A Review of Building Integrated Photovoltaic system and its scope of application in developing countries like India.

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Abstract: Facade Engineering is the art of resolving aesthetic, environmental and structural issues to achieve the enclosure of habitable space. Today lightness and transparency are properties that both architects and clients try to obtain. This has rapidly increased the use of glass in facades. Renewable energy sources like solar energy, wind energy, tidal energy etc. are the alternatives of the non-renewable sources. India is blessed with abundant sunshine & solar energy is getting the importance it deserves in recent times. High-rise buildings in urban areas which are major consumers of energy need to be utilised as sites for Solar PV. Though roof-top Solar PV has been getting due attention, facades of high-rise buildings also offer a great opportunity for Solar PV. This review paper aims to review the potential for savings & reduction in GHG emissions using Solar PV Facades in high-rise buildings. Saving in land resource is also an advantage in using Solar PV for Facades. As electrical output of Solar PV Facade can be consumed in the high-rise building itself, it is a form of distributed generation with captive consumption avoiding transmission infrastructure & losses.

Index Terms **- Solar energy, BIPV, Photovoltaic,**

1.INTRODUCTION

The use of glass in the exterior facades provided more of light and good ambience to the occupant of the building which gave rise to the increasing use of glass. For the architectural point of view the use of glass gave aesthetic view to the building itself. The non-renewable sources or fossil fuels will be the history as the consumption of the energy is increasing day by day by humans. As the electricity demand is increased and more fossil fuels burnt to fulfil the demand, the air pollution is also increased. That's why we are looking for renewable energy sources like solar energy, wind energy, ocean tides etc. to generate electricity by which we can reduce not only air pollution but also we can save our environment too, and hoped to fulfil the energy demand by these sources. Distributed generation is a key aspect of Solar PV in India. Green building norms under TERI – GRIHA and IGBC-LEED certification process require energy efficiency of about 14% for the Building Envelope & 10% of the total building energy be drawn from solar power [1].

- Building Integrated Photovoltaic (BIPV) System

A Solar Tile is a PV module that could be combined with roof tiles for additional function of energy production and a sensitive result. Similarly Solar Shingles and Solar Slates are PV modules that could be combined with roof shingles and roof slates for additional function of energy generation and a sensitive result. Materials such as ceramics, metal, stone or sometimes glass is used in the manufacturing of a Tile. Fibre glass or asphalt is used in Shingles manufacturing, which are roof covering materials. Slate a fine grained, foliated and homogeneous rock which is used for roofing.

Building integrated photovoltaic (BIPV) are not only used to generate electricity but also used as integrated materials of the buildings. In the market there are very large categories and BIPV is a prominent product among them. It is a multifunctional technology product used for generation of electricity and also designed for weather protection, shading, curtain walls, glazing, skylights etc. Solar PV Façade is aesthetically pleasing, generates electricity & helps in better energy performance of the building. Transparency in Solar PV Façade can be obtained by spacing between solar cells or see through thin film solar cells. Light effects can also create nice patterns on the same. An example of Solar PV Façade is the City Hall in Freiburg (Germany).

Figure 1. Examples of BIPV tiles

With a surface of approximately 13.000 m², the overall PV output of 220 kWp is generated by a total of 880 solar modules, using special seamless double-glass modules with the dimensions of 3.5 m height on 60 cm width, weighing 100 kg each [2]. The City Hall completely matches with the principal standards of a zero-energy building.

Figure 2. City Hall in Freiburg (Germany)

2. STATE-OF-THE-ART OF BIPV.

2.1. BIPV Categorization.

The range of BIPV products is very wide, and they may be categorized in different ways.
Within this work, the categorization is mainly performed based on the product descriptions from the manufacturers and what other material types the products are customized to be combined with. In this work, the BIPV products or systems have been categorized into the following groups:

1. BIPV foil products.
2. BIPV tile products.
3. BIPV module products.

- **Solar cell glazing products.**

In addition, related to the different BIPV products, the group building attached photovoltaic (BAPV) products should also be mentioned:

- **BAPV products.**

Building attached (applied/added) photovoltaic (BAPV) are regarded as add-ons to the buildings, hence not directly related to the building structures' functional aspects That is, BAPV are not BIPV, i.e., BAPV are not integrated into the outer building envelope skin, thus not replacing the traditional building parts as BIPV are doing. Some BIPV products exhibit a variety of properties, thereby making it more difficult to categorize them. Yet, in other cases, it might even be rather difficult to determine whether a PV product should be considered as a BIPV product or not, e.g., due to lack of information and uncertainty about how the product is mounted.

2.2. BIPV Foil Products.

BIPV foil products are lightweight and flexible, which is beneficial with respect to easy installation and prevailing weight constraints for roofs. The PV cells are often made from thin film cells to maintain the flexibility in the foil and the efficiency regarding high temperatures for use on non-ventilated roof solutions. Unfortunately, currently, there are few manufacturers on the market that provide weather tight solutions. Table 1 and Figure 3 present an example of one BIPV foil product. PV foil products

have a low fill factor due to both the low efficiency and the large solar cell. Electrical resistances of thin film cells. However due to their flexibility and relatively low weight, these solar cell foil products may easily be applied to a lot of different building surfaces.

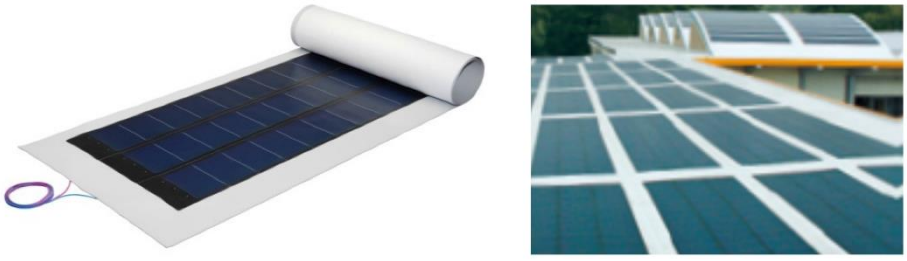

Figure 3. BIPV Foils. (Source: www.mdpi.com)

2.3. BIPV Tile Products.

BIPV tile products may cover the entire roof or selected parts of the roof. They are normally arranged in modules with the appearance and properties of standard roof tiles and substitute a certain number of traditional roof tiles, thus also enabling easy retrofitting of roofs [3]. The cell type and tile shape varies. Some tile products may resemble curved ceramic tiles and will not be as area effective due to the curved surface area, but may be more aesthetically pleasing.

Figure 4. BIPV Tiles. (Source: http://lumensolar.wordpress.com)

2.4. BIPV Module Products

The BIPV module products presented are somewhat similar to conventional PV modules. The difference, however, is that the BIPV modules are made with weather skin solutions. Some of the products may replace various types of roofing, or they fit with a specific roof solution produced by its manufacturer. These mounting systems increase the ease of installation.

2.5. Solar Cell Glazing Products

BIPV as solar cell glazing products provide a great variety of options for windows, glassed or tiled facades and roofs. Different colours and transparencies can make many different aesthetically pleasing results possible. The solar cell glazing modules transmit daylight and serve as water and sun protection. The distance between the solar cells depends on wanted transparency level and the criteria for electricity production, but normally the distance is between 3 and 50 mm [4]. The space between the cells transmits diffuse daylight. Hence, shading, heating and natural lighting are provided while producing electricity. Human comfort aspects related to solar cell glazing products are also important and being investigated. The solar cell glazing manufacturers usually offer customized products for specific projects, regarding shape, cell material, and colour and transparency level.

Figure 5. BIPV Cladding (Source: www.terrabeati.com)

4. ECONOMICAL ASPECTS OF BIPV.

The global market for BIPV is expected to grow from \$1.8 x 10^9 in 2009, to \$8.7 x 10^9 in 2016, according to consulting firm Nano Markets, New York. In addition, Nano Markets say that copper indium gallium selenide (CIGS) solar cells will account for 17% of the BIPV market by volume in 2016 and polysilicon-based BIPV volume will drop from 75% of the market to 33% by 2016 [7]. As PV panels occupy a large area for installation, the associated financial challenge could be best answered by space-saving technologies like BIPV .When compared to glass, steel or other more conventional cladding materials, installing BIPV adds only a marginal extra cost (2%–5%) to the overall construction costs of a commercial building [5]. The BIPV technology is a growing technology and is still rather expensive. Furthermore, one may note that the building sector is rather price-sensitive. In addition, as BIPV is still far from being a mature technology, uncertainty about BIPV and their implementation is another crucial aspect to be considered. This uncertainty includes many factors, e.g., installation, electrical aspects, safety issues, integration aspects, building physical aspects, protection versus climate exposure, durability, maintenance, demolition, life cycle assessment, possible to sell surplus electricity to the grid or not architectural aspects and others. Naturally, all these factors may also lead to increased costs. A better solution would be to distribute the electricity locally and then buy from/sell to the grid whenever needed, even though this might result in a more difficult technical solution for the electricity companies [6]. For a building owner, the installation and operation cost of the BIPV system might be offset by selling the surplus electricity to a utility company .Over time, the cost of a PV system will decline with the improvement of technical advances, resulting into a lower price per kW installed.

5. ADVANTAGES AND LIMITATIONS

Advantages:

BIPV is the future of the building designs and architecture must follow the BIPV to build green and environment friendly buildings. After that the value of the buildings will be increased and the image of the buildings will be changed.

Some advantages of BIPV are as follows:

- BIPV system can be used as ventilation system after integrated PV modules into the buildings by which they can create an ambient temperature in the building. For example public buildings like schools, office complexes, shopping malls and the private buildings like gardens and terraces of the houses.
- BIPV as skylights at entrance, atria and courtyards can be economical for using solar energy.
- BIPV systems are small and environmental friendly and it can install anywhere in the world unlike other conventional energy systems.
- BIPV system could be applied after building structure or during construction of the building. No moving parts are used in the system so no noise pollution.

Limitations:

Partial shading on the BIPV system can reduce the generation of power. BIPV system is normally installed either on pitched roof or facades of a building. Limited airspace for cooling affects the power output of the BIPV system.

6. CHALLENGES FOR LARGE SCALE APPLICATION IN INDIA.

The challenges for Solar PV Facades in India can be listed as follows –

- As Solar PV Façade may hinder ventilation, heating up of the interiors may happen.
- There is absence of integrated codes, standard and regulations in regard to Solar PV Facade systems.
- The customer and all the construction value chain members have to be convinced on the importance of Solar PV Facades for the particular project from the project inception stage till the construction is over.
- Trained personnel are needed for execution of Solar PV Facade.
- Cleaning of Solar PV Façade has to be regular as dirt may reduce the output.

7. CONCLUSION.

State-of-the-art building integrated photovoltaic (BIPV) products existing on the market today offer a wide range of integration of photovoltaic (PV) systems into buildings. New and innovative solutions may reduce costs and increase the market share. Furthermore, there is also a need for development of new standards and methods, e.g., regarding long-term durability versus climate exposure. BIPV can be installed any of the building to make that one energy efficient or green building like Hotels, Colleges, Schools, Universities, Embassy, Building Apartments, Offices and Shopping Malls etc. Architectural and sustainable strategy must go hand in hand in the design of the façades of buildings, and both passive and active design thinking should inform this process. In addition to facilitating views and the appearance of the building, each façade (and each part of that façade) can contribute to daylight, solar control, energy generation, insulation and/or thermal buffering according to its exposure to sunlight.

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