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Chapter 1

BIPV VENTILATION SYSTEM

1.0 Introduction: Building integrated photovoltaic (BIPV) system is the integration of energy saving materials to the building design and construction.

Fig. 1.0 BIPV in a typical building

1.1 Requirement: for this integration to be effective a different method of construction has to be imbibed and uncommon materials and techniques are used for this purpose.

1.1.1 Space: spacial requirement is a very important aspect and criterion for BIPV integration in buildings. The addition of extra components to the building and often times materials that poses difficulties during integration is a hard task. Therefore space for such materials must be provided. Every building requires space for ventilation and for other uses. Depending on the type of building, additional space may be required to install an energy harvesting system which will alternate the traditional power supply. For this to be possible the design has to incorporate such functions from conception.

Fig 1.2 BIPV roofing

1.1.2 Design: the design is the foundation of every construction work, at design stage every component of the building is integrated to fit into the desired specification and serve the purpose. BIPV system is basically the work of the design team. Every designer and builder should do their work with innovation and challenges in mind, considering space, climatic conditions, energy saving, occupants safety and comfort on a long term is the core of designing. Lowest cost, quality and minimal need for maintenance are additional requirements.

In this report we will discuss the workability of the BIPV ventilation system, the advantages and the challenges it faces in the construction industry.

1.2 History of buildings and BIPV: building is almost as old as mankind, from times past humans have tried to create a common shelter for themselves. As advancement in technology took over the building industry, various designs have been introduced, some designs have been too eccentric that they do not connote to the structural capability and comfort of the occupants. That is where the government came in to regulate buildings and make design teams work hand in hand with structural engineers to make sure that the building does not pose future threat to the public and its occupant. The issue of public safety cannot be over emphasised, buildings consume a lot of energy for domestic use and more energy in industrial and commercial buildings. In the late 1970's, the department of energy in the United States sponsored a project on PV systems. This advancement was in collaboration with the industry to integrate this into buildings. **Solarex** and **Sanyo** developed PV prototypes but faced various technical challenges and high cost, thus commercialisation of the product was impeded **(SDA and NREL 1998).** Today there is a good partnership between PV manufactures, architects and building-material suppliers, they are striving to address the barriers and suggest a new competitive product to the market **(Fraile et al 2008)**

1.3 Ventilation system in buildings: it is a major obligation for an architect to design a building with as much cross air ventilation as possible, these days due to locations and functionality natural ventilation has reduced in modern buildings, giving room to artificial ventilation system. In various countries, so much energy and money goes into artificial cooling and heating systems in buildings. Many buildings do not provide spaces for these artificial cooling and heating units; their installation become additional labour, counter the design of the building or mar the facades of the building. Modern buildings however have made more rooms for these units, some are either buried in walls and others are inserted in cubicles. Yet again the problem arises – energy use

2.0 Problem statement:

Energy used in buildings is a major concern to builders and the government as well, several countries are facing an ultimatum to reduce energy consumption in buildings and industries. The issue of green and sustainable buildings is no longer news, just as the building designs had to change to accommodate the artificial cooling and heating unit components, the design has to be modified again to accommodate this green building initiative.

2.1 **Special requirement:** when we are talking about green building we definitely start from the design to the materials used and to the energy used. The issue of energy use in buildings has been debated over the years; sustainable energy source has been suggested and used in various buildings. Examples of these clean energy sources are the wind turbine generated energy and the solar panel generated energy. The focus now is how to integrate these materials into the building structure, to maintain the aesthetics and also save and generate its own energy

2.2 Cost

2.2.1 **Installation cost:** this has to do with the racking hardware and labour cost. This hardware serves as a direct interface between PV modules and the building panels, this BIPV eliminates the need for this robust material interface and labour cost. The size of the BIPV roofing material will enable developers to use low-cost roofing contractors with the traditional roofing methods [Fraile D et al 2008). The assumption is that BIPV roofing will only take 65% less time to install.

2.2.2 **Module cost:** materials are specific to product design, which includes framing, flashing, adhesives and materials to lessen heat gain. BIPV materials don't really have a vast difference from the traditional roofing system. It follows almost the same pattern for roofing materials like asphalt.

2.2.3 Flexible packaging cost: BIPV does not require flexible form factors, the products being deployed are rigid and uses c-Si technologies (ceron et al 2010). This is the room for further research on the flexibility of the roof structure, to integrate into the design of various architects. There are doubts therefore for the crystalline silicon to be developed into a flexible panel, however the thin film can be developed into a flexible material. The flexible materials tend to have a lighter weight than glass modules about 90% lighter. They however have lower shipping and installation cost. But trying out the flexibility will bring up additional cost of flexible barrier materials and long term product safety example long term UV radiation exposure. **(Kempe 2009)**

2.2.4 Building material cost offset: if this product eventually replaces traditional building materials, there would be a cost offset. This however a great task knowing that is building materials requires higher durability than PV devices, **(IEA 2011).**

The cost and performance of standard roofing materials vary. Asphalt products are very common, they last for about 17-20 years and the cost \$118-\$2/m^2 **(RSMeans 2010).**

3.0 Scope:

BIPV can be used in all forms of building, all it needs to function fully is the space and design as discussed above, however, we are considering PV materials being integrated into commercial buildings. The common use of high-rise buildings provides enough space to use BIPV as a facade envelope. Commercial buildings spend a lot of money on glazing, and more money on thermal comfort, ventilation and sun screening. BIPV provides all in one product, providing the much needed facade, thermal comfort and energy generating material to power the artificial ventilation in the building.

3.1 Optimising design: PV materials have been in use for some time now, however the PV materials have distorted the original design of the building. This is why the BIPV system is recommended; this system can generate a reasonable amount of energy and which can be directed to the artificial ventilating units in a commercial building

3.2 **Types of ventilation system**: from estimate, about 90% of our time is spent indoors, and with the introduction of more airtight buildings, ventilation has become a major concern. In some buildings the façades like the windows are the major sources of ventilation in buildings. Commercial buildings however integrate air handling plants with the air-conditioning.

There are about four major types of ventilation in buildings, they are as follows;

3.2.1 Rapid ventilation: this is defined as ventilation openings about 1.75m above floor level, example are the open windows.

3.2.2 Background ventilation: this is the ventilation opening(s), examples includes; the trickle ventilators, and the airbricks. these forms of ventilation are also 11.7m above ground level.

3.2.3 Extract ventilation: These are the mechanical extract ventilation operated manually or by remote controllers

3.3 Objectives: this work aims to promote and improve on the types of buildings we have these days, since every building starts at the design stage, the need for energy and comfort in building cannot be overemphasised. Ventilation and thermal comfort in buildings are the requirement of every developer. In commercial buildings it is however difficult to get a high percentage of natural ventilation; therefore artificial ventilation is popularly used. The cost and energy to generate this artificial ventilation is getting high by the day. Builders and manufactures have decided to bring in materials that will not alter the design of the building yet generate power to the building. Building components like the roofing panels and the building facade are being used for this purpose. This study aims to discuss the need for these panels to be incorporated into commercial buildings for ventilation purposes. Since ventilation in commercial buildings is not limited to a particular time of the day, year or climatic condition, we therefore suggest the materials that would withstand any harsh condition. This material should not only harvest and generate energy, but should be able to store energy for those times when solar energy is low.

3.4 Summary

The BIPV will address the value for aesthetics, the market data have shown that consumers are willing to pay for BIPV **(Barbose et al. 2011)**

There have been policy opportunities to support BIPV through programmed incentives, awareness to promote sustainable buildings and efforts to address building codes and regulations. Switzerland for example has a law that inhibits PV products unless they are integrated into buildings **(Zanetti 2010).** Such solar access laws are not only good for the environment but raise the market stance of BIPV.

The decrease in module cost, the much needed awareness to spur consumer interest and policy schemes that support the distribution of BIPV products will increase its market rate. The design aesthetics and installation cost reduction will lead to more solar products that may replace traditional building materials.

Despite the high interest from solar energy stakeholders, extensive research, advancement efforts and policy support in some market, the use of BIPV is still below 2% (250-300MW) according to the record from 2009. It is however suggested that the primary reason for such unpopularity is that the market price BIPVs are higher that the mounted PV products. This study aims to discuss ways to reduce the installation prices and offsetting the traditional building materials. The c-Si BIPV and the CIGS BIPV are however cheaper than the rack mounted c-Si PV.

There is an unnoticed competition between the BIPV materials and the PV product; the PV products are experiencing a decline in market prices, this however gives the BIPV manufactures and marketers a lot to ponder over. This study will suggest ways to make the BIPV as popular as the traditional building materials.

Chapter 2

Literature review

2.0 Introduction:

The term building integrated photovoltaic (BIPV) refers to the method of integrating photovoltaic elements into the building enclosure. This is the incorporation of architectural design, structural engineering with the multi-functional properties of the building materials and renewable minute energy generation.

These photovoltaic modules (PV modules) replaces the normal construction materials, this is not a new idealistic concept, but it is not so popular, due to the strenuous planning architectural challenges being faced in the building trade.

BIPV can be used in all part of the building envelope, roof surfaces are most preferred due the advantage it has in harvesting energy, facades, doors and windows can also be used.

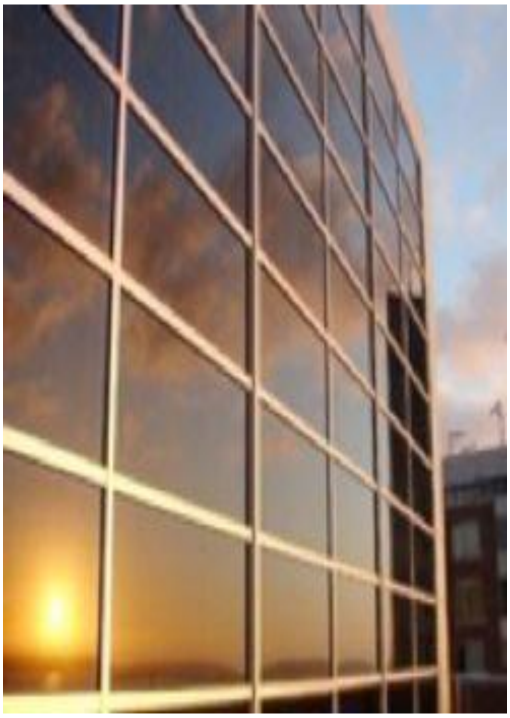
In urban centres however the façade is more likely to be recommended, due to the height of the building, this provides a larger panel for the BIPV, compared to the roof where other facilities would diminish the much needed space.

BIPV presents the opportunity to make renewable energy generation cost competitive, by using solar PV modules for the building envelopes.

2.1 PV materials: there are different types of PV materials, the PV market as innovative and competitive industry offers different technologies, there is a greater demand for colourless and transparent glass that provides electricity in buildings. The PV is the answer to the future. These materials include the following;

2.1.1 Crystalline silicon: these solar cells are harvested from grown silicon crystals, these crystals are sliced into semiconductors. They consist of about 150 x 150mm (6"x6") square plate with a metallic blue or black surface, they are segmented by a silver grid which collects the electrical current. It is difficult to mold the crystalline silicon into various shapes as this will interrupt the circulation of electricity through the electric cells.

The solar cells absorb a specific range of energy, the remaining energy is either reflected or transmitted. In this case the range of high energy photons (UV, Violet and Blue) gives low answer to cells and is very effective to wavelengths located in the red seen. **M. Fathi et al (2012)**



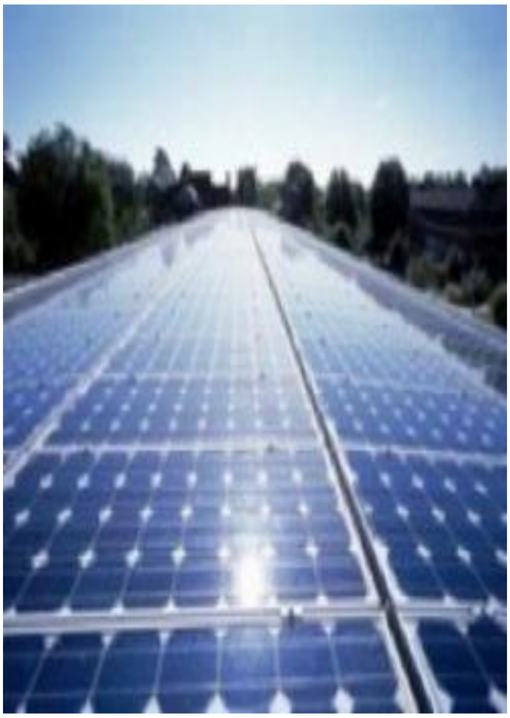


Fig 2.0 BIPV Design

2.1.2 Thin film modules: these materials consist of a semiconductor a few micro meters thick, these conductors are deposited on conductive glass, and the coating is subdivided into thinner linear cells. The size of the module is determined by the size of the carrier plate. This plate allows 20% light (T200 <700) to be transmitted across the whole surface. When mass-produced, this offers an advanced technology at a low cost.

2.2 Design parameters: putting the aesthetics into consideration, the integration of PV module should blend into the overall design or dominate the building shape. The appearance of a PV module is determined by the type of technology used in the PV cell, the selection of materials determines the design possibilities.

2.2.1 Module design: solar BIPV are usually laminated glasses or metal/plastic films. Facades use glazing while the roof uses metal/plastic films or glass/metal film, they are designed to meet structural and design requirement.

2.3 Features:

2.3.1 Transparency: This can be achieved by the combination of transparent unoccupied areas and an opaque solar cell. This is also called semi transparency; the arrangement of the solar cells within the module determines the level of transparency. If the module doesn't require transparency, the unused areas can however be coloured. Currently there are no fully clear solar panels, since the panels require cells for absorption of sunlight for energy.

Fig 2.1 Transparency of BIPV modules

2.3.2 Colour: colouration can be achieved in various ways. Not all colours can absorb spectrums of light, therefore variance in colour is limited. A typical solar cell is usually black or blue in the case of crystalline silicon, and black or brown for thin film.

No doubt colour coating and filming can be used in other cases. There is always a reduction in the output in some cases where certain colours are chosen, this brings the need for compromise between design and output.

Fig 2.2 BIPV module colour

2.3.3 Glass surfaces: a toughened glass or different thickness of glazing is required, although all available quality grades and types of glass can be used for solar modules. For a better yield, a white glass with low iron oxide content and high transmission (this reduces the greenish tint of the glass) is recommended. The surface of the glass is wave-shaped, those depressions act as light traps, bringing back all radiations that would have been lost to refraction.

2.3.4 Pliability and flexibility: this depends on the materials used, the substrates and thickness of the cells. It is easier for the thin film to be made flexible, but it is really difficult to try such with the crystalline silicon.

2.3.5 Cell contact: polysolar conductors are used to create electrical conductive contacts, which connects the individual cells.

2.4 How BIPV is designed

The design of BIPV system is a very complex process because we need to reach a common ground between the architectural context, structural requirements, economic aspect and the building regulations requirement.

However, the design strategy, environmental variables, multifunctionality, construction system, installation situation, module design, electrical components and economic aspect are the guidelines for BIPV design consideration.

In 2005, the use of renewable energy was displayed in the new concept in architecture; the CIS tower in Manchester (UK) was built as the largest BIPV vertical installation in Europe. Architects and developers are really keen in renewable energy in buildings.

Fig 2.3 CIS Tower Manchester UK BIPV building

2.4.1 Architects: architects have the role of understanding the importance of BIPV, and discussing this with the developer and incorporate that in their design.

The environment: when designing BIPV there must be a compromise between the requirement of energy yield optimisation and the architectural environment.

Orientation: the amount of solar radiation on a PV module depends on the orientation and the angle of inclination. This depends on the latitude of the installation site. In cases where we need to meet the architectural design, proper alignment may not be totally possible. Shading is another concern in the BIPV system, it can affect the yield of a PV system, a good module design can mitigate that.

2.5 Advances in the field

The concern about global warming has brought about the interest in naturally ventilated buildings and renewable energy source to buildings. There are various BIPV materials and construction forms now. They include; the design for pitched roofs, flat and curved roofs and facades.

2.4.1 Pitched roof: the PV modules are mounted in between the roofing sheets or as the roofing sheets. The small solar tiles-shingles slates are used when PV laminates are adhered on a tile-like substrate**. (www.solon.com)** the skylight and semi-transparent roof, prefab solar roof and the large solar tiles shingles-slates are also used for the pitched roof. There are many advancement in this field, for example in Germany, the concept of conventional glass-back foil c-Si of size 117883mm x 1044mm is used in the Netherlands the glass-glass laminate multi-si, 544 cells is used. There are about 29 companies producing the PV modules for the pitched roof in both large and small tiles.

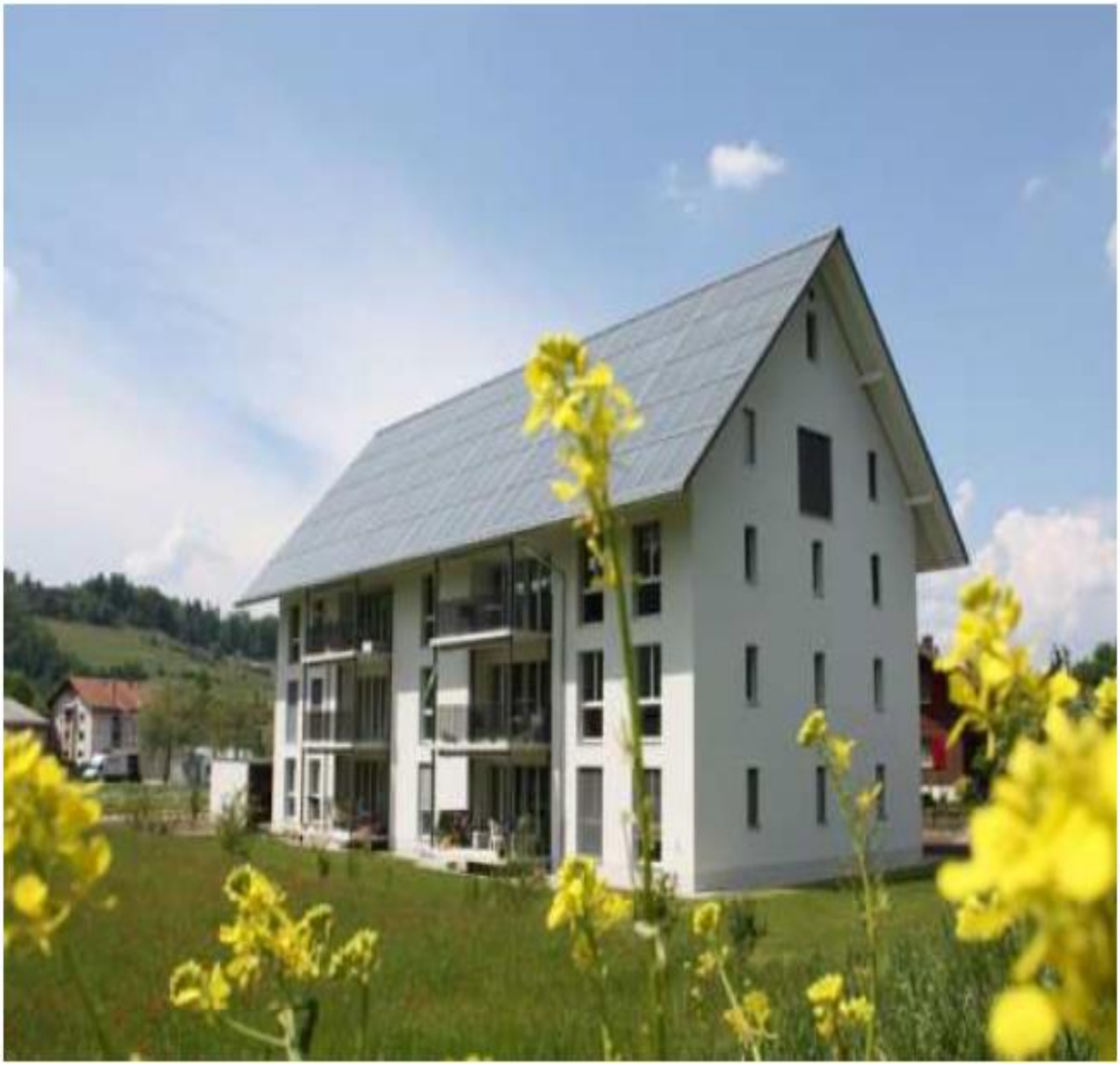


Fig 2.4 prefab solar roofing

Table1

Pitched roofs: In-roof systems overview table

Company	Country	Product name	Weight (kg/m^2)	Power density (Wp/m^2)	Height [mm]	Width [mm]
Solon	DE	Solitaire	13,2	139	1044	1783
Schott Solar	DE	Indax	12,1	137	999	1769
Scheuten Solar	NL, DE	Integra Vitro	15,92	140	1038	1520
Conergy	DE	SolarDelta	12,2	148	986	1651
CentroSolar	DE	S Class	12,6	155	831	1663
MegaSol	CH		12,8	151	832	1593
MecoSun	FR	mv3	-	-	-	-
Gehrlicher Solar	DE	GehrTec Intra	-	-	600	1200
Gehrlicher Solar	DE	GehrTec Intra	-	-	1000	1650
RotoSunroof	DE	Sunroof SRP	-	-	-	-
Renusol	DE	IntraSole CL	-	-	-	-
SolarWatt	DE	Easy-In	13,8	140	1035	1764
IRFTS	FR	Easy roof	-	-	-	-
Schüco	DE	MSE-500	20	137	1256	2156
Solar-Fabrik	DE	Incell	-	145	1023	1710
Aleo Solar	DE	Solrif	11	144	1016	1704
Heliosphera	GR	Venus	-	90	1106	1306
Win Win Precision Technology	TW		11,5	135	673	1498
SCX Solar	NL	Solo Roof			1000	1650
Average			**13**	**145**	**916**	**1604**

2.4.2 Flat and curved roofs: the skylight and semi-transparent roof can also be applicable here. Since flat and curved roofs have to be flexible, there are usually roofed by the thin film organic PV (OPV).

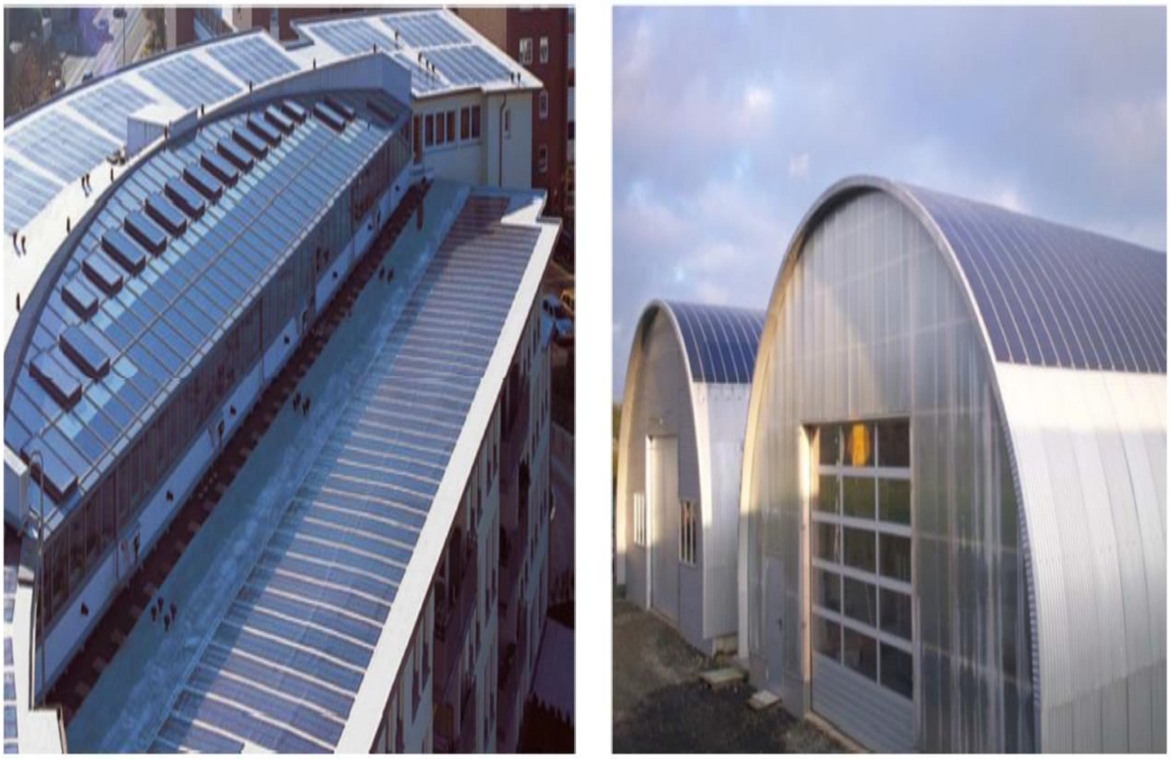


Fig 2.5 Flat and curved BIPV roofing

2.4.3 Facades: the facades includes the cladding system, the semi-transparent façade system (glass silicon with filtered vision), louver system and the construction integrated façade systems. The louver system is when the blinds are angled at a certain angle to admit light and air, solar cells are thus laminated on these planes. The construction integrated façade is when the PV is used as the facades www.schott.com/architecture

Fig 2.6 BIPV used as façade

Fig 2.7 BIPV louver facade

3.0 Summary

The report has shown the genesis of the BIPV system in construction, the need for PV modules in building is well known, the idea of incorporating those PV modules in the building envelop to replace traditional building components and also save energy which is used to power mechanical ventilators is the BIPV ventilation system. However, there are different designs for this product and various building designs can integrate this product either as roofs or facades. BIPV is not without criticism or challenges.

3.1 Challenges: The challenges facing the BIPV system are as follows;

3.1.1 Roof integration and façade installation: the challenges in this area are

- the integration of shingles and tiles
- gurantee that run off water will not penetrate through the roof
- heat and humidity transmission
- fire safety
- static evaluation, size and weight of the products
- installation to subconstruction
- corrosion protection
- noise and heat protection
- reliability and longetivity

Other challenges include the overhead glazing; the installation, load calculation and safety . Noise protection is also a challenge above all, the resistance against the elements is a major concern for BIPV system.

3.2 How project will help

3.2.1 Economic considerations: the misconception is that the cost of BIPV is higher than standard PV systems, but that has changed, thanks to new technologies and manufacturing competition. Since BIPV systems are used to replace other construction components, if we subtract the cost of those components and the PV modules we will appreciate the cost of BIPV system. These products are environmentally friendly and they help reduce the amount of Co2 emission in the environment. **(Guide to BIPV 2012)**

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