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Solar Photovoltaic Installation Cost Reduction through Building Integrated Photovoltaics in Ghana.

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Abstract

The growth and use of photovoltaic (PV) cannot be disputed as the world craves for cleaner energy options. Energy demands also keep on rising and buildings alone contribute about 40% of energy use in the world. This means that even if the world shifts completely to cleaner energy options, buildings will still demand more energy and therefore sustainable energy sources for buildings should be encouraged. Again, the initial setup cost of fossil fuel energy is lower than renewable energy. To make renewable energy attractive, cheaper setup cost should be achieved and this can be done by a cost offset through building element replacement by PV. This means the use of Building Integrated Photovoltaic (BIPV) is of high potential for financial offset than Building Applied Photovoltaic (BAPV). Quantitative data was gathered on roofing sheets cost and solar integration into roof cost. The average cost of roofing sheets for an area of 24m^2 roof spaces is $2,160.00 and the cost of integrating a solar PV on that same space is $9,600.00. The cost of constructing the space with roofing sheets is used to offset the cost of installing the solar PV to reduce it to $7,440.00. Autodesk Ecotect software was used to know the energy generated from roof integration of solar and this is 16,512kWh. This energy generated is converted to monetary value of $3,302.00 per year. The breakeven time after offset reduction is approximately 2 years 6 months due to monetary returns on the solar PV.

Keywords

Building — Cost — Installation — Integration — Photovoltaic

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Introduction

The use of photovoltaic is rapidly increasing over the years due to its lower carbon dioxide (CO_2) emissions. Even though it has its own challenges, the world is gradually embracing it. A research by Schmela [1] demonstrates that PV production in 2001 and 2002 grew by approximately 40% per annum. This means that quantities of PV production were almost doubling every two years. This growth makes it clear that there is a demand for the use of PV. The doubling of PV production can be attributed to the growing use of Building Integrated Photovoltaic (BIPV). BIPV is when PV modules are used as an integral part of the building envelope such as roof, walls or cladding and windows. Prior to this, Building Applied Integrated Photovoltaic (BAPV) was the most dominant. This involved the application of PV modules on an already existing building envelope. Where integration proves difficult, BAPV may be the answer. These differ from BIPV in that BIPV substitutes building materials where BAPV is added onto, on top of, or above existing building materials. Some examples include thin-film laminates layered on metal roofs or panels installed as a curtain wall or on top of building cladding,

perhaps as a rain-screen for example. Of course, substitution of building materials in the case of BIPV creates significant economic advantage over BAPV. The estimated technical potential for BIPV by 2025 in the UK is around 266 TWh per year but the practicable potential is around 37 TWh per year. This figure is higher than onshore wind, tidal, small hydro and waste to energy [2]. This means research and development into BIPV will give a platform for more clean energy production. A lot of developments have been made into BIPV and now you can have roofing shingles, claddings and complete windows made with PV modules. Travis Lowder of National Renewable Energy lab states that, “BIPV systems generally carry a larger price tag than do flat panel systems, though the reasons for this are somewhat unclear”[3]. But this higher price tag can be attributed to their custom nature. However since they will be replacing a building element, some cost savings can be looked

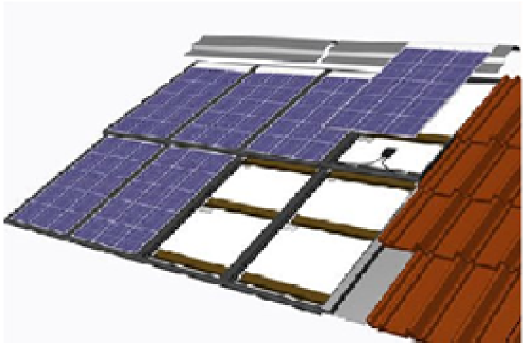

Figure 1. Image of a PV system integrated into a roof.

at. Various researches [4-10], all show the potential of BIPV. This potential can be attributed to the various points outlined in the table below.

Table 1. Potential Opportunities for BIPV Market Growth

Reason	Explanation
Installation cost reductions	**Lower non-module costs** -"Elimination of racking hardware and greater use of traditional roofing labor and installation methods -Cost offsets for displacing traditional building materials -Lower supply chain costs -Leverage more established channels to market
Improved aesthetics	**Consumer willingness to pay premiums in some markets** -Broader appeal for residential solar product designs
Higher technical potential	**Increased PV** -Suitable space on buildings
Solar industry interest	**Showcase applications** -High growth potential -Technology differentiation may help suppliers distinguish themselves -Possible cost reductions and new channels to market
Government support	**Maintain historic/cultural building designs** -BIPV -Specific incentives in select international markets

Source:James et al [11]

Another typical example of integration is seen in Strong's article "Building Integrated Photovoltaic". In this article it shows that the use of PV in roofing systems can provide a direct replacement for batten and seam metal roofing and traditional 3-tab asphalt shingles [12]. This integration above means there will be no roofing material in all the areas the PV will be covering and therefore a cost reduction. Most of these researches have been done outside Ghana and there has not been any financial analysis on them. The biggest question one can ask is can this construction cost reduction be an offset to the cost of installing a PV on a roof? In Ghana, there is a general idea that initial installation cost of solar PV is expensive. Due to this people shun from the use of solar in their buildings. But if there is an existing document that proves otherwise especially with BIPV, this can be changed. Analysis is done to determine the effect of this trend whether positive or negative. This research aims to analyse the financial benefit BIPV can give to the user or owner of a building in Ghana. The Ghana Renewable Energy Act which was passed in 2011 has come to stay and it encourages the use of renewable energy. Ghana is at the moment faced with a great hurdle of energy crises due to high energy demands. This research also seeks to enlighten developers in the residential industry with the option of BIPV and its financial implications. With developers knowing it to be profitable, there can be a shift into BIPV which will help reduce the high demand on the national grid. Result from this research informs academia on the need to learn and research more into BIPV than BAPV and stand – alone PV systems. Green building systems have been advocated for over the years due to its environmental friendliness. However, a lot of people reject this because it is assumed expensive. This research can break this barrier and make advocacy work on green practices easier.

1. Materials and Methods

The key variables this research thrived on are:

- The cost of building material to be replaced by BIPV per m^2
- The cost of BIPV per m^2
- The amount of solar radiation converted to energy by BIPV
- The monetary value energy generated

1.1 Sampling

Literature reveals that, BIPV are mostly used on roofs, walls, cladding and sometimes shading devices. But in Ghana, roof integration is the most dominant option and therefore in sampling, this research focused on roof integration. This is also because roof integration in the tropics tends to have more incident solar radiation on them. Sample size for data on building material cost was set to 5. The average of all 5 was used as the figure for input and analysis.

1.2 Data

With an experimental research design and quantitative approach, data on the key points above were collected. Table 2 table shows the choice of appropriate data, their sources and the mode of collection.

1.3 Tools used

Even though the modes of collection of various data forms have been outlined in table 2, certain tools were used to aid in the collection and analyses of data.

- For key variable one and two, an interview guide was developed to ask the right questions for the information needed. Data was then inputted into Microsoft Excel for average values
- Variable 3 involved a lot of tools but the main tool used was Autodesk Ecotect. This software has the capacity to determine the available solar radiation, incident solar radiation and generated energy on a given surface using the appropriate weather data. Some of the results from Ecotect are in a graphical form and was exported as an image for use. Other forms of data was tabulated and inputted into Microsoft Excel for analysis. Interview guide was developed to know the various facts about PV available in Ghana. Data was then inputted into Microsoft Excel for average values.
- An official mail was written to PURC on the current feed in tariff and was directed to download link. This data was then used to determine monetary value of energy generated.

Table 2. Data requirement and collection methods

Key Variable	Data Required	Source of Data	Mode of Collection
1. The cost of roofing material to be replaced by BIPV per m2.	Data on cost of roofing sheets in Ghana and literature on roofing cost.	Companies fact sheets, websites, articles and journals	Direct and phone interviews and online downloads to laptop.
2. The cost of BIPV per m2	Data on cost of BIPV and literature on BIPV cost as well.	Companies fact sheets, websites, articles and journals	Direct and phone interviews and online downloads to laptop.
3. The amount of solar radiation converted to energy by BIPV	Available and Incident solar radiation. BIPV modules efficiency, slope angle and energy from radiation.	Online search and Weather data analysis. BIPV companies fact sheets.	Weather file and company fact sheet downloads.
4. The monetary value energy generated.	Feed in tariff figures	PURC, Ministry of Energy, Energy Commission	Downloads from website or personal request and collection.

1.4 Analysis

This research mainly involved content analysis. Content analysis involves two levels of analysis namely, primary and secondary levels of analysis. Primary analysis was basically a descriptive account of the data. This involved the processing (that is data classification and summarization) and presentation (in tables and charts). Secondary analysis on the other hand adopted a more discursive, implied and inferential processes that tried to attribute meaning to the responses. This gives a reader a clear and logical understanding of the existing situation rather than just the raw data. This is because content analysis gives the actual description for any reader. Data goes through processing and it is summarized for better and clearer understanding. A bit of comparative analysis was used to gather data on BIPV cost and roofing sheet costs.

2. Results

2.1 The cost of roofing material to be replaced by BIPV.

There are a lot of roofing sheets available in Ghana, however after data collection; this research used Aluzinc roofing sheets as the base for this research. This is because it is widely used for new buildings. After data collection from companies such as Britak, Domod, DBS, Rockster and Raincoat, an average cost of $90.00 per m2 of roofing sheet was arrived at. This means that a cost of roofing material to be replaced will be $90.00 X 24m^2. This gives a value of $2,160.00 and this implies an automatic reduction of cost of BIPV by $2,160.00.

2.2 The cost of BIPV

Customised BIPVs are a bit expensive and thus the study used the normal PV panels existing on the Ghanaian market for integration. This could easily be done by fixing the PV first on the roofing frame followed by the other roofing elements such as sheets. Data as well from PV companies in Ghana gave an average figure of $400.00 per m^2 to install a PV on a roof. This meant that with an area of 24m^2, the cost of installing PV on roof within that area is $9,600.00. This value however is on the high side looking at the average annual income of the average Ghanaian which is GHc1,217.00 ($468.00). Gladly the amount can be further reduced by inculcating BIPV in the roof. BIPV can further reduce this amount to $7,440.00. This figure still remains high and requires further reduction which can be achieved through energy generated by BIPV.

2.2.1 The amount of solar radiation converted to energy by BIPV

This part gives in depth into PV cells integration on the roof of building and the energy to be generated. The total roof space is 28m^2, however not all this space can be used to mount BIPV. An offset of 0.20m was therefore done from each side and then this was used as the effective area for BIPV cells. An approximate area of 24m^2 was used and modelled in Autodesk Ecotect. The angle used for simulation was 26^o since a lot of roof in Ghana normally adopt a gentle slope. The image above

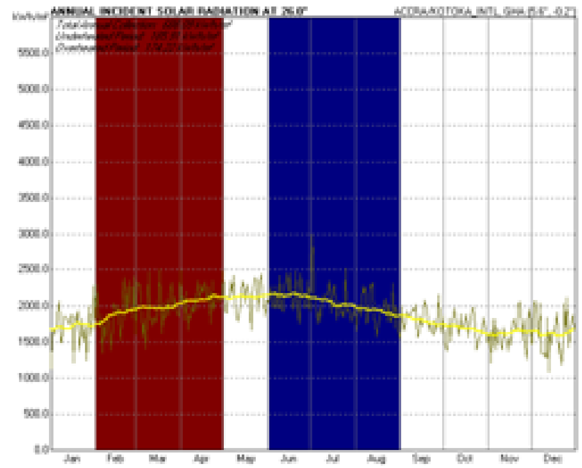

Figure 2. Image showing solar radiation. (Source: Autodesk Ecotect)

shows monthly incident solar radiation on a roof with BIPV. The lowest incident value is recorded in December whiles the highest is in April. This is as a result of available solar radiation in April. The image shows both direct and indirect incident solar radiation and this is a guide to know the solar radiation pattern of the chosen site. The tabulated data of monthly averages was taken from Ecotect and discussed. From table 3, it is clear that the total energy generated from BIPV is 688kWh/m2 and this is corresponding to the total annual collection in fig. 2. The average monthly available solar radiation in Accra, Ghana is 5750kWh/m^2 but the average incident solar radiation is 1147kWh/m^2. These figures show that only a fifth of available solar radiation is incident on the roof. Angle of roof slope and cloud cover can be factors affecting this reduction. Average monthly energy produced is arrived at using five percent (5%) panel efficiency, therefore energy generated is just 5% of the incident radiation. 5% is a very low efficiency value and thus a more efficient panel or module will generate more energy. Since the area with the BIPV is 24m^2, it was multiplied with 688kWh/m^2 to give an annual energy generation to 16,512kWh. The monetary value of the energy generated was then looked at.

Table 3. Solar radiation and their respective energy generation

MONTHS	Average Monthly Available Solar Radiation kWh/m^2	Average Monthly Incident Solar Radiation kWh/m^2	Average Monthly Energy Generated from PV in kWh/m^2
January	6000	1150	57.5
February	6200	1200	60
March	6400	1250	62.5
April	6100	1350	67.5
May	5700	1140	57
June	5300	1020	51
July	5200	1005	50.25
August	5300	1050	52.5
September	5500	1100	55
October	5700	1160	58
November	5900	1180	59
December	5700	1155	57.75

3. Discussion

Generating 16,512kWh of energy per annum is over the required energy needed for an average home in Ghana. The monetary value of this energy generated is therefore calculated to help determine the energy savings achieved. This is because this building will not be paying for electricity throughout the year. With the feed - in tariff of $0.20 cent/ kWh for solar PV set by the Public Utilities and Regulatory Commission (PURC) of Ghana, the monetary value of energy generated per year is $3,302.00. This amount is not physical money but excess energy that can be fed into the national grid using the net metering system and this gives you energy credits with the national grid. The introduction net metering system has also come to help reduce a cost in solar PV generation. This is because the huge cost of batteries which normally adds up cost due to energy storage is avoided. It is clear from the results that for a roof space of 24m2, the cost of roofing is $2,160.00 and to install PV within this same space it will cost $9,600.00. With the replacement of roofing sheets for BIPV, this cost is reduced to $7,440.00. This figure is still high but since the BIPV will be generating energy, there is further reduction through the energy produced by PV. The energy produced has a monetary value of $3,302.00 and therefore an estimated time for breakeven will be 2 years 6 months. This monetary value is actually possible when dealing with grid connected systems where net metering can be done. It is net metering that gives the opportunity for this to thrive. For off-grid systems, there is the need for batteries for storage and this adds up to cost. In a nut shell, initial installation of PV can be reduced by using a grid connected system with BIPV.

4. Conclusion

The use of solar PV is growing around the world and this is mostly so in temperate regions where monthly available solar radiations are quiet low. Germany is among the world's largest users of solar PV but its average solar radiation per year is 2681.5kWh/m^2. Ghana on the other hand has about twice of Germany's solar radiation. Due to this, the use of solar PV therefore should be encouraged in Ghana for electricity generation. But there is a setback on the use of solar PV due to its high initial setup cost. BIPV offers an opportunity to reduce this cost and this research looked at it. The results and discussion of this research proves that BIPV in Ghana is of great potential. But the biggest challenge in achieving this is the technical ability of the construction industry in Ghana. Therefore there is the need for further research into the technicalities for integration of PV in the buildings. This is because since the PVs will be placed on the roofing frame, the roof constructors will need some technical knowledge into PV as well. The potential of BIPV in Ghana can also be looked at as an option. This will enlighten policy makers and implementers the potential for BIPV in Ghana as in the case of UK.

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