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Building Integrated Photovoltaic is a Cost Effective and Environmental Friendly Solution

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Abstract

Building integrated photovoltaic (BIPV) market is under developing stage with a relatively low number of installations worldwide. However, integrating photovoltaic technology into buildings is straight forward as no additional space is required and building materials are simply replaced by PV modules. Although BIPV is considered a promising technology, especially where land for large-scale PV plants is rare, several factors continue to constrain its wide-spread adoption BIPV thus promises to become an attractive alternative for both end users and for national policy makers. In this paper we analyse the investment of BIPV, benefits of BIPV power system and cost of BIPV power system.

Keywords: *BIPV, payback period, LCC, tax incentives, cost of BIPV*

1. Introduction

A large global emission of carbon dioxide (CO_2) gas, are pushing the world into dangerous condition. Because of industrial revolutions, carbon emission from burning fossil fuels has grown exponentially. By end of the year 2030, the total emission of CO_2 is expected to exceed 10 billion tons [1]. Moreover, because of sharp increase of fossil fuel prices and concern about global warming, there is a trend of wide acceptance for the power supply to consider more and more renewable energy sources in many parts of the world [2]. The European commission has set a target of achieving 20% of total energy budget from renewable sources by the year 2020 [3]. This will stabilize the greenhouse gas emission thus reducing the contribution to global warming. Among all the renewable resources, solar energy is the most abundant, inexhaustible and clean one [4]. World's present energy requirement is 15Tera Watt (15×10^{12}) i.e. 10^4 times smaller than solar energy incident on the planet. It is estimated that the solar energy received within less than one hour would be sufficient to cover one year of world's energy budget [5]. Photovoltaic technology is one of the elegant technologies available for the efficient use of solar power [6]. Without any environmental harm, this technology produces electrical power by converting solar irradiance into direct electric current by using semiconductors [7]. In future scope for PV application, there are four major factors must be considered viz. cost reduction, increase of efficiency, BIPV applications and storage system [8]. BIPV technology transforms building from energy consumer to energy producer [9]. In this advancement, construction technology is required to be merged with BIPV technology for better performance [10]. Here, the photovoltaic modules become true construction element serving as building exteriors, such as roof, facade or skylight [11]. The BIPV also serves as weather protection, thermal insulation, noise protection etc. Moreover, since solar energy generators are normally located near the customers, there is no need to construct further transmission lines. Therefore, financial resources can be saved and power losses in distribution networks and security risks are minimized. Also, there is no need to construct more major power plants due to the fact that renewable sources can be utilized as emergency suppliers. In addition, solar energy can help the main network during peak load hours and shares the heavy burden [12, 13]. The power generated from solar energy is still insignificant as compared to other types of power production techniques, but the recent growth cannot be ignored [14]. The world experienced more than 150% growth in PV production in the past 5 years, [15]. For example during the last decade, European photovoltaic companies have reached an average annual production of 40% and in 2005, global solar markets earned 11.8 billion dollars which is up 55%

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more than 2004 figures. The ultimate goal is to double the existing efficiency in order to increase rapidly clean energy production [16]. The International Energy Agency (IEA) predicts that solar systems will produce one fifth of the whole global energy by 2050 and anticipates 60% rise by the end of this century [17]. Although we can see this significant rise of tendency toward solar systems around the world, but a lot of problems have to be solved if we want to keep this trend.

2. BIPV Investment Analysis

This section identifies general methods of investment analysis and explains how they may be applied to the assessment of building-integrated photovoltaic (BIPV) power systems. Figure 1 shows the Global BIPV installation and prediction of its expansion rate.

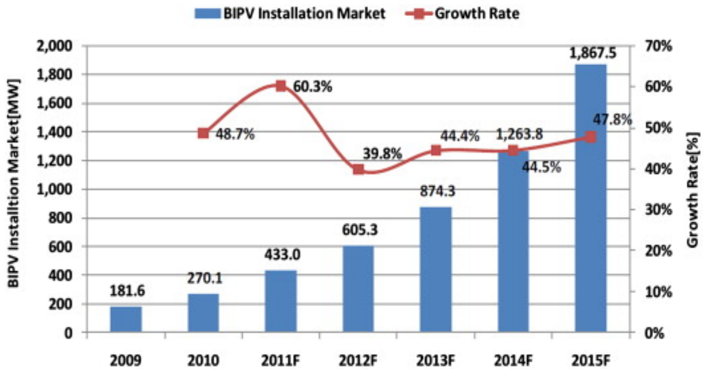

Figure 1. Global BIPV installation and prediction of its expansion rate [19]

2.1. Economic Benefits

Investment evaluations of energy systems generally include an assessment of the projected benefits compared to the estimated costs of the system. The direct financial benefit of a BIPV system is primarily the value of energy generated. These direct benefits may be considered as: Projected benefit is same as value of electricity generated. The direct economic costs of a BIPV system may be defined as addition of capital cost, periodic costs and replacement cost. When photovoltaic (PV) technology is adapted and used as a building component, as example of BIPV, its economic costs and benefits may be shared between the occupant and the utility company. For a building owner, the added costs of installing and operating a system to generate electricity may be offset by the avoided costs of purchasing electricity or by selling surplus electricity to the utility company. Figure 2 shows the development status of different countries in BIPV market and their future progress.

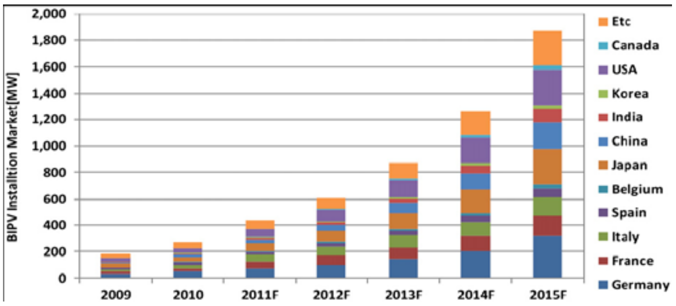

Figure 2. Development status of different countries in BIPV market and their future progress [20]

2.2. Payback period

The payback period is the minimum time it takes to recover investment costs. The payback period for an energy system is calculated as the total investment cost divided by the first year's revenues from energy saved, displaced, or produced. In payback analysis, the unit of measurement is the number of years to pay back the Investment cost. Projects with short payback periods are perceived to have lower risks. Simple payback analysis takes into account only first costs and energy savings at present cost. This method omits several significant cost factors, including the cost escalation rate and the cost of capital. Thus, simple payback analysis can overestimate the actual payback period and, consequently, the length of time to recoup the investment. The two main variations are payback after taxes and discounted payback. Payback after taxes includes and evaluates marginal tax rates and depreciation schedules. In the discounted payback method, future year's revenues are considered to have less value than current revenues. Discounted payback is the time between the points of initial investment and the point at which accumulated savings (net of the accumulated costs) are sufficient to offset the initial investment costs. Costs and savings are adjusted to account for the changing value of money over time. For investors who seek rapid turnover of investment funds, the investment increases in attractiveness as the payback period decreases. However, a shorter payback period does not necessarily indicate the most economically efficient investment. An investment with a longer payback period may be more profitable than an investment with a shorter payback period if it continues to yield savings for a longer period. The payback measure is essentially a break-even measure of system life. Payback can be used to determine the minimum time a system must last in order to recover the investment costs. The payback method is often used as a rough guide to cost effectiveness. If the payback period is significantly less than the expected system life, the project is likely to be considered cost effective.

2.3. Life Cycle Cost Analysis

In life-cycle cost (LCC) analysis, all relevant present and future costs (less any positive cash flows) associated with an energy system are summed in present or annual value during a given study period (e.g., the life of the system). These costs include, but are not limited to, energy, acquisition, installation, operations and maintenance (O&M), repair, replacement (less salvage value), inflation, and discount rate for the life of the investment (opportunity cost of money invested). The unit of measurement is present value or annual value dollars. A comparison between the LCC of an energy system to an alternative determines if the system in question is cost effective. If the LCC is lower than that for the base case and in other aspects is equal, and the project meets the investor's objectives and budget constraints, it is considered cost effective and the preferred investment [18].

3. Benefits of BIPV Power System

3.1. Electricity Benefits

The value of electricity generated by a BIPV power system is determined by the amount of electricity consumed plus the value of surplus electricity generated. Typically, facility electricity bills are paid monthly out of annual operations budgets. The O&M budget will decrease by using the solar energy source. The value of BIPV electricity generation to the building owner is the difference of the estimated baseline energy bill and the actual cost of the solar energy source. If a backup system is installed, the cost of backup fuel must also be taken into consideration when determining the value of BIPV electricity generation.

3.2. Thermal Benefits

The energy generated by the BIPV power system can be evaluated by assessing the cost of surplus electricity generated plus the system's energy contribution to the building's thermal performance. As such, the BIPV power system can be designed according to the building's heating, cooling, and day lighting loads. The system can also be deliberately oversized to generate surplus energy, depending on how it is valued by the utility and how much it costs to generate. The added costs associated with the hardware and design of hybrid BIPV/thermal systems would necessitate a careful economic evaluation. Empirical data on hybrid system performance and benefits are currently limited. One of the ways BIPV power systems may contribute to a building's thermal performance is through the thermal effect of the shading function on air conditioning loads, which a BIPV awning system provides during the summer. In contrast to shading, the heat cogeneration of a BIPV hybrid system in the winter provides another contribution to a building’s thermal performance. This heat is produced when ambient air is vented behind the BIPV glass panels to cool the solar cells (PV cells perform more efficiently at lower temperatures). The captured warm air may then be used to preheat water or air for building services.

3.3. Environmental Benefits

When generating electricity, BIPV power systems produce no harmful environmental emissions. A stakeholder can account for avoided environmental cost associated with not using fossil fuel-generated power. This value can be included in an LCC analysis. However, this value should not be considered when assessing decisions in which environmental effects plan no role (e.g., Energy Savings Performance Contracting would not include qualitative environmental benefits that do not directly affect cash flow in the economic analysis).

3.4. Tax Incentives

The four categories of U.S. taxation incentive programs that may apply to BIPV power systems i.e. tax credits, tax rate, tax basis, and taxable entity. Tax credits permit a percentage of expenditures to be deducted from the net taxes owed to the government. In the United States, the taxation parameter is divided into federal, state, and local tax obligations. A reduction to the tax rate can provide a financial advantage in three ways: (1) It can exempt certain activities, products, or entities from taxation, or tax them at a lower rate than their market substitutes; (2) Entire entities (e.g., some publicly owned electric utilities) may be exempt from federal income tax even though they compete with other providers of the same service that are taxed; and (3) a lower tax rate may permit a particular type of firm to pay a lower percentage tax on certain activities (e.g., lower tax rates on capital gains). The tax basis can be reduced by decreasing the taxable income on which a given percentage tax is applied. This is accomplished by either accelerating the timing of the tax deduction or by excluding portions of income subject to taxation. Firms may be allowed to deduct costs of PV investments from taxable income much faster than the investments actually depreciate. The reduction in current taxes is greater than the reduction in future taxes. The current tax savings (e.g., accelerated depreciation on plant and equipment) can also be invested and earn interest. Altering the taxable entity will affect the definition of a tax payer. This change may enable profits to be offset by losses and have a beneficial effect on tax calculations. Exceptions to rules on consolidating tax returns can give rise to subsidies, which allow profits to be shifted in a large, vertically integrated corporation (such as occurs in the oil industry). For example, when the taxable entity is difficult to define and transactions between divisions are done at artificially set transfer prices, profits can be shifted among divisions and countries to minimize the tax burden.

4. Cost of BIPV Power System

As with many renewable energy technologies, system prices in dollars per installed watt of direct current peak power capacity ($\$/W_p$ DC) have a significant effect on PV development. In general, the installed prices of BIPV systems are higher than PV system prices, but the cause of these price premiums—higher costs, higher margins, or other considerations—and the potential for price reductions remain uncertain. In today’s solar market, few BIPV products are fully integrated with building materials as envisioned in these BIPV cases; therefore, the cases should be seen as near-term possibilities. In contrast, the PV Reference Case represents a 2010 benchmark system price from an NREL study that uses the same methodology to assess objective system prices [21]. The bulk of the BIPV cases potential savings stem from eliminating the cost of module-mounting hardware—which rack-mounted PV systems need but BIPV systems do not—and from offsetting the cost of traditional building materials. BIPV labour savings result from the elimination of mounting hardware and our assumption of lower-cost roofing contractors in place of electricians. Some installation labour costs increase, however, due to the increased time that is required to install a greater number of smaller BIPV modules for a given area (i.e., more total electrical interconnections and wiring). Module costs and efficiencies are key factors that contribute to overall system prices across all of the cases, and we assume that the BIPV cases have lower efficiencies. If BIPV products completely replace traditional building materials, overall system costs should reflect a commensurate cost offset. Developing multifunctional products is a central challenge for BIPV product designers because building materials often require higher durability than PV devices, and BIPV must meet codes and standards for both PV and building products. The costs and performance of standard roofing materials vary. Asphalt shingles are the most common product installed on U.S. residential rooftops; they account for more than 50% of U.S. residential sector market share (National Roofing Contractors Association 2011 b). For most conditions, asphalt shingles last about 17–20 years, and installed costs are between \$18–\$32/m^2 [22]. More expensive rooftop products such as clay tiles may last more than 50 years and often provide better insulation and fire protection than less costly products. Table 3 lists the values for several roofing materials to illustrate general cost trends.

Table 1. Average Installed Retail Prices for Traditional Residential Roofing Materials, Converted to \$/W Based on the BIPV Derivative Case (13.8%-efficient, 0.58 m^2)

Roofing Product	**\$/m2**	**\$/w**
Asphalt shingle	\$25.08	\$0.18
Wood shingle	\$51.13	\$0.37
Concrete tile	\$57.86	\$0.42
Slate tile	\$78.58	\$0.57
Metal tile	\$101.45	\$0.74
Clay tile	\$116.52	\$0.85

PV products have a range of efficiencies, and lower-efficiency products require more space than higher-efficiency products for equivalent system power capacities. Similarly, lower-efficiency BIPV technologies require more space and displace more traditional products than higher- efficiency BIPV technologies; thus, in terms of \$/W, offsets are inversely related to PV efficiencies: a 6.3%-efficient device has more than double the offset value of a 14.5%-efficient device for an equivalent roofing product. Table 4 lists the approximate offset values for selected technologies and building materials, illustrating the possible range of residential offset values by highlighting a low-case offset (shingles) and a high-case offset (clay tiles).

Table 2. Estimated Offset Values for the Residential BIPV Cases

Technology	**PV metrics**		**Residential material offsets**	
	efficiency	**W$_p$/m^2**	**Asphalt single**	**Clay tile**
a-si	5.8%	58	\$0.43	\$2.01
CIGS	11.2%	113	\$0.22	\$1.03
c-si	13.8%	138	\$0.18	\$0.85

5. Conclusion

Although the deployment of BIPV is relatively low, opportunities remain promising. Decreasing module costs, increasing consumer interest in solar energy, and policy schemes that support distributed generation systems have the potential to increase rates of BIPV market growth. The commercialization of solar products that have the full functionality of building materials has been very limited, but systems are increasingly being developed to account for design aesthetics and installation-cost reductions. This range of integration is leading to more solar products that may fully replace traditional building materials.

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