FLORIDA SOLAR ENERGY CENTER®

A Program Plan for Photovoltaic Buildings in Florida

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A PROGRAM PLAN FOR PHOTOVOLTAIC BUILDINGS IN FLORIDA

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INTRODUCTION

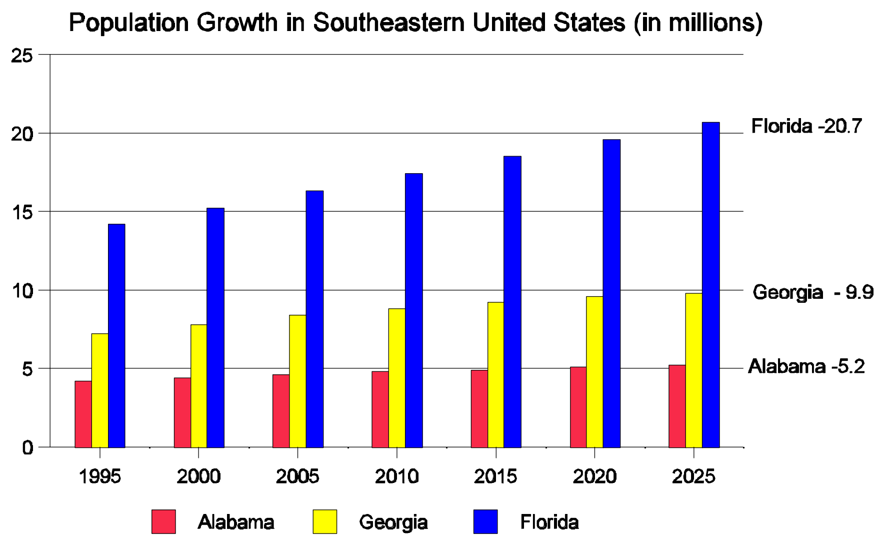
This document outlines plans developed by the Florida Solar Energy Center (FSEC) to support photovoltaic (PV) building applications in the State through the next decade. Implementation of the plan will be a collaborative effort among the Florida Energy Office (FEO) of the Department of Community Affairs, Sandia National Laboratories (SNL), the photovoltaic industry, nine end-user groups, and FSEC. Throughout the document, this plan will be referred to as the Florida PV Buildings Program.

FSEC and other organizations believe that PV building applications represent one of the largest potential markets for renewable energy technologies in Florida for a number of reasons:

- Florida is one of the country's fastest growing states with a large and rapidly growing building construction industry. It also has a significant manufactured building market. The large number of new and renovated buildings in Florida presents an attractive market for photovoltaic building applications, assuming price reduction goals can be achieved.
- Worldwide demand for photovoltaic products is increasing rapidly, resulting in expanded manufacturing capacity and a corresponding reduction in manufacturing costs. These lower manufacturing costs will reduce hardware prices substantially when a better balance exists between supply and demand.
- Utilities are showing increased interest in photovoltaics for both on-site and distributed generation.
- More and more homeowners and building owners have expressed interest in renewable technologies as a means to preserve a greener environment and reduce dependence on depletable resources. They are asking for the option to choose renewable energy resources from the utility's generating mix.
- New interconnection standards, revisions to the National Electrical Code, and testing of inverters to new Underwriters Laboratories' standards will help alleviate utility concerns about safety, equipment protection, power quality, and reliability of service.
- FSEC provides a wide range of technical support services in both PV and building technologies that can be used to produce higher quality system installations.

Despite this optimistic outlook, many questions need to be answered concerning the true costs and value of photovoltaic-generated electricity – questions that this state program plans to answer. The answers will be found by conducting high quality application experiments with targeted user groups. Through these experiments, some of the known barriers to the commercialization of the technology will be reduced, perhaps eliminated, and user confidence will improve. The information gathered will be useful in reducing system costs as well as in assessing value.

The federal government has set a goal of one million solar installations in the U.S. by 2010. Census Bureau population projections indicate that Florida will make up about 5.84 percent of the U.S. population by 2010. Therefore, based simply on population growth, Florida's "share" is approximately 60,000 solar systems, including solar domestic water heating, pool heating and photovoltaic systems. However, because of its sunshine and a strong solar thermal industry, and because of a high level of building construction, Florida is above average when competing with other states in the renewable energy marketplace. Consequently, assuming the national goal is achieved, it is estimated that at least 140,000 solar thermal systems and as many as 20,000 photovoltaic building systems may be installed in Florida by 2010.



Based on U.S. census projections, Florida's population is expected to increase by 46% between 1995 and 2025, well above projected growth in other southeastern states, such as Georgia and Alabama which are projected to grow 37% and 23%, respectively.

Figure 1. Population growth shows that Florida is not only larger, but is also growing faster than most other sun belt states.

To properly prepare for photovoltaic building markets in Florida, the following ingredients are needed:

- Funds to subsidize the cost of PV installations until price reduction goals are met.
- High quality PV systems that meet performance expectations.
- Growing confidence in the value and benefits of photovoltaic buildings by major end users.

The steps involved in identifying photovoltaic building markets in Florida are as follows:

- Establish the financial and technical resources to conduct application experiments.
- Elicit participation of targeted end users in these experiments.
- Conduct the application experiments, collect data, and document lessons learned.
- Based on data and lessons learned, delineate the value and benefits of the most attractive applications.

Program Goals

The four major goals of the Florida PV Buildings Program are:

- Achieve a ***revenue*** stream to support application experiments with photovoltaic building systems.
- Successfully complete a wide range of ***application experiments*** by 2010 as a foundation for developing long-term markets for PV building applications.
- Document procedures for successfully controlling the ***quality*** of installed systems, including component hardware, system design configurations, and competency levels of installation practitioners.
- Provide sufficient data and information for targeted end users to clearly assess the ***value and benefits*** of utility-interactive photovoltaic systems.

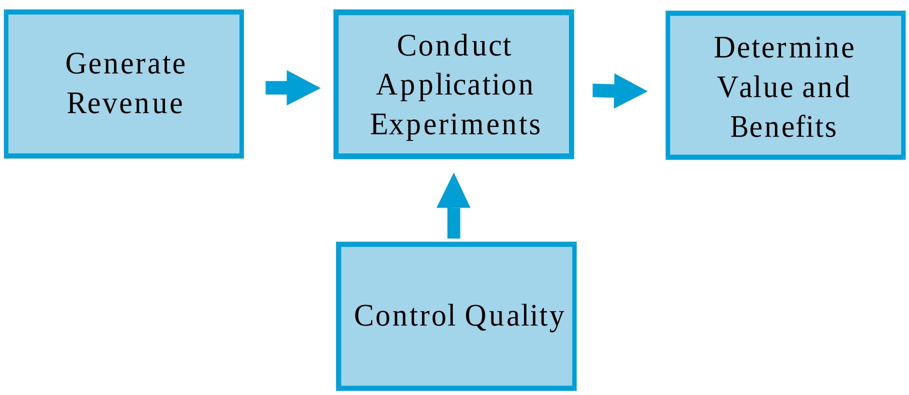


Figure 2. Four key elements comprise the Florida PV Buildings Program.

Program Emphasis

The emphasis of the Florida PV Buildings Program is on identifying and increasing the value of rooftop systems to targeted end users through the use of application experiments. Application experiments are simply PV system installations that are appropriately monitored to provide end users with the data and information they need to assess their value. The program places considerable importance on better quality control of system installations, gathering information, learning, and improving.

GENERATING REVENUE

Sources of Revenue for a Subsidized Market

A prerequisite to developing long-term markets for PV building applications is establishing a revenue stream to subsidize the costs of system installations. Subsidies will be required until price reduction goals are achieved and real markets develop. Sources of revenue for the program include:

- Photovoltaic system buy down (present through December 2001).
- Green pricing (present to 2010 and beyond).
- Buy up by end users.
- Contracts, grants and other subsidies.

Photovoltaic System Buy Down

The Florida photovoltaic buy down is a collaborative effort among the Florida Energy Office, the U.S. Department of Energy through Sandia National Laboratories, and the Florida Solar Energy Center. FSEC will administer the buy down for FEO and manage the application experiments in collaboration with Sandia.

Florida's photovoltaic system buy down is scheduled for three years, beginning January 1, 1999, and is a small but important part of the overall PV buildings program. The Florida Energy Office (FEO) is funding buy downs through the Florida Solar Energy Center. The purpose of buying down systems is to provide startup revenue for PV application experiments. The total amount of funds available is $600,000, of which $525,000 will be used to buy down the cost of PV system installations (i.e., hardware plus labor), and $75,000 will be used for performance monitoring. To complement the buy downs, the U.S. Department of Energy, through Sandia National Laboratories, is funding systems engineering research in the PV buildings area at the Photovoltaic Southeast Region Experiment Station (SE RES).

The typical buy down for a rooftop PV system is $2 per peak watt, based on FSEC module ratings (or equivalent). Installed system prices must not exceed $7 per peak watt. (Note: As a point of reference, data from the Sacramento Municipal Utility District, or SMUD, shows installed system costs of $6.87/Wp in 1995, $6.21/Wp in 1996, and $5.07/Wp in 1998. Their projected installed system cost for 2002 is less than $3 per watt.)

Initially, buy-down funds will be distributed in two ways:

1. Contract awards for projects involving multiple system installations.
2. Rebates for single system installations.

The contract awards will be limited to a maximum of $100,000 and will be for winning proposals submitted in response to a request for proposals (RFP) issued by the University of Central Florida (on behalf of FSEC). The contract funds can only be used to subsidize the cost of the system installations, typically at a rate of $2 per peak watt. Additional subsidies are available for uninterruptible PV building power systems and for systems installed on model homes.

The criteria used in selecting winning proposals are as follows:

- Potential for developing sustainable widespread markets (20%).
- Potential for reducing installation and other non-module costs (20%).
- Number of system installations per request for funds, with preference given to projects with a larger number of installations (20%).
- Unit price of installed systems (20%).
- Capabilities of project team (20%).

Rebates will be made directly to PV system suppliers upon acceptance of system installations that meet all requirements. The PV system supplier must make application for a rebate certificate prior to the installation of the system. The maximum rebate for a utility-interactive rooftop PV system (with no batteries) is $8,000. Thus, for the most anticipated type of system configuration (i.e., one without batteries) with an array output of 4 kW or more, the system supplier (usually the installer) will receive a rebate check of $8,000 after the installed system has passed inspection and acceptance tests. Larger rebates, up to $10,500, are available for uninterruptible PV building power systems and for systems on model homes.

Specific information, instructions, and application materials for both the request for proposals and the rebate certificates are available from FSEC.

To receive buy-down funds (contract award or rebate), the requirements are as follows:

- The installations must be utility-interactive PV systems on buildings.
- The array output must be at least 1 kW at STC using FSEC ratings.
- System designs must undergo design review and approval by FSEC. Only listed modules, inverters, and major components may be used.
- Systems must be installed by licensed solar contractors or electrical contractors. In addition, installation contractors must pass a recently developed examination specifically for utility-interactive photovoltaic systems. To assist contractors in passing the examination and becoming certified installation contractors for participation in this program, FSEC will offer a one-week short course on installing code-compliant, utility-interactive rooftop photovoltaic systems.
- Installed systems must pass acceptance tests prescribed by FSEC.
- Installed systems must comply with all applicable codes.
- Installed systems must comply with all applicable utility interconnection requirements.
- End users must sign an agreement stating their willingness to share performance and reliability data according to FSEC prescribed procedures and formats.
- Installed systems must carry a two-year warranty on parts and labor. In addition, manufacturers’ warranties for modules, inverters, and other major components must be transferred to the end user when the system passes acceptance testing.

- Installed system prices, including parts and labor (but not including the cost of batteries for uninterruptible building power systems), must not exceed $7/Wp.

Green Pricing

The second and by far the most important source of revenue is green pricing. Successful implementation of green pricing statewide is the linchpin of the entire Florida PV Buildings Program. The goal is to raise $20 million from green pricing by 2010. Successfully implementing green pricing involves considerable expense for marketing, promotion, public awareness campaigns and solar project implementation. Investor-owned utilities can request that these costs be included either in their rate base or in the conservation and environmental cost recovery provisions. Several of Florida's investor-owned utilities have implemented or are considering implementing green pricing programs.

Municipal utilities and rural electric cooperatives, which account for approximately 30 percent of Florida's utility customers, generally have fewer resources to devote to green pricing. Consequently, because of its importance to the future of the program, green pricing is being pursued at a statewide level with municipal utilities and rural electric cooperatives. The advantage of statewide green pricing is a consolidation of resources, which will considerably reduce the costs to the participating utilities. For example, core marketing materials can be developed and shared by all participating utilities, who can then customize them for their needs and individual identities. It is a unique strategy in that it brings together players in a highly competitive industry. It is also unique in that considerable technical and implementation support is available at the state level through the Florida Solar Energy Center. Green pricing is long term in nature, can cover all system installation costs, and will produce significantly more revenue than is presently available for the buy down of systems. From a scheduling standpoint, the intent is for green pricing to achieve considerable momentum by the time buy-down funds are exhausted.

Buy Up by End Users

The third source of revenue is "buy up" from various end users. If there is to be an eventual real (unsubsidized) market for different end uses, there is a threshold price at which the technology becomes economically attractive to those end users. For example, $3 per watt might be the threshold price for a municipal electric utility; $4 per watt might be attractive to many energy conscious homeowners; and $5 per watt might be the threshold for a large number of government agencies. Buy up simply suggests that various end users buy up (i.e., pay) their corresponding threshold price. The question is: What are the threshold prices for various end users? Unfortunately for rooftop PV applications, the answers can only be estimated until much better data is available on costs for interconnection, insurance, operation and maintenance, array-roof life cycle, etc., as well as the data confirming the value to the end user of the PV electricity produced over time. One of the main reasons for the application experiment approach is to obtain data to establish costs, value and benefits of PV and building applications. Note that many decisions to procure renewable energy devices may not be based on economic considerations, especially for early adopters of new technologies. For these individuals or organizations, threshold prices may be considerably higher than average.

Contracts, Grants and Other Subsidies

The fourth source of revenue is from contracts, grants and other subsidies, including long-term, low-interest financing. These sources have been extremely important in the past and will continue to play a major role in the future. Examples include UPVG TEAM-UP awards, and a host of funded activities from the Florida Energy Office. Included in the latter are the super energy-efficient PV residence, other utility-interactive rooftop PV systems in Lakeland, and matching funding for the UPVG-supported portable classroom project in Polk County.

CONDUCTING APPLICATION EXPERIMENTS

The Concept of an Application Experiment

As mentioned previously, an application experiment is simply a PV installation that is appropriately monitored to provide end users with the data and information they need to assess the value of the application. Application experiments should not be confused with research experiments normally associated with new and unproven technology. Photovoltaic modules and other system components are highly reliable and well established. However, despite the fact that photovoltaics is a proven technology, answers are needed to many questions associated with distributed applications of utility- interactive systems, such as:

- The effects of distributed generation on utility operations
- Photovoltaic business opportunities for utilities and energy service companies
- The interaction of distributed PV generation and various load management strategies
- The potential for reducing non-module costs associated with PV system installations
- The most effective combinations of building energy efficiency measures and PV production
- Recommended configurations for uninterruptible PV building power systems
- Recommended approaches to building integrated photovoltaics
- The performance of alternative inverter configurations, including micro-inverters

Also, questions concerning the marketability of different PV building applications, and which ones will gain the greatest acceptance, need to be answered.

Finally, there are questions concerning end-user groups, and which ones will most strongly embrace photovoltaic building applications.

The application experiments of the Florida PV buildings program are designed to answer these questions in as comprehensive a manner as possible. The results of the experiments will not only verify technical performance, but they will also provide the data and information needed by end users to evaluate a variety of different applications, and to assess and compare their value. In that sense, application experiments may also be thought of as "value experiments."

Targeted End Users

The Florida program has initially identified nine target groups for rooftop PV application experiments:

- Municipal utilities and rural electric cooperatives
- Commercial building owners and operators
- Government agencies
- School and church organizations
- Manufactured building corporations
- Investor-owned utilities and energy service companies (ESCOs)
- Commercial roofing companies
- Builders and developers
- Homeowners and buyers.

The marketability of rooftop PV systems depends largely on the value end users associate with the technology and specific applications. Consequently, one of the important aspects of the program is to develop application experiments with each of the nine target groups that will allow them to assess value. Developing an application experiment with a particular end user involves:

- Defining the application experiment and the desired outcomes.
- Specifying the roles and required actions of the end user and related groups (e.g., customers of the end user).
- Listing alternative application experiments and delineating tradeoffs.
- Clearly stating the anticipated value and benefits to the end user and related groups.
- Estimating the future economic and business impact of the application.
- Conducting the application experiment and documenting lessons learned.

Note that application experiments will often involve more than one target group. For example, a municipal utility may collaborate with a builder/developer and a commercial roofing company on a project involving multiple buildings with rooftop PV systems.

Using Application Experiments to Overcome Barriers to Commercialization

Studies and surveys have identified some of the key barriers to the commercialization of solar systems. Many of the barriers affect both solar water heating and photovoltaic markets. Often the prospects for overcoming the various barriers depends on the end user. ***Application experiments will produce data and information to reduce or eliminate the effects of the following barriers to commercialization:***

Lack of solar access represents a significant barrier to PV applications for all end users. Sites should be selected that have a clear view of the sun throughout the daylight hours for the entire year, if possible. Photovoltaic arrays do not have as high a tolerance for shading as thermal collectors, and the higher system costs encourage larger solar windows. This barrier can be overcome through proper site selection and surveys.

High first costs represents a major barrier to homeowners, builders, commercial roofing companies, and manufactured building corporations. Each of these end users generally requires a more rapid return on their investment. In working with end users to develop application experiments, one important objective is to identify approaches to reducing non-module related costs of rooftop systems. These costs typically account for about 50 percent of the installed cost of a PV system, with the costs of installation labor being a major contributor. A number of the application experiments, such as building integrated and factory-installed PV, are specifically directed toward reducing system installation costs.

Also important to note is that high first costs may not be a barrier to all end users. For example, commercial building owners do not require as rapid a return on investment as homeowners who know they may move within a few years. Another possibility is that homeowners will not have to pay the high first costs if another end user (e.g., the utility) owns or is providing financing for the system.

High life cycle costs represents a major barrier to all end users. This barrier is significantly diminished for end users who eventually realize a return on their investment. Those end users most likely to consider PV building applications despite the high costs are commercial building owners, government agencies, and school and church organizations. In addition, homeowners and early adopters from other end-user groups who do not make decisions based purely on economics may pursue rooftop PV applications. Application experiments will look at strategies for reducing life cycle costs. For example, we will evaluate the installation of systems on metal and tile roofs, which have lifetimes equal to or longer than photovoltaic arrays. Eliminating the need to remove an array for reroofing may significantly decrease the system life cycle cost.

Costly and cumbersome interconnection requirements represent possibly the most significant barrier to utility-interactive photovoltaic system applications at the present time. Requests for interconnection are usually handled on a case-by-case basis, and may involve costs to review the design, costs to assess the impact on the utility grid, costs for redundant protection equipment, and costs for liability insurance, which may be considerably inflated because of perceived high risk by the insurance industry. Although these costs are largely determined by the local utility, much data will be developed by the experiments to support standardizing the procedures for interconnection so that each request does not require a separate study.

The technical issues associated with interconnection are being addressed by the following standards revisions:

- IEEE P929 draft interconnection standard defines the equipment and functions necessary to ensure compatibility between the PV system and the utility. It is now ready to go to ballot, and is expected to be approved by mid-1999.
- UL 1741 inverter test standard deals with safety issues of grid-tied PV inverters, addressing electric shock hazard, fire hazard and utility compatibility. It will also be available by mid-1999. A utility-interactive inverter that passes UL 1741 will be a non-islanding inverter and satisfy the interconnection requirements of IEEE P929.
- The 1999 National Electrical Code requires all utility-interactive PV systems to use listed inverters that pass UL 1741. In effect, any small utility-interactive PV system in compliance with the 1999 NEC will automatically be in compliance with IEEE P929.

The application experiments should clearly demonstrate that redundant protection equipment to isolate the PV system when the grid is down is not necessary. They should also demonstrate low risk of injury with utility-interactive photovoltaic systems, thus eliminating the need for excessive liability insurance and associated premiums.

Mobility of homeowners and buyers represents a reason not to buy a rooftop PV system, especially if there is no clear indication that the PV system will increase the selling price of the home. Note that this is not a barrier to utilities, commercial building owners, government agencies, or schools and church organizations.

Fear that system performance will not meet expectations represents another reason for homeowners not to buy a rooftop PV system. Most homeowners and buyers do not have the resources to accurately assess the status of a relatively new technology and application. Consequently, many lack the confidence required to make a significant long-term investment in a photovoltaic system. System performance is a function of quality, which includes site selection, system design, component hardware, and competency of installers. Through improved quality control, and as documented results verify that performance does meet expectations, this fear can be eliminated for all end-user groups. Technical support services offered through this program will help ensure the quality of systems and installations.

Fear of component failures and system malfunction and associated costs pose another obstacle to rooftop PV applications, especially for homeowners. Again, this fear will be overcome through improved quality control. Application experiments will provide real experience with typical failures, resulting in solutions and effective ways of handling problems. Greater understanding will lead to well established procedures, standardized designs, and the beginnings of a PV industry infrastructure, which will include highly experienced professional installers.

Costs associated with re-roofing the building represents a major barrier to rooftop applications that is often overlooked and not included in most life cycle cost analyses. A number of the application experiments will investigate durable array-roof configurations. Experience with solar thermal systems has shown that many solar collectors are removed, never to be reinstalled, when the roofing material is replaced. The most common roofing material in Florida is asphalt shingle, which in a warm, humid climate usually should be replaced every seven to ten years. The labor cost to remove a photovoltaic array and then reinstall may be substantial. Just one re-roofing event may significantly increase the life cycle cost of a rooftop PV system. And for 30-year arrays, re-roofing may occur three or four times! Like the renewable energy industry, the roofing industry has compared the life cycle costs of different roofing materials, such as asphalt shingle, fiberglass shingle, concrete tile and metal. Metal roofs are particularly attractive for hosting PV arrays because they last 30 to 50 years, and their life cycle costs are usually less than half that of asphalt shingles. Consequently, a number of the application experiments will involve PV arrays on metal roofs. Tile is another roofing material that will be included in experiments with durable array-roof configurations.

Reluctance to change, while not usually considered a barrier, is certainly a part of human nature that slows the adoption of new technologies. Most people hesitate when faced with change; e.g., opting to buy and install a PV system when they already receive utility supplied electricity. Why should they accept the risk of the unknown, especially if it will cost them more money?

The utilities can play a major role in helping end users overcome this reluctance. For example, homeowners who are ready to embrace the idea of “green power” like the idea of getting a portion of their home’s electricity from renewable resources, but may not be willing to incur the costs of buying a PV system, hiring someone to install it and going through the necessary procedure to have it hooked up to the utility grid.

Nor may these homeowners want the responsibility of maintaining or repairing the system. On the other hand, they may willingly pay the utility an additional $5 per month in exchange for the utility’s owning, maintaining, and repairing the system for them. Everyone wins. The homeowners get a portion of their electricity from renewable resources, at no risk and for a minimal cost. The utility benefits as the system helps offset peak loads, and the state benefits from a cleaner environment. As this scenario becomes more common and becomes less an unknown, people’s reluctance diminishes as well.

In summary, the planned application experiments address all of the identified barriers. These barriers won’t all go away at once and different end users are less encumbered than others in being able to surmount them. This consideration has contributed to estimates of long-term market potential for each end user discussed later in the document. The three end-user groups that can most easily overcome these barriers are municipal utilities, commercial building owners, and government agencies.

Nine Application Experiments

This section describes nine application experiments. The objective of these experiments is to identify and increase the value of rooftop photovoltaic systems and to eliminate or reduce barriers to their commercialization.

1. Distributed Generation

Objectives: Provide utilities with sufficient information to make prudent business decisions concerning investments in photovoltaics technology. This requires experiments with a large number of systems over a sufficient period of time. It also requires time-of-day information on power production.

Alternative experiments:
- Statistically significant experiments
- Multiple systems on a single distribution transformer
- New, retrofit and manufactured buildings

Figure 3. A residential PV system in Lakeland, Florida that is typical in size and design to those proposed for distributed generation experiments.

2. Community Developments

Objectives: Provide utilities with business planning information, including interactions with other demand side management strategies; provide developers with information on the marketability of green communities and reductions in unit labor costs associated with multiple installations.

Alternative experiments:
- Manufactured building communities
- Energy-efficient communities
- Load management (possibly combined with energy efficiency)

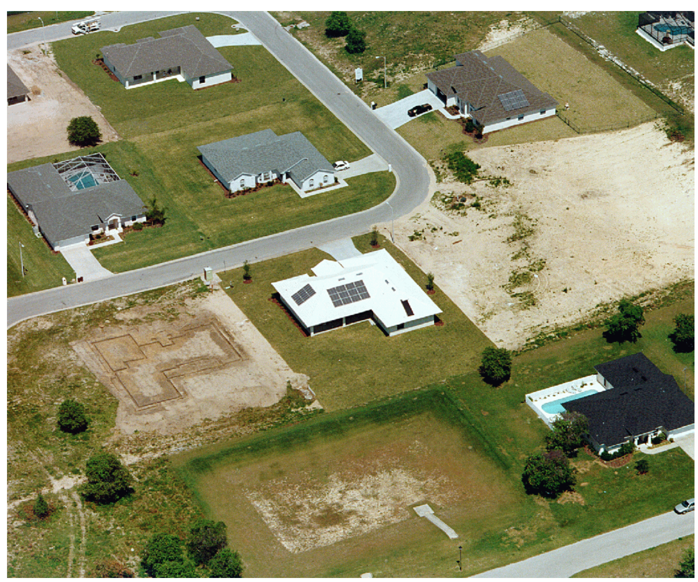


Figure 4. The Woodwind Hills subdivision in Lakeland will have seven residential PV systems as part of the new development.

3. PV and Energy-Efficient Buildings

Objectives: Quantify economic tradeoffs for various energy reduction strategies; determine the marketability of energy-efficient PV buildings.

Alternative experiments:
- Envelope, HVAC, appliances
- Mid-term payback on selected energy-efficiency features
- Energy management by owner

Figure 5. This PV residence in Lakeland combines the best in building energy and photovoltaic technologies.

4. Fault- and Weather-Tolerant Buildings

Objectives: Evaluate the performance and marketability of fault- and weather-tolerant buildings, incorporating PV systems that meet very stringent building code requirements; determine economic and performance tradeoffs for alternative configurations.

Alternative experiments:

- Maintaining electrical power over short term (e.g., 3-24 hours of autonomy)
- Maintaining electrical power over mid term (e.g., 48-96 hours of autonomy) with building structure withstanding building code design wind speeds
- Maintaining electrical power over long term (e.g., 120-168 hours of autonomy) with building structure withstanding 155 mph wind speeds

Figure 6. This 12-kW PV system is designed to withstand a category 3 hurricane.

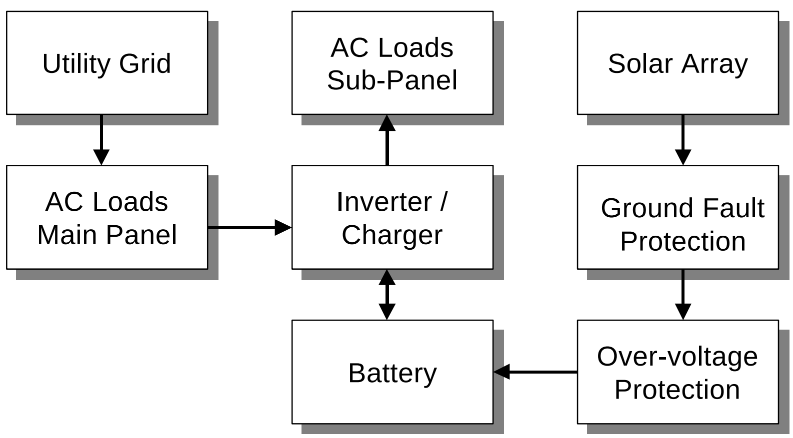


Figure 7. Block diagram for a building power system that provides electricity to critical loads when the utility is down.

5. Durable Array-Roof Configurations

Objectives: Evaluate the performance and life cycle economics of array-roof configurations designed to last at least 30 years.

Alternative experiments:

- Conventional stand-off array on metal roof
- Conventional stand-off array on tile roof
- Other configurations on roofs with at least 30-year lifetimes

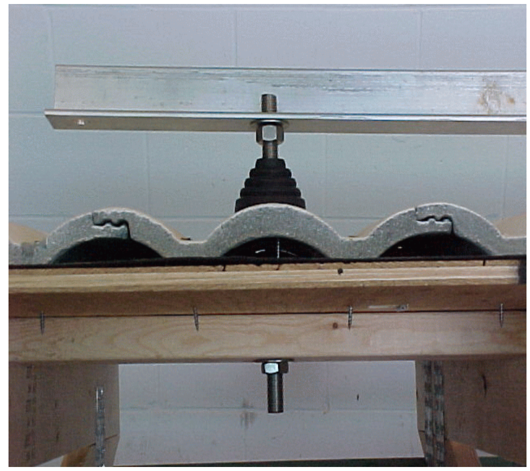


Figure 8. This array mounting configuration eliminates direct loading on the tile roofing material. No re-roofing should be required over the 30-year life of the PV array.

Figure 9. Conventional stand-off arrays mounted on metal roofs may have lower life cycle costs than almost any other array-roof configuration.

6. Arrays Laminated onto Metal Roofing

Objectives: Evaluate the performance of PV materials laminated onto metal roofs; evaluate the integrity of the adhesive bond for on-site and proximity lamination compared with factory laminated modules; evaluate the economic tradeoffs for laminated versus conventional array mounting.

Alternative experiments:
- On-site lamination
- Proximity lamination
- Assimilation of lamination process into normal factory/warehouse operations

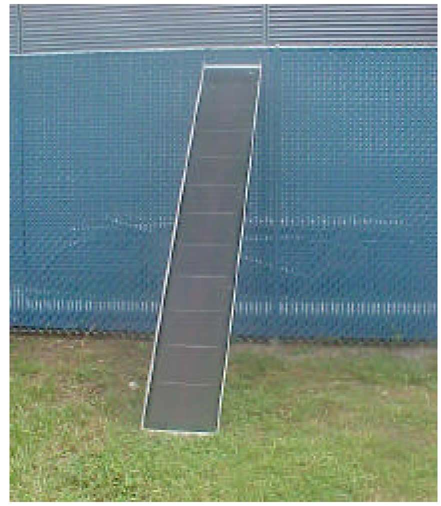


Figure 10. PV material bonded to a metal roof panel. If this bonding process can be done at or near the site of the installed PV system, costs may be significantly reduced.

7. Building-Integrated Photovoltaics

Objectives: Evaluate the economic advantages of replacing conventional roofing materials with PV products; evaluate the installation processes associated with building-integrated PV.

Alternative experiments:
- PV shingles
- PV roof tiles
- Other PV products that replace building materials

Figure 11. This is an example of a building that integrates flexible PV laminates and conventional metal roofing. (Photo courtesy of United Solar Systems Corporation.)

8. Factory-Installed PV Systems

Objectives: Evaluate the reduction in labor associated with factory-installed systems; evaluate the potential for improving quality control in a factory environment.

Alternative experiments:

- Mounting brackets, junction boxes and electrical BOS installed in the factory (array panels and inverter installed on-site)
- Entire system installed and tested in the factory
- Other experiments in a manufactured building plant

Figure 12. Installing all or part of a photovoltaic system on manufactured buildings in a factory environment may significantly reduce non-module costs and provide greater quality control.

9. Alternative Inverter Configurations

Objectives: Evaluate the performance on micro-inverters in warm, humid climates; provide data to support reasonable interconnection requirements and costs, including the cost of liability insurance.

Figure 13. Several different inverters will be used in application experiments involving utility-interactive photovoltaic systems.

Alternative experiments:

- Alternating current (ac) modules (one inverter per module)
- One inverter with multiple arrays (e.g., densely concentrated manufactured buildings)
- Special experiments related to interconnection (power quality, islanding, etc.)

Application Experiments for Targeted End Users

To make the program manageable, the number of application experiments for each end-user group will be typically limited to three, as shown in the table below.

Application Experiments / End-user Groups	Distributed generation	Community developments	PV and energy-efficient buildings	Fault- and weather-tolerant buildings	Durable array-roof configurations	Arrays laminated onto metal roofing	Building-integrated PV	Factory-installed PV systems	Alternative inverter configurations
Municipal utilities and rural electric cooperatives	x	x							x
Commercial building owners and operators			x	x			x		
Government and public agencies					x	x		x	
School and church organizations						x		x	x
Manufactured building corporations			x				x	x	
Investor-owned utilities and ESCOs	x	x							x
Commercial roofing companies					x	x	x		
Builders and developers		x	x	x					
Homeowners and buyers			x	x	x				

Table 1. PV building application experiments for nine end-user groups. This matrix shows that three application experiments are planned for each end-user group.

In the following sections, the nine targeted end users are described in terms of the roles they may play in developing a long-term market for rooftop PV. Each section defines a specific desired action for that end user (e.g., a builder or developer buys a PV system, installs it on the roof of a model home and sells other new homes offering PV as an option). The section also lists the application experiments, the most likely sources of revenue, barriers to commercialization, benefits, and opportunities. Each of the application experiments is designed to address key issues and to reduce or eliminate barriers.

A. Municipal Utilities and Rural Electric Cooperatives

Florida's municipal utilities and rural electric cooperatives provide energy to over one million electric customers, and more than 30 percent of the state's population. Because they are community owned and locally managed, public utilities have an obligation to satisfy the needs and interests of their customers, including their customers' desire for clean, renewable energy sources. The potential for developing widespread markets among municipal utilities and rural electric cooperatives is considered high, assuming price reduction goals are met.

Desired action by end user: The utility buys, has installed, owns, operates and maintains rooftop (and possibly some non-rooftop) photovoltaic electric generators.

Application experiments: Distributed generation; community developments; alternative inverter configurations.

Revenue: Green pricing.

Barriers: Overcomes major barriers of interconnection, mobility, concerns about performance and reliability, and eliminates net metering as an issue.

Benefits: Provides green image; provides customer choice; takes advantage of economies of scale for both hardware procurement and installation; involves small investment at very little risk.

Opportunities: Assess customer response over time; assess the value of distributed generators; assess future business opportunities based on significant data and experience; evaluate synergism between distributed generation, energy-efficient building technologies, load and demand-side management strategies; implement large community projects; promote green image; improve public relations.

B. Commercial Building Owners and Operators

The potential for developing a large market for PV systems among commercial building owners and operators is considered high. Monthly advertising budgets for many within this group, such as national chains like Wal-Mart, K-Mart, Target, etc., are large compared with the cost of small to moderately sized PV systems. And image among customers is a high priority.

Desired action by end user: The commercial building owner or operator buys, has installed and operates a relatively small to moderately sized rooftop PV system.

Application experiments: PV and energy-efficient buildings; fault- and weather-tolerant buildings; building-integrated photovoltaics.

Revenue: Florida buy-down funds; significant buy up.

Barriers: Utility interconnection requirements.

Benefits: Promotes green image; improves public relations; possibly increased sales; high coincidence between PV production and demand; high direct utilization of PV energy on-site; low cost compared with advertising and other budget categories; no risk.

Opportunities: Promote green image in advertising.

C. Government Agencies

The potential for developing a large market for PV and building applications with government agencies is considered high. Government should lead by example and apply capital and operating budgets to demonstrate the value of renewable energy technologies.

Desired action by end user: The government agency buys, has installed and operates a relatively small to moderately sized rooftop PV system.

Application experiments: Durable array-roof configurations; arrays laminated onto metal roofs; factory-installed PV systems.

Revenue: FEMP and possibly other sources of government funds.

Barriers: Utility interconnection requirements.

Benefits: Demonstrates leadership by example; shows concern for the environment and need to reduce dependence on depletable fuels; high coincidence between PV production and demand; high direct utilization of PV energy on-site.

Opportunities: Increase public awareness of promising new technologies and their favorable consequences in preserving a cleaner environment.

D. School and Church Organizations

The potential market for rooftop PV applications among schools and churches is considered moderate. However, these institutions exert considerable influence throughout their respective communities and may favorably affect markets with other end users.

Desired action by end user: The school or church buys, has installed and operates a relatively small to moderately sized rooftop PV system.

Application experiments: Arrays laminated onto metal roofing; factory-installed systems; alternative inverter configurations.

Revenue: Florida buy-down funds; capital and operating funds; foundation contributions; grants.

Barriers: Utility interconnection requirements.

Benefits: High visibility; public approval; positive influence on community with possible spinoff effect; high coincidence between PV production and demand; high direct utilization of PV energy on-site.

Opportunities: Application can be tied to education and research mission of the institution, including related academic curricula and research agendas; direct participation of students and faculty.

E. Manufactured Building Corporations

Manufactured buildings represent approximately 30 percent of the new housing stock in the U.S. and as high as 60 percent in parts of Florida. The potential market for rooftop PV systems with this end-user group is considered moderate.

Desired action by end user: The manufactured building corporation buys PV system hardware kits in bulk, installs the PV systems (completely or in part) in a controlled factory environment using optimized assembly processes, and sells manufactured PV buildings.

Application experiments: PV and energy-efficient buildings; building-integrated photovoltaics; factory-installed PV systems.

Revenue: Florida buy-down funds; green pricing (for utility-owned PV systems); contracts and grants.

Barriers: High first costs; high life cycle costs; utility interconnection requirements.

Benefits: Better quality control of factory installations; lower unit costs because of bulk hardware purchases; much lower installation costs because of optimized assembly processes; increased marketability of low energy PV buildings; replacement of conventional roofing materials with PV products.

Opportunities: Penetration of large and attractive new housing market; significant reduction in installed system costs, especially the non-module related costs; beneficial teaming arrangements with community developers and the electric utility, whereby the utility would own, operate and maintain the PV systems; attractive new product for the export market, especially to countries without reliable sources of electricity.

F. Investor-Owned Utilities and Energy Service Companies (ESCOs)

Investor-owned utilities supply approximately 70 percent of Florida's population with electric energy. Unlike municipal utilities and rural electric cooperatives, which are owned by and responsible to their customers, investor-owned utilities and ESCOs are primarily responsible to their shareholders. If price reduction goals are met, a large market for PV-generated electricity may develop with investor-owned utilities. However, it is anticipated that a significant percentage of these applications will consist of larger PV systems on utility property, rather than a large number of smaller distributed PV systems. Consequently, the potential market for rooftop PV systems with investor-owned utilities is considered moderate. Prospects for ESCOs may be better, but are highly dependent on developments with deregulation in Florida.

Desired action by end user: The utility buys, has installed, owns and operates rooftop or ground-mounted PV systems.

Application experiments: Distributed generation; community developments; alternative inverter configurations.

Revenue: Green pricing.

Barriers: Overcomes major barriers of interconnection, mobility, concerns about performance and reliability, and eliminates net metering as an issue. Constrained somewhat by commitments to shareholders and by regulatory requirements.

Benefits: Provides green image; provides customer choice; takes advantage of economies of scale for both hardware procurement and installation; involves small investment at very little risk.

Opportunities: Assess customer response over time; assess the value of distributed generators; assess future business opportunities based on significant data and experience; evaluate synergism between distributed generation, energy-efficient building technologies, and load and demand-side management strategies; implement large community projects; provide green image; improve public relations.

G. Commercial Roofing Companies

Commercial roofing companies represent an attractive market because of their potential to incorporate innovative PV roofing materials (i.e., shingles, laminates, tiles, etc.) into their product lines. The potential market for rooftop PV products with commercial roofing companies is considered moderate.

Desired action by end user: The commercial roofing company buys PV roofing materials in bulk, installs them on their roofing products, and sells to builders, manufactured building corporations, and construction companies.

Application experiments: Durable array-roof configurations; arrays laminated onto metal roofing; building-integrated photovoltaics.

Revenue: Florida buy-down funds; contracts and grants.

Barriers: High first costs; fear of poor system performance and reliability; utility interconnection requirements; concerns about product acceptance.

Benefits: Lower costs for PV hardware because of large bulk purchases; reduction of installed system costs; attractive re-roofing option.

Opportunities: Assess the performance, reliability and durability of innovative PV roofing products; evaluate and compare the effectiveness of lamination in the factory or warehouse with on-site and proximity lamination; beneficial teaming arrangements with community developers and the electric utility, whereby the utility would own, operate and maintain the PV roofing systems.

H. Builders and Developers

The building construction industry is one of the largest in Florida and would appear to be an attractive market for rooftop PV applications. However, the solar water heating industry has had difficulty in making a large penetration into this market because of the low margins at which many builders operate, and because of the large demand for non-solar buildings. In short, builders feel they can make a larger profit without adding a solar system.

One approach that has worked well in getting solar water heating systems on new homes is the SunBuilt Program sponsored by the Florida Energy Office (FEO). FEO funds pay for the solar water heating hardware (only), and then the builder (or solar system supplier) installs the system on a model home. Home buyers visiting the model home may select solar water heating as an option. Industry literature describing the system is available to all visitors to the model home. This same approach can be applied to rooftop PV systems, whereby a given system on a model home is offered as an option to prospective buyers. Overall, the potential market for rooftop PV systems with builders and developers is considered low.

Desired action by end user: The builder buys a PV system, installs it on the roof of a model home, and sells other new homes offering PV as an option.

Application experiments: Community developments; PV and energy-efficient buildings; fault- and weather-tolerant buildings.

Revenue: Florida buy-down funds; contracts and grants; possibly green pricing.

Barriers: High first costs; low profit margins; concerns about system performance and reliability; utility interconnection requirements.

Benefits: High visibility of model homes; giving buyers the option to choose renewable energy; green image; increased marketability of homes; lower building energy ratings.

Opportunities: Possible collaboration with the electric utility in offering green, energy-efficient buildings with distributed rooftop generation of electricity; promoting low building energy ratings and demonstrating the reductions due to PV, solar water heating, and building energy efficiency; more customer options, including financing.

I. Homeowners and Buyers

Homeowners are an extremely important end-user group and have traditionally been early adopters of renewable energy technologies. However, the potential market for rooftop PV systems (of say a kilowatt or larger) with this group is considered to be small, unless there are significant price reductions and very attractive financing options. On the other hand, homeowners may have a very strong influence on the development of rooftop PV markets by leasing roof space to the utility, which in turn will own, operate and maintain the system.

Desired action by end user: The homeowner or buyer buys, has installed, and uses the rooftop PV system.

Application experiments: PV and energy-efficient buildings; fault- and weather-tolerant buildings; durable array-roof configurations.

Revenue: Florida buy-down funds; contracts and grants.

Barriers: High first costs; high life cycle costs; mobility of homeowners; concerns about performance, reliability and durability; re-roofing requirements; metering issues; utility interconnection requirements and costs.

Benefits: Preserving a cleaner environment; reducing dependence on depletable resources.

Opportunities: Option for early adopters; testing the availability of net metering; including the value of PV, solar water heating, and building energy efficiency in the building energy rating; long-term, low-interest financing.

Potential Long-Term Markets

As mentioned previously, we have limited to three the number of experiments planned for each end user. However, we believe many of these applications may become attractive in the long term to the other end users, as summarized in Table 2.

End-User Groups / Long-Term Markets	Distributed generation	Community developments	PV and energy-efficient bldgs	Fault- and weather-tolerant bldgs	Durable array-roof configurations	Arrays laminated onto metal roofing	Building-integrated PV	Factory-installed PV systems	Alternative inverter configurations
Municipal utilities and rural electric cooperatives	x	x			x				x
Commercial building owners and operators		x	x	x	x	x	x		x
Government and public agencies			x	x	x	x	x	x	x
School and church organizations			x	x	x	x	x	x	x
Manufactured building corporations		x	x	x	x	x	x	x	x
Investor-owned utilities and ESCOs	x	x			x				x
Commercial roofing companies					x	x	x		x
Builders and developers		x	x	x	x	x	x	x	x
Homeowners and buyers		x	x	x	x	x	x	x	x

Table 2. Potential long-term markets for PV buildings for nine end-user groups.

PROVIDING QUALITY CONTROL

Improving and Managing the Quality of Installed Photovoltaic Systems

Through FSEC, Florida has technical resources that can be used to improve and manage the quality of rooftop PV installations. The steps involved in quality management are as follows:

- Reviewing and pre-approving system designs.
- Establishing performance expectations based on test data rather than on dealer claims.
- Establishing minimum competency requirements for installation practitioners.
- Training system designers, installers, code officials, building professionals, utilities and other end users.
- Verifying compliance with design specifications via acceptance testing.
- Offering comprehensive technical support services.

Supporting Project Development and Implementation

The Florida Solar Energy Center offers services to end users to assist in project development and implementation. These services include:

- Presenting technical briefings and status reports on PV and building technologies.
- Providing training on design, installation, code compliance, and integration of PV systems into buildings.
- Providing information and assistance in implementing green pricing.
- Providing needs assessments, site surveys and analyses, project definition and planning.
- Supplying product information and industry directories.
- Identifying project partners and assisting in proposal preparation.
- Providing direct assistance in project implementation.
- Publicizing projects and programs using FSEC's web site and links, newsletters, other publications and presentations.

In addition to these general services, FSEC also offers both pre-installation and post-installation technical support services to help ensure project success.

Providing Pre-Installation Technical Support

Because photovoltaic technology is relatively new, and because utility-interactive rooftop applications are even newer, buyers often need assistance in specifying what they want, knowing what they should get, and then determining what they got. Pre-installation technical support services can help new end users make better decisions up front concerning buying and operating rooftop PV systems. These services include:

- Preparing technical specifications to be used for procurement as part of requests for proposals/quotations.
- Preparing acceptance test procedures consistent with the technical specifications so that compliance can be verified.
- Reviewing and approving PV system designs.
- Testing (previously untested) components and characterizing performance.
- Performing field evaluations and troubleshooting existing photovoltaic systems.

Many of the pre-installation technical support services are already performed well by various end users and members of the industry, but, upon request, FSEC can provide them as well. The most critical aspect, design review, is where FSEC can play a significant role, serving as an impartial third party.

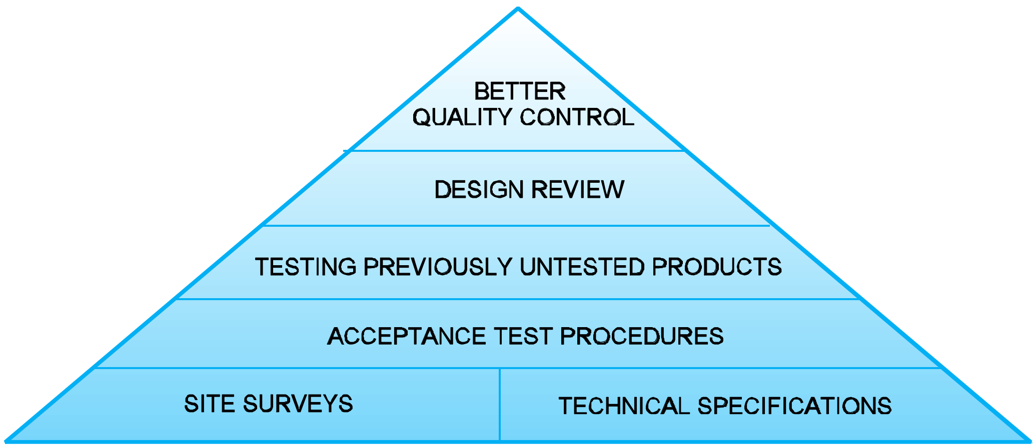


Figure 14. These are the pre-installation technical support services that will enhance quality control of rooftop PV systems.

Providing Post-Installation Technical Support

Once the photovoltaic systems have been installed, FSEC provides the following technical support services:

- Conducting or assisting in conducting acceptance tests.
- Installing appropriate instrumentation and monitoring performance.
- Developing and providing ready access to databases at the FSEC web site.
- Providing training to end users on the operation, maintenance and troubleshooting of photovoltaic systems.
- Providing periodic site visits to buildings with PV systems, performing field evaluations of the status of the systems, and troubleshooting any problems that the systems may be encountering.

Providing Training Courses and Workshops

FSEC has developed three major courses to support the Florida PV Buildings Program. The first of these new courses provides ***training on the design of utility-interactive PV and building systems***. This course is for both system integrators and building design professionals and builds on material developed by FSEC over the past 15 years.

The second new course provides ***training on installing code-compliant utility-interactive photovoltaic systems on buildings.*** This course is for installation contractors (i.e., solar, electrical, building) and is being developed in collaboration with other states. As part of the instructional development process, a competency examination is being prepared to assess learning. Successfully passing this examination is required for receiving Florida buy-down funds.

Figure 15. State-of-the-art training facilities accommodate a wide variety of teaching styles and instruction media.

The third new course provides ***training on inspecting utility-interactive photovoltaic systems.*** This course is for both electrical and building inspectors, and will help them carry out their responsibilities to ensure that rooftop PV systems comply with all local electrical and building codes.

The offering of the above courses will often be tied directly to the implementation of specific projects. For example, an installation course might be offered to a utility (and its contractors) interested in buying, installing, owning and operating a number of distributed rooftop PV systems.

Special programs and workshops will complement the above course offerings. Workshops on important technical issues, such as interconnecting small photovoltaic systems to the electric utility grid, will be offered on an as-needed basis.

Added Cost for Quality Control

Quality control requires labor, training, documentation and, in some cases, more and better hardware. These components will add cost to the industry initially, but will save money in the long run. By forcing the industry to better document designs, and possibly to incorporate better hardware, systems will become more reliable. Improvements, in turn, will lead to standardized designs and kits, saving the time and effort now required for custom design. FSEC will provide technical support to ensure quality through SE RES funding from Sandia National Laboratories.

DETERMINING VALUE AND BENEFITS

Determining the Value of Utility-Interactive Photovoltaic Systems

The emphasis of the Florida PV Buildings Program is on identifying and increasing the value of rooftop systems to targeted end users through the use of application experiments. The application experiments will provide useful information and data for cost-benefit analyses and for value assessments.

They will be designed to provide sufficient information and data to answer the following questions:

- What is the impact of distributed generation on utility operations?
- What is the value of distributed generation as a future business opportunity?
- What is the relationship between distributed generation and load management strategies?
- To what extent can non-module costs be reduced?
- Which are the most effective combinations of building energy efficiency and PV generation?
- What designs should be recommended for fault and weather tolerant buildings?
- How can PV materials be better integrated into buildings?
- How do the performance and reliability of alternative inverter configurations compare?

The methodology for collecting information and gathering data is described below.

Monitoring Performance

Three instrumentation and data collection packages have been developed to provide three distinct levels of performance monitoring: Level 1 (most sophisticated and expensive); Level 2 (simpler and less expensive); and Level 3 (simplest and least expensive). The philosophy in developing the monitoring packages was to use off-the-shelf instrumentation and data acquisition systems, and thereby avoid the high costs associated with custom design.

Level 1 monitoring is used to collect performance data for both components and the system versus time-of-day. The performance of various appliances, such as an air conditioner or solar water heater, may also be monitored. Irradiance and environmental parameters are also measured versus time-of-day. Because of the relatively high cost, Level 1 monitoring will typically only be used to evaluate new, unique, or innovative products, designs and configurations. For example, systems using new PV laminates that replace conventional roofing materials would be good candidates for Level 1 monitoring. Researchers, designers and manufacturers are the groups that would generally have the most interest in the results of Level 1 monitoring.

Level 2 monitoring is simpler and considerably less expensive than Level 1. Level 2 monitoring is used to collect both PV system ac power output and solar irradiance versus time-of-day. Level 2 monitoring will be used extensively with utility-owned PV systems. It provides utilities with the system performance information they need to assess the value of distributed PV generated electricity throughout the day, especially during periods of peak demand.

Level 3 monitoring simply involves using a watt-hour meter to collect data on monthly energy production by the PV system. Data from Level 3 monitoring will provide non-utility system owners (e.g., home and building owners) with information they can use to analyze the economics of their investment. Level 3 data will be collected from participating utilities on a monthly basis and entered into FSEC's PV database.

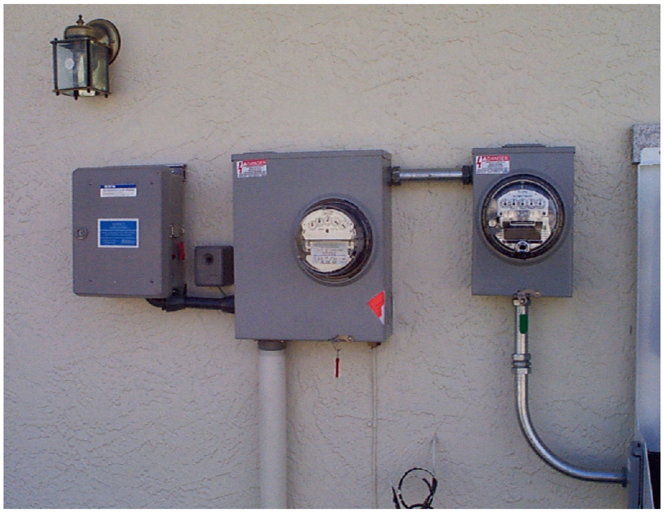


Figure 16. The box on the left contains equipment for Level 2 monitoring, which costs approximately $500. Also shown are watt-hour meters for Level 3 monitoring.

Data collected from Level 1 and 2 monitoring at remote sites typically is transferred via telephone lines to FSEC's data processing center for analysis and reporting. To provide other interested individuals and organizations with the capability to collect Level 1 data, FSEC has also developed a version of its Level 1 monitoring package that users can easily interface with their personal computers.

The following table shows the level of monitoring which would typically be used for each of the application experiments.

Application Experiments / End-user Groups	Distributed generation	Community developments	PV and energy-efficient bldgs	Fault- and weather-tolerant bldgs	Durable array-roof configurations	Arrays laminated onto metal roofing	Building-integrated PV	Factory-installed PV systems	Alternative inverter configurations
	Level of Monitoring								
Municipal utilities and rural electric cooperatives	2	2							1
Commercial building owners and operators			1	1			1		
Government and public agencies					3	1		1	
School and church organizations						1		1	1
Manufactured building corporations			1				1	1	
Investor-owned utilities and ESCOs	2	2							1
Commercial roofing companies					3	1	1		
Builders and developers		3	1	1					
Homeowners and buyers			1	1	3				

Table 3. Possible monitoring levels for the three application experiments planned for each end-user group.

Collecting Operation and Maintenance Data

In addition to performance monitoring, operation and maintenance (O&M) data will be collected for all application experiments. PV system end users will be asked to make entries for all O&M events using log forms developed by FSEC. This information will be entered into FSEC's PV database. For systems equipped with Level 1 and 2 monitoring packages, significant events will often be corroborated with data showing performance anomalies.

PV System Maintenance and Inspection Summary	
Project Information	
Project Code (DB):	LAK1
Project Description:	Lakeland Utility Interactive Residential PV Systems
Project Location:	Address
Owner/Operator:	City of Lakeland Electric and Water Utilities
Contact:	Person + number
System Installation Date:	Apr-98
Project/Contract Sponsor:	Sandia/FEO
System Information	
PV Module/Array	Siemens Solar SP-75, 54 modules total.
Manufacturer's DC Peak Rating	4050 Wp at STC
PV Array Configuration	Six parallel connected array source circuits, consiting of three parallel panels of three modules each.
Parallel Array Source Circuits	Three parallel connected panels per subarray source circuit, 6 total source circuits. Surge suppression and GFI for each source circuit.
PV Panels	Three series connected modules per panel, 18 total panels. Blocking diode and disconnect fuse on each panel.
Power Conditioner	Trace Engineering 4048 UPV
Metering	Recording kWh meters for PV system and residential loads. Lakeland utility accesses kWh meter data with Metrotek pulse recorders via phone line.
	Two FSEC dataloggers installed at site and accessed via phone lines. One DAS measures PV and buildings data, the other PV data only.
Maintenance Record Entry 1	
Date of Activity	1-Mar-98
Field Crew	Installers
Purpose for Field Visit	During installation
Background	
Inspection/Maintenance Activity 1	
Measurements and Observations	Terminal on power conditioner GFI input circuits were not trimmed properly, making it difficult to attach array source circuit conductors.
Interpretation	Manufacturing problem
Corrective Actions Taken	Terminal block removed and wiring from GFI terminal strips to board trimmed.
Need for Follow-Up	Notify Trace Engineering.

Table 4. Sample form used by FSEC to collect data and information on the operation and maintenance of PV systems.

Cost of Data Collection and Information Gathering

Developing instrumentation and data acquisition systems for Level 1, 2 and 3 monitoring involves both hardware and labor costs. The cost of a Level 1 monitoring package is approximately $6500 (delivered). Note that this does not include the cost of actually collecting the data. The cost of a Level 2 monitoring package is approximately $500; the cost of a Level 3 watt-hour meter is about $35 and is usually supplied by the utility.

Note the distinction between monitoring data and O&M data. Monitoring provides information on performance, thus establishing value and benefits. O&M data provides information on reliability, maintenance, and associated costs. The combination of both types of data will lead to more meaningful cost-benefit analyses.

Determining Economic Value

Better cost data is necessary to improve economic models and to properly value utility-interactive PV systems. Many past economic analyses have considered the following information:

- Module costs.
- Non-module hardware costs.
- Installation labor costs. Better data is needed in this area.
- Assumptions concerning operation and maintenance costs, usually as a percentage of first costs. Better data is needed in this area.
- Assumptions concerning the amount of PV-generated electricity and its value. Better and more comprehensive data is needed in this area.
- Required economic assumptions concerning inflation, discount rates, etc.

Most economic analyses do not include, but should account for:

- Array and system output considerably less than expected.
- Degradation in array output over time.
- Operation and maintenance costs using statistical data based on actual experience.
- Costs associated with re-roofing, including disassembly and re-installation of the array (possibly more than once over the life of the array). These costs may be substantial.
- Interconnection costs, including utility studies, redundant protection equipment, premiums for liability insurance, and metering. These costs are almost totally dependent on the utility interconnection requirements.

Application experiments in Florida will provide sufficient data to more accurately determine all the costs associated with PV building systems.

Making Information and Data Accessible

A major challenge of the Florida program is handling the volume of data and information that is produced from the application experiments so that all stakeholders can learn and benefit from it. For over a year, FSEC has been upgrading its capabilities in database management to help meet this challenge. By taking advantage of modern digital networking, FSEC's web site will provide ready access to component and system performance data, analyses and evaluations, technical reports, lessons learned and recommendations.

SUSTAINING THE PROGRAM

Sustaining the Florida PV Buildings Program will require resources: financial, technical, and management.

Funding and financial resources have been discussed in a preceding section, ***Generating Revenue***, which explained that photovoltaic system buy-down funds will be available from the present through December 2001. Green pricing will continue indefinitely, as will buy up by end users. As prices decrease and barriers are overcome, the value of PV buildings should become more and more apparent to various end users. Other sources of funding may also come into play as a result of deregulation or legislative mandates. To help sustain the Florida PV Buildings Program, the distribution of presently available funds will favor those applications with the best prospects for developing early markets.

Although absolutely necessary, funding by itself is not sufficient to sustain the program through 2010 and beyond. In addition to continued funding, five technical and management processes have been identified as keys to program sustainability:

1. *Achieving consistency in installing high quality systems.* The marketing of solar thermal systems over the past several decades suffered significant setbacks because of systems that did not perform up to expectations, were unsightly, or were viewed as overpriced. Because rooftop PV systems have relatively large arrays and may represent a sizable investment for many end users, it is critical that these systems be properly installed, meet performance expectations, and be aesthetically appropriate for the application.
2. *Achieving significant price reductions and eliminating major barriers to commercialization.* Without significant price reductions, prospects for a sustainable widespread market for utility-interactive PV buildings become much less certain.
3. *Improving industry capability and increasing capacity.* Florida has a strong solar thermal industry. Some of these companies are also involved in marketing and installing stand-alone photovoltaic systems. Florida also has a relatively small number of companies that deal exclusively in specific stand-alone photovoltaic applications, such as outdoor lighting. However, Florida has only a handful of companies that have experience in utility-interactive photovoltaic system installations. An eventual and necessary outcome of this program is a significant increase in the number of companies marketing and installing utility-interactive photovoltaic systems. It is important to use FSEC's technical resources to continuously improve the capabilities of this new

industry. In addition, Florida has no major manufacturer of photovoltaic power modules or utility-interactive inverters. A desired outcome of this program is the establishment and growth of Florida-based manufacturing of PV modules and other system components.

4. *Regularly and effectively communicating lessons learned to all stakeholders.* This is necessary to improve products and practices, and to make value more readily apparent. As mentioned previously, this program emphasizes learning and improving. To facilitate the communications process, lessons learned will be shared via several means, including a Florida annual PV Buildings Program review. Such a forum may be of interest to the DOE Regional Support Offices and representatives from other states interested in PV building applications. A second means to share the results of this program is to use the Internet. FSEC has been developing a new photovoltaic database for its web site over the past year, and it is in the early stages of implementation. The web site is regularly updated and, for some experiments, it provides access to real-time or near real-time data. A third means of disseminating program results will be through conventional forums, such as the PV Performance and Reliability Workshops, ASES conferences, Soltech and other meetings and conferences. And finally, the advice and guidance of respected professionals from industry, end-user groups, and the research community will be solicited through advisory committee meetings and direct communication.
5. *Providing continuity, persistence, and flexibility in marketing, managing and implementing the program through the next decade and beyond.* The key organizations responsible for the success of the program are the Florida Energy Office of the Department of Community Affairs, Sandia National Laboratories, and the Florida Solar Energy Center. All three organizations are committed to the success of the program. The Florida Solar Energy Center has operated the Photovoltaic Southeast Region Experiment Station (SE RES) under contract with Sandia since 1982. Utility-interactive photovoltaic systems were the focus of attention for the SE RES when the program began and, because of the Million Solar Roofs Initiative (MSRI), are once again an important area of systems engineering research. It is the hope and expectation that this support will continue well into the future. Finally, it should be mentioned that FSEC is a large, well-established research institute within the Florida State University System. Because of its size and stature within the State, FSEC has the stability to withstand fluctuations in funding from external sources. This stability is important because of the long-term nature of the Florida PV Buildings Program.

In summary, it appears that there are sufficient financial, technical and management resources, and the stability to sustain the Florida PV Buildings Program through 2010 and beyond.

CONCLUSIONS

The Florida PV Buildings Program is a collaborative effort among the Florida Energy Office of the Department of Community Affairs, Sandia National Laboratories, the photovoltaic industry, nine end-user groups, and the Florida Solar Energy Center. It complements the federal government's Million Solar Roofs Initiative (MSRI), which calls for one million solar installations in the U.S. by 2010. Based on the present level of activity and assuming a relatively small growth rate, it is estimated that approximately 140,000 solar pool and domestic water heating systems will be installed in Florida by the end of the next decade.

The market for utility-interactive rooftop photovoltaic systems is expected to be largely subsidized until significant price reductions are achieved. If price reduction goals can be met, and if major barriers to commercialization can be overcome, it is estimated that as many as 20,000 utility-interactive photovoltaic systems may be installed in Florida by 2010. Thus the total number of rooftop solar installations (thermal and photovoltaic) in Florida is estimated to be 160,000 by 2010.

During the period of subsidization, the Florida program chooses to invest both time and money in learning and preparing for new markets based on value. Learning will be achieved via application experiments with nine end-user groups. Emphasis has been placed on reducing installation and other non-module costs; on determining the impact of distributed generation on the utility grid; on designing energy-efficient PV building systems; on optimizing uninterruptible building power systems; on evaluating desirable and cost-effective array-roof configurations; on identifying better ways of integrating PV materials into buildings; and on improving the reliability and durability of alternative inverter configurations, including micro-inverters, in warm, humid climates.

The data and information from the applications experiments will allow different end users to assess the value of various photovoltaic building applications. It is important to note that the value many end users associate with photovoltaic systems may not be strongly tied to economics. Examples include the value associated with a cleaner environment; the value of less dependence on imported and depletable fossil fuels; the value of a green image; the value of improved public relations; the value of having uninterruptible building power; and, in the case of utilities, the value of providing customers with the option to choose renewable resources to meet a portion of their energy needs. The data and information collected will help market-focused organizations prepare value propositions for a variety of PV building applications. End users will be much better prepared to establish performance expectations and make decisions concerning photovoltaic building systems. They will also have much better data upon which to base life cycle cost analyses and business planning.

In summing up this program and its objectives, here is where we are now and where we expect to be in the future.

Where we are now:

- At present, the estimated number of utility-interactive PV systems in Florida is less than twenty.
- There is no significant PV buildings industry nor is there a market for utility-interactive PV.

Where we expect to be in 2002:

- By 2002, the goal is to have at least 200 PV systems connected to the grid.
- Green pricing will be generating revenue for perhaps ten or more utilities.
- A small number of PV system suppliers will establish the foundation for a growing PV buildings industry.

Where we could be in 2010:

1. By 2010, Florida could have 20,000 rooftop PV systems connected to the grid.
2. Green pricing and other sources of funding will continue to provide revenue.
3. A strong PV buildings industry will include established companies with experienced, highly trained system designers and installers.

In closing, it is important to restate that the thrust of this program is to establish value based on data and real experience and to reduce or eliminate all major barriers to commercialization. The intent is *not* to blindly push for large numbers of system installations and promote artificial markets. For scenarios where value and benefits can be clearly established and price reduction goals can be achieved, real markets will follow.

SUPPORTING DOCUMENTS AND INFORMATION

The following FSEC documents, document packages, and sources of information are integral parts of the Florida photovoltaic buildings program. They provide much more specific information in each of the topic areas listed below than is available in this ***Program Plan for Photovoltaic Buildings in Florida.***

1. ***Request for Proposals (RFP) for Photovoltaic Building Projects***. Includes the RFP, instructions for preparing proposals, associated forms, and general information. Contact: Jennifer Skislak, 407-638-1427, jskislak@fsec.ucf.edu.

2. ***Rebates for Suppliers of Utility-Interactive Photovoltaic Systems on Buildings.*** Includes an application form, instructions, general information, rebate certificate, and references. Contact: Jennifer Skislak, 407-638-1427, jskislak@fsec.ucf.edu.

3. ***Statewide Green Pricing Program***. Includes a proposed program developed by the Florida Solar Energy Center in partnership with the Florida Municipal Electric Association and the Florida Energy Office of the Department of Community Affairs. Contact: Jennifer Skislak, 407-638-1427, jskislak@fsec.ucf.edu.

4. ***Design Review and Approval of Photovoltaic Systems***. Includes the purpose, description, procedures, checklist, approval form, and references. Contact: Jerry Ventre, 407-638-1470, ventre@fsec.ucf.edu.

5. ***Examination and Experience Requirements for Installers of Utility-Interactive Photovoltaic Systems on Buildings***. Includes the purpose, description, procedures, application forms, certificate, and references. Contact: Jim Dunlop, 407-638-1474, dunlop@fsec.ucf.edu.

6. ***Photovoltaic Module Performance Characterization***. Includes the purpose, description, procedures, checklist, application forms, test report format, certificate, and references. Contact: Gobind Atmaram, 407-638-1472, gobind@fsec.ucf.edu.

7. ***Acceptance Testing of Photovoltaic Systems***. Includes the purpose, description, procedures, checklist, acceptance form, and references. Contact: Stephen Barkaszi, 407-638-1473, barkaszi@fsec.ucf.edu.

8. ***Performance Monitoring of Photovoltaic Systems***. Includes the purpose, description, monitoring options, procedures, checklist, agreement forms, and references. Contact: Stephen Barkaszi, 407-638-1473, barkaszi@fsec.ucf.edu.

9. ***Collecting Reliability Data for Photovoltaic Systems and Components***. Includes the purpose, description, procedures, log forms for recording events, agreement forms, and references. Contact: Stephen Barkaszi, 407-638-1473, barkaszi@fsec.ucf.edu.

10. ***Developing Technical/Procurement Specifications for Photovoltaic Systems***. Includes the purpose, description, procedures, checklist, templates, and references. Contact: Gobind Atmaram, 407-638-1472, gobind@fsec.ucf.edu.

11. ***Providing Site Surveys***. Includes the purpose, description, procedures, checklist, and references. Contact: Brian Farhi, 407-638-1457, bfarhi@fsec.ucf.edu.

12. ***Offering Photovoltaic Training Programs***. Includes the purpose, description, general information, target audiences, objectives, syllabi for various course offerings, facilities, certificates, and references. Contact: Jim Dunlop, 407-638-1474, dunlop@fsec.ucf.edu.

13. ***Inspecting Photovoltaic System Installations***. Includes the purpose, description, procedures, checklist, approval forms, and references. Contact: Jim Dunlop, 407-638-1474, dunlop@fsec.ucf.edu.

14. ***Disseminating Results and Lessons Learned***. Includes the purpose, description, general information, target audiences, objectives, annual review process, and role of advisory committee. Contact: Jerry Ventre, 407-638-1470, ventre@fsec.ucf.edu.

15. ***Updating Databases and the FSEC Photovoltaic Website***. Includes the purpose, description, general information, target audiences, objectives, database categories, updating procedures, and references. Contact: Shiva Jaganathan, 407-638-1436, shiva@fsec.ucf.edu.

16. ***Interconnecting Small Photovoltaic Systems to Florida's Utility Grid***. Includes the purpose, description, compendium, summaries of technical presentations, results of consensus building, and references. Contact: Jerry Ventre, 407-638-1470, ventre@fsec.ucf.edu.

17. ***Photovoltaic Programs at the Florida Solar Energy Center***. Includes descriptions of major photovoltaic programs and projects at FSEC, their importance, facilities, and funding sources. Contact: Jerry Ventre, 407-638-1470, ventre@fsec.ucf.edu.

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