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History of Applying Photovoltaics to Disaster Relief

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HISTORY OF APPLYING PHOTOVOLTAICS TO DISASTER RELIEF

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ABSTRACT

Hurricanes, floods, tornados, earthquakes and other disasters can happen any place, any time. Major disasters destroy homes and businesses, and leave many people without adequate medical services, potable water, electrical service and communications. In response to the need for electrical service, solar energy offers a source of quiet, safe, pollution-free power. Over the last few years, photovoltaic (PV), or solar electric, powered systems have provided energy for vaccine refrigerators, medical equipment, lighting, radios, fans, communications, traffic devices and other electrical power needs. This report presents known applications of photovoltaic power used during recent disaster relief efforts.

1. INTRODUCTION

Monday, August 24, 1992, Hurricane Andrew struck the coast of south Florida with a tremendous destructive force. The storm severely damaged at least 85,000 buildings. An estimated 34,000 homes had to be replaced, which left hundreds of thousands of people homeless in Dade County. Thousands of businesses and homes that were still standing were without electrical service, functioning water and sewage systems, communications, and medical services for days, even weeks, after the storm. Also, shelters, medical clinics, hospitals, FM stations, and police stations suffered damage and loss of utility services.

Emergency management teams, the military, and countless public and private organizations became involved in the massive relief and rebuilding efforts and required varying amounts of electrical power, both small and large, to provide food, water, and medical supplies.

The utilities' electrical distribution system in Dade County was virtually destroyed, requiring several weeks to rebuild in some locations. The University of Miami, Field Epidemiology Survey Team (FEST), knowing the value of photovoltaics, requested the use of any available photovoltaic system to power their medical clinics. In response to the call for help, the Florida Solar Energy Center and Sandia National Laboratories assembled several 1 kW systems and deployed them at the temporary clinics for use until utility power was restored. This was the beginning of an organized effort to apply PV to disaster relief activities.

2. PROGRAM EFFORTS

Sandia National Laboratories has contracted Florida Solar Energy Center to document the recent application of photovoltaic power to relief efforts. This report is part of a needs evaluation and resource development project in applying photovoltaic energy to disaster relief efforts.

Since Hurricane Andrew, photovoltaics have been used only a few times after a disaster. PV has been introduced to several emergency organizations by members of the PV industry, FSEC, SNL and DOE. Emergency organization awareness of PV has increased as well as PV industries' desire to supply viable equipment. To identify the role PV can play in this application, previous experiences need to be identified and evaluated to understand the reasons behind the successes and failures and the obstacles encountered in its use.

3. PV USAGE DURING DISASTERS

Since its creation, there has been limited use of PV in disaster relief efforts. However, in recent years, photovoltaics have supplied emergency power after hurricanes, such as Hugo and Andrew, and after other disasters, such as the Northridge Earthquake in southern California. Most applications were the work of members of the PV industry, FSEC, SNL and DOE.

3.1 Hurricane Hugo

In 1989, Hurricane Hugo cut across the island of St. Croix, disrupting power all over the island. A Florida PV distributor, 12 Volt Catalog, assembled PV systems using both Sovonics Solar System and ARCO Solar PV modules. Modules were individually connected to a deep-cycle Interstate battery to make a small portable system. The units were used at various disaster shelters, medical facilities, and emergency management offices to power 12 VDC fluorescent lights, fans and ham radios as shown in Figure 1. These companies have since become Geosolar, United Solar Systems and Siemens Solar.

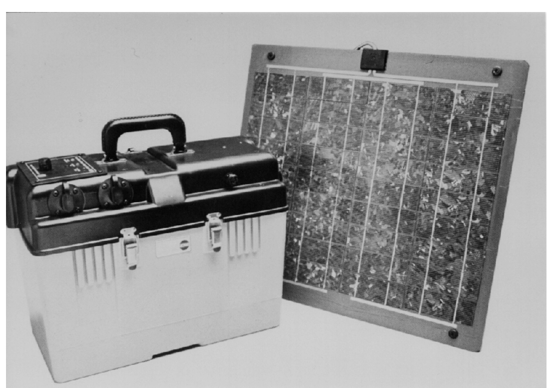

Figure 1. Portable PV Tote

When PV power is needed for a mainland disaster, workers rely on cars, trucks, and an infrastructure of roads, and usually have more than one access route for transporting supplies to a site. In contrast, when emergency power is needed on an island, workers must rely on ships or planes, which are expensive to operate, and likely have more limited access to a site via one or perhaps two ports or airstrips. Consequently, after Hurricane Hugo some large PV equipment never reached St. Croix. Small, low power PV systems made it to the island and maintained valuable communication services, a vital means of linking islanders to one another and to those outside—on other islands and on the mainland. Larger systems, though, which could have provided power at medical facilities, could not be shipped.

When Hurricane Hugo later struck South Carolina, a trailer-mounted, PV-powered generator was transported to the devastated area to assist with relief efforts. This Solar Emergency Response Vehicle powered a law enforcement traffic facility and an orphanage until utility power was restored. The unit, built by Arizona Solar Energy Office and Photocomm, supplied 12 VDC, and 115 and 220 VAC of electrical power (shown in Figure 2).

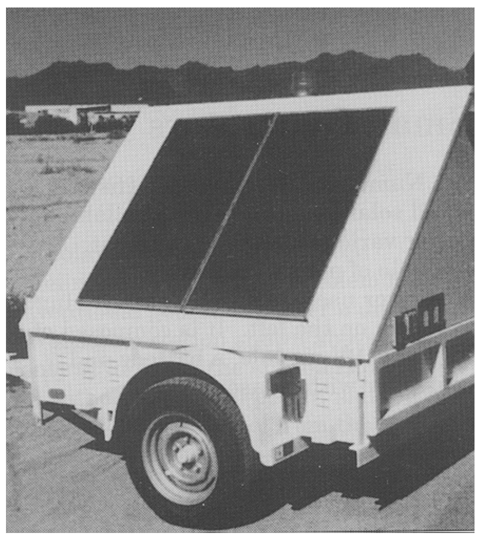

Figure 2. Trailer-Mounted PV Generator

The unit operated 24 hours per day from a 2,640 peak watt PV array. The load at the traffic facility became greater than the unit could provide, as more and more people tried to use the unit. Several days after arrival at the transportation facilities, power was restored and the unit was moved to the orphanage. The unit operated more successfully at the orphanage, where demands for power were not as large and critical.

Weight and transport distance are important considerations in conveying a trailer-mounted PV system for emergency assistance, as commercial rush shipment across great distance is very expensive. The unit in Figure 2 weighed 5,000 lbs. and was transported almost 2,000 miles to South Carolina two days after requested. With the assistance of the U.S. Air Force, the unit was flown to the disaster.

3.2 Hurricane Bob

Block Island, an island off the coast of Rhode Island, took a direct hit form Hurricane Bob in 1991. Although the island lost power for days, an existing PV system suffered no damage and continued to provide power to the owners throughout the incident. This stand-alone photovoltaic project, built by Solar Design Associates, is shown in Figure 3. The ground-mounted array of ASE America's, formerly Mobil Solar, provides 2 kW of power to a battery bank, which powers the residence. The system continues to provide uninterrupted power today.

Figure 3. ASE America's
Ground-Mounted Array

3.3 Northridge Earthquake

In the summer of 1991, an Emergency Mobile Communications and Lighting system was built by Barrett Manufacturing for use during the earthquake recovery efforts at Northridge in Los Angeles, California. The trailer-mounted PV system contained 4 Siemens 48-watt PV modules, as shown in Figure 4. The system provided reliable stand-alone electrical power at both 12 VDC and 120 VAC for site communication and lighting.

Figure 4. Emergency Mobile
Communications and Lighting Unit

3.4 Hurricane Andrew

The Miami Emergency Management Office sent out requests for emergency communications assistance after Hurricane Andrew struck in August 1992. Staff at the Florida Solar Energy Center (FSEC) transported a small PV system to Miami to power an amateur radio station, which was used at a shelter. The system was a PV workshop training unit with two 40-watt modules. It was selected because of its capability to operate as a portable stand-alone PV system and was of sufficient size to power a 30-watt amateur radio as shown in Figure 5. This system successfully assisted with initial response emergency communication and was returned after two weeks of service.

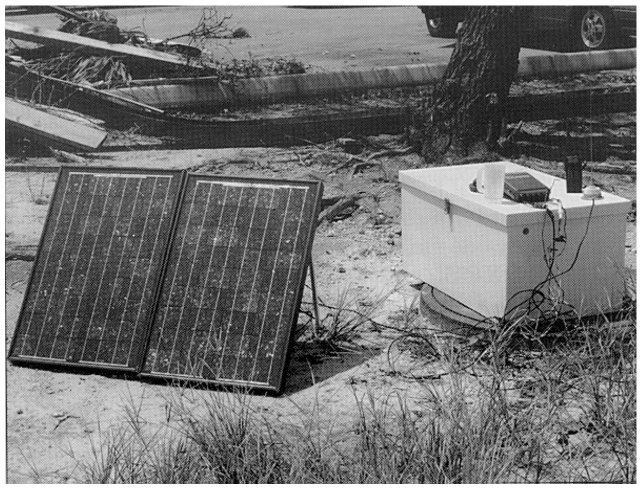

Figure 5. FSEC Training System Powering Amateur Radio Communications

FSEC, together with SANDIA National Laboratories, responded to a request from the University of Miami, Field Epidemiology Survey Team (FEST), for PV systems to power temporary medical clinics in south Dade County. Five PV systems were assembled in about a week and delivered to the disaster area. Each system consisted of a 1-kWp PV array, battery bank, controller, charger and a 2 kWh DC/AC inverter.

They provided power 24 hours per day for medical services desperately needed by people injured not only in the storm, but also during the cleanup and rebuilding. One system, located at Saint Anne's Mission, is shown in Figure 6.


Figure 6. FEST PV System

Lights, radios, fans and medical laboratory equipment were powered by these PV systems. Some old 12-volt DC vaccine refrigeration units were brought along and installed at three of the sites.
The refrigeration units were previously obtained for testing for the World Health Organization. Small refrigerators are most effective for medical clinics, as larger ones are used to cool everything and are opened so often that they consume more power than needed. Shown in Figure 7 are the balance of system components and appliances used at the clinics.

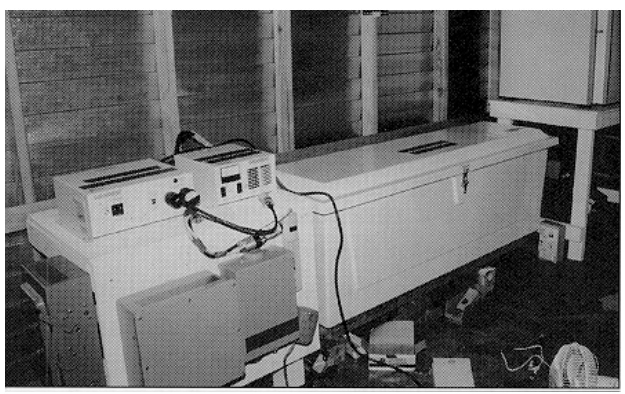
Figure 7. Balance of System Components

Because Andrew's destruction was so great, PV systems were used for weeks after deployment. However, the complete systems were designed and assembled two weeks after the disaster, and therefore were not in use when initially needed. For more effective use, PV systems need to be off-the-shelf units ready for deployment and use. Because these systems were custom built and not mobile, final assembly was on site. Therefore, this application was very labor intensive and required technical expertise.

The manual switching of component and system controls was too complicated for some users. Fully automatic operation and a detailed status display are needed so users can fully benefit from the system. This PV system suffered from user overloading. Systems with dedicated loads would be more useful to inexperienced relief workers, since workers wouldn't need to switch loads, change components, or inadvertently overload the system.

Long before Hurricane Andrew struck, PV-powered street lights had been installed in Montego Bay, a south Miami suburb. After the storm, all 33 street lights were still standing and provided the only light in the area until utility power was restored. Each streetlight consisted of a pole-mounted fixture that contained a battery and controller enclosure, two PV modules and a fluorescent lamp. The street lights were manufactured locally by Solar Outdoor Lighting and were among the few lights still operating after the storm.

Later, additional lighting units were installed at command centers, security stations, temporary medical clinics, and shelters in the disaster area. Security lighting became very important for the safety of survivors trying to rebuild, offering protection from vandals and dangerous debris. A National Guardsman stationed in front of one unit is shown in Figure 8.

Figure 8. PV Lighting at
Security Checkpoint

The Florida Department of Transportation was already equipped with numerous PV-powered traffic devices used for road construction. When Andrew struck, a PV-powered highway advisory radio unit, built by Digital Recorders, was operating along I-75 in the Everglades, transmitting messages about rest stops and tolls. After the storm, the unit's AM radio transmitted road hazards and route changes in the disaster area. Additional trailer-mounted units were installed along the Florida Turnpike to provide further information to travelers, as shown in Figure 9. The system worked flawlessly, as if custom made for this application.

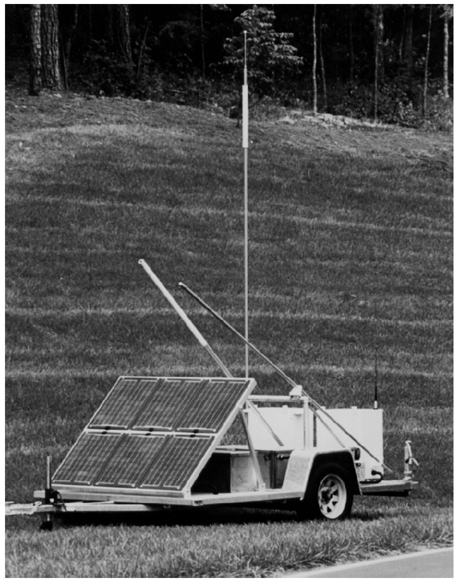

Figure 9. PV-Powered Radio
Transmitter Along I-75

Other PV-powered traffic devices were transported to the disaster area to assist in the relief effort. Traffic control was increased by use of changeable highway message signs, flashing arrow boards, and warning signals and signs. Changeable highway message signs were invaluable to relief workers arriving from outside the area, directing them to staging areas and shelters (see Figure 10).

Figure 10. PV-Powered Changeable
Message Sign

Two PV-powered traffic signals were developed, constructed, and shipped to Dade County Transportation Department. The systems initially were underpowered and were modified by the manufacturers. Three months after Hurricane Andrew, they were tested at an intersection where power and traffic lights were not restored yet. After testing, the systems were not used as they were considered unsafe and did not meet all of the DOT standards.

Many families could not relocate and leave behind everything they owned. Since it took weeks for utility power to return to those staying, flashlights became prize possessions and batteries were in great demand. Kyocera America provided several hundred solar lanterns to the American Red Cross, which distributed them at shelters. The lanterns had a 3-watt fluorescent lamp powered by a 2.5-watt PV module and a battery, as shown in Figure 11. The lanterns were very useful for close area lighting, but not for large area lighting, such as for construction site spotlights. The lanterns were more expensive than flashlights, and not as convenient because of the need for solar charging. Also, they were more likely to be stolen, which made them closely guarded for their valuable light.

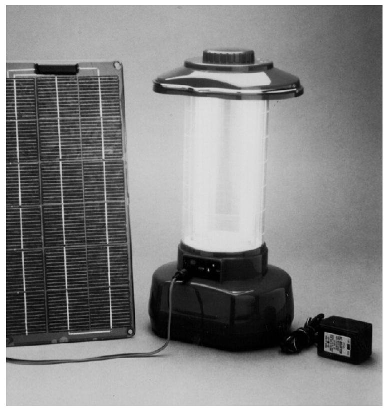

Figure 11. PV-Powered
Lantern Used in Miami

3.5 Hurricane Erin

In 1995, Hurricane Erin cut across central Florida near the old location of FSEC. Luckily, the storm was not strong enough to damage any of the PV-powered buildings at the center. Other PV-powered equipment located in the area continued to operate while utility power was in the process of being restored. Several security and street lighting systems located in the area were not damaged by the storm and continued to operate while power was out for several days. One such light is shown in Figure 12. PV lighting systems that offer little wind resistance seemed to survive the storm best.


Figure 12. PV Security Lighting

3.6 Hurricanes Luis and Marilyn

In 1995, Hurricanes Luis and Marilyn struck the Virgin Islands within a week of each other. The island of St. Thomas was totally devastated and without grid power for months. Ham radio operators at Emergency Operation Centers successfully used portable tote PV systems to power radios for local and between-island communications.

After Hurricane Luis, Miox Corporation provided PV-powered water purification units to the Virgin Islands. The unit shown in Figure 13 was capable of producing several hundred gallons of potable water per day. Two units were shipped but were never used because no one knew what they were or how to set them up.


Figure 13. PV Water Purification Unit

On the island of St. Thomas, two PV systems supplied power to a medical supply company, Supply

Resources, Inc., and the supply company owners' home. Though the buildings were damaged, both PV systems survived the storms, allowing the store to re-open the next day. Repairs to the home and store were completed faster because electrical power was readily available. The owners offer testimony to the value of solar power, having enjoyed it in their lives daily, as well as having reaped its benefits after these devastating storms. Neighbors benefitted from use of the system in rebuilding their homes, too.

Two resorts, Maho Bay Camp and Concordia, on the Island of St. John in the Virgin Islands, were already PV powered when Hurricane Luis struck. The buildings received minimal damage, but the PV systems remained operational. Lights, refrigerators, fans, and communications equipment in the resorts used the PV-generated power as the owners repaired the resorts. Since PV already supplied the owners' needs each day, the utility power outage posed no problem for them. Because the resorts were two of the few places with power, they became shelters and medical centers for other residents affected by the storms.

3.7 Hurricane Iniki

When Hurricane Iniki struck the island of Kauai in the Hawaiian Islands, PV systems were already powering several buildings. These systems were not affected by the storm and provided continuous power to the owners. In other buildings, connected only to the utility, residents were left without power for weeks. This is another example of a PV-powered building withstanding a storm and becoming a shelter and medical clinic in the recovery effort.

4. TABULATED USES

Since 1989, PV systems have provided power for recovery efforts after seven disasters. The types of systems and their applications are shown in Table 1 below:

Table 1. PV Power Applications Used in Disaster Recovery Efforts
(H=hurricane)

Application	System	Disaster	Year	Location
Lighting/Communications	tote	H. Hugo	89	St. Croix
AC Power	trailer	H. Hugo	89	S. Carolina
Home Power	fixed system	H. Bob	91	Rhode Island
Lighting/Communications	trailer	Earthquake	91	Northridge, CA
Communication	portable	H. Andrew	92	Miami, FL
AC Power	fixed system	H. Andrew	92	Miami, FL

Security Lighting	fixed fixture	H. Andrew	92	Miami, FL
Radio Communications	trailer	H. Andrew	92	Miami, FL
Traffic Signs & Lights	trailer	H. Andrew	92	Miami, FL
Portable Lighting	fixture	H. Andrew	92	Miami, FL
Security Lighting	fixture	H. Erin	95	Titusville, FL
Building Power	fixed system	H. Erin	95	Cocoa Bch., FL
Water Purification	fixture	H. Luis & Marilyn	96	Virgin Islands
Radio Communication	tote	H. Luis & Marilyn	96	Virgin Islands
Building Power	fixed system	H. Luis & Marilyn	96	Virgin Islands
Building Power	fixed system	H. Iniki	96	Kauai, HI

5. CONTACT LIST

Several organizations have been involved in the application of PV to disaster relief presented in this report. A contact person at each organization is provided in the following list:

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6. CONCLUSIONS

Photovoltaic power systems have been used for a number of disaster relief efforts and have been successfully applied to medical clinics, communication operations, shelters, and individual needs. PV is a viable source of electrical power for disaster relief applications that require low-power, long-term use, and where survivor support is difficult to provide. The stand-alone operations of solar energy systems make them a valuable, cost-effective resource for electrical power, due to low operating cost and the capability for sustainable operation. In a large scale disaster, solar-powered systems are a natural solution because they are designed specifically for stand-alone operation where utility power is unavailable.

Each application presented in this report was a success except one. Some applications had obstacles that need to be addressed for future use. For example, the water purification application suffered from people's lacking training and familiarity, which is also an obstacle to using conventional disaster relief equipment. As in any technology, the right equipment needs to be applied to the right application.

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