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CURRENTSCENARIO OF BUILDING INTEGRATED PHOTOVOLTAICS

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ABSTRACT

The Building-incorporated photovoltaics (BIPVs) are photovoltaic materials that are used to supplant traditional/conventional building materials used in parts of the building envelope, for example, the rooftop, bay windows, or veneers. They may represent a powerful, versatile and eco-friendly tool for achieving the goal of ever increasing power demand for zero energy and zero emission buildings of the proximate future. In this respect, BIPVs offer an aesthetical, cost-effective and practical solution, to integrate solar cells reaping solar radiation in order to produce electricity inside the climate coverings of the buildings. This work summarizes the most recent stage in the development of the BIPVs, incorporating the newest ideas and features of BIPVs, including the BIPV tiles, foils, modules and solar cell glazing products.

INTRODUCTION

As it is a well-known fact that the world's energy demand is increasing at a rapid rate, hence, a stage has arrived where focus should be on renewable & non-polluting energy, combined with high energy efficiency. Further, Buildings are to be designed with the concept of zero energy and zero emission. In order to make a building complied to the concept of zero energy and zero emission building, it is needed to crop its energy requirements from its surroundings itself, where energy from the sun is one of the available options. BIPV systems are the systems where solar cells are embedded within the climate envelopes of buildings and these solar cells exploit solar radiation to produce electricity at justified operational cost, and represent a more powerful and versatile tool for reaching the goals of clean and renewable energy with respect to aesthetical, cost-effective and technical solutions. BIPV systems can offer savings in materials and electricity expenses, lesser usage of fossil fuels and lower emission of ozone depleting gases (CFCs etc.), and also enhance architectural attentiveness of the building. Further, building integrated photovoltaic (BIPV) systems may replace the parts of the traditional building materials and systems within the climate casing of buildings, such as the roofs, skylights and frontages. BIPV frameworks are to be considered as a utilitarian part of the building structure, or they are structurally coordinated into the building's configuration (Peng, 2011), Hence, the BIPVs serves as a building envelope material as well as power generator (http://www.wbdg.org/resources/bipv.php). This research work essentially concludes the current scenario of the developments of BIPVs, including the BIPV tiles, foils, modules and solar cell glazing products, also citing building attached photovoltaic (BAPV) systems. Building-applied photovoltaics (BAPV) is sometimes referred as photovoltaics that are a retrofit – incorporated into the building after construction work is complete. For auxiliaryoverview and embellishments including investigations of some possible research prospects and conduits for the future BIPVs, reference (Jelle, 2011), may be referred.

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Building integration of photovoltaic cells

First of all, the probable spaces in the building envelop has to be recognized for the integration of photovoltaic cells/modules. Building integration of photovoltaic (PV) cells are basically carried out on slanted roofs, level roofs, fronts and solar shielding systems. PV cells may be riding above or onto the existing or traditional roofing or wall covering systems. Though, BIPV systems replace the outer building envelope membrane, therefore serving simultaneously as both a climate screen and a power source by generating electricity. Hence, BIPVs may provide savings in both materials and labor, further reduce the electricity costs. However, the Building-integrated photovoltaics (BIPVs) function as the climate shelter screens, which requires to have satisfactory or strict necessities of rain tightness, toughness and durability.

Many aspects have to be taken and evaluated with respect to the integration of the PVs into the outer building envelope casing. One of the aspect is to ensure an air gap below the solar cells in order to provide an air flow so as to reduce the temperature of the solar cells, as a high temperature decreases the efficiency of the solar cells, specifically for mono- and polycrystalline Si cells. Other aspect to be considered is the leaning of the BIPVs, for both existing and new buildings, as the solar cells essentially need to follow the roof inclination (or the wall) to be integrated solutions. Also the geographical position, orientation towards the sun and exposure area are yet another factors to be considered during integration process of the BIPV systems. Some BIPV companies also offer dummy modules to provide a more aesthetical and reliable appearance of the roofs and frontages. Henceforth, it is concluded that BIPVs have to fulfill all the necessities, with respect to different properties, of the building envelope membranes which they are substituting. Along the above explained factors, other building physical subjects like e.g. moisture and heat transport in the building envelope are also to be considered and accounted for. Solar cell glazing products offer a solution for using the fenestration with respect to sunshine, solar-heat gain, solar shading, and finally solar energy gain by transforming solar radiation into electrical energy.

BIPV’s architectural traits

BIPV systems serve not only to create architectural appeal but also provide savings in materials that would otherwise be used and reduced electricity costs. Along with this, these systems will help protect against the weather and will be a source of clean, renewable energy. In terms of availability, Numerous options for innovative architectural design are available with us provided by leading manufacturers of BIPVs, which may also be aesthetically soothing. BIPVs may also be utilized as screening devices and also provide a solution for semi-transparent elements of fenestration (European Committee for Electrotechnical Standarization, 2007). Also, silicon tiles may be applied to make a BIPV roof look very much similar to a standard tiled roof, whereas semi-transparent modules may be applied to frontages or glass ceilings to create different soothing visual effects. Some wants BIPV roof as a roof giving a clear visual impression and is preferred by most architects, while others want the BIPV roof to look like a standard roof as much as possible. More info about building integration of solar power systems and building integration of BIPVs in particular, may be found in references (Peng, 2011 and Hestnes, 2000) i.e. the studies made by Peng *et al*. (Peng, 2011), and Hestnes, Farkas *et al*. (Hestnes, 2000) respectively.

Test methods and standards

Assessment of BIPVs involve several deciding factors, e.g. solar cell efficiency $\eta = P_{max}/(\Phi A)$ where Φ is the input solar radiation in W/m^2 and A is the solar cell surface area in m^2, maximum power point P_{max} in Wor Watt-peak (Wp), open circuit potential or voltage V_{oc}, short circuit electrical current I_{sc}, fill factor $FF = P_{max}/(V_{oc}I_{sc}) = (VI)_{max}/(V_{oc}I_{sc})$, band gap E_g and quantum yield Φ = number of photo-electronsdivided by number of photons.

The values of different parameters of BIPV claimed by solar cell manufacturers are mainly obtained by the test done at standard test conditions (STC) or nominal operating cell temperature (NOCT). The binding standards for BIPV modules are the standards: EN-61646 ”Thin-film PV modules: designer qualification and type of approval” (European Comitee for ElectrotechnicalS tandarization, 2008), EN-61215 ”Crystalline Si terrestrial PV modules: Designer qualification and type of approval” [7], EN-61730-1 ”PV modules safety qualification – Part 1” [8], EN-61730-2 ”PV module: design &safety qualification” [9] & UL-1703 ”UL-standards for safety flat-plate PV module & panel” [10]. The above mentionedstandards may be referred for further information.

Current scenario of BIPVs

BIPV classification

The available range of BIPV products in market is very wide, which may be categorized in several different ways. This work of categorization is mainly done based on the product specifications from the companies and what other materials, the products are customized to be combined with. Based on these two factors, the BIPV products or systems may be classified into the following categories:

- BIPV foil products
- BIPV tile products
- BIPV module products
- Solar cell glazing products

In addition to the above categories, the group building attached photovoltaic (BAPV) products should also needs to be cited:

BAPV products

The major difference between the two BIPVs and BAPVs is that Building attached photovoltaic (BAPV) products are observed as attachments to the buildings itself, hence they are notdirectly related to the building structure’s functional aspects (Peng *et al*., 2011). That is, BAPVs are not BIPVs, because the BAPVs are not integrated into the building envelope skin as like BIPVs do, thus not replacing the traditional building parts as the BIPVs do, they may be referred as attachments to the building, which is done after the construction work is finished. Some of the BIPV products exhibit a variety of properties, thus it is more difficult to categorize them. However, in other cases it might even be somewhat difficult to decide whether a PV product should be considered as a BIPV product or BAPV product, all because of lack of information and uncertainty about how the products going to be mounted. For a comprehensive review of the BIPV systems, including references and contact-info, it may be referred to the work by Jelle *et al*., (2012).

BIPV foil products

These are the flexible and lightweight products, which are advantageous with respect to easy& fast installation and prevailing weight constraints for roofs. In these, the PV cells are often made from thin-film cells to uphold the flexibility in the foil and the efficiency at high temperatures for use on non-ventilated rooftop solutions. Unfortunately, currently there are only a few manufacturers available in the market that provide weather tight solutions. Some BIPV foil products available in the market are given below in Table 1. They specifically have a low fill factor due to the lower efficiency and the large solar cell resistances of thin-film cells. However, as an advantage it is always possible to alter the degree of inclination of the BIPV foil product to providea flexible solution.

BIPV tile products

BIPV tile products are the roofing tiles, which may cover the entire roof or part of the roof and act as the replacement for conventional tiles use on the rooftops. They are side-by-side arranged PV modules with same appearance and properties as of standard roof tiles and act as asubstitute to thetraditional roof tiles, thus also enabling easy retro-fitting of roofs. The tile shape and cell type varies with the manufacturer. Some tile products may look like curved ceramic tiles but as a drawback effective area will be lesser due to the curved surface, but it may be added aesthetically pleasing. Few examples of BIPVtile products available in the market today are given below in Table 2. The BIPV products from top manufacturers Solardachstein, Solar Century and Lumeta provide the highest FFsindicating high efficiencies. In fact, Solar Century provides an efficiency of 20 percent/ cell for their C-21e Tile. Further, the available design concept of the Solé Power tile and the STEP design is one module design similar to standard roof tiles that may replace several standard roof tiles. In fact, the module has an integrated panel of monocrystalline or polycrystalline cells. i.e. portions of the module are not externally covered with PV cells, hence the area efficiency will not be much high. Also, the STEP design solution from Solardachstein may be mounted on different tile products. The C-21e Tile from Solar Century has a larger active area than the other products since monocrystalline Si cells shield the whole area of the module, and has compatiblity with a series of tiles and slates. Solé Powertile from SRS-Energy has an outline much like standard rooftop tiles and the indistinct Si cell spread from Uni-Solar is like the surface film of the tiles.

BIPV module products

The BIPV module products are very much similar to conventional PV modules. The only difference is that the BIPV modules are serve dual function i.e. generating electricity as well as provide weather skin solutions. Some products may replace various types of roofing, or other may fit with a specific roof solution made by its manufacturer. Further, these mounting systems makes the installation of BIPV modules more easy. There are numerous products in the market and some are promoted as BIPV products in spite of the fact that they do not function as weather skins, while other products do not provide any information about how they are to be mounted which leads to ambiguity whether they are BIPVs or BAPVs. Some BIPV module products are pre-made modules with thermal insulation while other elements are included in the body itself. Some examples of BIPV module products are given in Table 3.

Solar cell glazing products

Building Integrated PVs as solar cell glazing products provide abundant variety of choices for windows, glassed or tiled frontages and rooftops, Different transparencies and colors can provide different aesthetical results. Some of the solar cell glazing product examples are given below in Table 4.The solar cell glazing modules serves dual functions i.e. they transmit daylight and also serve as water and sun protection. The space between the solar cells (normally 3 - 50 mm) depends on desired transparency level and the amount of electricity to be produced. The gap between the cells transmits diffused sunlight in the daytime. Therefore, both natural lighting and shading are provided along with electricity production. The solar cell glazing manufacturers generally provide customized products about the shape, cell material, color and different transparency level, i.e. the space between the cells. Generally, the transparency level varies from 16 % to 41 % for various Vidursolarmodels, while it is 25 % for the Abakus Solar AG Peak in P210-60 item.

Table 1. Specification sheet for a BIPV foil product [3].

Manufacturer	Product*	η (%)	V_{oc} (V)	I_{sc} (A)	P_{max} (W)	FF	Area (mm x mm)	P_{max}/ Area (W/m2)
Alwitra GmbH & Co.	Evalon V Solar 408		138.6	5.1	408.0/ module	0.58	1550 x 6000	42.90
	Evalon V Solar 136		46.2	5.1	136.0/ module	0.58	1050 x 3360	38.50

*Different other models are also available from the producer in the Evalon V Solar series.

Table 2. Specification sheet of few BIPV tile products [3]

Manufacturers	Product*	η (%)	V_{oc} (V)	I_{sc} (A)	P_{max} (W)	FF	Area (mm x mm)	P_{max}/ Area (W/m2)
SRS Energy	Solé Powertile		6.30	4.6	15.75/ module	0.54	868 x 457.2	39.70
Solardachstein	STEPdesign		23.75	2.40	1.36/ cell	0.76	8 units 100 x 100	136
Solar Century	C-21e Tile	20/cell	12.0	5.55	52/ module	0.78	1220 x 420	101.5
Lumeta	Solar Flat Tile		7.41	5.20	28/ module	0.73	432 x 905	71.60

*Lumeta has also a Solar S Tile available.

Table 3. Specification sheet of few BIPV module products [3]

Manufacturer	Product*	η (%)	V_{oc} (V)	I_{sc} (A)	P_{max} (W)	FF	Area (mm x mm)	P_{max}/ Area (W/m2)
Abakus Solar AG	Peak On P235-60	14.6	37.21	8.48	235	0.74	1630 x 1000	144.20
Creaton-AG	Creaton Solesia		13.86	8.46	90/module	0.77	1778 x 355	142.60
Suntech	MSZ-190JD		45.2	5.62	190/module	0.75	1641 x 834.5	139
Solar Century	C-21e Slate	20/cell	12.0	5.55	52	0.78	1174 x 318	139.30

*Different models are available from various producers.

Table 4. Specification sheetoffew solar cell glazing products [3]

Manufacturer	Product*	η (%)	V_{oc} (V)	I_{sc} (A)	P_{max} (W)	FF	Area (mm x mm)	P_{max}/ Area (W/m2)
Vidursolar	FV VS16 C36 P120	21.60	7.63				1600 x 720	
Glaswerke Arnold GmbH &Co KG	Voltarlux- ASI-TMono 4-fach		93	1.97	100/ module	0.55	2358 x 1027	41.3
Schott Solar	ASI-THRU-4IO	6.0	111	2.21	189	0.77	1123 x 2620	64.72
Sapa-integrated Building System	Amorphous Silicon(Si) thin film	5.0/cell			32/ cell		576 x 976 /cell	50
	Polycrystalline	16.0/cell			1.46-3.85 /cell		156 x 156 /cell	120
	Monocrystalline Highlyefficient	22.0/cell			2.91-3.11/cell		125 x 125 /cell	155

*Different models are available from various producers.

Table 5. Specification sheet of few of the BAPV products [3]

Manufacturer	Product*	η (%)	V_{oc} (V)	I_{sc} (A)	P_{max} (W)	FF	Area (mm x mm)	P_{max}/ Area (W/m2)
Hauptsitz	SunPower 220 Solar Panel	17.70	48.60	5.75			1559 x 798	
Uni-Solar	PVL-68		23.10	5.10	68/module	0.58	2849 x 394	60.60
	PVL-144		46.20	5.30	144/module	0.59	5486 x 394	66.60
Isofoton	ISF-240	14.50	37.10	8.45	240	0.77	1667 x 994	144.80

*Different models are available from various producers.

The distinctive models from Sapa Building System utilizes either formless, polycrystalline or monocrystalline cells with various cell detachments.

BAPV products

The BAPV products are added on rather than integrated in the roof or frontage like BIPV products. They are extra attachments to the building and installed after the construction of building is completed. The BAPV products are not the main focus of this study, but due to their similarities with BIPV products, it may be interesting to look at some of them. The Uni-Solar laminate (BAPV) available in the market is flexible, thus making it easy to incorporate with other building materials. Some other examples of BAPV products are given in Table 5.

Economical aspects of BIPVs

As per the report of consulting firm Nano-Markets, New York (Coons, 2009), the global market for BIPVs is expected to grow from \$1.8·109 in 2009, to \$8.7·109 in 2016. Further, Nano-Markets state that Copper Indium Gallium Selenide (CIGS) solar power cells will account for 17 % of the BIPV market in 2016and polysilicon-based BIPVs will drop from 75 % of the market to 33 % by 2016 in terms of volume [11]. As PVpanels requires a large installation area, the associated financial challenge may be best countered byspace-saving technologies like BIPVs (Paul, 2010). BIPV systems often have lower overall costs than other conventional PV systems which require separate, dedicated, mounting systems. Further, Integration of PV materials into building products such as roofing materials, windows, sunshades and glassed frontages provides the opportunity for cost reduction by substituting common building materials with BIPVs at peripheral costs (Norton, 2011), When BIPVs as a covering material is compared to glass, steel orother more conventional covering materials, installing BIPVs adds only a marginal extra cost (2 - 5 %) tothe overall construction costs of a commercial building (Eiffert, 2003), While the installation and operation cost of the BIPV system might be reduced by selling the surplus electricity to a regional power distribution company and may become a profit business (IEA-PVPS, 1999).

Meanwhile, the cost of a PV system is on decline with the improvement of technology advancement and increasing competition in the market, resulting into a lower price per kW installed (Sozer, 2007), which is avital part of the development to make installation and building integration of PV more profitable without government subsidies. To work out the energy payback time, the embodied energy of the system should be calculable (Hammond, 2012), For detailed knowledge of the energy payback time it may be referred to the literature (Hammond, 2012), Research and development in the field of PV modules and improvement in their technologies may have an even stronger impact on the nearby future of BIPVs.

Conclusions

Today the available building integrated photovoltaic (BIPV) products in the market, offer extensive range of integration of photovoltaic (PV) systems into buildings and roofing. The research and development is continued in both PV and BIPV materials and advancement in technologies will produce better and better BIPV solutions in the nearby future. The increased efficiency of solar cell, reduction in production costs and improved building integration will bang the future of solar BIPVs & BAPVs. Further, new and innovative solutions in the field of BIPVs may reduce costs and increase share in the market, amongst other in the retrofitting market.

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