Building Integrated Photovoltaics: Replacing with the Conventional Building Materials and Studying its Cost Effectiveness

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Abstract - *Building Integrated Photovoltaics, commonly abbreviated as BIPV, which accredits the integration of photovoltaic panels into the envelope of building itself. It is one of the most emerging technology world-wide with an average yearly growth of 15 to 25 % globally. BIPV is assumed to cross US $ 26 billion mark by the year 2025, which will bring out tremendous gains in the global growth. But still there are some factors due to which this technology is not accepted in some areas of the world. Cost is one of the major factors out of all. So this research study analysis the cost effectiveness of BIPV panels over the conventional glass facades in a school building model created in Revit software. The analysis is done by the Life Cycle Cost Analysis (LCCA) method of analysis. This might bring out some awareness about the cost effectiveness of the system and may increase in the acceptance of the technology worldwide. BIPV, being a system with multiple advantages, also projects a positive impact on the environment and has proved to be an environment friendly option for electricity generation.*

Key Words: **Building Integrated Photovoltaics (BIPV), Efficiency, Cost-effectiveness, Envelope, Glass Façade, Lifecycle Cost Analysis (LCCA).**

1. INTRODUCTION

Building integrated photovoltaics, commonly abbreviated as BIPV, is one of the emerging technologies around the globe. BIPV is the upgradation in the field of solar energy generation techniques i.e. the solar panels. It can be recognized as the upgraded version of the conventional solar panels, which are used to get installed on the rooftops of the buildings for the purpose of generating electric power from solar energy received by the sun.

BIPV panels, as the name suggests, are so designed that it can be integrated into the building envelope itself, replacing the conventional glass or other building materials. BIPV panels can be installed in the envelope part of the building such as roofs, facades and skylights. The major reason the construction industry have started incorporating the BIPVs into their buildings and infrastructure is that the initial investment cost can be offset by the electricity produced and the cost of labor and other materials is saved. Due to its multiple advantages, this technology is more and more accepted round the globe by the construction industry.

Somewhere in around 1970s, the photovoltaics were firstly installed on the rooftops of the houses in USA. They were installed in the areas where there was a very minute or no reach of electricity from the grid. These systems, initially, were inefficient. These systems were not able to produce the required and desired amount of electric power. After that era, there were some technological advancement in the photovoltaics and due to that performance of the products were gradually on the rise and also there was a remarkable decrease in the cost of system. Initially during the early phase of PV panels and systems, they were way too expensive and hence due to this, PV systems were not accepted by the people.

1.1 Working of BIPV

BIPV is an advancement of photovoltaics solar cells which are commonly used as a rooftop mounted solar systems. The working of the system is fully based on the solar radiations falling on it. The solar panels are fitted in such direction that it receives the maximum amount of sunlight throughout the year and hence make the most use of the solar rays and convert it to electric power.

Solar rays hits the panels and gets absorbed by the panel subject to its efficiency. This solar power or energy is then sent to the inverter which converts the direct current into alternating current. After the conversion of direct current to alternating current, the electric energy goes to the grid and from the grid, the energy, as usual, comes to houses, offices, schools, etc. and is ready for use. There are also some meters which indicates energy produced, energy used and energy saved. All this components of BIPV are connected through wired connection and cables.

2. METHODOLOGY

Primarily, the literatures related to BIPV were collected and reviewed. After reviewing the literatures, the data required was acquired from various sources such as internet, journals, articles, research papers and from various vendors, as required. When the sufficient data was collected, it was then analyzed by the Life Cycle Cost Analysis (LCCA) method. The LCCA method derived a comparison between the BIPV and the conventional glass facade which resulted out in the favor of the BIPV system in the area of cost effectiveness.

2.1 Life Cycle Cost Analysis method of analysis

Life Cycle Cost Analysis (LCCA) method is a tool which is used to discover the most cost effective alternative of the given alternatives. The method analysis the life cycle costs of the building or the product and determines the best alternative out of all the given alternatives.

The Life Cycle Analysis consists of costs such as initial cost, service cost, operation cost repair & maintenance cost and disposal cost. All of these costs are analyzed for all the available alternatives for the selected product.

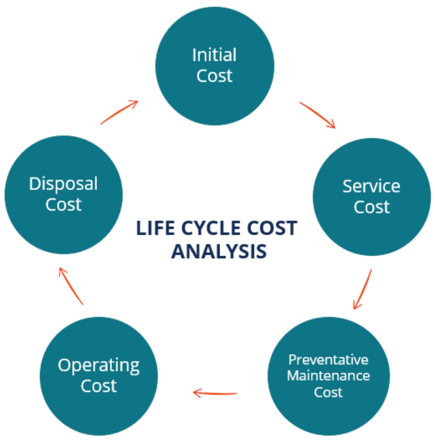

Fig -1: Life Cycle Cost Analysis

2.2 Data Collection

1. Project Details

Sr. no.		Details
1.	Building type	School building
2.	Construction type	Concrete framed structure
3.	No. of floors	3
4.	Total area	1759.927 m2
5.	Height of building	13.45 m
6.	Available area for BIPV installation	2150 m2

Table -1: Project Details

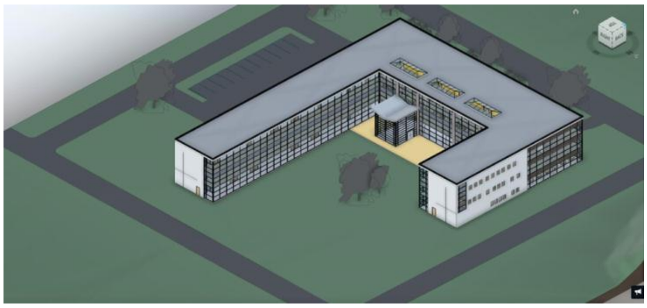

Fig -2: 3-D model of a school building

2. BIPV Details

Sr. no.		Details
1.	Company	NSA Solar Pvt. Ltd.
2.	Brand	Spark solar
3.	Dimensions	1955mm x 985mm
4.	Short circuit current	7.45 - 9.95 A
5.	Type of module	Polycrystalline
6.	Open circuit voltage	32.60 - 39.90 V
7.	Cable connector	MC4
8.	Capacity of module	250 Wp
9.	Cost of panel	Rs.25 Per watt

Table -2: BIPV Details

Fig -3: BIPV panel

3. Inverter Details

	Details
Model Name	Luminous solar nxi 25 kw on grid solar inverter
System Rating	25 KW, three phase

Maximum Solar Panel Connection (Watts)	25000 Watts
Efficiency	96.80%
Feed in Phase	Single phase
Topology	Transformer less
Number of MPPT Controller	One
Noise	< 30dBA
Weight (kg)	9.8 Kg
Dimensions [H *W *D]	339 * 565 * 172
Cost of inverter	Rs.1,40,000 /-

Table -3: Inverter Details

Fig -4: Inverter

4. Electricity tariff rates for school building

Charges	Monthly Slab	Rate
Energy Charges	First 200 Units	410 Paisa/unit
	Remaining Units	480 Paisa/unit
Fixed Charges	Single Phase	30 Rs/month/installation
	Three Phase	70 Rs/month/installation

Fig -5: Electricity Rates for School Building

5. Glass Façade Details

	Details
Color	Transparent
Material	Glass
Brand	Window Expert
Position	Exterior
Thickness	2-19mm
Glass Type	Toughened

Table -4: Glass Façade Details

3. DATA ANALYSIS

3.1 Data Analysis for BIPV system

Available area for BIPV installation = 2150 m2
Dimensions of 1 panel = 1.925 m2
Number of panels required = available area for bipv installation ÷ dimension of 1 panel
= 2150 m2 ÷ 1.925 m2
= 1116.8 ≈ 1117 nos.
Maximum capacity of 1 panel = 250 Wp
Total capacity of the system = 250 * 1117
= 279250 Wp = 279.250 kWp

Costing:-

(a)Panels = Rs. 25/watt
Total cost of panels = total watt * cost of 1 panel
= 279250 * 25
= Rs. 69,81,250 /-

(b)Inverter = Rs. 1,40,000/- per pc for 25 kW model.
Total no. of inverter required = Total capacity of BIPV ÷ 25 kW (inverter capacity)
= 279.250 ÷ 25
= 11.17 ≈ 11.
In inverter capacity + or – 10 % is permitted. So it is taken as 11 nos.
Total cost of 11 inverters = 11* 140000
= Rs. 15, 40,000/-

Life of inverters are approx. 10 years. So for a lifespan of 25 years of BIPV it is needed to be change at every 10 year span. So the total cost of inverters shall be multiplied by 2.5 times its original cost.

So,
Cost of 11 inverters = Rs. 15, 40,000/-
Total cost of inverters for 25 years = 15, 40,000 * 2.5
= Rs. 38, 50,000/-

(c) Wiring = 10% of cost of panels
= 0.1 * 69, 81,250
= Rs. 6, 98,125 /-

(d)Installation cost = 0.90 paisa per watt (including labor charges)
= 0.90 * 279250
= Rs. 2, 51,325/-

(e)Maintenance and repair = 1% of (a)+(b)+(c)+(d) .... (For 1 year)

= 0.01 * Rs. 6981250 + Rs. 3850000 + Rs. 698125 + Rs. 251325 = 0.01 * Rs. 1, 17, 80,700/- = Rs. 117807/- per year.

So,
Cost of maintenance for 25 years = 25 * Rs. 117807
= Rs. 29, 45,175/-

Now, adding up all the five costs for Life cycle cost of BIPV (a)+(b)+(c)+(d)+(e)

= Rs. 6981250 + Rs. 3850000 + Rs. 698125 + Rs. 251325 + Rs. 2945175

= Rs. 1, 47, 25,875/-

The total life cycle cost for 25 years including maintenance and repair for BIPV system is Rs. 1,47,25,875/-

3.2 Data Analysis for Glass Façade

(a) Glass panel = Rs. 350 per sq.ft
Available area for installation = 2150 m2 = 23,142.407 sq.ft
Total cost of glass panels = 350 * 23142.497
= Rs. 80, 99,842.45/-

(b) Installation = 20% of (a)
= 0.2 * 8099842.45
= Rs. 16, 19,968.49/-

(c) Maintenance = 1% of (a)+(b)
= 1% of 8099842.45 + 1619968.49
= 0.01 * 9719810.94 = Rs. 97198.10/- per year Approx. life of glass is 25 years.

So maintenance cost will be for 25 years
= 25 * 97198.10
= Rs. 24, 29,952.735 /-
Now adding up all three cost for life cycle cost of glass.
(a) + (b) + (c)
= 8099842.45 + 1619968.49 + 2429952.735
= Rs. 1, 21, 49,763.68/-

The total life cycle cost for 25 years including maintenance and repair for glass façade material is Rs. 1,21,49,763.68/-

3.3 Calculation for Electricity Generated By the BIPV System

The BIPV systems unlike any other cladding materials, generate electric power and that is what it is intended to do. It serves the purpose of electricity generation, thermal comfort, sound insulation and architectural aesthetics as well.

So, to calculate the lifecycle costing of anything, all the cost incurred during the lifetime of a particular thing shall be calculated to get more accurate outcomes from the calculation.

Calculation:-

Capacity of 1 panel (maximum) = 250 watt

Generally the power capacity mentioned on the panels is the maximum amount of power which generated only under STC – Standard Test Condition.

So calculating power generation @ 75% efficiency.

Capacity of panel @ 75% = 250 * 0.75
= 187.5 watt per panel

Total capacity of 1117 panels = 1117 * 187.5
= 209437.5 watt /day

The efficiency of the BIPV panels is not 100 % during its entire life span. It is as follows –
- Years 1 to 10 – 100%
- Years 11to 20 – 90%
- Years 21to 25 – 80%

So according to the above stated parameters, the average electricity produced is

Yearly = 70,329.10 kW
Monthly = 5860.75 kW

1 Kw electricity produces 4 to 5 units of electric power. These units are used for calculation of the electric bill and charges.

Calculating the electric costs by multiplying the amount of kW of electricity produced, by 4.

Monthly units produced = 5860.75 * 4
= 23443 units per month.
So according to the above tariff for school building,

(a) First 200 units – 200*410 paisa = Rs. 820/-
(b) Remaining units – 23243*480 paisa = Rs. 111566.4/-
(c) Total bill per month – (a) + (b)
= 820 + 111566.4 = Rs. 1, 12,386.4/-

Yearly electric bill amount = 12 * 1, 12,386.4
= Rs. 13, 48,636.8/-

Bill amount for life span of 25 years = Rs 13, 48,636.8 * 25
= Rs. 3, 37, 15,920/-

Payback period = Total cost of BIPV system ÷ Earnings (savings) through BIPV per month

= 14725875 ÷ 1348636 = 10.91 years.

This 10.91 years show that the investment cost would be off set in 10.91 years. So even if the initial investment cost of BIPV is more, the more efficient option from BIPV and glass would be BIPV system. The investment cost would be covered in 10.91 years of usage of BIPV, which would not happen in simple glass façade as it does not serves the purpose of producing electricity.

4. CONCLUSION

4.1 General Conclusion

BIPV is a vast area of research as it is one of the emerging technologies am also one of the fastest growing technologies of the current era. The BIPV systems plays an important role in utilizing the solar energy to convert it and produce to electric power for the usage of buildings and infrastructure. Still the researchers are finding the techniques by which the BIPV panels can be more efficient and can produce more electricity at a comparatively lower cost.

4.2 Research Specific Conclusion

Cost effectiveness and comparison of BIPV panels over the regular glass facades were performed in this research work by LCCA method of analysis. The BIPV systems, although with a higher investment cost compared to glass façade, came out to be more cost-effective. The life cycle cost of BIPV was nullified after usage of 10.91 years.

Total cost of BIPV system	Rs. 1,47,25,875/-	Higher investment cost but more cost-effective over the years. Does not harms environment. Eco friendly.
Total cost of Glass façade	Rs. 1,21,49,763.68/-	Lesser investment cost but lacks the cost-effectiveness and do not produce electricity. Also it is not an eco-friendly option.
Total cost of electricity generated	Rs. 3,37,15,920/-	Generated from solar energy which serves an advantage of an eco-friendly system.

Table -5: Cost comparison of BIPV and Glass façade

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