SUSTAINABLE DEVELOPMENT OF BUILDING INTEGRATED PHOTOVOLTAIC FACADE TECHNOLOGY

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Abstract:

A sustainable technology that provides the opportunity for generating electricity and replacing conventional construction materials is building integrated photovoltaic (BIPVs). Building construction and usage consume one third of the primary electricity in India. BIPV systems generate electricity by converting solar energy into useable power to supply building electrical loads. As a leading renewable technology, it is poised for widespread use by design teams in the non-residential construction industry across India. With an abundance of accessible solar energy, India is a prime location for photovoltaic technology and BIPV applications. However, photovoltaic technology has the potential to take a much larger role in supplementing or replacing nonrenewable generation sources for electricity in the future. Building construction and usage consume one third of the primary electricity in India. This paper describes about BIPV's multiple functions that improvise the building performance and reduce the energy consumption of building, development of BIPV systems and design strategies of it. Also, this paper depicts the BIPV current market trend and its futuristic forecast in coming years.

Keywords: Building Integrated Photovoltaic(BIPV), Facade technology, Building energy performance, Sustainable development, Renewable energy, Building envelope.

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I. Introduction

Buildings account for 20 to 30 percent of the total primary energy consumption in India. Past decades have seen alarming fluctuations in energy prices, reliability issues, and increasing awareness regarding buildings' intensive energy consumption and environmental impact. The building industry is recognizing the increasing importance of energy efficiency. Building-integrated photovoltaic **(**BIPV**)** is integrating of photovoltaic modules into the building envelope such as roofs or windows. These solid-state devices are used to replace conventional building materials to generate electricity out of sunlight with no maintenance and help in fighting global warming as the produce no pollution. Electrical and space-conditioning inefficiencies squander energy. Designers are attempting to minimize energy consumption by specifying increased thermal insulation, higher-efficiency lighting, high-performance glazing and HVAC equipment, air-to-air heat exchangers, and heat-recovery ventilation systems. After minimizing the overall building load, using renewable energy to meet the remaining loads is the preferred sustainable approach. A leading technology in the field of renewable energy is photovoltaic (PV) systems. Among commercially available PV technologies, BIPV systems are capturing a growing portion of the renewable energy market. BIPV modules are building elements providing multiple functionality to the building envelope beside electricity generation such as Weather proofing, Aesthetical integration, Shadowing/sun protection, Thermal insulation, Noise protection, Safety.

The fundamental first step in any BIPV application is to maximize energy efficiency within the building's energy demand or load. This way, the entire energy system can be optimized. Holistically designed BIPV systems will reduce a building's energy demand from the electric utility grid while generating electricity on site and performing as the weathering skin of the building. Curtain wall systems can provide R-value to diminish undesired thermal transference. facade shelves can be designed to increase day lighting opportunities in interior spaces. This integrated approach, which brings together energy conservation, energy efficiency, building envelope design, and PV technology and placement, maximizes energy savings and makes the most of opportunities to use BIPV systems. The advantage of BIPV over normal standard PV panels is that they integrate into the buildings. Also they help in saving the amount of money spent on building materials and labour that would normally be used to construct the part of the building . These advantages make BIPV one of the fastest growing segments of the photovoltaic industry with some people estimating that the use of BIPV will increase at more than 50% annually over the next few years. BIPV can perform multiple additional functions as a building material as shown in figure 1.

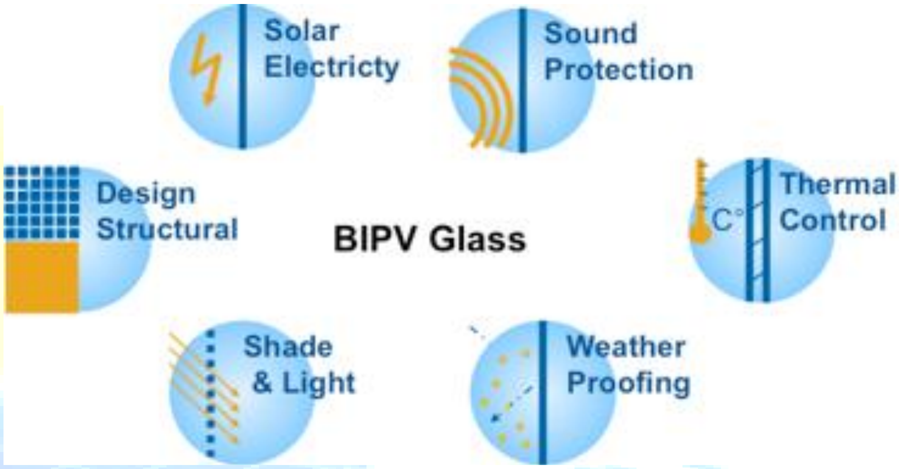

Figure. 1 Multiple functions of BIPV facade system

II. Building Integrated Photovoltaic System

Photovoltaic applications for buildings began appearing in the United States and elsewhere in the 1970s. Aluminum-framed PV modules were connected to, or mounted on, buildings that were usually in remote areas without access to an electric power grid. In the 1980s, PV module add-ons to roofs began being demonstrated. These PV systems were usually installed on utility-grid connected buildings in areas with centralized power stations. In the 1990s, BIPV construction products specially designed to be integrated into a building envelope became commercially available. Internationally, the past decade has steer in a many of BIPV demonstration buildings and other structures. In both new projects and renovations, BIPV is proving to be an effective building energy technology in residential, commercial, industrial, and institutional buildings and structures. BIPV systems are considered to be multifunctional building materials, and they are therefore usually designed to serve more than one function. For example, a BIPV skylight is an integral component of the building envelope, a solar energy system that generates electricity for the building, and day lighting element.

The standard element of a BIPV system is the PV module. Individual solar cells are interconnected, encapsulated, laminated on glass, and framed to form a module. Modules are strung together in an electrical series with cables and wires to form a PV array. Direct or diffuse light (usually sunlight) shining on the solar cells induces the photovoltaic effect, generating unregulated DC electric power. This DC power can be used, stored in a battery system, or fed into an inverter that transforms and synchronizes the power into AC electricity. The electricity can be used in the building or exported to a utility company through a grid interconnection.. The basic building block of BIPV technology is a PV module. Solar cells are assembled to form a module, and modules are wired together to form a site-specific array. Since PV systems produce direct current, they are usually connected to batteries and/or inverters. Additional components and wiring are referred to as "balance-of-system" components. BIPV systems are made up of BIPV construction materials and balance-of-system (BOS) hardware. The BOS hardware is composed of cabling, wiring, and structural elements that hold the modules in place, as well as grid-metered connections, fault protectors, a power conditioning unit (inverter), and an electricity storage system (usually batteries), as needed. Two basic types of BIPV systems which can be integrated into the building components, that is "stand-alone," which requires batteries for storage as shown in figure 2, and "grid-connected," which uses the electric grid as the storage component as shown in figure 3. Although the collection process can be similar in these two setups, the nature of the BOS is significantly different. In the first case, batteries serve as the only buffer for any delay between electricity generated and the building's electric load. A standalone system has as much backup electricity as the batteries can store. It can deliver electricity only when the sun is shining or there is a charge remaining in the batteries. Such systems frequently have backup generators. In the case of a grid connected system, the utility grid works as the backup and serves as an infinite buffer and storage component.

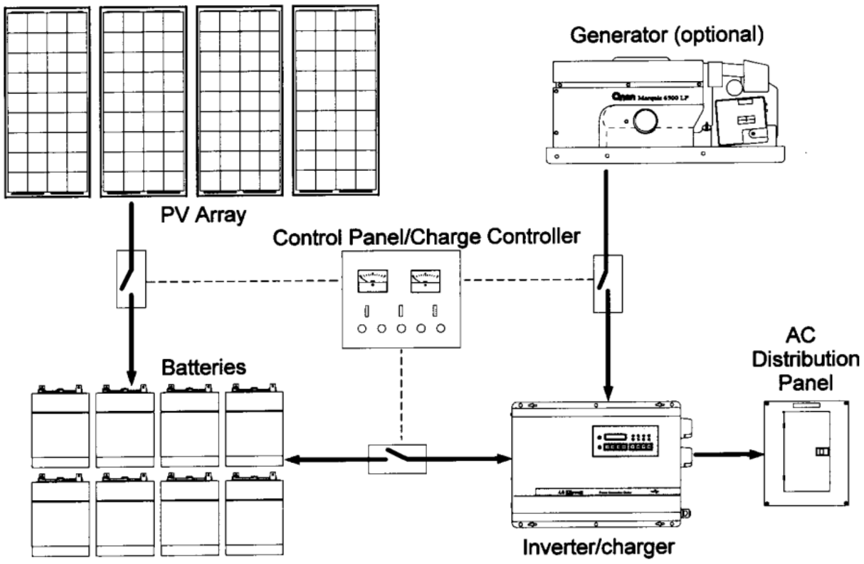

Figure. 2 Schematic of a typical stand-alone PV system

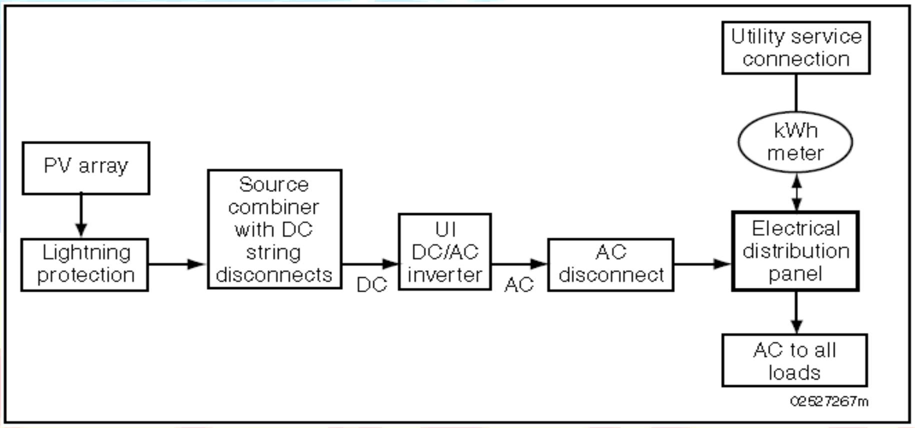

Figure. 3 Block diagram of a utility-interactive PV system

The economics and aesthetics of BIPV systems are optimized when PV is integrated into the building during preliminary design stages. In order to be effective, BIPV products should match the dimensions, structural properties, qualities, and life expectancy of the materials they displace. Like standard construction glass, cladding, and curtain wall materials, they can then easily be integrated into the building envelope.

III. Integration Strategies of BIPV System

In general, the performance of a BIPV system is optimized when it is integrated into a building during the initial stages of design. However, decisions regarding where and how to best integrate BIPVs into building designs are greatly influenced by the potential amount of electricity generated from a specific application and its cost effectiveness. For example, horizontal applications like roof BIPVs which serves as building envelope and vertical applications like curtain walls have different material/installation costs and electrical output curves due to each one's position relative to the sun. Optimum BIPV integration utilizes the specific characteristics of a project, such as building layout (i.e., low-rise or high-rise), sitting (i.e., topography, views, and orientation), and surroundings (i.e., landscape, height limits, and adjacent shading elements) to evaluate and select the best integration strategy for BIPV applications. As a result, different BIPV applications can have markedly different efficiencies. Façade applications typically include vertical curtain wall, inclined curtain wall, and stepped (recessed) curtain wall; roof applications normally include inclined roofs and skylight monitors. Different strategies for PV building integration are briefed below.

A. Inclined Roof/Atrium Space

An inclined roof is one of the most efficient BIPV collection strategies (as shown in fig. 4.1 below). Tilt angle and orientation may differ depending on desired seasonal performance. As a roof element, the PV system is part of the building skin and requires attention to weatherproofing, structural, and snow accumulation issues.

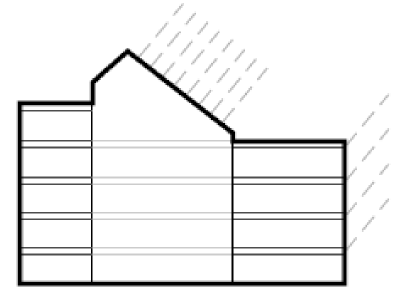

Figure 4.1 Inclined Roof/Atrium Space

B. PV Skylights (shed roof system)

PV skylights combine day lighting benefits with good overall PV efficiency. PV skylights can also be easily used in existing building renovations. Figure 4.2 below depicts PV skylights(shed roof system)

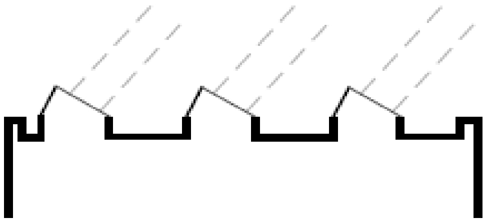

Figure. 4.2 PV Skylights (shed roof system)

C. Inclined PV/Stepped Curtain Wall

A PV system on an inclined wall is an efficient collection strategy for building envelope curtain wall (as shown in fig. 4.3 below). It is a less efficient use of the building footprint and requires a more complex curtain-wall construction.

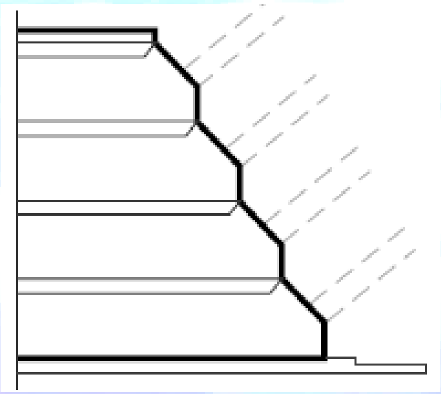

Figure. 4.3 Inclined PV/Stepped Curtain Wall

D. Vertical Curtain Wall (with windows)

Relatively complex detailing may be required to successfully integrate PV panels into a curtain wall (to minimize sealing problems and avoid overshadowing). In general, vertical curtain wall applications with an opaque PV, semitransparent PV, or clear glazing can be used as a fairly economical and standard construction strategy as shown in fig 4.4 below.

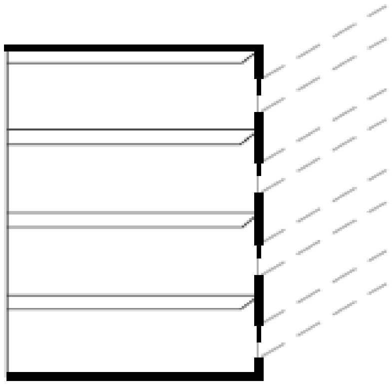

Figure. 4.4 Vertical Curtain Wall (with windows)

E. Sawtooth Vertical Curtain Wall

A sawtooth vertical curtain wall as shown fig 4.5 can work efficiently for certain orientations. It provides passive self-shading/day lighting control and multiple "corner" windows.

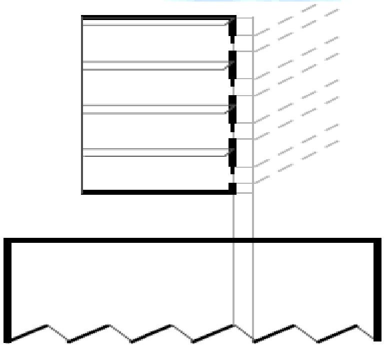

Figure. 4.5 Sawtooth Vertical Curtain Wall

IV. Design Strategies of BIPV System

Beyond comfort and aesthetics, BIPV design considerations encompasses both environmental and structural factors. Environmental factors include a structure's solar access as well as average seasonal outdoor temperatures at the site, local weather conditions, shading and shadowing from nearby structures and trees, and the site's latitude, which influences the optimum BIPV system orientation and tilt. Structural factors include a building's energy requirements, which influences the size of the system, and the BIPV system's operation and maintenance requirements. These factors must all be taken into account during the design stages, when the goal is to achieve the highest possible value for the BIPV system. Some of the major design considerations unique to solar energy systems are solar access, system orientation and tilt, electrical characteristics, and system sizing. Designing a BIPV system requires skill and in-depth knowledge of the building profession. To best integrate BIPV design strategies into current building practices by minimizing electric loads, optimizing system configuration and electricity generation, maximizing efficiency of energy storage, meeting aesthetic criteria. Design strategies for BIPV capitalize on the multifunctional nature of building components that also generate electricity. When integrating BIPV into a building, design teams should consider using an integrated design approach to successfully address issues surrounding aesthetic and construction requirements, and electricity demand and generation. The major considerations when integrating BIPV into a building are discussed below.

A. Minimize Electric Loads

The first consideration in BIPV applications is to maximize efficiency in the building's energy demand or load. Designers should minimize the electricity load by utilizing integrated energy design strategies such as building envelope improvements, day lighting techniques, and natural ventilation applications. Additionally, installing energy-efficient lighting and cooling equipment throughout a building minimizes energy loads. In BIPV applications, the goal is to minimize the building's energy needs and then supplement the remaining loads supplied by the local utility grid with PV-generated electricity. By minimizing the electricity needs and utilizing BIPV, the designer maximizes the potential energy cost savings.

B. Optimize the Generation of Electricity

BIPV system should be designed to optimize electrical output. It is important to note that the availability of solar radiation generally matches commercial building electric loads throughout the day and throughout the year. For example, typical energy use for office buildings peaks near midday and during the summer season, the time when there is the greatest solar potential For maximum energy output, it is important to determine the orientation, tilt angle, size and location of the BIPV system in relation to the building site and design. Flexibility exists in the placement (tilt and orientation) of BIPV, so it is best to match the time of day, month, and season when peak solar generation occurs with the peak electrical needs of the building.

1. Tilt: Maximum solar intensity occurs on a flat surface perpendicular to the sun's rays. Inclining the panels toward the sun increases the amount of sunlight striking the surface and will increase the output. The sun's path sweeps a daily arc that changes seasonally throughout the year. In this way, the sun follows a prescribed solar position described by an altitude angle (vertical) and azimuth angle (horizontal). By orienting the BIPV panels to be perpendicular to the sun at certain times of day and year, it is possible to optimize solar exposure to match loads. Studies have shown that, because of the relationship between tilt and output, the tilt of the installation directly affects the economics associated with energy savings.

2. Orientation: The total amount of energy that strikes a surface is a function of both tilt and orientation. On east- and west-facing façades, BIPV systems are less efficient than systems oriented south. Nevertheless, vertically mounted BIPVs with east/west orientation can yield up to 60 percent of the optimally inclined southern orientation. For these east/west orientations, low sun angles at the beginning and end of the day account for the majority of the power generated. In general, largely horizontal southern or vertical western installations are best to supply typical commercial daytime applications.

3.Sizing: Even with supplemental on-site PV generation, commercial buildings generally remain net importers of electricity because of their significant energy requirements. Design constraints (space availability, efficiency of placement, building envelope requirements, and costs) typically determine the capacity of BIPV systems rather than electric load requirements. For this reason, commercial BIPV systems are often designed to serve a dedicated (frequently DC) load, such as landscape lighting or irrigation control, to more directly link output to demand. Seasonal climatic conditions (temperature and solar radiation) and available surface areas also affect the sizing of BIPV systems.

4.Location: BIPV's should be placed where they have secured long-term solar access. It is critical not to locate BIPV panels where neighboring landscapes or structures that may shadow the system are present or anticipated in the future. Full or partial shading of the panels inhibits the production of electricity. The system performs best if there is homogeneous solar access because the solar cell with the lowest illumination level determines the operating current for all of the cells wired in that series.

C. Maximize Efficiency of Energy Storage

Since BIPVs only generate electricity while the sun is shining, proper energy storage is critical. In most commercial applications, integration with the electric grid is advisable. Hybrid systems, which are battery plus grid-connected configurations, provide the added benefit of protection from power interruptions. Additionally, battery-stored energy may provide peak shaving opportunities by offsetting grid-power needs during periods of high-energy costs. The following considerations are important when sizing a battery for proper PV energy storage.

- Assess the anticipated time period when the system is expected to provide power without receiving an input charge from the solar array.
- Multiply the time period by the daily power requirement (amp-hours).
- Add a safety factor to the battery sizing equation for the depth of discharge. This is a safety factor to avoid over draining of the battery bank.
- In certain climates, a multiplier may be necessary to account for reduced performance due to extreme ambient temperature conditions.

D. Meet Aesthetic Goals

BIPV products on the market today make visual statements by adding patterns, textures, colors, and visual ill repute to the roof or façade of a building. Whether it is the shiny exterior of a BIPV curtain wall or the inscribed patterns of semitransparent BIPV glazing products, architects may design visually distinctive applications. buildings that employ new and emerging technologies like BIPV tend to have a higher profile than standard designs and may be distinguished as "green." Several prominent architectural firms have used BIPV designs to achieve a dual image of being aesthetically appealing and environmentally responsive. Consequently, BIPV integrated designs have brought added value and recognition to both designers and owners of numerous public and private buildings To maximize the aesthetic benefit, BIPVs should be fully integrated into the design, rather than appliquéd. By using a "whole building" approach, it is possible for the BIPV elements to complement rather than compete with other attributes of the building. For designers that wish to create an aesthetically appealing building with distinctive "architectural features," BIPV may be an appropriate and welcome addition to any architectural program.

V. Emerging BIPV Benefits and Futuristic Scenarios

BIPV systems are being designed to blend with traditional building materials and traditional design for a high-technology, future-oriented appearance. Emerging benefits include Semi-transparent arrays of spaced crystalline cells that can provide diffused, natural lighting. Multifunctional BIPV components prevent fires, act as UV filters, and provide heat and sound insulation. Self-cleaning systems are being implemented. Solutions have been sought out for BIPV elements to help reduce the cooling load and glare associated with large expanses of architectural glazing. BIPV may also be important in obtaining LEED [Leadership in Energy and Environmental Design] certification. Figure 5 below shows the various savings associated with using distributed generation such as BIPV systems to supplement grid electricity include the demand charge reduction, free real estate for electric generation, potential for a more diverse and resilient energy system, possibility of increased reliability, elimination of costs and losses in transmission and distribution. BIPV-generated electricity may render significant cost savings for building owners by displacing retail-level utility costs. In many cases, additional cost savings may be achieved by using PV generated electricity as part of demand reduction strategies during high-priced utility periods.

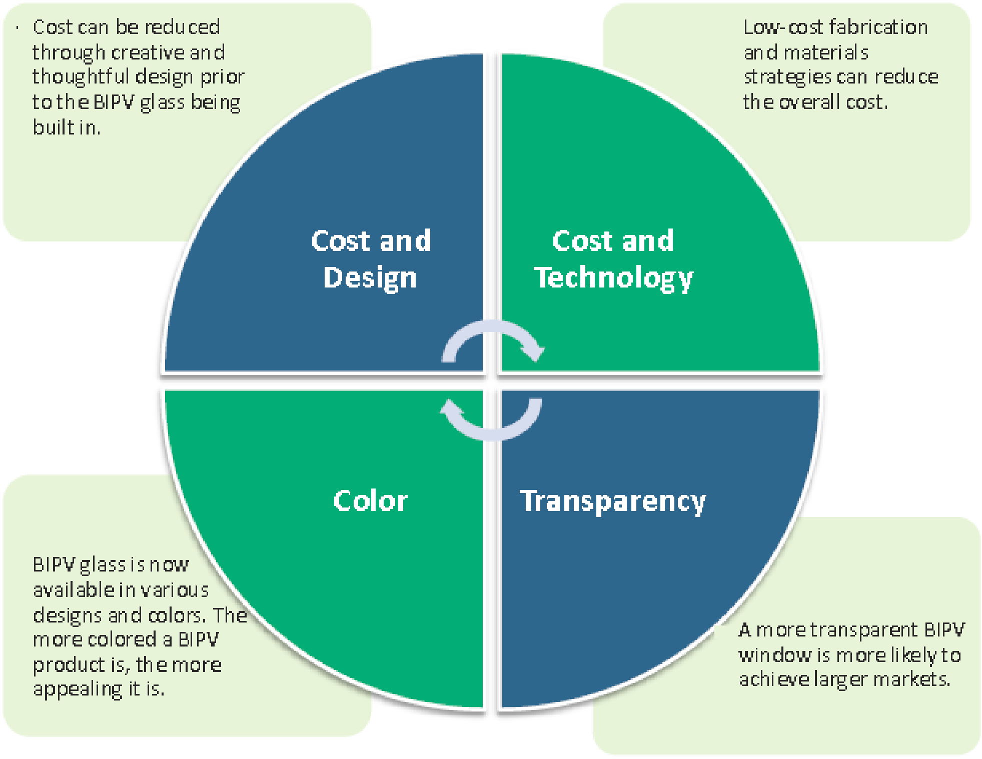

Figure. 5 Emerging developments in BIPV glass system

The economic consideration that have been achieved by BIPV in the recent years, it can be estimated that the cost reductions will be reached within only a few years, indicating that BIPV will rapidly become interesting and competitive. PV, well integrated into the architectural design of the building, can enhance the aesthetics of the building and give the property owner a ’green’ and self-sufficient image. Owners of commercial buildings are increasingly more interested in installing PV systems as a high-value feature of their property. Projects are being realized with limited or no government support at all, indicating that cost reductions of a mere 25% to 50% are sufficient for opening up the market. Up scaling of the near-term BIPV market will, moreover, be possible only if non-technical barriers that impede the application of BIPV are addressed and dealt with successfully.

VI. Conclusion

Understanding the basics of BIPV design strategies and architectural applications, the principles of BIPV systems and integration, and the various economic and non-economic benefit factors implies critical success of a BIPV project. With its multifunctional nature, BIPV technology adds a new dimension to the design and construction fields. In addition to replacing traditional building envelope materials, BIPV products provide a natural source for supplementing grid-generated electricity. When a building is designed with a BIPV system, The team should first design the building to be energy efficient. By reducing electric loads through design strategies and energy efficiency equipment, the supplemental electricity generated from BIPVs is able to displace a larger percentage of the grid-energy load. Another consideration for designers is to optimize the BIPV system configuration and electricity generation. Designers should work to closely match the BIPV peak output to the building's peak energy demand. It is also important to properly design a storage system (grid-tied, hybrid, or stand-alone) and the balance of system components to fully maximize the BIPV application. The application becomes a contributing component to the operation of the facility over the building's life. By taking energy from the sun and turning it into useable electricity for a building, BIPVs are a reliable and environmentally responsive source of renewable energy. BIPV offers the real opportunity to make micro renewable energy generation cost competitive with conventional fossil fuels. By substituting conventional building envelope construction materials for solar PV modules, the additional installed cost of the PV energy generation element is only marginal within the total build and in some cases cheaper on a square meter basis. Though high initial costs and design constraints have impeded the economic progress of BIPV applications, the economic and environmental attractiveness of Building Integrated Photovoltaic's continues to grow. Therefore, this formulate BIPV system to succeed well and achieve higher growth. New technologies and cost reduction strategies would help BIPV products to penetrate end-user segments aggressively in the future.

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