Linking Solar Photovoltaics with Building Disaster-Resistant Communities

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ABSTRACT

Disaster preparedness is a key issue for large urban areas, especially in areas that experience not only natural disasters such as floods, high winds and earthquakes, but also power outages on the local, regional and multi-state areas.

Solar Photovoltaic (PV) systems are a natural and wise solution for disaster preparedness because of their sustainable, stand-alone operation capabilities. The question is not whether solar photovoltaics can be used as a part of disaster and security operations, but an identification of the applications and conditions for which solar energy is the preferred alternative. Within the City of San José, we have undertaken a project to explore, identify and test priority applications of renewable energy systems for disaster relief and for building disaster-resistant communities. The City is particularly interested in identifying "dual-use" applications, such as the use of solar electricity on school facilities that are also used as shelters during disaster situations.

Our approach to spurring widespread application of PV for disaster relief is to get PV equipment in the hands of emergency response teams, enable the use of the equipment for training and during emergencies, and evaluate the effectiveness of the technology in meeting their needs. In addition, we will be working with our area schools to identify collaborative projects that could install solar PV on those schools that also double as community shelters during a disaster.

The project has the assistance of an Advisory Committee comprised of city and area emergency managers, fire, police and buildings departments, along with regional and national representatives from the energy and disaster preparedness agencies.

Background

Disaster preparedness is a key issue for the City of San José, a city of more than 900,000 residents. In the most recent years, we have faced not only natural disasters such as floods, high winds and earthquakes, but power outages on the local, regional and multi-state areas. In a recent address to a group of mayors and local officials of the National League of Cities, Energy Secretary Bill Richardson warned that the summer of 2000 could see a repeat of power outages if reliability problems in the electricity industry are not addressed.

During a disaster, food, shelter, medical and communication services are key life supporting resources provided by emergency response organizations. Each of these services and resources require electrical power. When the local utility power source is down, these agencies typically rely on gasoline or diesel generators.

The City is proud of the disaster and emergency preparedness programs that have been established within our community. *San José Prepared!* is the City's award-winning community emergency response team-training program that helps San Jose residents be

better prepared for self-sufficiency following a disaster. This program provides them with the training and knowledge needed to provide emergency assistance to their families and neighbors. This program enables people to work as a team in their neighborhood in the event of a major disaster. (For more information: www.ci.san-jose.ca.us/oes/prepared.html)

The City also has a strong commitment to the environment, as evidenced in its current mission statement where the City strives to be a "leader in environmental programs." This is best evidenced by the leadership shown by the City's Environmental Services Department, whose mission is to "work with our community to conserve natural resources and safeguard the environment for future generations."

In August of 1994, San José's City Council adopted San José 2020 as its general plan. Included within the plan was a new strategy entitled the "Sustainable City Major Strategy." The Sustainable City Major Strategy is a statement of San José's desire to become an environmentally and economically sustainable city. A "sustainable city" is a city designed, constructed, and operated to efficiently use its natural resources, minimize waste, and to manage and conserve them for the use of present and future generations.

The City of San José is working to become an environmentally and economically sustainable city, one characterized by responsive and efficient policies and programs, and by successful public-private partnerships. The City's Sustainable City Major Strategy and environmental policies and programs are based on the premise that natural resources are not inexhaustible commodities to be exploited but are limited assets which should be wisely managed for the benefit of present and future generations. By planning for urban sustainability, the City of San José aims to promote resource efficient land, transportation, energy and water use, and resource conservation.

The City of San José has used a broad array of policy, fiscal, administrative and program tools to create and maintain its sustainability initiatives. Examples abound throughout the City departments and offices, from watershed management and economic development, to community education and environmental compliance, green building guidelines and educational program and responsible legislative advocacy.

In 1998, the City of San José undertook a Department of Energy-funded project to identify renewable energy projects and activities that could be undertaken by local governments. That research indicated that there are a variety of applications for renewable technologies on the community level. In addition to the building sector, both commercial and residential, there are solar applications that enhance other community services. Some of these include: signs, pathway security lighting, median water irrigation, electric vehicle charging stations, vehicle battery charging, emergency call boxes, bus stop shelter lighting, and traffic hazard signs.

Understanding the possibilities and recognizing our strengths in the areas of innovative energy planning and implementation, sustainability and emergency preparedness, the City proposed to conduct a technology transfer project that would showcase solar applications as a part of emergency planning, providing the applications of on-site and portable renewable energy systems to mitigate the impact of power outages and disasters and to reduce greenhouse gas emissions. That project was subsequently funded by the Department of Energy through the Urban Consortium-Municipal Energy Management Program.

Research on Solar Technologies and Disaster Management

In recent years, there has been some use of photovoltaics in disaster relief efforts. They have proven to be an effective alternative to gasoline or diesel power generators. PV modules can be a substitute for gasoline or diesel powered generators in some of the disaster operations. They are very simple systems which allow for quick response to a disaster. Lighting, communications, water treatment, etc. are needed by the relief workers to operate and these can be immediately met with solar electricity. The Florida Solar Energy Center (FSEC) and the National Renewable Energy Laboratory (NREL) have been the leaders on using photovoltaic power for emergency situations. They have both developed and used PV powered disaster relief equipment in the aftermath of disasters. FSEC, for example, provided PV equipment to produce power for shelters and hospitals after hurricanes Andrew and Hugo. NREL has provided technical advice to the Federal Emergency Management Administration (FEMA). NREL has given guidance on how to educate FEMA's staff on the uses of photovoltaics for disaster relief and for building disaster-resistant communities.

PV for Emergency Services

In recent years, PV systems have provided emergency power in the aftermath of many past disasters:

- Northridge Earthquake, 1994: The earthquake caused widespread power outages throughout the Los Angeles area and beyond. The entire Los Angeles Department of Water and Power systems went down. This led to 1.3 million customers to be without electricity. Half of the customers recovered power within six hours, and within 24 hours, 95 percent of the customers were back on line. Despite the utility's timely restoration of power, close to 100,000 homes and business were without electricity for more than 24 hours. Water supply was also disrupted due to breaks in the supply and distribution lines. The use of PV kept some communications links operating. It also supplied power to Southern California residents that had installed systems on their homes. (U.S. DOE 1995)

- Hurricane Andrew, 1992: The storm left about 3 million homes and businesses without power, including 1.4 million Florida Power and Light customers. Water and wastewater utilities were also hit hard, as trees fell over water mains and distribution lines. The power outages also disabled the water pumps. Some parts of Dade County (Miami area) had electricity back within two weeks but other areas, such as the southern end, did not have power for at least a month. Solar PV systems provided power to shelters and medical clinics. They also powered street lights and communication systems. (U.S. DOE 1995)

- Hurricane Hugo, 1989: On September 21, 1989, the category 4 hurricane hit South Carolina. Charleston, Folly Beach, Sullivan's Island, Isle of Palms and McClellanville were hit hard. Hurricane Hugo left 26 people dead in South Carolina alone. The damage estimate would go as high as $7.2 billion (in 1990 dollars). Sixty buildings in downtown Charleston were flattened. 5,100 homes were destroyed. 11,928 more homes were left uninhabitable. Damage was reported in twenty-nine counties, most of which were designated as federal disaster areas. Ninety-eight percent of the city's residents lost power, and for some, repairs were not made for more than two weeks. Power outages

caused large amounts of raw sewage to bypass treatment plants and flow into streams throughout Mecklenburg County. (Hurricane Hugo 1997) A portable solar electric generator powered a community center for six weeks after the storm. (U.S. DOE 1995)

Other Applications of PV in Emergency Relief

Photovoltaic systems can supply electricity to provide some important emergency services.

Communications. Communication systems are very important to fire and rescue personnel, medical personnel and the police during a disaster. When emergency services are needed, radio or phone communications are important to obtain those services. When communications are down due to power loss, PV can keep radio and phones working. (William Young, Jr. April 1998) Perhaps the best application for solar power by response teams is to use PV panels to power portable repeater stations that extend the range of hand-held radio communications. Ham radio operators used solar power to maintain vital communication links following Hurricane Andrew in Florida and the Loma Prieta Earthquake, which struck California's Bay area in 1989. Ham radio stations often come through following disaster when much more sophisticated communications systems fail. They are ideal candidates for solar power.

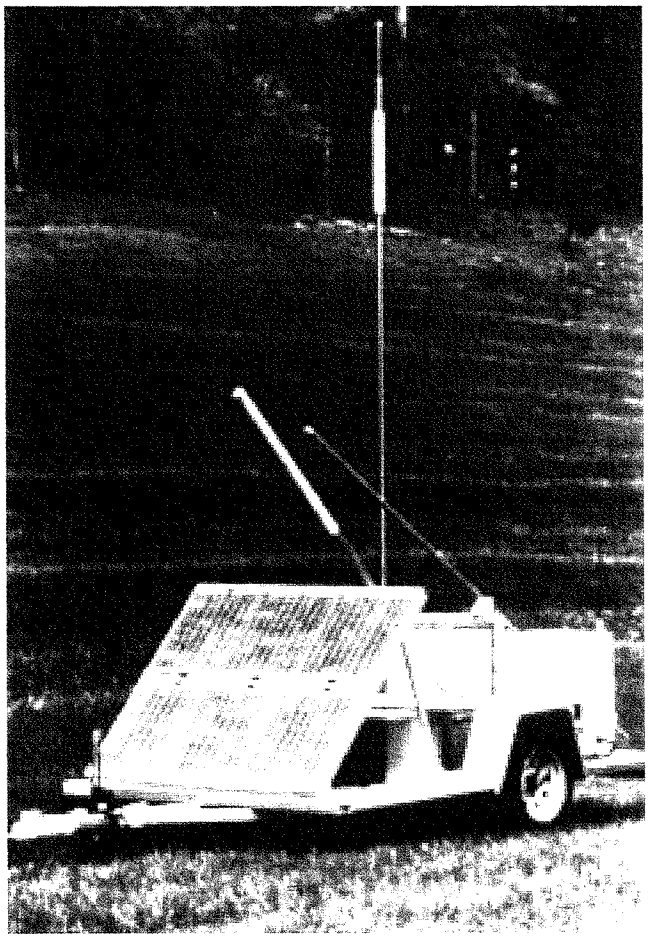

Figure 1. Mobile PV-powered highway advisory radio system (photo courtesy of Digital Recorders).

Transportation aids and warning signals. Travel often becomes hazardous after a disaster. Portable PV-powered traffic control devices such as changeable message sings, flashing arrow boards and signs, and highway advisory radio can assist with traffic control. (William Young, Jr. April 1998) The Florida Department of Transportation used a mobile PV-powered highway advisory radio system, shown in Figure 1, as communications tools following Hurricane Andrew. Drivers could tune in for information on traffic and emergency assistance. Solar-powered changeable message signs also communicated traffic information and alerted motorists to the advisory radio systems. These systems, along with PV-powered emergency telephone call boxes, flashing barricades lights and other warning signals, come in extremely handy not only during times of crisis, but also for day-today use. The signs and barricades inform motorists about road construction projects, and highway call boxes play an important safety role.

Battery charging. Another potential use for PV in the disaster response arena is for charging batteries. When rechargeable batteries are used to power such items as hand-held radios and cellular phones, they sometimes lose their power before the workers can return to the base camp to recharge them. When their battery packs run down, they are unable to communicate until someone brings them a fresh one or they return to camp.

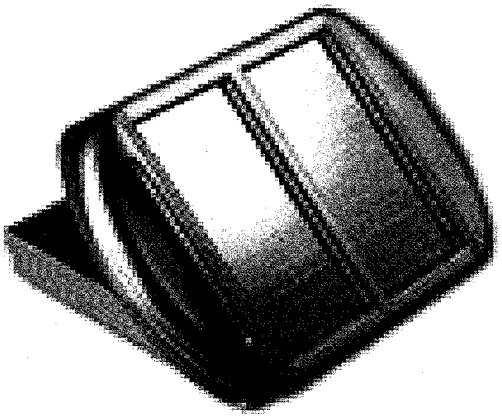

Figure 2. Solar Battery Charger

One round of AA alkaline batteries lasts about 24 hours, as compared to 8 hours for rechargeable. It makes more sense to use alkaline batteries whenever possible. However, in situations where crews work long shifts and the use of rechargeable batteries cannot be avoided, workers could use small solar battery chargers, such as the one shown in Figure 2, to charge depleted battery packs while in the field. The U.S. military uses PV for charging batteries to maintain communications between units and headquarters.

Portable power. Portable PV power systems are especially well suited for meeting long-term emergency power needs at small-scale isolated sites. For example, following Hurricane Andrew, four PV power systems were installed throughout hard-hit South Florida. Three of the systems, similar to the system shown in Figure 3, were installed at small medical clinics and one provided electricity for a relief operations center. They were used to operate vaccine refrigerators, lights, fans, medical equipment, and small radios and televisions. Solar power was especially ideal at the clinic locations because it kept patients away from prolonged exposure to the noise and fumes of portable generators. It also enhanced the operation of medical instruments (stethoscopes, for example) that require a quiet environment for proper use.

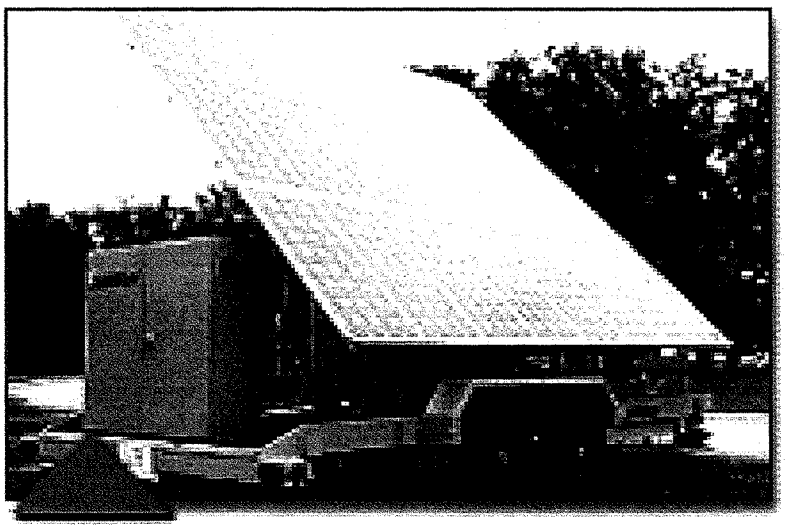

Figure 3. FEMA's 1-kW Mobile System

Outdoors lighting. Street, security, hand-held and portable lighting can be powered by photovoltaics. Photovoltaic-powered lighting can be installed in a relatively short period of time in any location to either replace destroyed conventional lighting or provide temporary lighting where utility power has not been restored. The clinics and relief shelters that hosted PV power systems following Hurricane Andrew also benefited from PV-powered outdoor security lights. Though they were low power systems compared to traditional streetlights (30 watts versus 250 watts), they provided comfort in the total darkness. Figure 4 shows a picture of a PV streetlight in Homestead, a suburb of Miami. In Homestead the PV lights were not only the only structures to survive Hurricane Andrew, but they provided the only source of light for several weeks. Many different types and sizes of lights are PV-powered, and their performance is comparable to conventional lights. PV can also power portable personnel lights, from flashlights to lanterns.

Figure 4. Before and after photos of a PV streetlight in Homestead (photo courtesy of Solar Outdoor Lighting, Inc.)

Water purification. Water system disruptions seem to be almost as common as utility grid failure following disasters. And although rescue workers are proficient at quickly mobilizing clean emergency water supplies into areas of need, it may be more efficient in some cases to transport not water supplies but water purification equipment.

Water pumping. PV could also be used to pump water during emergency situations. Some portable solar pumping systems do not require batteries but work directly off the power supplied by the array.

PV Powered Applications in Emergency Situations

Solar PV in emergency situations has powered the following equipment:

- Lights
- Radios
- Fans
- Flashing warning signals and signs
- Amateur radio unit (portable PV)
- Traffic devices (for road construction)
- PV-powered water purification units
- Building or backup power
- PV powered generator (for power and lights)
- Solar lanterns
- Refrigeration
- Folding man packs
- Call boxes
- Flashing arrow boards
- Medical and laboratory equipment
- Streetlights

- Hand-held radio transceivers
- Highway advisory radio
- Instrumentation equipment
- Flashlights
- Photovoltaic generators
- Portable AM/FM radios
- Portable pumping stations
- Radio base and repeaters stations
- Refrigerators and coolers
- Security lights
- Small battery chargers
- Streetlight traffic signals
- Victim detection equipment
- Water purification

(William Young, Jr. July 1997)

Local Government Role

The City of San José's Environmental Services Department (ESD) submitted a proposal in 1999 to the Department of Energy through the Urban Consortium Energy Task Force—Municipal Energy Management Program. The objectives of San José's project are to:

- Develop a Sustainable Energy Emergency Action Plan for the City of San José, identifying priority disaster, emergency, community and/or security applications which can be better served by solar PV power;
- Install and evaluate a solar PV system at one or more of the City's key locations or mobile units; and
- Work with regional and state Emergency Managers' Associations to provide information on the emergency and disaster applications of solar photovoltaics.

As of this writing, staff within the ESD has been working primarily with the San José Office of Emergency Services (OES) and General Services Department. Through the City's OES, ESD is able to coordinate with other departments who play an active role during an emergency--Police, Fire, Streets and Traffic and other essential services.

Working with those Departments, staff is currently undertaking a review of possible solar PV applications. A matrix has been developed which outlines the potential application, current energy source, level of power needed, period of time used, and solar equivalent. Using this information, applications will be prioritized and bids prepared for equipment purchase. Equipment will be evaluated based on its application, power supply, power source (fuel), cost to operate (fuel costs, maintenance cost), reliability of conventional equipment, hours of usage per month, cost of backup PV equipment, backup PV equipment cost to operate, and backup PV equipment reliability. Based on this evaluation, a pilot project will be selected.

Key applications that are being identified include:

- Dispatcher-In-A-Box: Dispatcher-in-a-box is a new innovation intended to improve the service to the community during a disaster. The communications building contains all the necessary equipment necessary to provide the dispatcher's services. However, if the dispatchers were forced to evacuate the building, they would not be able to provide their services. Dispatcher-in-a-box would help remedy this and we are looking at the possibility of powering the equipment with solar panels.

- Mobile Emergency Information Trailer: The Office of Emergency Services owns two mobile emergency information trailers which broadcast important information to the community after and during a disaster. It informs the community about shelter sites, medical services, road closures, etc. Diesel generators power these trailers. PV panels can be primary source of electricity.

The City's General Services Department will be providing funding for one or two small solar PV applications. Following the bid process, installation and testing will ensue. At this time, City staff anticipates pilot applications for communications equipment, security lighting, battery charging or power supply for the Police/OES Mobile Emergency Information trailer.
In addition to testing solar equipment in the field, the City also conducted a "Solar Technology and Disaster Management" workshop. This workshop, held April 14, 2000, provided information on case studies, procedures, and available equipment. Speakers included representatives from the National Renewable Energy Laboratory, Federal Emergency Management Association, and local solar PV equipment providers and installers. This workshop was targeted to emergency managers and communication personnel within cities, counties, hospitals and other key personnel who are involved in disaster relief situations. The attendance to this workshop included PV suppliers, emergency personnel from cities and counties around the Bay Area, High School district representatives, local university representative, PG&E and San Francisco International Airport representatives. Most of the attendees had little of no knowledge of the use of PV systems for disaster relief purposes previous to the workshop. After the workshop, attendees were very pleased with the information that was presented to them and encouraged the City to continue educating people about the use of PV for disaster relief. Attendees, on an evaluation sheet, stated that after being presented with examples of PV power disaster relief equipment, they would probably buy PV equipment for their disaster relief efforts.

Market Transformation Potential And Future Applications

The City of San José's project has several market transformation and technology transfer applications.

Potential to stimulate market demand. The use of solar for emergency and disaster mitigation situations could be a growing market, especially for local governments. Solar is a proven technology in disaster situations, and more governments need to know about the purchasing opportunities and potential applications.

Ability to act as a catalyst for increased deployment of solar electricity applications. Using solar in smaller, low-power situations will help defray the fear of some municipal employees and installers/technicians that solar is still "too new" of a technology and not applicable for other situations. Providing "real world" installations, combined with training and installation assistance will help technicians gain the knowledge to try solar technologies in other areas.

Involvement with the community and others about solar electricity. Linking solar technologies with a city program that is already active within the community is a wise choice. Living in "earthquake" prone state, the City is constantly providing information to the community about emergency planning and relief opportunities. Seeing solar systems in use on emergency/disaster communication vehicles and at designated shelters will provide the community with an increased awareness of the variety of uses for solar technologies.

Model for implementation for other local governments. Within this project, key contacts have been made with the Santa Clara County Emergency Managers Association, the Association of Bay Area Governments and the California Emergency Services Association. This project will be closely monitored, and information shared throughout the project in an effort to educate other emergency planning agencies.

Future applications. School auditoriums are often used by local governments for sheltering those individuals who may have lost their homes or apartments during a disaster. Ensuring reliable power for lighting and other uses at those shelters is a key issue for emergency managers. Within the state of California, there are several key programs for assistance to schools and agencies for the purchase of solar equipment. As part of the City's project, we will be initiating a discussion with key school personnel to explore the possibilities of installing solar energy systems at a school location.

Conclusion

The City's approach to spurring widespread application of PV for disaster management is to get PV equipment in the hands of emergency response teams, providing personnel an opportunity to use the equipment for training and during emergencies. PV equipment in the hands of emergency response teams allows for an evaluation on the effectiveness of the technology in meeting their needs. The test project being conducted during 2000 will allow for an evaluation and a determination of the effectiveness of solar PV for disaster management at the local government level.

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