IEA INTERNATIONAL ENERGY AGENCY

Building Integrated Photovoltaic Power Systems

Guidelines for Economic Evaluation

PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Report IEA PVPS T7-05: 2002

Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic co-Operation and Development (OECD) which carries out a comprehensive programme of energy co-operation amongst its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (PVPS) is one of the collaborative R&D agreements established within the IEA and since 1993 its participants have been conducting a variety of joint projects concerned with the application of photovoltaic conversion of solar energy into electricity. The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. Currently activities are underway in seven Tasks.

The twenty-one members of IEA PVPS are: Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), European Commission, Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR), and United States (USA).

Within PVPS, Task 7 is the international collaborative effort focusing on building-integrated PV, linking developments in IEA countries worldwide. The overall objective of Task 7 is to enhance the architectural quality, technical quality and economic viability of photovoltaic power systems in the built environment and to assess and remove non-technical barriers for their introduction as an energy-significant option. Task 7 started its work in January 1997, building on previous collaborative actions within the IEA (Task 16 of the Solar Heating and Cooling Program).

Primary focus of this Task is on the integration of PV into the architectural design of roofs and facades of all type buildings and other structures in the built environment (such as noise barriers). Task 7 motivates the collaboration between urban planners, architects, building engineers, PV system specialists, utility specialists, the building industry and other professionals involved with photovoltaic technology.

This report has been prepared under the supervision of PVPS Task 7 by: Patrina Eiffert Ph.D. Director of ImaginIt LLC USA in co-operation with the following countries: AUS, AUT, CAN, CHE, DNK, DEU, FIN, ITA, JPN, NLD, ESP, SWE, GBR, USA and approved by the PVPS programme Executive Committee. The report expresses, as nearly as possible, an international consensus of the opinions on the subject. More information on the activities and results of the Task can be found on www.task7.org or www.iea-pvps.org.

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Much of this work is based on guiding principles already established by the National Institute for Standards and Technology (NIST) within the U.S. Department of Commerce's Office of Applied Economics. NIST pioneered the development of building life-cycle cost analysis relative to energy usage and conservation in buildings. The authors wish to acknowledge the valuable contributions of Rosalie Ruegg from NIST.

Executive Summary

The objective of the *Guidelines for the Economic Assessment of Building Integrated Photovoltaic Power Systems* is to identify the economic parameters of BIPV systems. The guidelines are structured in three major parts: the investment analysis itself (i.e. methods and ownership issues), the benefits and the costs of BIPV systems. Also, a short comment is paid to measurement and verification.

The (brief) outline and evaluation of the various general methods to analyze investment showed their effectiveness for BIPV systems. Naturally, all investment methods can be used to evaluate the BIPV economics (in relation to other techniques). However, for the purpose of designing and sizing BIPV systems, either the net present value method or the life-cycle cost method is recommended as BIPV has the tendency to have increased net benefits and/or leads to reduced (future) life cycle costs.

The criteria for the cost-effectiveness are subjective depending on the investment decision-maker. The most likely investor / decision-maker is the long-term owner-occupant as he / she is best positioned to reap benefits from BIPV systems, as these are capital-intensive and have low operating costs.

The benefits of BIPV cover a broad range of aspects, as there are: multiple (building) functions, electricity benefits, grid-support benefits, control of load growth by utilities (institutionalized by utility and national incentives & programs), demand savings, power quality and reliability, promotional & educational benefits, environmental benefits, shading and thermal benefits, security. Each of these topics are addressed, if possible with (international) examples.

The costs of BIPV depend on the system technology, utility interconnection costs, labor & installation costs, associated costs for building permits, maintenance costs, costs for replacement & repair and the salvage costs (or value). Each of these topics are addressed, if possible with (international) examples.

As the international market BIPV is divers, rapidly developing and market by various market segments, no general quantitative data could be presented of *the* cost and benefits of BIPV. However, this report reflects an extensive list of valuable data addressing all possible economic factors, relevant for an economic analysis. As incorporated in the title, the report can be used as a guideline to perform an economic analysis of BIPV systems.

Guidelines for the Economic Evaluation of Building Integrated Photovoltaic Power Systems

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0 Introduction

Traditionally, electrical service for buildings has been provided by one pre-determined supplier; the utility company. Electricity industry restructuring and successful R&D on building-integrated photovoltaics (BIPV) has raised a dilemma for building owners to consider: Is photovoltaics for individual buildings worth the investment?

A BIPV system operates as a multi-functional building construction material; it generates energy and serves as part of the building envelope. The objective of the *Guidelines for the Economic Assessment of Building Integrated Photovoltaic Power Systems* is to identify the economic parameters of BIPV systems.

Section 1 identifies general methods of assessing the economic performance of BIPV systems. A major barrier to analyzing renewable energy systems is assembling and presenting the technical and financial data in forms that will help an investor determine if a BIPV system would make economic sense. Economic methods of investment analysis, such as payback period, net benefit analysis, savings-to-investment ratio, adjusted internal rate of return, and lifecycle cost analysis are presented. Sensitivity analysis based on building ownership, owner-occupant, owner-investor, and owner-developer, are considered.

Section 2 describes the benefits of BIPV systems, which can affect the decision-making process. These benefits derive 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 benefits may be difficult to quantify and are considered qualitative.

Section 3 characterizes the relative costs of BIPV systems for the building-owner. Limited objective published data is available on BIPV system costs. A preliminary survey conducted in this study indicates that manufacturer marketing representatives and system integrators offer widely varying cost estimates. Consequently, a 3-5 vendor bids should be collected and reviewed prior to making an investment decision. There can also be hidden or unexpected costs, which will be examined in this section.

Section 4 specifies measurement and verification (M&V) protocols for BIPV systems. Prescribing an internationally accepted guideline for M&V can ensure that generation and savings requirements in BIPV systems will be accurately, consistently, and objectively determined.

This booklet presents financial data in US Dollars (USD). For conversion from Euro to USD, a conversion rate of 1 USD = 0.9105 Euro was used.

1 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) systems. A major barrier to analyzing renewable energy systems is assembling and presenting the technical and financial data in ways that will help an investor decide if a BIPV system would make economic sense. Economic methods of investment analysis, such as payback period, net benefit analysis, adjusted internal rate of return, and life-cycle cost analysis can be used to evaluate BIPV systems from the standpoint of the owner-occupant, owner-investor, and owner-developer.

At forehand, two remarks are made. First, in each economic method of analysis, Page: 9 the discount rate plays a major role to take into account the future uncertainties of alternative costs. As there are numerous good and extensive papers on this issue, this discussion is not recalled here. Second, the economic value of the PV power generated, i.e. the determination of the annual revenues of the PV system, is addressed in more detail in section 3.

1.2 Economic Benefits and Costs

Generally, most architects use some form of quantitative analysis such as net benefit analysis, length of payback period, or internal rate of return as a financial criterion to evaluate a building investment. However, there are a variety of barriers to the widespread investment in BIPV systems according to a survey of American architects. These architects were surveyed at a one-day workshop entitled “Building Integrated Photovoltaics for Design Professionals”, which was sponsored by the National Renewable Energy Laboratory (NREL) and the American Institute of Architects (Wenger and Eiffert 1996). Many respondents indicated that a major barrier to analyzing renewable energy systems is assembling and presenting the technical and financial data to help a client determine if a BIPV system would make economic sense.

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 benefits and the direct economic costs of a BIPV may be viewed as:

Projected Benefits = Value of Electricity Generated
Estimated Costs = Capital Costs + Periodic Costs + Replacement Costs

Quantitative analysis is a tool that facilitates ranking and choosing among investment alternatives. As such, quantitative procedures appear to be straightforward. However, numerous factors influence comparative evaluations. A building owner's economic expectations about future interest rates, inflation, and fuel costs directly affect investment decisions, as can utility interface requirements, environmental regulations, and tax incentives.

When photovoltaic (PV) technology is adapted and used as a building component, as exemplified in 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.

Consequently, guidelines to identify the economic value of a BIPV system can be used to help establish rate precedents and calculate an equitable rate structure for taking electricity from or

supplying it to the electricity grid. This can be assessed along with the architectural value and performance expectations of PV as a building component. Then the value of a BIPV system can also be weighed against the indirect economic benefits or qualitative advantages and disadvantages associated with image, public perception, and visual and environmental impact.

1.3 Economic Methods of Investment Analysis

Five relevant economic methods of financial analysis that are often used for making building investment decisions are payback analysis, net benefit analysis, saving-to-investment ratio (SIR), adjusted internal rate of return (AIRR), and life-cycle cost (LCC) analysis. This study will assess the usefulness of these methods in evaluating the economics of BIPV.

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 years' revenues are considered to have less value than current revenues. Discounted payback is the time between the point 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 return 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. 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.

Net Benefit Analysis

Net benefit analysis can be used to express the net difference between the benefits and costs of one energy system relative to an alternative in present or annual value dollars. Net benefits, also called net present values (NPV), represent the difference between the present value of benefits (revenue or savings) and the present value of costs of the alternative. A system is cost-effective if the net saving or net benefit is positive.

Savings-to-Investment Ratio

The savings-to-investment ratio can be used to compare savings to costs of one energy system relative to an alternative energy system. For positive net savings, the SIR must be greater than one. The higher the ratio, the greater the savings realized relative to the investment.

Adjusted Internal Rate of Return

The adjusted internal rate of return is a discounted cash flow technique that measures the annual yield from a project, taking into account reinvestment of interim receipts at a specified rate. With this methodology, estimating the cost-effectiveness of a project involves comparisons of the calculated AIRR of a project to the investor's minimum acceptable rate of return (MARR). The project is cost-effective if the AIRR is greater than the MARR.

The AIRR is calculated by taking the nth root of the ratio of the terminal value (TV) of all cash flows (except investment costs) to the present value of investment costs (PVI) and then subtracting one [(TV/PVI)1/*n*-1]. The AIRR may be contrasted with the internal rate of return, which computes the yield on original investment and is calculated by a trial-and-error process that involves selecting compound interest rates and discounting the cash flows until a rate is found for which the net value of the investment is *zero.*

Life-Cycle Cost Analysis

In Life-Cycle Cost Analysis (LCC), 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 the 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 (Reugg 1990).

Various tools have been developed to calculate (and compare) investments. The Building Life-Cycle Costs (BLCC) software program developed during the 1980s by the U.S. Department of Commerce is only one (www.nist.gov, National Technical Information Service Order Number PB96:199229). The BLCC software program is designed to evaluate and compare the cost-effectiveness of building energy conservation components and systems by quantifying all project-related costs. The lowest LCC of the measured energy options is regarded as the most cost-effective. The BLCC software provides payback analysis, SIR, AIRR, NPV and lifecycle costs of BIPV systems such that they can be compared to other energy measures.

Evaluation

Examples of decisions that may confront a building owner or operator are the following: will a particular BIPV system be cost effective for a specific building? For example, given a limited budget to retrofit a building for energy efficiency, ten alternative modifications (including the BIPV system) are available to the building owner that together equal a total of four times the planned budget. The dilemma is to determine which combination of the ten alternatives should be selected in order to optimize the investment.

While the methods of investment analysis 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 payback method is the least reliable, but in many cases, will also provide a clear indication of cost effectiveness and can be used as a screening tool.

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 savings-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 SIR method and the AIRR method are the preferred measures. In most cases, choosing projects in descending order of their SIR or AIRR until the budget is spent will result in maximum returns to the investor. The choice among technologies and the designing and sizing of the candidate systems can be combined in an overall optimization approach.

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 the next best alternative energy system, and simple payback period less than the life of the BIPV system (Table 1.1).

Table 1.1: Minimum evaluation criteria.

Evaluation Criteria	Economic Measure
Payback Period	Payback Period < Life of Building
Savings to Investment Ratio	SIR > 1
Adjusted Internal Rate of Return	AIR > Discount Rate
Net Present Value	Net Present Value > 0
Life-Cycle Costs	Lower Than LCC for Alternative

1.4 Building Ownership Issues

Given the inherent high first cost and reduced operating costs associated with BIPV systems, investments are sensitive to and dependent on building ownership issues. The three primary types of building owners (owner-occupant, owner-investor, and owner-developer) differ in investment criteria and time horizons.

Owner-Occupant

An owner-occupant expects to own a building for a long time. This positions him or her to control the decisions related to the choice of the energy system. Minimizing the operating costs is in that owner-occupants best interest. A higher initial capital investment may be acceptable if it will reduce operating costs. The owner-occupant may make investment decisions during the early stages of building design, construction, purchase, and renovation, and directly experience financial savings, system reliability, and building comfort. Consequently, the owner-occupant may be motivated to consider BIPV systems in new construction. But more often, the occupant will inhabit an existing building and will not be making the initial building design decisions. In

these instances it is advantageous for the building owner to consider retrofitting a PV system to the existing building.

Owner-Investor

An owner-investor will purchase and develop property to rent or lease to a third party. To maximize returns on investments, the owner-investor will be interested in minimizing O&M costs unless the tenant is responsible for the user-energy costs. The owner-investor may consider solar technologies, such as PV systems, particularly if there are federal, state, or local government tax incentives that provide the basis for an enhanced return on investment.

Owner-Developer

In this case, ownership is assumed to be temporary, from purchase through development and sale. Investment decisions will include energy-conscious design only if the owner-developer perceives that it will help sell the property if potential buyers place value on energy features. Minimizing development capital costs is important to the owner-developer. Operating costs are not a primary consideration. Given the occasions of high initial capital costs and long-term returns associated with energy investments, there is little incentive to consider energy-conscious designs. The owner-developer may be able to capture tax incentives for implementing solar energy systems, but these benefits may not provide sufficient financial incentive to motivate the investment. In an even more negative scenario, the owner-developer, rightly or wrongly, may perceive that this technology and its associated costs will adversely impact the sale of the property and may actively avoid the investment.

Evaluation

Speculative building developers often base design and investment decisions on first costs only. Future operating costs, including energy costs, may be considered in the financial decision-making process if the building is owner-occupied, or if a potentially lower energy bill can be used as a marketing attraction.

Given that BIPV systems are capital-intensive investments with low operating costs, in most instances the long-term owner-occupant is best positioned to reap benefits from a system and, therefore, is the most likely investor.

2 Benefits of BIPV Systems

The value of BIPV systems can directly affect the decision making process. These benefits can be identified and evaluated based on direct economic impact, indirect economic impact, and qualitative value. These three distinctive categories are defined below and followed with a series of arguments which benefit the application of BIPV. Numerous international examples are presented.

Direct economic impact
An integrated building energy system is generally procured through a construction budget. Electricity generated by the BIPV system creates savings that reduce operating budgets. A BIPV system can save the building owner money by reducing construction material costs and electricity costs, enhancing power quality and power reliability, and providing tax credits. The combined savings may accrue in a variety of budgets that will affect the investor's entire fiscal portfolio performance.

Indirect economic impact
Each building owner has a value related to strategic goals, business interests, or organizational mission. With a multifunctional BIPV system, additional costs and benefits may accrue and may be hidden or not obvious, due to accounting methods and the directly and indirectly affected budgets. An organization, for example, may be able to assign a credit or value for BIPV for environmental emissions reduction if they can be quantified, valued, and even traded. However, if an economic effect cannot be captured or understood by, a decision-maker, it is generally not included in the investment analysis.

Qualitative value
Some benefits of BIPV systems are subjective and are difficult to quantify. For the building owner, a considerable value of a BIPV system may be associated with a positive image, public perception, or impact on the built environment when the technology is installed. Table 2.1 summarizes these values according to electrical, environmental, architectural and socio-economic aspects. In these guidelines, these benefits are considered subjective considerations, no dollar value will be assigned to them, but they do impact the value of the BIPV system to the consumer.

Table 2.1: Summary of non-energy benefits which can add value to BIPV systems.

Category	Potential Values
Electrical	KWh generated; kW capacity value; peak generation and load matching value; reduction in demand for utility electricity; power in times of emergency; grid support for rural lines; reduced transmission and distribution losses; improved grid reliability and resilience; voltage control; smoothing loan fluctuation; filtering harmonics and reactive power compensation
Environmental	Significant net energy generator over lifetime; reduced air emissions of particulates, heavy metals, CO_2 , NO_x , SO_x resulting in lower greenhouse gases, reduced acid rain and lower smog levels; reduced power station land / water use; reduced impact of urban development; less nuclear safety risks
Architectural	Substitute building component; multi-function potential for insulation, water proofing, fire protection, wind protection, acoustic control, daylighting, shading, thermal collection and dissipation; aesthetic appeal through color, transparency, non-reflective surfaces; reduced embodied energy of the building; reflection of electromagnetic waves; reduced building maintenance and roof replacements

Socio-Economic	New industries, products and markets; local employment for installation and servicing; local choice, resource use and control; potential for solar breeders; short construction lead-times; modularity improves demand matching; resource diversification; reduced fuel imports; reduced price volatility; deferment of large capital outlays for central generation plant or transmission and distribution line upgrades; urban renewal; rural development; lower externalities (environmental impact, social dislocation, infrastructure requirements) than fossil fuels and nuclear; reduced fuel transport costs and pollution from fossil fuel use in rural areas; reduced risk of nuclear accidents; symbol for sustainable development and associated education; potential for international cooperation, collaboration and long-term aid to developing countries

Source: "Added Value of PV Power Systems", Report IEA PVPS T1-09: 2001

2.1 Building Functions

Building-integrated PV systems are designed to serve more than one function. As a construction material, such as a BIPV glass facade, it is an integral component of the building envelope and generates electricity. Hence, a BIPV system is defined as a multi-functional building material. Recognizing the financial value of displaced building materials, and reducing installation costs, could also improve the economics of BIPV systems. In order to be effective, BIPV products should match the dimensions, structural properties, qualities, and life expectancy of the materials they displace. Standardized construction glass, cladding, and roofing materials can then be easily integrated directly into the built environment.

Example: Identifying Multiple Benefits

A 13.5 kWp photovoltaic-integrated roof was installed at the visitor complex at the Centre for Alternative Technology, located in Wales. In addition to forming a waterproofing layer, thereby saving on the cost of a separate waterproof layer for the roof, the system will save 10,000 kg/year in carbon dioxide emissions. The system will offset 80% of the 7.85 MWh/year of diesel-generated electricity and will give 3 MWh/year back to the grid. (Caddet).

2.2 Promotional and Educational Benefits

A BIPV system may have promotional and educational benefits. Technology demonstration provides education and outreach that correspond with some agencies' missions. If education is the primary purpose of the system, it is the deciding factor in using the technology. The economics of the system performance become ancillary. Cost justification, therefore, may not be a requirement when a technology is used for demonstration.

Example: Corporate Public Relations

A BIPV installation at an environmentally conscious company could be used as part of a promotional campaign. This funds from public relations become available. The value of the installation is identified as a benefit to the company's public relations.

Example: The Leasing Value of Enhanced Office Space

In 1994, a BIPV facade was used to renovate the Ökotec office building in Berlin. The environmental-friendliness aspect of this building technology was used as a marketing tool that seemed to enhance office space leasing. In fact, the Ökotec building is the first new office building in the city to be fully rented out as a result of the attention given to the BIPV façade. The 8,100-m^2 building is almost completely powered by the energy generated by the façade and any excess energy is sold back to the utility grid. According to a May 1996 International Energy Agency (IEA) report, "Despite surplus office area in Berlin, the Ökotec-building was almost completely rented immediately, following several press publications referring to the PV-façade." This benefit could be treated as lost-rent avoided in dollar value LCC analysis, provided the impact of the BIPV system on the probability of renting the space could be quantified. (http://www.nrel.gov/ncpv/documents/seb/seb11.html)

Example: Business-line Promotion

A small family owned business in Schluchse, Germany decided to expand their facilities at Dilger Metallbau GmbH and create a building that would best represent their business. By designing the new building to present their strengths in architectural glazing systems and integrating custom made BIPV modules the owners have opened up many new possibilities in the market place. The building has surpassed performance expectations by gaining an early return on the investment and provides additional revenue sources from an expanded marketplace.

2.3 Thermal Benefits

The energy generated by the BIPV 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 system can be designed according to the building's heating, cooling and delighting loads. For example: the application of semi transparant PV modules in atria is an excellent application of PV: it provides shading, reduces the cooling load, admits daylight and and generates electricity.

Another way BIPV 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 co-generation of a PV/T system provides another contribution to a building's thermal performance. For example, 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. However, technology review studies show that currently no proper technology is available for these medium temperature applications (Leenders, 1998 and Soerensen, 2001).

Example: BIPV Serving Multiple Functions

Multi-functional Covered-Parking Systems - One strategy for reducing the cost of PV systems is to use PV in applications where there is additional value beyond electric power production. In the example of covered parking, structural and land requirements for the PV system are eliminated. For new construction, the PV modules can provide shade and weather protection, resulting in an additional cost credit. In a few applications, the value of the shade may be much higher than the value of the electricity, so the value of the PV system/parking system combination may be as much as 5 USD per watt.

Assumptions:

- 18% of the full capital cost is needed each year for principal, interest, taxes, and insurance
- O&M cost of 0.01 USD per kilowatt-hour (kWh)
- Electricity generation of 1600 kWh/year per installed kilowatt (kW)
- Electricity value of 0.10 USD per kWh
- One kW covers 1.25 parking stalls
- Shaded parking costs 2.00 USD per day per parking space
- Utilization factor of 0.9. That is, assume a parking stall is used only 90% of the time.

Note that covered parking can be very popular at an airport where the climate is extremely sunny and hot.2.00 USD per day is relatively very inexpensive for parking.

Based on these assumptions, the annual value of a 10 kW PV covered parking system is:

Electricity value	1600 USD
Shade/weather protection value	8212 USD
Total annual value	9812 USD

For comparison, the annual cost of a 10 kW installation at 5,000 USD per kW::

Capital costs	9000 USD
O&M costs	160 USD
Total annual cost	9160 USD

A typical cost is about 600 USD for a covered parking stall, or 0.75 USD per watt, assuming 800 watts ac per stall.

(Lepley 1997)

Example: PowerLight's PowerGuard System

Patented by PowerLight Corporation, the PowerGuard System tiles incorporate PV cells backed with insulating polystyrene foam, turning the sun's free energy into usable power while increasing building thermal insulation and extending roof life. PowerGuard works over new roofs and as a retrofit over existing roofs. The system protects the roof membrane from harsh UV rays and thermal degradation for 30 years. It also reduces air conditioning and heating costs with R-19 insulation and roof shading.

Example: Sun Shading in Korea

In Korea, approximately 35% of the country's total energy consumption is used for heating and cooling of buildings. One way to help reduce this number is to design buildings that use sunshading to help reduce the heat gain in the summer, as well as reducing heat loss in the winter.

The first BIPV system in Korea at the Institute of Construction Technology at the Samsung Corporation in the Gihung area, has installed PV sunshade models over the windows of the building, as well as roof mounted PV modules.

Over the course of 1997, data was collected on the temperature differences between the air surrounding the PV module. The results showed that there is a significant temperature difference between the shaded and unshaded modules. (Yoo, Lee, & Lee, 1998)

Example: Cooling Panels and Preheating Air with BIPV

In Europe, the first documented building with a hybrid BIPV/SolarThermal system is the Aerni Fenster Factory in Switzerland. In 1993, the hybrid BIPV system produced 70 % of the combined electrical and thermal requirements of the factory.

The BIPV system is composed of an 8-kW BIPV façade and a 53-kW BIPV skylight system. By cooling the backside of the panels with ambient air, the equivalent of 115 kW of thermal power is captured to heat the factory This significantly increased the economic performance of the PV/solar thermal system. (Posnansky, Gnos, and Coonen).

2.4 Electricity Benefits

The value of electricity generated by a BIPV 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 back up system is installed, the cost of back up fuel, operation & maintenance costs, depreciation etc. must also be taken into consideration when determining the value of BIPV electricity generation. Especially, operation & maintenance can go down seriously when the number of running hours are reduced, by installing a PV system

2.5 Metering

Metering can account for the electricity generated by BIPV systems, or by paying the building owner retail electricity rates or utility avoided cost rates for surplus energy generated by grid-connected BIPV systems. A commercial or institutional building is occupied during daytime hours and generally will consume all the BIPV electricity produced. However, for more than one-third of annual daylight hours, most commercial office buildings and institutional buildings are

unoccupied, and surplus energy may be generated on weekends and holidays. If the energy generated by a grid-tied BIPV system exceeds the energy requirements (power for security, communication, or refrigeration systems) building's unoccupied, the utility company may purchase the surplus electricity at an agreed upon rate. Net billing bills for electricity provided by the utility less the surplus sold back to the utility and credits the difference if the surplus exceeds the electricity purchased. To encourage private investment in renewable energy technologies, net billing may be mandated by regulatory authorities.

The economic value of BIPV metering can be easily identified and measured by the annual or monthly dollar reduction of the facility's energy bill**.** Net billing accounts for the electricity generated by the BIPV system by paying the producer for surplus energy either at retail electricity rates or utility avoided cost rates. Retail rates versus avoided costs can significantly affect the economics of BIPV systems. These two accounting methods, dual metering and net metering, are discussed below.

Dual Metering
In this 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. In practice, the value of photovoltaic electricity is determined relative to coal-fired kWh power. 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. This method does not complement the multi-functional simplicity of BIPV technology.

Net Metering
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.

Net metering benefits the power generator by providing retail rates for surplus electricity. Over the billing cycle, if the BIPV system produces less power than required, the retail rate is paid to the utility. If an excess of power is produced in the billing cycle, the lower wholesale rate or the rate set by the regulatory authorities is paid to the building owner.

In summary, there are two forms of net metering: one, where a standard meter runs forwards and backwards, and another concept where two meters (or a dual counter meter) are involved with one running forward and one backward. Though the one-meter concept is the best by far, one meter running two ways is impossible in countries using electronic meters (e.g. the Netherlands). Even though the power does flow from the PV system to the main, the counter will ***not*** run backwards, essentially meaning that the rate of PV power sold back to the utility is reduced to zero.

Example: Effects of Net Metering on Utility Bill with Solar

Net metering encourages direct customer investment in small-scale renewable energy systems, simplifies interconnection by avoiding meter replacement, improves economics of small-scale renewables, and reduces metering and administrative costs for the utility. (Starrs 1999)

Assumptions:

- 2 kWp solar PV System
- PV system generates 263 kWh/month
- Residence uses 600 kWh/month
- Retail price is 0.06 USD/kWh
- “Avoided cost” price is 0.02 USD/kWh
- PV-to-load ratio is 0.40

Example: Net Metering

State: New York
Eligible Technologies: Photovoltaics,
Applicable Sectors: Residential,
Investor Owned Utilities,
Incentive Type: Net Metering
Date Enacted: August 2, 1997
Expiration Date: none
Legislative Code: 1997 Assembly Bill 8660, Senate Bill 5400

In the summer of 1997, New York enacted a net metering law for residential photovoltaic systems of 10 kW or less. A similar law was vetoed in November 1996 over concerns about interconnection safety issues. New York's new net metering law also includes an income tax credit allowing residential customers to claim a credit of 25 % of the cost of a qualifying PV system. The maximum allowable system size is 10 kW and utilities are obliged to accept customers into the net metering program on a first come, first serve basis until the capacity signed up for net metering equals 0.1% of the utility's 1996 peak demand. Individual utilities, however, can choose to allow a greater capacity to enroll in net metering. At the end of each month, net excess generation is credited toward the following month's bill. At the end of the annual billing cycle, if there is any net excess generation by the customer, consumers are paid the utility's avoided cost for that generation.

2.6 Demand Savings

Demand savings offers an opportunity to maximize the economic performance of BIPV systems. Utilities apply a demand charge relative to the peak energy load for a building. A periodic average reading of the building’s electrical consumption (e.g., every 15 minutes) determines the peak electrical demand. Building-integrated PV 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 realized. Therefore, having no back up storage system, such as a battery bank, may yield only uncertain savings. It should be noted that a back up system will 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 the additional costs.

Under the PV:BONUS Program in the United States the University of Delaware’s Center for Energy and Environmental Policy and the Applied Energy Group have developed a dispatchable

peak-shaving system with battery storage to reduce the time-of-day charges. This system could also be designed and sized to reduce demand charges. It is currently being tested and monitored in five locations throughout the United States.

Additionally, the cost analysis of the peak shaving system conducted by Kiss & Co. Architects (1995) estimates that demand charges may be reduced by 20 % of the PV system capacity.

2.7 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. A power quality problem most likely exists 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 not handle these faults without shutting down or being damaged. Building-integrated PV systems can be designed to augment power quality by serving a dedicated load. Unfortunately, the value of power quality may be difficult to quantify. It can be increased to ride over a brownout if the PV system provides voltage support at the load (Coles et al. 1995).

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 includes batteries, a storage area, controllers, and associated electronics. A BIPV system could similarly 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 benefit of such a system can be expressed as the avoided cost of an emergency back up power source.

Studies have been conducted on the additional value of PV as an emergency power supply for reliability (Byrne 1997, 1994). A device has been designed that can shave peak electricity demand and switch to a UPS system when a power outage occurs. Power quality and reliability are the benefits of such a system. E.g. Wilk et al. (2001) reported on these items, presented electric schemes and an example of the Suglio building in Switzerland (www.suglio.ch). As with demand savings and UPS, additional hardware must be purchased for a reliable power benefit of a BIPV system. The specific battery storage capacity would have to be engineered and sized to meet the building's needs and energy loads.

2.8 Photovoltaics Benefits to Grid-support

The Kerman PV plant on the California utility, Pacific Gas & Electric (PG&E), system is the first and largest plant designed and built to measure the benefits of grid-supported photovoltaics. The plant, designed at 500 kilowatts a.c. and rated by PVUSA at 498 kilowatts a.c., was completed in 1993. Nontraditional benefits consist of externalities from reduced fossil fuel use, local reliability enhancements, real and reactive energy loss savings, deferral of transformer replacement and load-tap-changer maintenance, transmission capacity deferral, and power plant dispatch savings. Table 2.2 summarizes the estimated value of these benefits. Table 2.2 shows nontraditional benefits ranging from a low of 138 USD per kilowatt per year to a high of 214 USD per kilowatt per year. IEA PVPS Task 5 is working on this issue in more detail.

Table 2.2: Kerman Photovoltaic Plant Non- traditional Benefits (USD 1995) (Wenger, Hoff & Farmer, 1994).

Benefit	Definition and Economics Driver	Technical Validation Results	Nominal Estimate (USD per kW/Year)	High Estimate (USD per kW/Year)
Externalities	Generation fuel mix and externality valuation	Offset 155 tons of CO_2 and 0.5 tons of NO_x each year	31	34
Reliability	Postpone planned reliability improvements	Voltage support of 3V per 120V base	4	4
Loss Savings	Reduce kWh and kVAR losses	Save 58,500 kWh and 350 kVAR each year	14	15
Substation	Reduced transformer upgrade expenditures	Transformer cooling increases capacity by 410 kW at peak; extend load-tap-changer maintenance by more than 10 years	16	88
Transmission	Marginal cost of transmission capacity	Increase of 450 kW on peak	45	45
Minimum Load	Marginal cost of keeping peak load-following units on line	90-percent coincidence with peak load-following unit dispatch	28	28
Total			**138**	**214**

2.9 Utility Incentives

A variety of utility incentive, energy conservation, and demand-side management programs were successful during the 1980s. These arrangements provided a win-win scenario in which the consumer reduced energy consumption and the utility controlled its load growth. In the United States, the Utility PhotoVoltaic Group (UPVG) is a non-profit organization funded by the U.S. Department of Energy (DOE). The UPVG comprises over 85 member utilities, and is involved in a wide range of activities that supports the development of PV as an energy supply. The UPVG provides utility and customer incentives, such as cost sharing, to accelerate the commercialization of PV technology.

As the 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 (see: www.greenprices.com).

Some utility companies have rate structures with differing time-of-day rates. Typically, a BIPV 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.

2.10 Utility Incentive Programs

Utility incentive programs may provide innovative financing and contractual mechanisms for energy conservation measures and the implementation of renewable energy technologies.

Incentives may include system buy-down or cost sharing, leasing, financing, hosting systems, and net metering.

Example: Utility Rate-based Incentives

An important market development for photovoltaics is growing in Germany. Rate-based incentives allow the public to install PV systems and recover their investment over time through a per kilowatt-hour payment for clean energy generation. The payback is funded through a low surcharge on electric utility bills.

The first initiative known, dates from 1994 when the city of Aachen implemented a rate-based incentive program. PV investors receive two deutsche marks per kilowatt-hour (1.34 USD/kWh) so that they can fully recover their cost of purchasing and installing the PV system. The 2 DM/kWh, periodically subject to reviews, is paid for twenty years, the average life of a PV system. The surcharge on electricity bills is less than 1 % per kilowatt-hour; which essentially means utility ratepayers are asked to contribute less than half a dollar per month to support clean energy generation and improve the environment. (Solarenergie-Forderverein, 1994)

Although not that many PV installations were installed, the program was followed by a national incentive program in 2000. (see also section 2.13)

Example: Switzerland's Solarstrom Stock Exchange

The original EWZ- Model of the "Solarstrom Stock Exchange" created for the promotion of solar electricity has evolved into a very successful project. At the beginning of 2000, 1570 kW nominal PV power has been installed with 42 PV power plants are under contract, producing a total solar electricity value of 1,200,000 kWh a year.

5700 EWZ customers ordered more than 850,000 kWh of solar power at a current price of 0.65 USD/kWh. Negotiations with suppliers indicate that prices for solar electricity are available below the 0.50 USD/kWh. Cost reduction of 20% for installed PV plants could be achieved due to the EWZ "Solarstrom Stock Exchange" mode. (Ruoss, Taiana, 2000)

2.11 Security

The concern for security can range from petty vandalism to international terrorism. Building-integrated PV technology as back-up power or UPS can play a role in preventing such crimes. Standard UPS systems operate within a brief three-second to three-minute time frame. Photovoltaic systems with accompanying battery storage can provide long-term back up power for days. The value of the PV system providing security, which would not be obtainable by any other means, could offset the current market cost of the system.

2.12 Environmental Benefits

When generating electricity, BIPV systems produce no harmful environmental emissions. A stakeholder can account for avoided environmental costs 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 play 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).

Noise is also an environmental concern that has been addressed by PV and transportation engineers. As part of the infrastructure, noise barriers offer an additional and clever opportunity to integrate PV. The first PV noise barrier was constructed in 1989 near Chur, Switzerland and six more prototypes have been built in Germany and Switzerland as a result of an international idea competition.

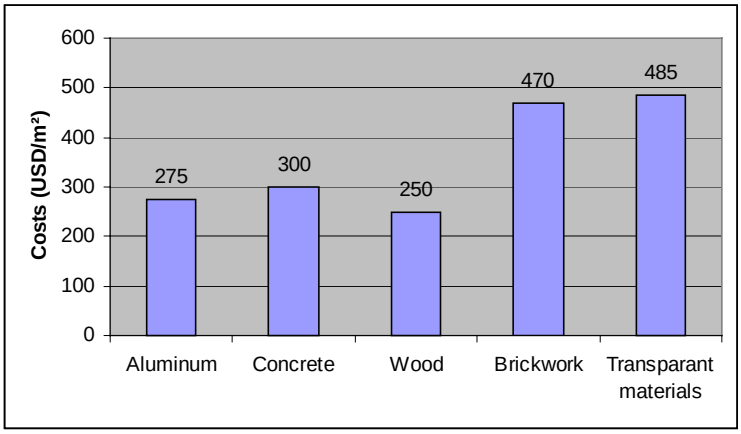
Example: National Environmental Strategies

Australia is incorporating photovoltaic programs into their greenhouse gas reduction strategies and clean air programs. An Australian commercial high-rise PV integrated building illustrated this goal by reporting reductions of 1,640 tons of carbon dioxide per annum. (Wren & Barranm, 2000)

Example: Sound barriers

Figure 3.2 shows the average costs of traditional sound barrier materials in Germany, including labor and engineering. Photovoltaic materials can substitute or displace a considerable part of the costs. The transparent materials may be the most interesting materials to substitute.

Figure 2.1: Average costs of traditional sound barrier materials (Germany, 1996)



Example: Environmental Benefits

The world's largest and most technically advanced rooftop photovoltaic plant is installed on top of the New Munich Trade Fair Center. This grid-connected system, with a peak output of one megawatt, has supplied more than one million kilowatt-hours of electrical energy in the last twelve months. This is equivalent to the annual power consumption of around 340 German households and has meant a reduction in carbon dioxide emissions of 1000 tons per year. (http://www.siemenssolar.com)

Example: Avoided Environmental Emissions Costs

According to DOI, NPS, Denver Service Center Guideline 82-1, in all LCC assessments, environmental emission costs will be part of the analysis. This is applicable to new construction, renovation, and power system replacement. NPS, DSC Guideline 82-1, 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 USD/lb (0.0088 USD/kg), sulfur dioxide emissions to be 0.75 USD/lb (1.65 USD/kg), and nitrous oxide emissions to be 3.40 USD/lb (7.48 USD/kg). (DOI, NPS, Denver Service Center Guideline 82-1)

2.13 National Incentive Programs

BIPV installations are becoming commonplace around the world. The greatest impact by government in the commercialization and widespread use of this technology is through the implementation of national incentive programs for early adopters of the technology. Currently one of the most comprehensive national incentive programs is in the Netherlands. In the Netherlands the government is working with the PV industry, the building sector, and utilities to make PV commercially viable within the next 7 to 10 years. Photovoltaic system costs have fallen from 17 Euro in 1991 to 5 Euro in 2000 as a result of the "PV Learning Program", a 1996-2000 incentive program (Schoen 2000).

Example: National Incentive Programs
Germany

On 25 February 2000, the German Parliament adopted the Renewable Energy Law (REL) for the priority access of electricity from renewable energy sources. The REL combines the elements of the 1990 Electricity Feed Law and a flexible quota on the electricity supplier level. The overall objective of the law is to contribute towards doubling the share of renewable energy in the electricity market from 5 to 10% by 2010. This is fully in line with the targets set in the European Commission's 1997 Renewable Energy White Paper.

By setting specific tariffs for each renewable energy technology based on its real cost, the new law clearly recognises the contribution of renewable energy to reducing greenhouse gas emissions and saving depletable fossil fuel reserves. Its aim is to initiate a self-sustaining market for renewables by compensating for the distortions in the conventional electricity market. Simultaneously it creates critical mass by a significant market introduction programme that does not lead to any additional burden for the taxpayer. Under this framework, renewables are to be made competitive with conventional energies in the medium and long-term. The REL also includes both degressive and differentiating elements, as well as a regular bi-annual revision process which allows for a regular adaptation according to technological and market development. A time limit of 20 years is set for each power plant.

The Challenge of Falling Electricity Prices
As liberalisation and increasing competition have developed rapidly in the German electricity market since 1998, a new concern has arisen for renewable energies. This concern is because the drop in the tariffs paid by consumers has led to a similar decrease in the renewable energy feed-in tariffs (REFITs), which are linked to average electricity prices. The new situation worried financial institutions in particular, but also wind turbine manufacturers, owners and potential developers. Actually, the situation started to endanger the viability of both existing and proposed project, which are moving increasingly inland due to site restrictions in the more windy coastal areas. The government has therefore followed a new approach, moving away from a system where the REFITs are linked to the average electricity tariff and towards a more clearly fixed price based on actual generation cost of the various renewable energy technologies (RETs).

Encouraging Solar, Biomass, and Geothermal Electricity
The new law applies to power generated wholly from any wind, solar or geothermal source; from hydro, landfill, sewage or mine gas plant of 5 MW or below; and from biomass sources of 20 MW or lower. Geothermal is added, and the rated capacity for biomass plant has been raised from 5 to 20 MW.

Solar PV (photovoltaic) systems will now receive DM 0.99/kWh (0.50 €), with a degression of 5 per cent for new installations starting in 2002 which is reflecting the expected costs reduction potential of a technology which is still the least economic of all renewables. A new scheme has to be put in place as soon as an installed PV capacity of 350 MW has been reached.

Grid Connection Costs
For the first time, the costs for grid connection, as well as for grid enforcement and extension, are set in the law on the basis of reliable and fair terms. The costs for grid connection are to be paid by the developer. Transparency will increase because developers have the right to ask an independent third party to take care of the technical connection of the wind farm. The costs for grid extension or reinforcement that might ultimately be required in certain cases, however have to be borne by the grid operator who is allowed to add these costs as a surcharge on the grid fee.

Utilities Eligible for REFITs, too
Another important change compared to previous legislation is the fact that electricity companies will be eligible for the new REFIT rates as well. We hope that this would end their opposition against the renewable energy legislation, and expects an additional market stimulus by widening the scope of the REL.

(Hustedt & Michaele, 2001)

Example: National Incentive Programs USA

The US National Database of State Incentives for Renewable Energy (DSIRE)--through the Interstate Renewable Energy Council (IREC) to survey each of the 50 states for available information on financial and regulatory incentives. These incentives are designed to promote the application of renewable energy technologies. This information is being developed into a database that will detail the incentives on a state-by-state basis. Access is provided to much of the database via the Internet. By providing this information on a wide basis, it will be much easier for other states to get needed information for analyzing and replicating successful incentives in their own states.

The North Carolina Solar Center is the principal subcontractor to IREC for collecting and preparing the information. Some of the financial and regulatory incentives are identified by state, end-use sector, technology, and incentive type. The mechanics of financing and regulatory tools are available in the form of files and documents pertaining to statutes, legislation, fact sheets, brochures, and reports.
In the rapidly evolving power industry, the DSIRE can be the most effective method of obtaining current information. DSIRE's homepage can be found at http://www-solar.mck.ncsu.edu/dsire.htm. The following electronic resources are available: a table of state financial incentives, a table of state programs and regulatory policies, a searchable on-line database, a technical paper on DSIRE, and links for downloading. (http://www-solar.mck.ncsu.edu/dsire.htm 2000)

Example: Environmental Benefits of Solar Energy

As solar energy displaces other energy sources with higher emissions levels, it produces a benefit in the form of reduced emissions of pollutants. The US EPA Solar Power Calculator estimates SO_2 and NO_X emission reduction benefits using information from the Emissions and Generation Resource Integrated Database, which provides data on actual emissions associated with electric power generated by US utilities. Carbon dioxide emission reductions are based on a model that simulates marginal reductions in electricity use. In the calculator, emission factors (expressed in terms of pounds of pollutant per kWh of electricity) are multiplied by reduced electricity use. (http://199.223.18.230/epa/rew/rew.nsf/solar/index.html)

Buy-down Example: California

The 1996 California restructuring law (AB 1890) provided 540 millionUSD into a Renewable Resources Trust Fund supporting renewable generating technologies. This fund will be used to provide rebates or "buydowns" to customers who purchase small-scale renewable energy systems. The amount of the buydown will decline over the life of the program, starting with a block of funds at 3 USD per watt and ending with a final block of funds at 1 USD per watt. If just half of the funds go toward grid-connected PV systems, then California is likely to have 15 megawatts of new grid-connected PV generation in place within five years. This would roughly double the total existing grid-connected PV generation in the United States.

The California Energy Commission is offering cash rebates on eligible renewable energy electric-generating systems through the Emerging Renewables Buydown Program. In the Spring of 2001, the Commission approved an increase in rebate from 3000 USD per kilowatt to 4500 USD per kilowatt, or 50 percent off the system purchase prices (whichever is less). All types of electricity customers are eligible: residential, commercial, agricultural, and industrial. This rebate makes it more affordable for customers to generate electricity using renewable energy. System requirements are:

- The system's electricity production should not exceed 200 % of the site's historical or current electricity needs
- The retailer must provide a minimum five year warranty
- Individuals may install their system themselves, or have it installed by a licensed contractor. The difference is that labor costs of the contractor-installed system can be counted towards total eligible system costs while a "do-it-yourselfer" cannot include his or her labor cost as part of total eligible system costs).
- System components must meet national standards
- Customers may purchase their electricity from any electric service provider, but the proposed site must be within the electric utility service areas of Pacific Gas and Electric, San Diego Gas & Electric, Southern California Edison, or Bear Valley Electric Company.
- Customer must also be and remain connected to the utility grid.

2.14 Loan Incentive Programs

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 subsidizing interest rates, eliminating premium charged by the lender for default risk, allowing favorable repayment terms, or by operating insurance programs at a loss.

An investor or financier may perceive a BIPV system to have a greater risk than traditional grid-supplied electricity. Government can enact legislation that provides the means and opportunity to (1) specify regulations that can minimize the risk associated with a new technology to satisfy the risk assessment requirements of lending institutions and (2) provide financial incentives for building owners to make private investments.

Example: Interest Rate Reduction

A one-eighth point reduction on a residential home loan is available through the Environmental Protection Agency's Energy Star® Mortgage Program (U.S.).

A 20,000 USD BIPV roof system on a 200,000 USD home would result in a reduction of the interest rate on the full 220,000 USD mortgage over the life of a 30-year loan. This results in a savings in the mortgage of approximately 18 USD / month or 6,400 USD over the life of the loan.

Hence, the BIPV installation would reduce not only the homeowner's monthly utility bill, but also the mortgage bill.

Example: The Economic Impact of High Interest Rates

In Edmonton, Canada a capital cost of 0.37 CAN/kWh is charged if spread interest free over a 25-year period, but if a 6% interest rate is included the cost jumps to 0.93 CAN/kWh. PV technology produces high-value electricity and this compares with the residential rate of 0.0715 CAN/kWh in Edmonton.

This high interest cost is in addition to the PV systems cost and installation of 28,000 CAN in 1995 or 12 CAN/W. This number is expected to go down 60% by 2005.

Example: Increased Debt-to-Income Ratio "Stretch"

This ratio compares a borrower's expenses and income to determine the borrower's ability to meet monthly financial obligations. The U.S. Veteran's Administration allows the loan value to be increased up to $6,000 if the increase in the mortgage payment is matched by the reduction in the utility bill. This allows the veteran to borrow more money to install solar equipment. (DOE 1999)

Example: Loan Guarantee

The U.S. Small Business Administration (SBA) provides a loan guaranty program 7(a), which transfers the risk of borrower nonpayment, up to the amount of the guaranty, from the lender to the SBA. The business applying for an SBA loan is actually applying for a commercial loan with an SBA guarantee. The Government will reimburse the lender for any loss, up to the percentage of SBA's guarantee. These types of loan guarantee encourage lenders to provide funds for solar systems even though the lenders are unfamiliar with the technologies. (DOE 1999).

Example: Loan Incentive Programs

Germany's "100,000 Roofs Program" (2000 – 2003) is an example of a loan incentive program. This soft loan is distributed through the federal development bank with a 0% interest rate. The local banks offer the loan to end users while receiving a low margin for their transaction costs and risk approval. The local banks bear the credit risks, but the federal bank can overtake 50% of the total risk by reducing the bank's margin. The program is a ten-year credit with two years of grace period, equivalent to a 37.5% subsidy. This program can be used in conjunction with rate based incentive programs.

2.15 Tax Incentives

Government tax policy determines whether there will be tax incentives. Tax incentives are designed by public policy makers to encourage private capital investments that might not ordinarily occur. Solar 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 systems.

Solar 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. This legislation can be technically specific and disseminate educational and state-of-the-art information about BIPV systems. Federal regulations can reduce the investment risk to the lender and act as a financial incentive for the consumer or manufacturer to invest in the technology.

In general, four categories of taxation incentive programs that may apply to BIPV systems: tax credits, tax rate, tax basis, and taxable entity, will be discussed.

Tax Credits

Tax credits permit a percentage of expenditures to be deducted from the net taxes owed to the government. Taxation parameters are generally divided into federal, state, and local tax obligations**.**

Tax Rate

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).

Tax Basis

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.

Taxable Entity

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 minimize the tax burden.

Examples: Tax Incentives

Property Value
In California, A BIPV system does not add to the assessed property value until the property is sold. (Freedman 1995, SIJ 1993)

Sales Tax Recovery
In Connecticut, sales tax paid for a BIPV system can be recovered when filing an Annual tax return. (SIJ 1993, Freedman 1995)

Accelerated Depreciation
In Texas, a commercial business may apply an accelerated depreciation of franchise tax over five years for businesses that invest in the installation of a BIPV system. (Freedman 1995, SIJ 1994, SIJ 1993)

Reduction in Tax Basis
In Hawaii, the net income tax credit for BIPV systems is 35 % or 1,750 USD Maximum for single family residence, and 35 % or 350 USD maximum for multi-unit buildings, and 35 % for commercial buildings with no maximum. (Freedman 1995, SIJ 1993)

Example: US Tax Incentives

Currently, the U.S. Federal Government allows a 10% tax credit to offset the cost of PV systems in commercial buildings. The (U.S.) 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 systems; however, South Carolina has no such legislation.

2.16 Energy Tax

Apart from tax incentives, one can also induce energy taxes on non-renewable sources. Such taxes exist in a growing number of EU countries (Sweden, Denmark, Germany, The Netherlands); a EU Energy Tax is under debate.

3 Cost of BIPV Systems

Next to the benefits of BIPV, of course costs are important to perform the economic analysis. This section characterizes the relative costs of BIPV systems for the building-owner. Limited objective published data is available on BIPV system costs. A preliminary survey conducted in this research indicates that there is a wide variation in cost estimates provided by various manufacturer marketing representatives. Consequently, a variety of vendor bids should be gathered and reviewed prior to making an investment decision.

The BIPV system cost (technology related) depend on the type and size of system, on current PV technology, and on whether a custom product or a standardized 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 system should be used in economic assessments rather than the full costs, including those that would be incurred regardless of the BIPV system. If, after a preliminary screening, the economics are favorable for a BIPV system investment, a formal bid from the system supplier can be used to evaluate the system cost and benefits in more detail prior to purchase. Subsequently, the total BIPV system cost can be compared to conventional building component costs to determine the added cost of the BIPV system

3.1 Building-Integrated Photovoltaic System Costs

BIPV systems are composed of PV modules and balance of system (BOS) components, which include inverters, an electricity storage system, and/or a grid-metered connection, fault protection, cabling, and wiring. These costs, as well as the costs of integration design and installation, should be evaluated in comparison to the traditional construction products and systems in order to determine the marginal cost of the BIPV system.

Currently, PV manufacturers are in the early stages of technology development and commercialization and do not have the capacity to take advantage of quantity purchases of materials and of large volume production in order to offer lower-priced BIPV components and systems: nevertheless, there has been a decline in the cost of PV technology over time due to technical advances. In addition, the industry and government foresee further cost decreases as the demand for PV technology increases internationally and manufacturing economies of scale increase.

BIPV can be incorporated into new constructions at a relatively small additional cost. When compared to more conventional cladding materials such as glass or steel, installing solar photovoltaics adds only a marginal extra cost, 2 % - 5 %, to the total construction costs of a commercial building.

Example: Cost Comparisons – Traditional PV vs. BIPV

In one study on PV application for commercial building facades, two mounting cases were considered: a standoff technique recently used on the headquarters of IKEA in Almhult, Sweden, and direct mounting into a Kawneer 1600 Wall curtain wall using the PowerWall™ system.

This case illustrates the substantial cost advantages of truly integrated systems. The integrated system saves $1.62/Wp (USD) or 28% over a stand-off system. Not only are the costs of separate mounting structure and installation eliminated, the cost of a normal spandrel infill is also saved, resulting in a credit toward the cost of the PV system of $0.50/Wp. This figure assumes that an inexpensive fritted glass infill would otherwise be used. Some spandrel materials are many times as expensive.

Table 3.1: Cost comparison between stand

(USD/Wp)	Stand-off Facade	Integrated Facade
Modules	3	3
Bos & Installation	1.11	(0.50)
Central Inverter & accessories	1.71	1.71
Total	5.83	4.21

Example: Reducing Cost through Integration

An Australian commercial high-rise building demonstrated the substantial reductions in the cost of solar power generation through the use of a fully integrated design concept. With the price of stand-alone grid-connected solar projects in the order of $0.70 to $0.95/kWh (Australian), this commercial high-rise building realized enormous savings with the integrated design approach, generating solar electricity at the cost of $0.20 to $0.30/kWh. Cost reductions in the order of 60% are attainable through smart integration of solar power systems. This system also produced a estimated operating cost savings of $214,000 per annum and a return of 21.1% on a $1M additional capital investment in energy and water technologies.

Figure 3.1: Reference costs of façade cladding materials (source..)

3.2 Labor Costs

Because of low demand and low manufacturer production volumes in the United States, early BIPV system demonstration projects have incurred high design and final product costs. The time and money required for the electrical and mechanical engineering and the installation methods have been relatively disproportionate to the total cost of the system. (Kalin 1994). The standardization of BIPV building products, and simplification of system engineering, design, and installation methods will most likely reduce labor costs of future BIPV systems.

Currently, and until BIPV becomes a mainstream technology, there is a marginal 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 systems. A manufacturer may supply the BIPV system to the technical supervisor, or a system integrator may be contracted separately. The cost of additional specialized technical supervision over traditional craftsmen should be included when a BIPV system is evaluated.

Example: Reducing Cost of Installation

The New Munich Trade Fair Center's one-megawatt rooftop PV plant was built in a record time of seven weeks. The key to the rapid installation of the 7,812 solar modules was the successful use of a new installation system with shockproof connectors. The solar modules that were manufactured in Munich were delivered to the installation site pre-cabled, allowing for rapid installation and safe electrical connection.

3.3 Maintenance Costs

Maintenance costs can be significant in determining the long-term cost effectiveness of an investment. In lieu of including a major capital replacement as a standard item in the financial evaluation, the analysis may instead include maintenance costs deemed sufficient to keep the system operational over the time horizon of the decision-maker. Alternatively, system replacements may be included in the analysis. For the purpose of this guide, it is assumed that all repairs and replacements will be treated as part of maintenance costs. As in the case of other costs, maintenance costs should be treated in terms of the added maintenance costs attributable to the BIPV system, rather than the total building maintenance costs. The BLCC model includes a provision for maintenance costs.

Manufacturers recommend periodic systems checks and cleaning as part of a preventive maintenance routine. This includes regularly clearing away any debris and cleaning the PV surfaces exposed to the environment, which should be completed more often if the environment is particularly dirty. To determine the optimal cleaning schedule, the trade-off between the cost of cleaning the system to maximize power output and the value of the lost electricity without cleaning the system can be assessed. In some instances, particularly in high-rises or buildings with unusual geometric shapes, cleaning the system can be more costly than the reduced power output. As a rule of thumb, visual inspection of essential components, based on an inspection checklist provided by the manufacturer, should be made every six months. Molenbroek et al. (2000) present some clever schemes to assist PV system owners to evaluate the performance of their system.

The utility meter and bill can be reviewed monthly to determine whether output from the system is dropping (adjusting for seasonal or other mitigating factors). Further investigation is warranted if this simple screening indicates poor system performance.

Annual detailed electronic testing is recommended. The string voltage can be tested with a voltmeter. (A string that shows low voltage relative to the others may have a faulty module or connector.) A data logbook should be maintained by the facility maintenance personnel to record system performance, maintenance, and string voltage. Service adjustments and repair can be provided by the manufacturer, system integrator, distributor, or potentially by the utility company. For small, residential systems this might be quite costly, whereas for larger commercial building systems is might be very appropriate.

The labor costs for maintaining the system should be included in the economic analysis. Means Facility Construction Cost Data can be useful for estimating labor costs. Using the current Means Data, for example, will result in an annual salary of $26.60/hr for a facility services engineer to maintain the system. The projected maintenance costs, at eight hours per year will be $212.80 for a small system (less than 5 kW), $425.60 at 16 hours per year for a medium system (less than 100 kW), and $638.40 at 24 hours per year for a large system (over 100kW). Some manufacturers offer complete turnkey systems as well as optional service and maintenance contracts. Additionally, service contracts or personnel training and maintenance schedules can be negotiated as part of the project contract. Typically, training the facility engineer to service the system in-house will minimize the cost for system maintenance. Maintenance costs may comprise a routinely recurring part and a non-recurring part, each of which can be separately included in the BLCC model.

Example: Labor for Inspection and Replacement

In Gothenburg, Sweden on the south façade of the Energi's head office is a 180m^2 Amorphous Thin Film integrated system. The 570 pieces of the 12Wp modules are mounted on specially designed aluminum profiles bolted to the façade. This technique allows for rapid installation and the possibility to remove individual modules for easy inspection and replacement.

Example: Insurance Costs

In Germany two different insurances, housing and electronic, are important. Housing insurance is required on the PV-plant if the system is installed on the rooftop. Sometimes the insurance company increases the annual insurance rate, in other cases companies only include the new equipment in the contract. Electronic insurance is needed to mitigate the risk to the plant operator in case of environmental damages such as fire, lightning, or explosion, construction, and operation damages. Usually replacement costs at current prices will be reimbursed.

3.4 Utility Interconnection Costs

Utility interconnection costs are associated with the specific requirements determined by each state. State public utility companies have widely varying attitudes toward additional requirements and their requirements vary. 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. The cost of these requirements offset to some extent the incentive provided by net metering and may deter customers—particularly small power customers-- from participating.

A set of uniform interconnection standards can facilitate the implementation of net metering nationwide, and hopefully reduce this barrier of grid-connected BIPV. The renewable industry strives to work closely with utilities and standard-setting organizations in developing such standards.

Example: Utility-Interconnection Requirements for Professional Review Costs

A homeowner in New Mexico recently asked his utility for the forms needed to inter-connect his residential PV system, and received a 36-page contract, not including the requisite exhibits. Faced with the prospect of hiring an attorney and a licensed engineer just to get a 2-kilowatt PV system interconnected, it is not surprising that homeowners like this one frequently abandon their projects at this point. This review by an engineer and attorney can incur an additional 1,000 USD to the project cost.

The solution to the interconnection problem is uniform adherence to interconnection standards developed by recognized national authorities, including the National Electrical Code (NEC), Underwriter's Laboratories (UL) procedures, and Institute of Electrical and Electronic Engineers (IEEE) recommended practices. This can happen through voluntary acceptance by utilities or by legislative or regulatory mandates. (Starrs and Wenger 1998)

Example: Property Tax

In Alberta, Canada a PV system almost attracted an additional $755 annual property tax because it was exporting electricity across a property line. Any equipment that produces such electricity becomes "linear property" and is taxed at the municipality's mil rate. The mil rate for property in Edmonton was 26.96 USD in 1996.

Another striking example of unexpected taxes occurred in Italy and Spain, where under original tax law residential PV system owners were regarded as power producers by the tax department, obliging them to charge VAT over any PV power sold to the utility. (Chivilet, 2000) Task 7 meeting in Stockholm.

Example: Fee for Grid Connection—Australia

In Australia, the Mirvac Village Industry Consortium (MVIC) purchased several 1 kW PV systems to be integrated into 630 houses. Each house has two meters: one to the grid, and one from the grid, priced at 0.1015 AUS/ kWh in each direction. Homeowners are charged a quarterly $15 ($9.6 USD) fee for grid connection.

3.5 Costs Associated with Building Permits

A building permit is required before any construction, addition, moving, or altering 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 may vary from county to county, state to state and country to country. Generally, the fees are based on the estimated cost of construction or square footage. Therefore, permit fees may be increased by the addition of a BIPV system. Contact local land use and building design officials to identify specific project requirements. It is recommended to use only the added permit costs in an economic analysis of a BIPV system.

Governmental Data Services, Inc. (GDS) provides software for complete contractor management, including entering building permits and calculating permit fees. Access to permits is given by address, legal description, owner name, water billing number, water meter serial number, or contact name. (www.fastlane.net)

Example: Permit Fees

TOTAL VALUATION	FEE
0 - 3000 USD	*25.00 USD*
3001 - 50,000 USD	*25.00 USD for the first 3000 USD plus 6.00 USD for each additional thousand or fraction thereof, to and including 50,000 USD*
50,001 - 100,000 USD	*307.50 USD for the first 50,000 USD plus 5.00 USD for each additional thousand or fraction thereof, to and including 100,000 USD*
100,001 - 500,000 USD	*557.00 USD for the first 100,000 USD plus 4.00 USD for each additional thousand or fraction thereof, to and including 500,000 USD*
500,001 - up	*2,157 USD for the first 500,000 USD plus 3.00 USD for each additional thousand or fraction thereof.*

NOTE:
1. Construction cost estimated at 50 USD/ square foot.
2. Shell buildings' fees calculated at 80% of fee schedule.
3. Certificate of Occupancy at 10.00 USD each.

Example: Building Permits in Canada

In Canada the city of Edmonton, having no prior experience with PV systems, required two sets of permits before the installation of a PV array. Because the array weighed 300kg and covered 21m^2 for a load density of 14kg/m^2, the Edmonton Building Inspection Branch required a residential building permit as well as a building development permit to make sure that roof loads and mechanical fastening standards were met. Sketches were submitted showing the PV module layout as well as mounting sketches and a photograph of the site had to be taken before the permits were granted. (Howell 1999)

Example: Building Permits in Germany

In Germany a house-owner can install a PV plant on the rooftop without any permit, if the house is not classified as a national monument. The case is more complex if somebody rents a rooftop for the installation of a PV-plant. This renting procedure must legally be processed and a contract between the house-owner and the renting person must be signed. (Fraunhofer ISE)

3.6 Replacement and Repair Costs

Generally, the life of the BIPV system is specified to last 25 years, and it is presumed that none of the BIPV system subparts will require major replacement or repair during the study time frame, which is also often set equal to 25 years. (Minor repairs and small replacements needed to keep the system operational can be included in maintenance costs.) Of course, this is simply a modeling convention. In some instances, a part (likely, the inverter) may require major replacement or repair prior to 25 years and if preferred, these costs can be included separately in the BLCC model.

3.7 Salvage Value/Costs

As another modeling convention, it is usually assumed at the end of the study period that there is no residual value remaining for the BIPV system and no disposal costs. Again, however, this convention may not best fit the particular circumstances, and residual value and disposal costs can be explicitly estimated and included in the analysis. For example, an exception might arise if the BIPV system is composed of hazardous materials (associated with some thin-film PV technologies), which would require removal and generate significant disposal costs. Also, if batteries must be disposed, there may be a salvage value or disposal cost depending on possible reuse value or cost of disposal.

4 Measurement and Verification for BIPV

This section specifies measurement and verification (M&V) for BIPV systems. Prescribing an internationally accepted guideline for M&V can help to ensure that generation and savings requirements in BIPV systems will be accurately and consistently achieved.

4.1 Protocol Background

The International Performance Measurement & Verification Protocol (IPMVP) was created in 1997 to increase reliability and savings, cut efficiency investment costs, and provide standardization required to secure lower-cost financing in energy and water efficiency projects. The Renewables Subcommittee, composed of leading experts from around the world that share a goal of strengthening and fostering the rapid growth of renewable energy technologies, have laid the groundwork for extending the success of the IPMVP to include renewable energy technologies. The Renewables Chapter provides an industry consensus framework to measure project benefits that are important to realizing the promise of renewable energy.

4.2 Objectives

M&V may have several objectives from the earliest stage of renewable energy project development through the operation of the completed system:

- M&V can provide load profiles and information needed to establish project feasibility.
- M&V can serve as a commissioning tool to confirm that systems were installed and are operating as intended.
- M&V results may serve as the basis for payments to a financier over the term of a performance contract -- an alternative financing mechanism in which an energy service company guarantees that after energy measures are installed at a facility, energy cost will be reduced. In many respects, the success of a performance contract project hinges on verifying that the energy cost savings closely match that which was guaranteed in the solicitation.
- Data gathered from an M&V protocol can provide ongoing diagnostics and help sustain system performance and benefits over time.
- During financing contract development, a defined, accepted, and proven M&V protocol helps increase customer comfort and reduce transaction costs by facilitating negotiations.
- Finally, an M&V protocol is helpful to secure the full financial benefits of emissions reductions, such as emissions trading. In order to establish compliance with Emissions Reduction Targets, a regulating body will need to adopt a protocol for measuring emissions reductions.

M&V should be scaled to the value of the project. The value of the information provided by a project's M&V procedures should be proportional to the value of the project. The objective is to minimize 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. In general, the allowable relative error in an M&V program will be negotiated between parties, with all parties trying to minimize total cost. As a rule of thumb, M&V costs should fall within 3 %-10 % of typical project cost savings.

4.3 Options

An M&V program should be designed to measure and verify the specific performance claims of the deal or what the supplier is claiming to deliver. The M&V options may be classified into four general categories. They can be used individually or in combination, as complexity of

performance and cost factors dictate. These options are not necessarily listed in increasing order of complexity or cost. For example, inspection can be more or less costly than metering, depending on the application. The options follow:

Option A: Measured Capacity, Stipulated Performance -- engineering estimates based on system specifications are used to stipulate savings, and then the system is initially inspected to ensure that equipment was installed according to those specifications. The system is then periodically inspected to ensure the system is operating properly.

Option B: Measured Production/Consumption – long-term measurement of energy delivery over the term of a performance contract by directly metering building output, or indirectly by determining savings based on analysis of end-use electric or gas meters.

Option C: Utility Bill Analysis -- inferring savings by the statistical analysis of whole-facility energy consumption without end-use metering of the system.

Option D: Calibrated Models -- predicting the long-term performance of a system by calibrating (renormalizing) a computer model based on data from a short-term test.

Example: Measurement & Verification

"The U.S. Department of Energy's Federal Energy Management Program evaluated the energy and daylighting performance of a 1250-Watt BIPV power system at the Thoreau Center for Sustainability located at the Presidio of San Francisco, California. System performance parameters (dc output, ac power output, interior light level, and array temperature) were measured along with environmental conditions (ambient temperature, wind speed and direction, relative humidity, solar insolation). A computer model of the system was then renormalized to provide the best match with the measured performance. To estimate energy delivery, the calibrated model was fed TMY [typical meteorological year] weather data, which takes into account array orientation, shading and reflection off the building, and the actual in-situ performance characteristics of the array and inverter."

Azerbegi & Barker,

4.4 Importance of Measurement and Verification

Actual M&V results of existing projects based on the International Performance Measurement and Verification Protocol (IPMVP) can prove success and provide developers, investors, lenders, and consumers with more confidence in the value of future projects. It is the intention of the IPMVP Renewables Subcommittee that the new chapter of the IPMVP provides the renewable energy community with a valuable tool for the implementation of more renewable energy projects. As innovative renewable energy financing increases worldwide, so will the need for the IPMVP and its internationally standardized framework.

The IPMVP is available in a variety of formats at: http://www.ipmvp.org/.

5 Evaluation

As shown by the numerous variables influencing the economic assessment and the various examples, one can conclude that the international BIPV market is divers and rapidly developing. The examples show that various niches on the market are under development and / or being developed.

The report reflects an extensive list of economic factors, relevant for an economic analysis, so that the report can be used as a guideline to perform an economic analysis of BIPV systems. No general quantitative data could be presented of *the* cost and benefits of BIPV. However,

The (brief) outline and evaluation of the various general methods to analyze investment showed their effectiveness for BIPV systems. Naturally, all investment methods can be used to evaluate the BIPV economics (in relation to other techniques). However, for the purpose of designing and sizing BIPV systems, either the net present value method or the life-cycle cost method is recommended as BIPV has the tendency to have increased net benefits and/or leads to reduced (future) life cycle costs.

The criteria for the cost-effectiveness are subjective depending on the investment decision-maker. The most likely investor / decision-maker is the long-term owner-occupant as he / she is best positioned to reap benefits from BIPV systems, as these are capital-intensive and have low operating costs.

The benefits of BIPV cover a broad range of aspects, as there are: multiple (building) functions, electricity benefits, grid-support benefits, control of load growth by utilities (institutionalized by utility and national incentives & programs), demand savings, power quality and reliability, promotional & educational benefits, environmental benefits, shading and thermal benefits, security. Each of these topics are addressed, if possible with (international) examples.

The costs of BIPV depend on the system technology, utility interconnection costs, labor & installation costs, associated costs for building permits, maintenance costs, costs for replacement & repair and the salvage costs (or value). Each of these topics are addressed, if possible with (international) examples.

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Remote Power. http://www.nrel.gov/ncpv/documents/sweden.html

7 Appendix A – Acronyms and Abbreviations

AEG	Applied Energy Group
AIRR	adjusted internal rate of return
BIPV	building-integrated photovoltaic
BLCC	Building Life Cycle Costs
BLM	Bureau of Land Management (USA)
BOS	balance of system
CEEP	Center for Energy and Environmental Policy
CO_2	carbon dioxide
DOE	Department of Energy (USA)
DOI	Department of Interior (USA)
DM	Deutch Marks
DSIRE	National Database of State Incentives for Renewable Energy (USA)
DSM	demand-side management
EPA	Environmental Protection Agency (USA)
EREC	Efficiency and Renewable Energy Clearing House
ESCO	Energy service company
FEMP	Federal Energy Management Program (USA)
GDS	Governmental Data Services (USA)
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronic Engineers
IPMVP	International Performance Measurement and Verification Protocol
IREC	Interstate Renewable Energy Council USA)
IRR	internal rate of return
Kg	Kilograms
KWh	kilowatt hour
KWp	kilowatts peak
LCC	life-cycle cost
M&V	Measurement and verification
MARR	minimum acceptable rate of return
MVIC	Mirac Village Industry Consortium (Australia)
MWh	Megawatts per hour
MWp	megawatts peak
NB	net benefits
NCPV	National Center for Photovoltaics (USA)
NEC	National Electric Code (USA)
NIST	National Institute for Standards and Technology (USA)
NO_X	nitrous oxide
NPS	National Park Service (USA)
NPV	net present value
NREL	National Renewable Energy Laboratory (USA)
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration (USA)
PUCs	public utility commissions
RWG	Renewable Working Group
SIR	saving to investment ratio
SO_2	sulfur dioxide
TMY	typical meteorological year
UL	Underwriter's Laboratory (USA)
UPS	uninterruptible power supply
UPVG	Utility PhotoVoltaic Group
USD	United States dollars
U.S. State Department	Department of State
Wp	watts peak

8 Appendix B – Glossary

Balance of system (BOS) – BOS is a term used to refer to those components other than modules. BOS includes the power conditioning equipment (inverter and rectifier), array foundation, support structure, sun-trackers (optional), back up power (usually a battery bank), wiring, and electrical system protection devices.

Break-even analysis – A technique for dealing with uncertainty in cost and benefit estimates, which entails determining the minimum or maximum value that a variable can have, and still result in a project whose present value benefits (savings) will just cover its costs. (Note: The time to payback is a measure of break-even life.)

Cost of capital – The rate of return on the next best available use of investment funds. An investor typically uses this rate to establish the Minimum Acceptable Rate of Return (MARR).

Energy savings performance contracting (ESPC) -- Authorized by the Energy Policy Act of 1992 (EPAct), the ESPC option allows energy service companies to assume the capital costs of installing energy and water conservation equipment and renewable energy systems. In the ESPC process, the energy service company guarantees a fixed amount of energy cost savings throughout the life of the contract (up to 25 years) and is paid directly from those cost savings. Agencies retain the remainder of the energy cost savings for themselves. ("Energy cost savings" refers to any reduction in utilities at a federal building.)

First-cost approach – Selecting among alternatives based on which has the lowest up-front costs.

Life-cycle cost (LCC) – The sum of time-equivalent costs of acquiring, owning, operating and maintaining a building, system, or equipment over a designated study period. Comparing LCCs of alternative building designs, systems, or equipment that equally satisfy functional requirements is one way of choosing among them on economic grounds.

Low-E (low-emittance) coating or glazing –Microscopically thin and virtually invisible metal or metallic oxide layers deposited on a window or skylight glazing surface, primarily to reduce the U-factor by suppressing radiative heat flow. A typical type of low-E coating is transparent to the solar spectrum (visible light and short-wave infrared radiation) and reflective of long-wave infrared radiation.

Marginal (or added) cost – The difference between the total building system cost with and without the added photovoltaic system.

Marginal cost of capital—The rate of return on the nest-best available use of investment funds. An investor typically uses this rate to establish the discount rate and the minimum acceptable rate of return.

Minimum acceptable rate of return (MARR) – The minimum percentage return required for an investment to be economically acceptable.

Net benefit analysis – The net difference between two (energy) systems, taking into account the relative benefits and costs, expressed in present or annual value dollars.

Payback after taxes – This includes and evaluates marginal tax rates and depreciation schedules.

Payback period – The minimum time it takes to recover an investment. The "simple payback period" for an energy system is the total investment cost divided by the first year's revenues from energy saved, displaced, or produced.

Savings-to-investment (or benefit-to-cost) ratio – A ratio of savings to costs, or benefits to costs, for one building design, system, equipment, or strategy versus an alternative.

Time-value of money – The time-dependent value of money arising from price inflation/deflation and from its earning potential over time.

9 Appendix C – Methods of Assessing Capital Budget Decisions

Methods of Financial Analysis

Method Financial Analysis	**General Formulas**: All costs expressed as present value	**Selection Criteria**	**Benefits**	**Disadvantages**
Discounted Payback Period (DPB) Minimum time it takes to recover an investment	**DPB = Find Y, such that** $\mathbf{Y \sum (E_J - M_J - R_J + S_J) = P}$ $\mathbf{j=1}$ Y = summation from years 1 to Y E = reduction in electricity costs in year j M = differential maintenance and repair costs in year j R = differential replacement costs in year *j* S = differential salvage value in year j P = differential purchase and installation costs	Payback period is less than the project life	a) Simple payback is a quick screening tool	a) Only indicates when the system is paid for. This does not provide long –term evaluation of energy performance b) If simple payback, only accounts for investment costs, not comprehensive c) Investments with longer payback periods may yield greater returns
Net Benefit (NB) Analysis (B-C) Benefits net of costs expressed as an initial lump-sum amount.	**(B-C) = E-(P-S+M+R)** E = reduction in electricity costs P = differential purchase and installation costs S = differential salvage value M = differential maintenance and repair costs R = differential replacement costs	NB>0	a) Useful when there are multiple kinds of benefits and not just cost avoidance. b) Provides long-term evaluation of system performance. c) Good for designing and sizing systems.	Not always reliable for comparing one investment opportunity with other non-mutually exclusive opportunities.
Savings-to-Investment Ratio (SIR) Numerical ratio that represents how many times savings exceed costs, over and above compensating for the time value of money.	**SIR = $\frac{(E-M)}{(P-S+R)}$** E = reduction in electricity costs M = differential maintenance and repair costs P = differential purchase and installation costs S = differential salvage value R = differential replacement costs	SIR>1	a) Can be used to determine the cost effectiveness of a project. b) Can be used to rank projects when there is a limited budget	a) Ratio may change depending on which amounts are placed in the numerator or denominator. b) Does not directly show magnitude of net savings in monetary terms.

Method Financial Analysis	**General Formulas**: All costs expressed as present value	**Selection Criteria**	**Benefits**	**Disadvantages**
Adjusted Internal Rate of Return (AIRR) Measures annual yield from a project assuming reinvestment of interim proceeds at the MARR.	**AIRR = Find the nth root of the ratio of the terminal value of all cash flows (except investment costs) to the present value of investment costs and subtract 1** AIRR = (TV/PVI)1/n – 1 TV = terminal value of all cash flows Except investment costs PVI = present value of investment c Costs 1/n = n^{th} root of the ratio of TV/PVI	AIRR must be equal to or greater than the investor's minimum rate of return	a) Measure of cost effectiveness b) Ability to rank non-mutually exclusive projects when there is a limited budget.	Does not directly show magnitude of net savings or benefits in monetary terms.
Life-Cycle Cost (LCC) Present value sum of costs and benefits over life of a system	**LCC = P-S+M+R+E** P = purchase and installation costs S = salvage value M = maintenance and repair costs R = replacement costs E = electricity costs	Compare LCC among mutually exclusive alternatives. Minimum LCC LCC1 < LCC2	a) Cost effective measure b) Can be used to design or size a system where costs predominate c) Best for cost-focused decisions d) Can be used for qualitative trade-off analysis (e.g. is increasing LCC by a certain amount worth gaining a certain quantity of avoided emissions e) Comparison of two alternative LCCs yields net savings of the low relative to the high	Not sufficient for ranking among projects when there is a budget constraint

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