Solar Energy Development for the Nation

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ABSTRACT: The current study focuses on the use of alternative renewable energy sources, namely solar energy, to meet the energy demand in buildings. The paper contains a review of the literature on the types of field data needed, parameters for energy-efficient structures, estimation of solar energy output on buildings, techno-economic analysis, and the feasibility of Building Integrated Photovoltaics (BIPV). The team's findings in both cases show that retrofitting BIPV into an existing structure is more expensive than constructing a building with BIPV in mind. Furthermore, BIPV modules provided excellent architectural form and improved the overall aesthetics of the structure. The BIPV has been shown to be cost effective since it not only produces energy but also lowers the cost of the building materials it replaces. The payback time for BIPV is estimated to be 60-180 months, depending on the kind of connection, the amount of energy replaced by BIPV, and current government incentive programs.

KEYWORDS: Building Integrated Photovoltaics (BIPV), Economic Payback, Gandhinagar, Retrofitting, Self-Sufficient Building.

1. INTRODUCTION

With a GDP growth rate of approximately 7.38 percent, India has emerged as the world's largest energy consumer. According to the Government of India's Ministry of Statistics and Programme Implementation, per capita energy usage almost quadrupled between 1970 and 2010. However, India's annual energy consumption has increased fivefold during the past three decades, from 1980 to 2010 (3.8 quadrillion Btu to 21.8 quadrillion Btu: Fig. 1) [1].

Fig. 1: By 2050, Renewable Energy May Be Able to Power the Entire World.

This is due to improved urban living conditions and more sophisticated energy-use methods in the residential and industrial sectors. Buildings in India account for at least 29.8-39.8 percent of total energy consumption, and this demand is growing at a pace of 10.8-11.8 percent per year, which is double the country's average annual growth rate of 4.8-5.8 percent [2].

Building in India is seldom built to save energy on a large scale. Water conservation is becoming more popular. Despite this, the energy crisis has not been addressed. On a worldwide scale, building design for energy efficiency in India may be the most advantageous choice, since the building sector has the greatest potential for reducing GHG emissions [3]. The economics, as well as the size of the photovoltaic array, are affected by technical advancement. The grid-connectivity of the system, i.e. whether it is off-grid or grid-connected, influences the design [4].

We used solar passive design and BIPV to create a self-sufficient building while optimizing the claim for heating and day-lighting. As a result, combining the two components not only paves the way for net-zero energy, but also improves energy-efficient buildings. Potential location, climatic conditions, and the user's technical and socioeconomic status are all factors considered while designing. It should be noted that a possible installation site has the least amount of shadowing and receives the most sun irradiation throughout the day. It covers the direction, location, and size of the potential site. Among the climatic factors are solar irradiation and its relationship to the tilt and azimuth of the location [5].

2. LITERATURE REVIEW

S Wittkopf et al filed the business plan for Singapore's first Zero-energy BIPV building. Through its outstanding integration as a structural component, BIPV has established itself as a fundamental basis of power. The submitted research focused on the creation of BIPV prototypes, final design requirements, and tender evaluations. The commissioning occurred in the fall of 2008, and was followed by a year of assessment and fine-tuning. Until it is implemented, the rendering and efficiency estimates given here may be used as a guide for the actual performance. A preliminary energy balancing simulation combining monthly and daily energy consumption with PV supply shows that we are on track to meet the net-zero-energy target. BIPV has been viewed not just as an energy-generation technology, but also as a building component designed to improve architectural aesthetics. When the multifunctional behavior of PV was investigated by the Building Construction Authority in 2008, it made suggestions for integration. They investigated the feasibility of several installation sites, such as skywalks, walkways, and parking lots. When the proposed Photovoltaic structure is compared to the claim, the results are encouraging [6].

In a recent research study, S N Tabriz et al. integrated architectural design via the BIPV scheme, suggesting planning modifications with BIPV as a consideration. Daylighting is the use of natural light or skylights to brighten the interiors of buildings, and it has been shown to improve visual performance, lighting quality, fitness, human performance, and energy consumption. Houses that provide insulation, ventilation, cooling, and natural heating while also improving human health, as well as BIPV systems, have been highlighted. Because it is energy efficient, sustainable construction is one of the main themes of architecture throughout the world these days. It is excellent for updating buildings with Building-Integrated photovoltaic cells and collectors since it saves energy and maximizes daylighting [7].

In Shanghai, China, John Byrne et al. calculated the PV value, cost, and payback period of polycrystalline and monocrystalline Photovoltaic modules. In a 2001 study, rooftops and curtain walls were investigated for PV module installation. PV Planner, a program developed by the Centre for Energy and Environmental Policy (CEEP) in collaboration with the National Renewable Energy Laboratory in the United States, provides simulation and financial analysis of BIPV for a variety of infrastructure settings under various tool, policy, and financial circumstances. In a fictitious location, thin-film and polycrystalline PV modules are tested. The importance of BIPV multitasking is emphasized, and the payback time is anticipated to be less than five years. The study generates distinct economic pricing for investments in the United States versus China. We think that the legal framework around grid-connected BIPV is mostly to blame for this discrepancy. Finally, the research examines regulations related to BIPV development and makes recommendations for how China may make BIPV more economically attractive while also encouraging widespread usage in major cities [8].

K. Kurokawa et al. published a study on grid-connected photovoltaic systems for testing on industrial, commercial, and residential buildings. This page goes into great detail on PV implementations in urban areas. When a large number of PV systems are installed in the region, PV power may become very important, necessitating comprehensive optimization for the whole area. In terms of the architecture of community PV systems and the municipal energy distribution network. It focuses on centralized connections, with a 0.8 Megawatt Photovoltaic plant installed on home roofs. Assuming these conditions, contemporary trends in suburban areas, commercial zones, and industrial applications are studied. The technological difficulties associated with BIPV and electrical engineering are also summarized [9].

3. FORMULAE FOR CALCULATING ENERGY GENERATION

The BIPV system is designed to satisfy the whole energy demand of the building. The three types of BIPV panels were chosen for their suitability as a construction material, with 15.348 percent efficiency for Multi-crystalline C-Si panel with 249.8 Watt-peak, 9.8 percent efficiency for Multi-crystalline BIPV module (Glass-to-Glass laminate) with 134.8 Watt-peak, and 6.8 percent efficiency for Multi-crystalline BIPV module (Glass-to-Glass laminate) with 134.8 Watt-peak. Mounting, accessory, and labour costs would account for 24.8 percent of the overall cost, according to current market data. Other factors to consider include a Direct Current into Alternate Current DE rate factor of 0.68 (calculated using Indian conditions); a 29.8 percent administration funding up to 0.8 kW for housing installations and up to 99.8 kW for institutional and commercial installations; and a 29.8 percent government subsidy up to 99.8 kW for commercial and institutional installations [10].

The area required for PV was estimated iteratively. First, the maximum energy consumption is estimated/projected based on the main construction survey, and the BIPV region is computed using eq (1). An iterative method was used to connect the necessary area for BIPV fitting to the actual space available upon probable installation. The primary exteriors available for solar fitting in decreasing order have been sunshade, skylight, rooftop, and ultimately façade. The iterative procedure will terminate when the required area is equal to or less than the available space for BIPV. IWEC provides irradiance statistics utilized in region calculation as well as power generation across different apparatuses.

$$A_{req} = D/(\eta \times I \times l) \quad \text{eq. (1)}$$

Solar irradiances are used to estimate energy generation. As a result, the energy produced is given by

$$E = \eta \times I \times l \times A \quad \text{eq. (2)}$$

The SPT-1 building on the PDPU campus has ten classrooms, nine labs, a library, a faculty wing, offices, and a welcome area. The research team conducted a survey to gather construction drawings, current energy usage, and physical building characteristics. The house faces 298 degrees south of west; the façade wall's length was 98.2248 meters; the façade wall faces east; the wall receives 4.808 kilo Watt hour/meter2 solar irradiance on its vertical exterior on average in January at a 1/4-day exposure. During the inspection, it was discovered that the longest side of the structure is 98.218 metres long and faces east.

As shown in eq. (3), battery size was estimated based on fitting capacity, battery process duration, and available battery voltage. It is worth noting that the battery size was typically increased by 19.8-24.8 percent appropriate notwithstanding expected future claim accomplishment.

$$\text{Size of the battery} = \frac{(Installed\ capacity \times Hours\ of\ operation)}{Battery\ voltage} \quad \text{eq. (3)}$$

The time it takes to recover your investment is determined by the net cost, yearly savings, and annual profits. The cost of replacing building materials with the payback calculation for accelerated depreciation method as well as the BIPV panels are not included in this study.

$$\text{Payback for depreciation} = \text{Net cost}/\ (\text{Annual Earnings} + \text{Annual Savings}) \quad \text{eq. (4)}$$

The PDPU Gandhinagar Amenities and Logistics Department gathered the average daily demand from July 2009 to May 2012. The development was caused by a rise in tenancy and the increased usage of high-voltage applications. Furthermore, the chart shows that energy usage is lower from November to January and greater from March to September. Because of the high power consumption of the SPT-1 buildings, renewable energy sources must be used as a backup. The BIPV method has been chosen as an alternative power source to replace all of the consumption before half of the total usage.

The prices of Battery (11.8V, 99.8Ah) of $9,998 per unit; Inverter (7.48/Watt-peak); Multi crystalline A-Si Thin film module 249.8 Watt-peak (44.8/Watt-peak); and PV panels were originated to be BIPV module (Multi-crystalline) 134.8 Watt-peak (69.8/Watt-peak), based on a bazaar review conducted by the investigation crew.

Table 1: Characteristics of SPT-1 Construction Sites

Site	**Mean irradiance [kilowatt hour/meter^2/day]**	**Position of installation**	**Area available [m^2]**	**Dimensions of panel [m]**	**Types of panel used**
Sunshade	5.958	At 67^0 w.r.t., vertical	168.648	1.65 × 1	Multi-crystalline Carbon-Silicon 250
Adjacent fence	3.398	Vertical	280.58	1.65 × 1	Multi-crystalline Carbon-Silicon 250
Hole-in-the-wall	3.398	Vertical	314.438	2 × 1	Multi-crystalline BIPV 135

Based on the area estimated from the building design and elevation, probable solar sites accessible through the different devices of the façade fence, such as sunshade, neighbouring fence, and holes-in-the-wall, have been proposed for fitting. The energy usage from July 2011 to June 2012 has been used for this measurement. Table 1 illustrates the location, average irradiance, and panel type of the installation.

4. DISCUSSION

The lowest use is 277.8 kWh in January, followed by 299.8 kWh in February, and the highest is 767.8 kWh in July and June, respectively. However, it is further lowered by adding Accelerated Depreciation (an incentive) into the calculation of the remuneration duration, showing its viability. The BIPV method generates surplus throughout the year, but the need in June is exactly met. The whole surplus happens from January through April, when all demand has been met. The amount of CO_2 released into the atmosphere as a result of electricity usage has been set to zero. The size of the battery backup is calculated using eq. (3).

Generation outnumbers demand in both January and February, resulting in excess generation. Demand outnumbers supply throughout the remaining months of a calendar year. Because the time when solar power is available corresponds with generation being less than demand and peak demand for the bulk of the annual calendar, the generation is used at the site, eliminating the need for a battery bank and lowering the cost. Carbon dioxide emissions were decreased by 30.468 percent, demonstrating that BIPV is a viable option for reducing GHG emissions from building energy use. The largest decrease in CO_2 emissions is determined to occur at the macro level. The average decrease is the smallest in December. Furthermore, the payback is estimated using eq. (4) based on the cost of each component as well as existing government incentives for clean energy installations.

BIPV was regarded as a pre-thought for the building of a hypothetical residential structure of 9.8m 9.8 m in Gandhinagar. The aim was to create a residential structure that met the entire energy demand while also being aesthetically attractive. One of the most important factors to consider is the building orientation (179 degrees 58 minutes north); suitable feature and opening placement to provide a pleasant building atmosphere throughout the day. Outside planting in the veranda has been suggested to minimize ground reflection, providing noon illumination via comfort in terms of enclosed temperature. BIPV has become a planned component for construction design in order to meet energy requirements and to replace specific building structures, thus lowering the cost of the building materials it would replace. A few features stand out as possible future installation locations while looking at the structure, including the facade, the first floor sunshade, the skylight, and the roof.

The highlighted potions represent the chosen possible installation locations. In the development of a BIPV method, the necessary area measurement is performed using eq. (1). It displays the possible decrease for each location (in percent) as well as the requirements that remain unmet after each fitting. Sunshade has a reduction potential of 80.838 percent, skylight has a reduction potential of 38.648 percent, roof has a reduction potential of 29.758 percent, and façade has a reduction potential of 35.398 percent. As a result of the construction on all of the chosen sites, the energy need is completely met while there is a significant surplus. Monthly power output is calculated using eq. (2). The construction is justified since requirements are met throughout the year and excess electricity is generated, which is fed into the system.

5. CONCLUSION

In this research article, two cases were compared. The first is BIPV retrofitting, while the second is constructing with BIV in mind. According to the findings, rather than retrofitting an existing structure, it is preferable to design a building with BIPV in mind. The latter was found to be more expensive since it limits the number of possible locations and how the panel would be positioned. A modern template, on the other hand, ensures correct building orientation, which is difficult to do while retrofitting. An energy production and optimization model was created to determine the best location for BIPV installation. Rooftop, skylight, sunshade, and façade are prioritized for usable surfaces in decreasing order - was used to determine the cost and payback date.

The solar energy plan was developed to benefit installers and customers, resulting in a rise in solar installation throughout the country. The solar method has substantially shortened the payback time, which is now less than 84 months for a house and less than a decade for an official building without taking use of accelerated depreciation. Furthermore, it was found that BIPV is a technology that substantially reduces carbon dioxide emissions. Finally, it is claimed that BIPV is a gifted and hopeful technology with the ability to alleviate the country's power problem while simultaneously providing a justifiable way of reducing CO_2 emissions and promoting long-term growth.

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