. BIPVs can be incorporated into the façade and roof, and the industry offers various solutions for integrating them. There is an enormous potential for producing energy at the point of consumption, thanks to the open surfaces present on rooftops and façades. The amount of power produced by BIPV can range from 20 to 75 percent of a building's electrical needs, depending on the nation and the building's location (Saretta, et al., 2018). BIPVs can help reduce GHG emissions and emissions caused by energy transmission and distribution losses. The integration of BIPV systems into building envelopes paves the way for net zero energy buildings, whose potential to reduce energy use and the effects of global warming are increasingly recognized. In this study, we have examined the various types and functions of BIPV systems, as well as explored their market potential. Through our research, we have arrived at the following conclusions:

- BIPV modules are aesthetically pleasing and mix nicely with the architecture of the building.
- BIPV glass, which is available in a variety of hues, intensities, and levels of transparency, may be incorporated into the building's facades, skylights, canopies, railings, and other architectural features.
- BIPV guarantees thermal insulation as it warms up during energy conversion, preventing heat loss from the structure.
- The building walls are shaded by solar awnings, which have the effect of cooling the structure.
- Due to the mixture of the numerous layers, noise suppression up to a value of 25 dB is possible.
- BIPVs are pollution-free technology that is good for the environment.
- Building-integrated photovoltaic systems may be incorporated in several creative ways and are appropriate for a variety of building types and purposes.
- Increase the building's worth and status.
- Solar energy is used to lower a building's energy usage.
- Active noise canceling is provided by the BIPV module while replacing the wall.

VI. FUTURE APPROACH

As technology continues to advance, BIPV will likely become more commonly used in building applications. However, to optimize the performance of BIPV systems and accurately predict their energy behavior, further research is necessary to develop simulation programs. To ensure the widespread adoption of BIPV, it's important to establish industry standards, connect the PV and building industries, and provide guidance on ventilation techniques. Additionally, structural challenges must be addressed to make BIPV systems viable in a range of climates. Unlike rooftop solar and freestanding PV systems, the success of BIPV requires the integration of renewable energy policies with broader building energy and construction regulations. To promote the growth of the industrial sector and enhance the multifunctional capabilities of BIPV goods, the Indian government needs to focus on developing corporate strategies and policies. Specifically, they are required to lower the price of BIPV products and improve supply chain management for distributors and consumer technological preparedness. To ensure stakeholder involvement in BIPV programs, there is a high demand for awareness programs, which require thorough preparation and implementation. Additionally, collaboration with foreign groups is crucial to establishing a BIPV culture in India, a developing nation.

VII. ANNEXURE

BIPV	**Building Integrated PhotoVolatics**
NZEB	Net Zero Emission Building
GHG	Green House Gases
EV	Electric Vehicle

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