

ECONOMIC ASSESSMENT OF BUILDING INTEGRATED PHOTOVOLTAICS

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Abstract - A building integrated photovoltaic (BIPV) power system operates as a multi-functional building construction material; it generates energy as well as serves as part of the building envelope. The combination of electricity industry restructuring and successful photovoltaic research and development raise a dilemma for building owners: Is the investment and effort to engage in the process of generating electricity with photovoltaics for individual buildings worthwhile? This paper identifies four key parameters that will enable the decision-makers to appraise the economic feasibility and implications of investments in such building systems.

1. INTRODUCTION

The objective of the *U.S. Guidelines for the Economic Assessment of Building Integrated Photovoltaic Power Systems* is to identify the economic parameters of BIPV systems (Eiffert & Thompson, 2000). Identifying these four parameters enables decision-makers with the ability to appraise the economic feasibility and implications of investments in such building systems. The first parameter, *Investment Analysis*, identifies general methods of assessing the economic performance of BIPV power systems. Then the *Benefits of BIPV Systems* are derived from such factors as energy cost savings, revenue or credits from the sale of power, reduced construction costs, and other incentives. The *Costs of BIPV Systems* for the building-owner are then considered. Finally *Measurement and Verification Guidelines* for BIPV power systems can ensure that generation and savings requirements are accurately determined.

2. INVESTMENT ANALYSIS

Generally, most architects use some form of quantitative analysis as a financial criterion to evaluate a building investment. However, a survey of American architects, by Wenger & Eiffert, indicated that a major barrier implementing BIPV systems is assembling and presenting the technical and financial data to persuade a client that a BIPV system would make economic sense. The relative economic methods of investment analysis for BIPV include payback period, net benefit analysis, savings-to-investment ratio, adjusted internal rate of return, and life-cycle cost analysis. Examples of decisions, which may confront a building owner or operator, are the following: Will a particular BIPV system be cost effective for building X? Would other designs and/or sizes of the BIPV system be more cost effective? With a limited budget available to retrofit a building for energy efficiency, which of, say, 10 alternative modifications (including a BIPV system), that together total four times the available budget, be chosen?

While the economic methods presented can be helpful in making a variety of investment decisions, they are not equally well suited for all types of decisions. All of the methods, in most cases, can be used to determine if a BIPV system is expected to be a cost effective addition to a building, other things being equal. For this purpose, the pay-back method is least reliable, but in many cases will also provide a clear indication of cost effectiveness.

For the purpose of designing and sizing BIPV systems, either the net benefits method or the life-cycle cost method is recommended. As long as net benefits increase or life-cycle costs decline as more expensive designs are chosen or as system size is increased, it pays to go to the more costly design or larger system. The saving-to-investment method and the adjusted rate of return method can also be used for designing and sizing BIPV systems, but it is imperative that these methods be applied to incremental amounts rather than to totals in order to serve as a reliable guide. (Ruegg and Marshall 1990)

For the purpose of ranking non-mutually exclusive investment alternatives, the savings-to-investment ratio method and the adjusted internal rate of return are the preferred measures. Choosing projects in descending order of their SIRs or AIRR until the budget is spent will in most cases result in maximum returns to the investor. Choice among projects and the designing and sizing of the candidate projects can be combined in an overall optimisation approach.

Investments in energy systems commit the building owner to current and future cost expenditures. Appraisal methods should account for the relevant costs and compare them on a common basis to the next-best option. Not all costs are factored into the decisions of all building owners; investment decisions are a function of the building owner's time perspective, responsibility for specific cost items, and ability to realise various benefits that may result from BIPV systems. In particular, speculative builders are likely to emphasise first costs over future costs. Additionally, a building owner's ability to finance capital projects may be limited by the ability to borrow or raise equity, or by strategic business objectives.

The evaluation of energy investment alternatives is often done using payback period, NPV, SIR, or AIRR analysis. Primary distinctions among these methodologies are the time period over which the costs and benefits are calculated, the unit of measure, and, most importantly, their interpretation. Payback period is the minimum time it takes to recover the initial investment. NPV is the net of savings over costs expressed as a time-equivalent value, usually as a lump sum at the present or as a series of annual amounts. SIR is the ratio of savings to costs. AIRR is the annual rate of return assuming reinvestment of interim earnings or savings at a specified rate. LCC is the time-adjusted sum of all time-adjusted costs of a given system over the specified time period, and must be compared with the LCC of an alternative system in order to inform choice between them.

Criteria for cost-effectiveness can be subjective depending on the investment decision-maker. Some general guidelines are to define cost-effectiveness as any energy project with a SIR greater than one, AIRR greater than the discount rate, LCC lower than that for the next best alternative energy system, and simple payback period less than the life of the BIPV system.

3. BENEFITS OF BIPV SYSTEMS

Commonly used evaluation methodologies for traditional buildings, which emphasise first costs or ignore non-energy benefits of BIPV systems may underestimate their true value and result in an unreliable or inaccurate decision. The benefits of BIPV systems are derived from such factors as energy cost savings, revenue or credits from the sale of power, enhanced power quality and reliability, reduced construction costs, reductions in environmental emissions, increased rents, tax credits, rebates, and other incentives. Some of these benefits can be identified, evaluated in monetary terms, and entered into the calculation of economic performance. Other effects may be difficult to quantify and be considered qualitatively.

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. A

variety of utility incentive programs have been available in the US as arrangements to provide win-win scenarios in which the consumer reduced energy consumption and the utility controlled its load growth. As utilities are faced with the uncertainties and competition associated with deregulation, there is a strong economic incentive to maintain and build on its customer base. Consequently, some utilities offer special customer services, such as "green power" generated by PV. Under these programs, the consumer agrees to pay more for electricity generated from environmentally friendly sources.

Some utility companies have rate structures with differing time-of-day rates. Typically, a BIPV power system will produce electricity during the daytime peak rate hours and provide a high value of avoided electricity costs. If a building is subject to time-of-day usage rates, the economic benefit of PV generated power can be included as a direct fiscal impact. Utility incentive programs may provide innovative financing and contractual mechanisms, as well as net billing, system buy-downs or cost sharing, leasing, and financing.

3.1 Metering

The economic value of BIPV metering can be easily identified and measured by the annual or monthly dollar reduction of the buildings net energy bill. Net billing accounts for the electricity generated by the BIPV power system, by paying the producer for surplus energy either at retail electricity rates or utility avoided cost rates. These two accounting methods are dual metering and net metering. In the dual-metering accounting method, avoided cost accounts for the utility's marginal cost of fuel and is a relatively low electric rate compared to the retail rates. This requires two meters to be installed on the facility premises: one to account for electricity exported and one to account for electricity imported. This form of metering requires additional hardware and duplicate systems for accounting purposes only. Where retail net billing is permitted, the accounting method for importing and exporting electricity uses standard electric meters that can run forward and backward. When the BIPV power system produces more electricity than is consumed in the building, the meter runs backward. The meter registers the net energy, consumed or produced, and the occupant is billed or credited accordingly at the end of the monthly billing period. Along with providing a more efficient accounting method, net metering benefits the utility by reducing marginal energy costs and by using less hardware than dual metering.

3.2 Demand Savings

Demand savings offer an opportunity to maximise the economic performance of BIPV power systems. Some utilities apply a demand charge relative to the peak energy load for a building. A periodic average reading of the building's electrical consumption determines the peak electrical demand. BIPV power systems are subject to climate and weather conditions -- a passing cloud may diminish the system's performance in an instant and the demand savings would not be realised. Therefore, having no back-up storage system, such as a battery bank, causes the system to yield uncertain savings. It should be noted that a back-up system would also incur an additional cost for design, hardware, maintenance, and battery replacement. At that point, the demand savings benefit of the back-up system must be weighed against its additional costs.

3.3 Power Quality and Reliability

The measure of value attributed to electric power quality and reliability are dependent upon the operations of a facility. Power quality problems, such as equipment incompatibility within the supply of electrical power reflect system disturbances that can cause equipment malfunctions and even power outages. If the power supplied to a piece of equipment is subject to high levels of fluctuations, harmonics, sags, swells, dips, spikes, flickers, and outages, and the equipment can't handle these faults without shutting down or being damaged, a power quality

problem most likely exists. BIPV power systems can be designed to augment power quality by serving a dedicated load. Unfortunately, the value of power quality may be difficult to quantify.

To achieve power reliability, uninterruptible power supply (UPS) systems are designed and incorporated into building energy systems to protect specific equipment or critical loads from power interruptions. The additional equipment required include batteries, a storage area, controllers, and associated electronics. A BIPV power system can be designed and sized to serve an isolated load in the building that would automatically separate from the utility grid if a line disturbance or power outage is detected (Coles et al. 1995). The economic benefit of such a system can be expressed as the avoided cost of an emergency back up power source.

3.4 Remote Power Benefits

In a remote power situation, the avoided cost of grid-line extension can be evaluated as an economic benefit of a BIPV power system. The benefit is especially attractive if the customer will bear the cost of the utility line extension. In this instance, BIPV power systems will have greater avoided costs depending on location. Often a small power generator can serve the remote facility load more cost-effectively than a utility grid-line extension. Diesel and propane power generators with optional battery storage have typically been used at remote sites. The cost of transporting this fuel to a remote area can be taken into consideration as well as the reduced costs of the risk of environmental clean up. Diesel generators often create noise proportional to the power being generated. Sound transmission depends on the acoustical characteristics of the generator building. The U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) provides guidelines (OSHA 1910.95) on acceptable sound levels to protect against the effects of noise exposure, measured in decibels determined by octave band analysis. Additionally, there is value in reducing noise pollution where occupants and users desire a natural quiet setting.

3.5 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 daylighting loads, or it can 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.

3.6 Environmental Benefits

When generating electricity, BIPV power systems produce no harmful environmental emissions. For example, the US Department of Interior, National Park Service (NPS), Denver Service Center Guideline 82-1, includes in all LCC assessments environmental emission costs. Amendment No. 3 quantifies the environmental emissions cost of electrical power generation and the resulting emission releases. The NPS has determined that the environmental cost associated with carbon dioxide emissions to be \$0.004/lb (\$0.0088/kg), sulfur dioxide emissions to be \$0.75/lb (\$1.65/kg), and nitrous oxide emissions to be \$3.40/lb (\$7.48/kg). As such, one can account for avoided environmental cost associated with not using fossil fuel generated power in LCC analysis.

3.7 Tax Incentives

Tax incentives are designed by public policy makers to encourage private capital investments that might not ordinarily occur. Solar energy tax credit legislation is

designed to stimulate the social and institutional acceptance and accelerate the economic development of the industry by encouraging private investments in PV power systems. Solar energy tax legislation can influence the development of technical expertise through industry and trade association labor certification, bonding requirements, product quality, warranty and guarantee coverage requirements, and system certification to meet building codes. The four categories of U.S. taxation incentive programs that may apply to BIPV power systems - tax credits, tax rate, tax basis, and taxable entity - will be discussed in this section.

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. Currently, the federal government allows a 10% tax credit to offset the cost of PV power systems in commercial buildings. The Federal Solar Energy Tax Credit is augmented by state tax policies, based on local initiatives. There is a wide variety of tax legislation among the 50 states. For example, North Carolina has instituted a 35% income tax credit allowance for commercial buildings with PV power systems. A reduction to the **Tax Rate** applied to BIPV power systems 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; (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 either by accelerating the timing of the tax deduction or by excluding portions of income subject to taxation. Firms may be allowed to deduct costs of BIPV 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 taxpayer. 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 minimise the tax burden.

3.8 Loan Incentive Programs

The government can act as a risk-absorbing agent to allow the private sector loan recipient to benefit from the government's economy of scale in raising funds and insuring risks. This reduces the capital cost by directly subsidising interest rates, eliminating premium charged by the lender for default risk, allowing favorable repayment terms, or by operating insurance programs at a loss. The U.S. federal government has authorised a number of such financing mechanisms for solar energy systems. These mechanisms are summarised in a 1998 booklet, "The Borrower's Guide to Financing Solar Energy Systems: A Federal Overview," which has been prepared by the DOE. In a few states, such as California, energy offices, bureaus, or commissions may offer financial programs with low-interest loans to encourage the use of renewable energy technologies. For example, a commercial business eligible for such a loan may receive a sizeable financial advantage that offsets the system's high capital cost. A lower interest rate can reduce payments over the term of the loan. This affects the overall economic performance of a BIPV power system investment.

4. COSTS OF BIPV POWER SYSTEMS

The BIPV power system cost depends on the type and size of system, on current PV technology and on whether a custom product or a standardised manufactured product is used. Two primary types of commercial BIPV products, facades and roof materials, are available for both new construction and renovation projects. BIPV facade systems include laminated and patterned glass, spandrel glass panels, curtain wall glazing systems, cladding systems, and awning systems. These products can displace traditional construction materials. Roofing systems include BIPV shingles, tiles, metal roofing, exterior insulation roof systems, and atrium or laminate roof systems. These products can displace traditional construction materials or be sold as enhanced construction materials. As such, the added cost for a BIPV power system should be used in economic assessments, rather than the full costs including those that would be incurred regardless of the BIPV system. These costs, as well as the balance of system components, costs of integration design and installation, should be evaluated in comparison to the traditional construction products and systems in order to determine the added investment cost of the BIPV system.

4.1 Labor Costs

The standardisation of BIPV building products and simplification of system engineering, design, and installation methods will most likely reduce labor costs of future BIPV power systems. Currently, and until BIPV becomes a mainstream technology, there is an added labor cost of architectural design, engineering design, and installation. However, with technical supervision, traditional building tradesmen, including glaziers, roofers, sheet metal workers, and electricians, can install BIPV power systems. A manufacturer may supply the components of a BIPV system to the technical supervisor, or a system integrator may be contracted separately. Then only the additional cost of specialised technical supervision over traditional craftsmen should be included when a BIPV power system is evaluated.

4.2 Maintenance Costs

Maintenance costs can have an impact in determining the cost-effectiveness of an investment. Manufacturers recommend preventive maintenance routines of periodic system checks and cleaning. Annual detailed electronic testing is also recommended. The labor costs of the personnel who maintain the system should be included in the economic analysis. Typically, training the facility engineer to service the system in-house will minimise the cost for system maintenance.

4.3 Utility Inter-Connection Costs

Utility interconnection costs are associated with the specific requirements determined by each state. Costs can include large interconnection fees, net metering tariffs, metering calibration charges, engineering study fees, and standby charges. Additional requirements for liability insurance, property easement, legal indemnification, record keeping of all O&M, and additional protection equipment will contribute to even greater utility interconnection costs. The relative cost of meeting these requirements is much greater for small systems than it is for larger systems. A set of uniform interconnection standards can facilitate the implementation of net metering nationwide, and reduce this economic barrier to grid-connected BIPV.

4.4 Costs Associated with Building Permits

A building permit is required before any construction, addition, moving, or alteration of any building. Electrical permits are required for new, remodeled, or up-graded structures. Some of the costs include fees for land disturbance, residential or commercial building permit fees, and re-inspection fees. Building permit fees are based on the estimated cost of construction or square footage, and, therefore, may be increased by the addition of a BIPV system. One should contact local land use and building design officials to identify specific project requirements, and use only the

added permit costs in an economic analysis of a BIPV system. Software by Governmental Data Services (GDS), Incorporated, provides for complete contractor management, including the mechanism to enter building permits and calculate permit fees. To learn more, visit the GDS website at www.fastlane.net/~gdsinc/permits1.htm.

5. MEASUREMENT AND VERIFICATION GUIDELINES

The International Performance Measurement & Verification Protocol (IPMVP) was created in 1997 to increase reliability and savings, reduce investment risks, and provide standardisation required to secure lower cost financing in energy projects. Measurement and verification (M&V) guidelines serve several objectives:

- M&V can provide load profiles and information needed to establish project feasibility.
- M&V results may serve as the basis for payments to a financier over the term of a performance contract.
- During financing contract development, a defined, accepted, and proven M&V protocol helps increase customer comfort and reduce transaction costs by facilitating negotiations.
- Finally, a protocol is helpful to secure the full financial benefits of environmental emissions reductions, such as emissions trading.

The objective is to minimise the combined total cost of the M&V program plus the cost of uncertainty in the savings. The cost of uncertainty would most often be a higher interest rate. As a rule of thumb, M&V costs should fall within 3% to 10% of typical project cost savings. The International Performance Measurement & Verification Protocol (IPMVP) is available electronically via the World Wide Web at <http://www.ipmvp.org/>

CONCLUSIONS

This paper summarises the highlights of the *U.S. Guidelines for the Economic Assessment of Building Integrated Photovoltaic Power Systems*. The objective of this research is to identify the economic parameters of BIPV systems. By identifying these key parameters decision-makers are enabled with the ability to appraise the economic feasibility and implications of investments in BIPV power systems.

REFERENCES

Please refer to the following publication for a complete set of references:

Eiffert, P and Thompson, A. (2000). *U.S. Guidelines for the Economic Analysis of Building Integrated Photovoltaic Power Systems*, NREL/TP-710-25266.