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A Summary Report on the Application of Photovoltaic Systems and Metal Roofs

Author

Stephen Barkaszi

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Prepared for:

Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-1127

Prepared by:

Stephen Barkaszi, PE
Senior Research Engineer
Southeast Region Experiment Station
Florida Solar Energy Center
1679 Clearlake Rd.
Cocoa, FL 32922

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INTRODUCTION

A recent resurgence of interest in roof-mounted photovoltaic systems has prompted the Florida Solar Energy Center to assess the current state of the technology from a systems viewpoint. A major part of the system that is often underestimated in the performance and economics of the system is the roof structure. The type of roof can significantly affect both the initial cost of an installation and the life cycle costs.

CURRENT PRACTICES

Fiberglass shingles have been the standard materials for residential roofs in Florida. However, studies conducted by FSEC (Parker, et al., 1995) have shown that even light colored shingle surfaces present significant heat gain to a home due to the low reflectance of solar radiation. These reflectance properties also play a role in the life expectancy of the shingle roof subjected to high sunlight levels and elevated temperatures. A typical shingle roof can be expected to last 7 to 15 years in Florida's climate.

Economic projections for rooftop PV systems on shingle roofs in Florida must include the costs associated with removing and reinstalling the system due to re-roofing activities. These costs can be recurring and can be expected 3 to 4 times over the life span of a PV system installed on an asphalt shingle roof. The experience of FSEC researchers has indicated that the removal and reinstallation of a rooftop PV array requires approximately 3 man-days for an array of 2 kW or less. Thousands of dollars in maintenance expenses are added to the life cycle cost of a system by the required removal and replacement of an array several times over its life span. Eliminating the re-roofing requirement not only reduces costs but also reduces downtime and decreases the potential for damage to the system.

COMPATIBLE ROOFING SYSTEMS

Rooftop PV systems should be installed on roofs with compatible life expectancies to avoid additional costs linked to re-roofing. Two common roofing systems in Florida with compatible lifetimes are concrete tile and metal panels. Both of these materials are very durable, are well suited for the Florida climate, and are aesthetically compatible for residential and commercial applications. Additionally, these materials are often selected in 'green' architecture for their value in cooling energy reduction attributed to the reflectance properties of the surfaces.

Tile roofing has maintained a presence in the Florida market and the tile roof has a life expectancy in excess of 30 years. This makes it an excellent match for rooftop PV applications in terms of compatible life span. However, tile does pose problems in the means by which the PV array is attached to the roof. The mounting system must be connected to the structural components of the roof because the tile itself cannot support the PV array loads (Figure 1).

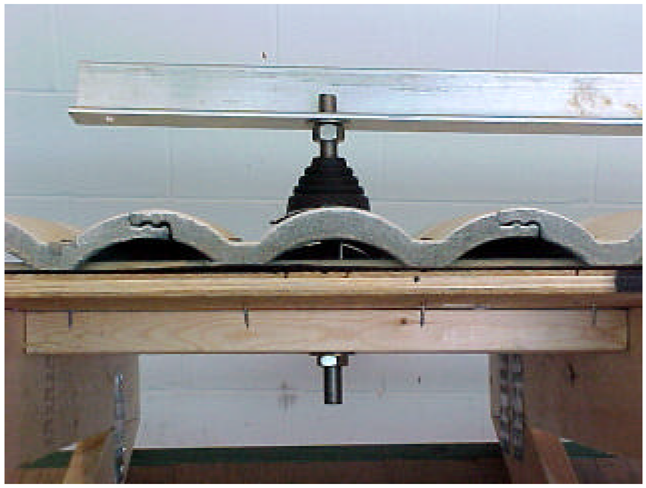

Figure 1. Mounting system for a PV array on a tile roof

A tile roof can also be more costly to install than other roofing systems due to structural requirements to support the weight of the tiles and labor involved in installing tiles. Life cycle costs for tile roofs are typically in line with or are less than other roofing systems. Tile is an excellent choice for Florida homes and for rooftop PV systems; however, the relatively high initial costs may be less attractive for mainstream applications. The costs may be less prohibitive in more expensive homes or commercial construction projects where the added costs are a smaller fraction of the overall cost.

Metal roofing is one of the fastest growing segments of the roofing industry today. Metal is being used in new construction and re-roofing applications for reasons that include aesthetics, performance, and cost. These roofs have minimum life expectancies of 20 to 50 years depending on the type of system selected. Metal roof surfaces can be highly reflective and can provide the performance benefits that tile provides to a building at a lower initial cost. Standard mounting techniques for rooftop PV arrays that are common for shingle roofs can be used with metal roofing systems. Metal roofing does have an initial installation cost greater than shingle roofing, but life cycle costs can be less than half (Chiovare 1997) because re-roofing, disposing of old materials, and re-decking are not required. Cost projections indicate that the 30-year costs for a shingle roof would be $34,800 versus $15,000 for a metal roof on a typical residential home.

PV SYSTEMS AND METAL ROOFS

A metal roof can accommodate a wide variety of array mounting designs. Traditional standoff mounting brackets used for shingle roofs work as well structurally on metal roofs installed over plywood decking (Figure 2). Some of the sealing and leveling problems associated with uneven shingle roofs are less troublesome with metal surfaces, although care is required during the layout to avoid the standing seams and ribs.

Figure 2. Standoff-mounted PV array on a metal roof

Metal roofing also lends itself to a unique mounting system in which the PV material is bonded directly to the metal roof surface (Figure 3). This permits the installation of PV modules to be no more complicated than installing a standing seam metal roof and uses no additional hardware or penetrations for mounting. However the installer must pay special attention to the presence of junction boxes and wiring for proper orientation, access after installation, and safety. Properly installed, the interconnect items and wiring can be concealed under ridge caps or on the underside of the panel. FSEC has limited experience with this relatively new technology and while the concept appears attractive, the performance of the product requires documentation and verification.

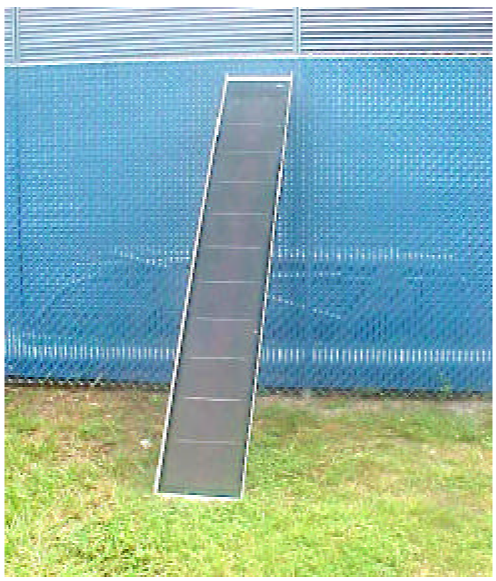

Figure 3. PV material bonded to a metal roof panel

INDUSTRY

United Solar Systems, Inc. (USSC) is currently selling architectural and structural standing seam metal roofing panels with triple junction amorphous silicon PV modules bonded to the metal roof surface. Currently 64W and 128W panels are available in 9.5ft and 18.3ft minimum lengths, respectively. These 16-inch wide panels have a standard profile and can be integrated into virtually any project where a metal roof is specified. The USSC metal roof products are currently produced in Troy, Michigan and are limited to a single manufacturer of roofing materials. Shipping costs of $0.50 to $1.00 per watt add significantly to the installed price of the PV system and are mainly due to the size and weight of the panels and packaging.

Sustainable Energy Systems, Inc. (SES) of Sarasota, Florida has been licensed by USSC to bond the amorphous silicon modules to metal roof panels at their facility. SES is currently in the process of setting up the required equipment and testing the process. This arrangement should be beneficial to customers in the southeast because it lowers the shipping costs of the PV material and permits the use of any metal roof panel manufacturer whose products have been approved by USSC. Initially, SES will verify this proximity bonding process at their facility in Sarasota (in the first quarter of 1999). However, the equipment used for the procedure has been prepared so that it can be transported and the bonding can be performed on site, further reducing costs associated with packaging, shipping, and handling the metal panels.

CURRENT PV AND METAL ROOF PROJECTS AT FSEC

The Florida Solar Energy Center has been conducting research in photovoltaics and buildings research for over 18 years. The benefits of PV for power production and metal roofing for reduced cooling energy use have already been verified for these two components as individual technologies. Current projects at FSEC involve the synthesis of the two technologies to realize the combined benefits for the entire building system and to evaluate new technologies. The following case studies and new projects represent some of the applications for PV and metal roofs.

Training and Display Area at FSEC

FSEC is completing a PV training and display area at the Center's facility in Cocoa, Florida that will demonstrate various rooftop PV applications. Five different roofing materials will be displayed and five different array mounting techniques will be used. The combinations include three different metal roofing systems: 1) USSC amorphous silicon modules bonded to structural standing seam metal roof panels as supplied by USSC, 2) USSC amorphous silicon modules bonded to architectural standing seam metal roofing supplied by SES, and 3) architectural standing seam metal roof with a glass framed module array with typical standoff mounts. Tile and shingle roofs will have arrays installed with different types of mounting hardware (through-bolts, angle brackets, etc).

PV Array Remounting on Metal Roofing for a Residence

A small PV array (300 W_p) was mounted on a metal roof in Cocoa Beach, Florida in July 1998. The PV array had originally been installed in 1992 on the home's existing shingle roof to power a swimming pool pump. The shingle roof was in need of replacement in 1998 and the homeowner had decided to have a white metal roof installed. The PV array, composed of six Siemens M-55 modules, and mounting hardware had to be completely removed to accommodate the re-roofing work. The array was remounted on the roof using L-shaped brackets. The mounts were fastened with screws through the roofing and into wood blocking that was positioned against the decking underside between the roof trusses. Neoprene rubber pads were used to prevent the brackets from puncturing the roofing and elastomeric sealant was used for waterproofing. The homeowner continues to benefit from the PV power and now has the additional benefits associated with decreased heat gains to the home (Figure 4).

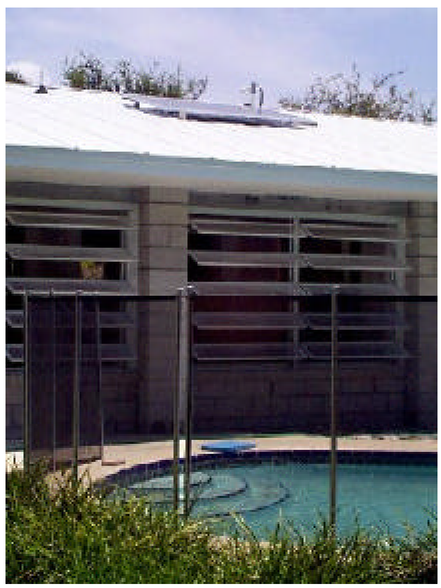

Figure 4. PV array mounted on a white metal roof for pool pumping

The labor required to disconnect and take the array off the roof was 1 man-day. The replacement of the array, installation of new hardware, and verification of system operation required 1.5 man-days. An additional 0.5 man-day was required to install the blocking for the array supports that had not been used in the initial installation. The cost for materials and supplies required for supporting the array, replacing a junction box, and sealing roof penetrations was approximately $100.00. The total estimated cost for the removal and replacement of this small array was $850.00.

The PV array will not need to be removed again during its useful life under normal conditions. This array would probably have to be removed and reinstalled at least once if the roof had been replaced with shingles again. The homeowner indicated that bids were obtained for the different roofing systems and the installed cost of the metal roof was $8,000 versus $5,000 for the 15-year rated 3-tab shingles.

The Disney / Nature Conservancy Wilderness Preserve Visitor Center

An 11,500 acre tract of land in Kissimmee, Florida has been set aside by Disney as a wilderness preserve and The Nature Conservancy manages the preserve. A new visitor's center complex will be constructed as part of the project, with several examples of 'green' architecture being featured. One of these features is a rooftop photovoltaic array.

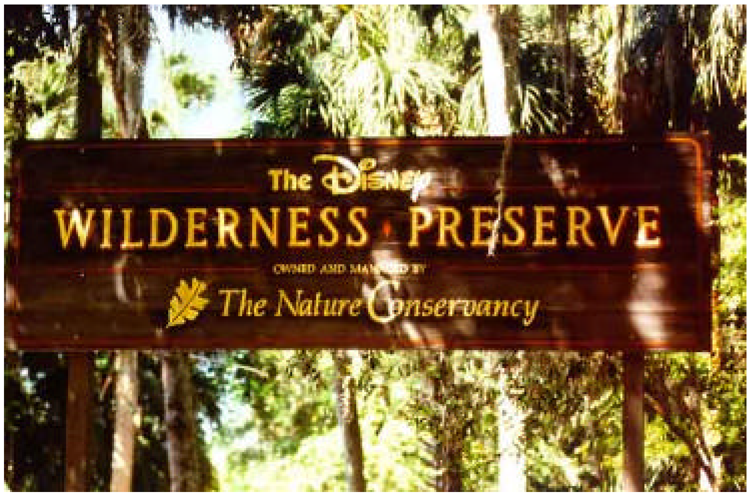

Figure 5. Disney/Nature Conservancy Wilderness Preserve, Kissimmee, Florida

The Disney/Nature Conservancy Wilderness Preserve Visitor's Center design incorporates an array of USSC PV laminate modules integrated with the standing seam metal roof. This project is scheduled to start construction in late 1998 and should be the first large-scale project for proximity bonding of PV material for SES. Funding for the project includes contributions from Disney, UPVG, and private sources. The PV laminate material (approximately 7 kW) will be shipped in bulk rolls from USSC, the metal roofing will come from a supplier in Florida, and the assembly will be completed in Sarasota, Florida. The estimated cost for shipping and handling the PV laminate in bulk form is $0.07 per watt. The completed panels will be transported to Kissimmee for installation on the structure.

FSEC will provide monitoring assistance by installing a comprehensive instrumentation package to collect data from the array and various building parameters. These data will be available to the public through the FSEC web site and a real-time display kiosk located at the visitor's center. The modules will be evaluated for long-term exposure performance and electrical output.

University of Florida Center for Construction and Environment
Summer House Project

The Summer House project is a proposed multi-purpose building at the Kanapaha Gardens in Gainesville, Florida (Figure 6). This project is a collaborative effort between the North Florida Botanical Society, the Center for Construction and Environment and the University of Florida, the Alachua County Government, and members of the local community. The building will be a demonstration of sustainable design practices for North Central Florida with an emphasis on minimizing resource consumption, protection of nature, and minimizing toxins in the environment.

Figure 6. Summer House at Kanapaha Gardens, Gainesville, Florida

The Summer House project has also been designed with the integrated PV metal roofing product as part of the roofing system. The product was selected based partially on the projects architects concerns in regard to sealing the multiple penetrations required by a array using standoff mounts. The project is coordinated by the Center for Construction and Environment and slated for construction in early 1999. This project will be similar to the Disney/Nature Conservancy project in that SES will bond the modules. However, depending on the progress made in using the new equipment at the time of construction, the bonding work may be conducted at the construction site with field lamination further reducing the shipping costs. The 3.2-kW grid-connected array will be installed on several south-facing roof sections that include two different array planes (23° and 34° from horizontal). FSEC will install a comprehensive monitoring system to evaluate system performance. This project is of particular interest to the utility service provider, Gainesville Regional Utilities, as this will be the first utility-interactive PV system tied to the municipal's grid that is not owned by the utility.

RESEARCH OBJECTIVES

Through the above described projects and other future projects, the Florida Solar Energy Center will thoroughly evaluate the technical and economic aspects of PV systems and metal roofing. The compatibility of the two technologies will be assessed in terms of initial and life cycle costs, PV system efficiency, aesthetics, energy production and use reduction, and system installation cost. Potential benefits to different markets such as homeowners and utility companies will be determined and reported.

A performance baseline will be established for the integrated PV laminate and metal roof panel for both power production and durability. Fielded systems will be tested and compared with newly installed arrays to determine changes in output. The bonding of the PV material to the roofing panel will be monitored over time to determine the effects of degradation of the adhesive and the performance of factory laminated panels versus field laminated panels. The labor savings associated with the use of integrated PV will be compared with the labor involved in traditional mounting systems for rooftop arrays.

SUMMARY

Metal roofing systems are a good match for roof-mounted PV arrays for both residential and commercial applications in Florida. The design life of the metal roof matches or exceeds the service life of typical PV arrays and eliminates additional maintenance costs associated with re-roofing. Traditional standoff mounts can be used with ease for framed modules. The new technology of bonded amorphous laminate shows great potential functionally and aesthetically, provided the performance and durability are acceptable.

FSEC will evaluate the performance of PV arrays and roofing systems with compatible life spans through laboratory and field testing. Fielded systems will be extensively monitored, with module, array, and system performance being priorities. FSEC will continue to provide technical support to consumers and to new industry participants such as Sustainable Energy Systems, Inc.

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Parker, D.S., Barkaszi, S.F., Chandra, S., and Beal, D.J., 1995. “Measured Cooling Energy Savings from Reflective Roofing Systems in Florida,” *Proceedings of the Thermal Performance of the Exterior Envelopes of Buildings VI*, DOE/ASHRAE, Clearwater, FL.

Chiovare, T., “Metal Roofing”, Roofer Magazine July 1997: 48 - 49

APPENDIX A

METAL ROOFING ARTICLE FROM ROOFER MAGAZINE

APPENDIX B

SOLAR ELECTRIC METAL ROOFING SPECIFICATION SHEET

APPENDIX C

PV POOL PUMPING INFORMATION

APPENDIX D

DISNEY / NATURE CONSERVANCY VISITORS CENTER

RENDERING AND INFORMATION

APPENDIX E

KANAPAHA GARDENS

PV ROOFING LAYOUT AND INFORMATION