Improving Economic Benefits in the Management of Multifamily Housing Using Solar Energy Conservation Strategies

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Abstract

With a shift from large, central power plants to smaller generating facilities, small renewable energy systems (SRES) are viable due to the coincidence of several events: 1) deregulation of the electric utility 2) development of BIPV roofing systems, and 3) federal and state tax credits. Roof mounted modules have been tested and used intensively, as seen in the solar roof programs around the world. However, despite the currently available technology, efforts to integrate PV systems into roof system have been minimal. Previous research shows that multifamily housing complexes are ideal candidates as small power producers (SPP) due to their 1) flexible roof configurations, 2) high percentage of roof area and 3) rent base management structure. Projected to provide up to 70% of a building's electric demand, integrated PV fenestration can offset the overall utility costs and produce energy that can be sold to the building's tenants. This paper presents findings from student centered research of a prototypical study of multi-family housing utility subsidiary that sells renewable electric energy produced by integrated photovoltaic roof systems to the tenants. The results show significant economic benefits while increasing the building's energy conservation.

Introduction

Projected to provide up to 70% of a building's electric demand when designed for their optimal energy production, research and application of building integrated photovoltaic (BIPV) systems integrate electricity producing building products to replace traditional building materials (Ashley 1992). Converting sunlight into electricity, these systems offset the energy use of the building while serving as weathering skin, sun shading, and roof and window systems. Because they provide a viable alternative and renewable method for generating electric energy, BIPV systems improve and secure our economic growth by reducing our dependence on non-renewable energy that we ourselves do not control.

Government Policy and Support

With a shift from large, central power plants to smaller generating facilities, small renewable energy systems (SRES) are viable due to the coincidence of several events: 1) deregulation of the electric utility 2) development of BIPV roofing systems, and 3) federal and state tax credits. The proposed SRES will convert solar energy into electricity and remain under the 100-kilowatt capacity limit set forth by the Federal Energy Regulatory Commission (FERC). It is important to remember that the Public Utility Regulatory Policies Act (PURPA) of 1978 and the Energy Policy Act (EPACT) of 1992 deregulated the sale of electricity and required the owners of transmission facilities to provide independent suppliers with open access to the electric grid to transmit power to wholesale utility customers (King 1996).

Roof mounted modules have been tested and used intensively, as seen in the solar roof programs around the world. However, despite the currently available technology, efforts to integrate PV systems into roof system have been minimal (Bendel et al. 1994). In all, previous research shows (Sylvester 2000) that multifamily housing complexes are ideal candidates as Small Power Producers (SPP) due to their 1) flexible roof configurations, 2) high percentage of roof area and 3) rent base management structure. In this case, SPP building owners, can value their PV generated electricity by offsetting the overall utility costs or by selling the energy back to the tenants as their energy provider, which can set forth in the lease agreement.

The unique value of the SPP building owners are seen in the 1) reduced investment costs, 2) their impact on energy conservation, and 3) their sustainability. With life expectancies of 30 years and warranties of 20 years, PV building products create clean renewable energy at the point of demand that integrate with the existing utility and electrical systems of the building. Further benefiting the building owner, state agencies permit the use of PV technologies to reduce the energy consumption of the building to levels acceptable by the prevailing state energy codes. To value this technology, Federal Investment Tax credits for solar property, also known as a Business Energy Tax credits, have been established as a part of the Energy Policy Act of 1992. This act allows an investment tax credit of 10% to commercial entities on the portion of the investment in solar property that is not subsidized by other financial institutions. Although the tax credit cannot exceed the total tax owed in any one year, credit not allowable in one year may be taken in other tax years.

In addition, an accelerated depreciation schedule can be used by any commercial entity that invests in a qualified solar property (U.S. Code Citation: 26 UCS Sec. 169). The actual deduction schedule is a Modified Accelerated Cost Recovery System (MACRS) five-year depreciation schedule that uses a 200% declining balance method.

To significantly increase the use of clean and renewable resources, President Clinton announced the Million Solar Roofs Initiative for the United States in 1994. Working with businesses and communities, the U.S. Department of Energy is coordinating the installation of solar panels on one million new roofs by the year 2010. The President's program targets: 1) electric utilities and energy service organizations, 2) PV manufacturers and PV infrastructure organizations, 3) community, city and corporate personnel, 4) community development organizations, 5) residential and commercial real-estate developers, 6) architects and energy consultants and 7) local and regional financial institutions (UPG, 1997).

Likewise, the Department of Energy promotes partnerships between the public and private sectors to lead to sustainable utility PV markets (UPG, 1997). The Technology Experience to Accelerate Markets in Utility Photovoltaics (TEAM-UP) program funds ventures that develop sustainable markets and opportunities for PV applications. It also funds programs that take advantage of business opportunities with PV technologies and supports the expansion of utility PV markets through collective market actions or pre-commercial installations. With continued support from the government and increased public awareness, the use of PV systems is expected to increase and expand into new applications.

Sustainable Renewable Energy Production

Few technologies can be considered to create electricity for small power producers. As rival technologies to BIPV roof systems, wind power and fuel cells are the only two other viable candidates. More importantly, these technologies have inherent limitations that restrict them to rural and coastal regions of the country in the case of wind, while fuel cells are limited by their current high costs and chemical conversion requirements. Furthermore, neither technology exists as a building product that replaces traditional building materials and subsequently offsets the cost of the building's construction.

The three most important steps that must occur are the development of 1) a comprehensive energy prediction method, 2) design and implementation protocols, and 3) system operation and maintenance procedures. In the planning and design of buildings, predicting energy consumption is a primary determinant of their feasibility that can have performance protocol as seen in the California Energy Code and the newly passed Texas Energy Codes. Although buildings using BIPV systems have been constructed for decades, our ability to simulate and predict the dynamics of these systems is relatively new. Moreover, our current inability to isolate known phenomena, such as reduced electricity demand charges that are due to the coincidence of the peak production of PV electricity and the peak consumption of the building, makes it more difficult to estimate, or even predict, the economic benefits of BIPV roof systems as electric utilities. To satisfy existing energy codes when using BIPV roofing products in new construction, a computerized comprehensive analysis method is required to demonstrate, not only the PV electric production, but also the effects of PV fenestration on the building's thermal performance.

Unlike large power producers that generate electricity with an alternating current (AC), BIPV systems produce electricity that is direct current (DC) and require an equal load match when choosing between AC and DC appliances and devices. Many DC devices are more efficient than those that use AC energy. On the other hand, using all DC devices in a home can be more consumptive than an all AC powered home. In lieu of this condition, the DC electricity produced by the PV system can be converted into AC electricity for use by the home. Thus, the disparity lies in the development of an appropriate energy strategy to meet the electricity needs of the building. These energy strategies must develop an appliance rating and load classifications that adhere to the varying programmed activities of multifamily housing complexes. Thus, a modified approach that balances the use of AC and DC electric energy must be developed to provide the most savings.

Case Study Analysis

In our current state of deregulation, multi-family building owners can now increase the earning potential of their real estate by creating small power utility companies that create and sell renewable electricity using BIPV roof systems (Table 1 and Table 2). These cost are estimates and do not include consultant fees that would be incurred to install the PV system. Further analysis is required to include this factor.

Table 1. Comparative Analysis of Roof Costs.

	Total Cost	Roof Costs	Federal Tax Credits	Simple Payback (yrs.)
Traditional Roofing	$4,000,000	$160,000 [1]	NA	NA
PV Roofing [2]	$4,118,853	$278,853 [3]	NA	3.56
PV Roofing [4]		$161,735	$117,118 [5]	2.06

[1] Base roof cost data are based on the banking industry standard for residential structures at 4% of the total estimated construction cost.
[2] Values do not factor federal tax credits.
[3] Values are based on a complex with one hundred units, construction costs of 50$ per square foot, an average unit size of eight hundred square feet, and PV estimates of five dollars per watt at one watt per square foot.
[4] Values associated with this category factor federal tax credits.
[5] A 10% investment tax credit, as well as a 5-year depreciation is allowed for solar property installed on commercial buildings. The total credit was estimated at 42% and applied to the initial cost for this study.

As a small power producer (SPP), the building owner prices and sells his electricity to the tenants or building management agency as their primary energy source. To meet the remaining energy needs of the building's tenants, the owner purchases energy from the local electric utility, which is interconnected with his BIPV system.

Table 2. Comparative Analysis of Annual Energy Consumption and Costs.

	Consumption (kWh)	Annual Energy Costs[1]
Electric Consumption	1,200,000[2]	$112,451
PV Electric Production	836,560[3]	$78,393
Energy from Utility	363,440	$34,058

[1] A fixed rate of $0.092 per kWh was used.
[2] Values for PV roof costs are based on a complex with one hundred units, construction costs of 50$ per square foot, an average unit size of eight hundred square feet, and PV estimates of five dollars per watt at one watt per square foot.
[3] PV F-Chart simulation program (F-Chart Software, Inc., 1997) was used, assuming a two story housing complex with forty thousand square feet of roof area. The cells were simulated at twelve percent efficiency.

The present value of future revenue over twenty years of the case study SPP is estimated at $1.6 million dollars. This value does not consider system maintenance, interest, escalation rates, or investment strategies.

System Operation and Maintenance Procedures

Because of building occupancy patterns that are typical of residential buildings (EIA 1994), there is a high probability that the PV electricity production will exceed the electricity demand of the residences at certain times of the day. However, during the night, there is no PV electricity production and the tenants must rely on the stored PV electricity which can be in batteries are the electric utility grid. As a power producer, the building owners must negotiate a billing structure with the local utility in the case of over consumption. Thus, several issues must be addressed: For the effective use of energy saving features, an operational strategy is necessary to determine appropriate implementation of BIPV technology as the primary electricity source.

With few limitations to the BIPV energy systems, the requirement of light to generate electricity is a dominating factor in the proposed system. That is, there electricity output is dependent upon the intensity of the sun, which result in no output during nighttime hours. It is import to note that the electricity production of these systems can be significantly reduced by shading of adjacent building or trees and that their production is higher when are normal to the sun. Overall, due to the seasonal variations of the sun, an average solar angle is used latitude as the pitch of the roof.

Several phases necessary to validate multi-family PV electric utilities that include a life cycle cost analysis to determine net present value and an internal rate of return of the investment. To conduct this analysis, one must conduct the following studies 1) meter an existing multifamily complex to determine energy use patterns, 2) compare and analyze material costs, 3) determine federal and state tax credits for solar property, 4) compare and analyze operating costs, 5) determine state and federal protocols for renewable energy utilities. The first stage of this validation requires the measurement of the whole building electric energy use of a typical unit, a typical unit cluster, and the entire complex. This procedure aggregates the electrical consumption for the various electrical devices, which include appliances, receptacles, and mechanical systems. This data will allow the development of energy use and occupancy profiles for used within the simulation model.

When using BIPV roof systems, an important benefit is to value the replacement costs associated with an equivalent material, such as metal seam roof or asphalt. It is important to note that the PV retrofit will have additional requirements not included in the base case, which are: 1) BIPV wiring costs, 2) electrical labor costs, and 3) power conditioning costs, if applicable. Offsetting these additional costs, the federal tax incentives for the purchase of solar must be applied. As stated earlier, the tax incentives can affect up to 44% of the first costs using an initial 10% credit and the 5-year depreciation method. In order to determine the operating cost, a calibrated energy analysis of the metered building must be conducted. An alternative case must then be developed by replacing the roofing material only. To compare the thermal performance of the BIPV product Conduct a calibrated energy simulation of the prototypical building using measured energy data. Overall, the simulation must include 1) the BIPV thermal properties, 2) the shading effect by surrounding buildings, 3) the electric energy production by the PV system, 4) the energy simulation of both conditions. A final comparison of the operating costs of the base case and the alternative will determine differences in energy and operation savings. To conclude prototyping, the author recommends the development of a demonstration project for comparison with the simulated conditions.

Conclusion

This study illustrates that BIPV systems are a viable investment for multifamily housing structures providing adherence to local and state energy codes and providing significant revenue that would otherwise be paid to the local utility. However, to resolve current energy regulatory issues, the author recommends the development of calibrated energy simulation data to a constructed demonstration project. Such analyses would develop non-existent data regarding occupancy profiles, energy use strategies, and operating procedures that would be used to determine the appropriate implementation of solar technologies as the primary electricity source. Likewise, a better understanding of the potential to save energy and the economic incentives of

BIPV fenestration will provide valuable information to aid in the development of sustainable buildings and cities. Buildings using solar electric energy will provide continuous renewable energy that would help to achieve municipal goals by assisting in the economic development of cities. Such buildings would also maintain and protect our quality of life by reducing environmental problems associated with inefficient electric energy use. Overall, buildings using BIPV fenestration contribute to our national security by reducing our vulnerability to fossil fuel shortages and price increases that are predicted for the near future.

In addition, this research has been used to increase the students' understanding of the energy consequences of BIPV systems when designing, engineering and constructing energy efficient buildings. With this aim, engineering, architecture and construction science students have conduct sophisticated thermal simulations that have assisted this work. Unfortunately, many graduating engineers, architects and construction managers do not learn these methods. To remedy this condition, this project sought to increased the students' awareness to energy conservation methods and solar engineering technologies at both the graduate and undergraduate levels.

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