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Solar 2007: Florida's Emergency Shelters Go Solar

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SOLAR 2007: FLORIDA'S EMERGENCY SHELTERS GO SOLAR
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ABSTRACT

Florida has its fair share of dangerous weather conditions including hurricanes, tornados and floods. Florida legislature passed various laws and made revisions addressing disaster planning which required that the Department of Education, in consultation with school boards and county and state emergency management offices, develop design standards for public shelters to be incorporated into State Requirements for Educational Facilities.

Last year, Solar for Schools, a state program, provided funds to put photovoltaic systems on schools that are classified as shelters, adding a new dimension to the educational program. Middleton High School is an example of an application to power the special needs part of a school shelter, as well as provide an educational experience for students, teacher and the surrounding community. During normal school operations, the ten kW photovoltaic (PV) array powers computers and other classroom equipment in one wing of the school. Students learn, not only about photovoltaics and other renewable technologies, but also about disaster preparedness and the importance of durable, energy efficient building design and construction.

1. INTRODUCTION

Florida is blessed with balmy weather and beautiful beaches, but it isn't always sunny in the Sunshine State. Florida has had its fair share of dangerous weather conditions including hurricanes, tornados and floods. In response to these natural disasters, Florida has developed top-notch disaster plans, established modern building codes, and created one of the most experienced Emergency Management teams in the nation. A century old expert in disaster response is the American Red Cross, who traditionally provides mass care of victims having developed modern standards for preparedness and operation in 1987. The Federal Emergency Management Agency and many other disaster relief organizations respond with massive and effective services for the survivors providing them with water, food, clothing and shelter as they begin the recovery process.

The days of one-room schoolhouses with wood stoves and oil lamps are gone in this country. In those days, churches, town halls and schools were gathering places for communities. After the 1930s, schools were built with their own heating and electrical generation systems, as technology changed and the electrical grid grew from centralized utility generating plants. Dating back to World War II and possibly before that, schools were the most common choice to be used as emergency shelters (1). By the 20th century, electrical power received through grid connections was commonplace and schools became multi-purpose centers providing many services besides education, including shelters during disasters.

People are most often evacuated into school shelters during disasters, both natural and man-made, if there are no other safe options available. Various disaster relief organizations provide the sustenance for life and help direct and support recovery efforts as people rebuild to pre-disaster conditions. Without power, emergency responders are hampered, shelters are miserable, and the rebuilding process is slowed. Beginning with the energy crisis of the 1970's, followed by escalating acts of terrorism today, creating energy security is of great concern. As we have seen with the active hurricane season in Florida in '04 and the devastation of Hurricane Katrina in '05 disasters can leave thousands upon thousands of people without their basic needs being met through lack of power. For all these reasons and more, developing energy independence with renewable energy technologies is finally on our radar screens. Now the move is toward distributed generation and the use of renewable energy sources as each disaster, storm, mechanical failure, human failure or just the age of the grid demonstrates the vulnerability of our present power grid structure.

2. EMERGENCY POWER

One way to overcome grid power outages is to have your own source of electricity. Conventional petroleum fueled engine generators can be your main source of electricity in a remote situation or as an emergency generator when connected to the grid. These engine generators have virtually no problems when permanently installed to the latest codes by licensed technicians. Portable engine generators purchased and operated by untrained users have several problems, beyond higher life cycle cost and the lack of fuel during a disaster. Safety is the biggest issue. Each year hundreds of people suffer injuries or death from asphyxiation, burns, fires, fuel explosions and electrocutions. Utilities and insurance companies consider portable engine generators hazardous and their use is discouraged. Noise is another problem adding to the traumatic stress of people already under strain by the disaster.

Large industrial diesel generators are usually used as backup and emergency generators at various facilities, businesses, hospitals, pumping stations, and shelters. These generators are professionally installed, maintained, and fueled. In the 2004 hurricane season, Florida experienced a fuel shortage due to the disruption of the fuel distribution system effecting transportation and generator operations. The emergency generator at the Brevard County Emergency Operation Center failed a week after Hurricane Jean and was not operational for 12 hours as parts were obtained to repair an otherwise properly maintained generator. In Florida, many counties have voluntarily put 25-50 kw diesel generators at their special needs shelters, while several counties have generators at all of their primary shelters.

3. CODES AND STANDARDS

The American Red Cross is the nationally recognized public sector leader in disaster response and shelter management, whereas the Federal Emergency Management Agency is the government leader directed by law. The Florida Department of Community Affairs (FLDCA) has recognized national and other state disaster standards, guidelines and "best practices" to ensure consistency within the state between organizations and programs. In 1993, after Hurricane Andrew, the Florida legislature passed revisions to the Laws of Florida requiring that the Department of Education, in consultation with school boards and county and state emergency management offices, develop design standards for public shelters to be incorporated into the State Requirements for Educational Facilities. Florida is a coastal state making the Southern Building Code (SBC/SSTD 12) and theAmerican Society of Civil Engineers standard ASCE 7 important when designing for hurricane winds and debris. In 2003, the International Code Council (ICC), National Storm Shelter Association (NSSA) and the Federal Emergency Management Agency (FEMA) started development of the International Standard (IS) *Standard for Design and Construction of Storm Shelters* (IS-STM) to set model codes to achieve uniformity in the technical design criteria in building codes and other regulations. The Florida Division of Emergency Management (FDEM) is under FLDCA and is participating in the development of this new standard. For now, the standard, codes and guides followed in Florida are in table 1.

TABLE 1: LIST OF CODES AND STANDARDS

NSSA	Industry Standard: Standard for the Design, Construction, and Performance of Storm Shelters.
FEMA 320:	Taking Shelter from the Storm, Building a Safe Room Inside Your Home
FEMA 361:	Design and Construction Guidance for Community Shelters
ARC 4496:	Guideline for Hurricane Evacuation Shelter Selection
ARC 3041:	Mass Care Preparedness and Operations
EHPA FS 423.25	Florida Building Code: Enhanced Hurricane Protection Areas
Florida Statue 1013.372:	Public Shelter Design Criteria.
FL DCA:	Statewide Emergency Shelter Plan
ASCE 7	Minimum Design Load for Building and other Structures.

The purpose of the new ICC standard is to establish minimum requirements to safeguard the public health, safety, and general welfare relative to the design, construction, installation, repair, operation and maintenance of storm shelters constructed for refuge from high winds associated with tornadoes and hurricanes. This standard also establishes requirements for natural and mechanical ventilation, emergency power system, life safety systems, standby lighting, and standby branch wall circuits. Though emergency generators are not required, provision to meet these loads are required by permanent, temporary or standby gen-set(s) that are independent of off-site utilities. As the people in the shelter are to be protected from the disaster design event, so are the gen-set and emergency electrical loads.

As a long term leader, the American Red Cross (ARC) in 1987, established several national standards such as the standard *Mass Care Preparedness and Operations* (ARC 3041). This standard defines the operation of a shelter in a disaster and the resources and services to effectively shelter the inhabitants. FEMA has its own standard (FEMA 361) with similar, but different criteria. Some of the resources of the two standards are listed in table 2.

TABLE 2: MASS CORE RESOURCES

Criteria	ARC	FEMA
Sleeping spaces - sq.ft. per person	40-60	15
Blankets - per person	2	0
Cots - per person	1	0
Food – calories per person per day	2500	700-1200
Potable water - gals per person per day	5	1
Toilets and showers 1 per x-# persons	40	75

Another ARC standard is *Standards for Hurricane Evacuation Shelter Selection* (ARC 4496) as the minimum hurricane shelter survey and evaluation criteria. This document defines the process of selecting which buildings make good shelters and for determining how many shelters are needed to meet the needs and required conditions for a facility to be described as "safe", "suitable", or "appropriate" for use as a public hurricane shelter. The new IC-STM standards should become the accepted standard when approved. This standard defines:

Site exposure
Surge inundation areas consideration
Rainfall flooding criteria
Wind Hazards/structural consideration
Wind Hazards/interior safety criteria
Hazardous materials consideration
Hurricane shelter selection process
Least-risk decision making process
Emergency Power and loads
Historical data and maps

4. SHELTER ENERGY NEEDS

In the threat of a disaster or after a disaster has occurred people in harms way leave town, visit relatives or friends or evacuate to a local shelter. There are two types of shelters, one for generally normal healthy people and the other for people with special health needs. General shelter energy needs include mechanical ventilation, emergency power system, life safety systems, standby lighting, and standby branch wall circuits. A shelter is not required to have air conditioning, but is required to have natural ventilation and minimal services for safe habitation. Design of the hurricane protected areas and selection of essential accessories equipment determines the energy needs. Rule of thumb load requirements are listed in the following table 3.

TABLE 3: ESSENTIAL EQUIPMENT REQUIREMENTS

Item	Power	Conditions
Mechanical ventilation	0.35 watts per cfm	15 cfm per person
Air conditioning	1000 watts	500 sq. ft./ton
Life safety systems	10 watts	LED exit light charger
Standby lighting	40 watts	backup ceiling florescent
Standby branch wall circuit	1800 watts	wall outlet receptacle

A special needs shelter is similar to the general shelter, with the added resources needed for medical treatment of their health issues. A special needs shelter will have a doctor, one nurse for at lease 6 patients and a personal care taker for each patient that they bring with them. Each special needs person will bring their own medical equipment, supplies and personal items. They may have more than one health problem needing one or more machines. In some cases, their health problem requires that they be in an air-conditioned space. These people may have been staying in an independent living center, hospital, nursing home, senior center, relatives or on their own, but are evacuated to a special needs shelter in time of a disaster.

A wide variety of equipment is used by disabled and special needs people. The energy consumed is different for each device, from a few watts to hundreds of watts. The hours of operation of each device is different, as some are only used once a day, while others are used continuously. Typical medical equipment that a special needs person would use is listed in table 4

TABLE 4: MEDICAL EQUIPMENT REQUIREMENTS

Medical item	Watts	Hours	Period
Oxygen concentrator	400	24	day
Ventilator	400	24	day
Apnea Monitor	120	sleeping	day
G-tube feeding machine	350	feeding	day
Track Tube machine	450	24	day
Nebulizer	20-40	0.2	3-4 hr
Dialysis/RO	2200	4-5	3 days
Defibrillator	160	0.1	as needed

5. SOLAR FOR SCHOOLS PROGRAM

In 2003, the Florida Department of Environmental Protection/Florida Energy Office (DEP/FEO) allocated $600,000 towards the installation of photovoltaic (PV) solar electric systems on Florida schools. This project, initially known as the PV on Schools program provided rebates of $5 per watt, based on the system's nameplate rating and up to $25,000 for systems without batteries. An additional rebate of $1 per watt was offered for systems that included a battery back up component to be used to provide electricity to a school designated as a disaster relief shelter. The purpose of the program was to encourage the installation of grid-connected PV systems on schools through partnerships with local school districts and communities, the state's electric utilities, corporate sponsors, and solar industry.

The program had several educational objectives including: raising awareness and understanding of solar and other renewable energy technologies, as well as expanding the classroom learning experience through inquiry lessons that used the photovoltaic system as a teaching and learning tool. As a result of this program, PV systems were installed on 29 schools, each of those schools incorporated a solar educational program into their curriculum. These inquiry lessons explore renewable energy technologies and also utilize data from the photovoltaic array to improve science and mathematics instruction. The Florida Solar Energy Center monitors these systems and provides real-world data to students via the Internet.

This program was initially designed as a way to raise awareness and understanding of photovoltaic technology among students, teachers and the general public. The key components of the program are the installation of photovoltaic systems on schools, training for teachers, hands-on materials and inquiry lessons that are easily integrated into the existing curriculum. As a requirement of the program, each participating school was obligated to allow two teachers to attend a one day professional development workshop on solar technology, coordinated by the Florida Solar Energy Center. The workshop included background information and hands-on inquiry based lessons in science, mathematics and social studies with renewable energy as the content focus. Utility partners provided hands-on materials to each school which encouraged the immediate integration of lessons into the existing curriculum. In addition to the teacher workshop, a one day workshop was held for facilities personnel to develop a fundamental understanding of the photovoltaic system components and their functions. This insured that each system would be properly monitored by a knowledgeable person.

In 2005-06, the PV for Schools program was renamed SunSmart Schools and was funded in the amount of $300,000 to install 1-2 kw demonstration systems and 10 kw emergency shelter PV systems on schools throughout Florida. Rebates for schools following program requirements are $4 per watt for the 1-2 kw grid-connected systems without battery storage and $5 per watt for the 10 kw grid-connected systems with battery storage installed on state-designated emergency shelters. Schools were selected to participate based on a number of factors, including the school's educational plan and the number of students and teachers affected. Of the 13 to 15 schools selected to participate, one was identified to receive the 10kw system due to its status as an emergency, special needs relief shelter. That school is Middleton High in Tampa, Florida.

6. MIDDLETON HIGH SCHOOL

In 2005, Middleton High School in Tampa was selected for the program to receive a 10 kw PV system with batteries for shelter operations, in addition to the educational activities (figure. 1). The Hillsborough County Emergency Management evaluated the school and selected the school as a special needs shelter. Six classrooms were selected as hurricane protected area to be rewired to the emergency sub-panel from the schools main power panel to be PV power. The shelter's essential accessories equipment electrical load was not fully incorporated into the emergency sub-panel, but the standby lighting and standby branch wall circuit was installed in order to provide lighting and power to selected medical equipment. The emergency sub-panel is wired to one 4,000 and one 6,000 watt dual-mode utility interactive inverter with a 50 kilowatt-hour battery pack.

For this demonstration project, a typical 1000 sq. ft. classroom with 8 patients and 8 caregivers are assumed. It was decided that there will be a piece of medical equipment in the list for each patient and their caretaker using all eight outlets in that room. If the medical equipment typically uses half of the nameplate energy during shelter operation, then approximately 17 kilowatt hours per day will be used per room per the list of loads and operation schedule. The

Fig. 1 Middleton shelter PV emergency system

backup light load of approximately 0.4 kilowatt hours will add to this medical equipment load consuming the power generated by the PV system. The 10 kw PV array produces about 50 kwh per day for an average central Florida day. Thus the existing PV system will run 3 rooms in this configuration or 1 room with air conditioning and ventilation. Typically, hurricanes are 3 days of clouds followed by 3 days of sun so the 50kwh batteries would provide storage for 1 room for three days or 3 rooms for 1 day of utility power outage. In real life, the medical equipment load may be very different based on who actually enters the shelter and what their actual health needs are. The shelter's essential accessories equipment load (air conditioning, ventilation, etc.) was not fully incorporated in this demonstration project.

Fig. 1 Middleton shelter PV emergency system

Further work is required to study and have a better understanding of actual usage verses nameplate rating. Also, study distribution of patient medical requirements and better understanding of average hours of day use of the medical equipment. There needs to be training and feedback to the medical staff on the energy needs to effectively schedule system energy consumption so the needs are met.

7. CONCLUSION

The present disaster codes, standard, practices make shelters as safe as possible for their inhabitants in time of a disaster. Presently, energy efficiency and passive solar design is not a requirement for shelter design. Presently, solar thermal or photovoltaics is not part of the disaster codes, standards or practices. Presently, emergency power for essential accessories equipment is defined, but not supplied.

At least emergency industrial diesel generators are not required, but provisions are made for their connection as needed. Minimum shelter essential accessories equipment load requirements are defined and are not out of the range of being powered by PV. Selecting across the board representation of special needs medical equipment to be housed in a typical classroom from our Middleton example makes an electrical load that can be powered by PV. In a

disaster, the American Red Cross shelter manager has the choice of requesting a generator or moving the sheltered people to a shelter with power.

Ideally, not only the safety and construction of the building should be a consideration, but also the energy use and flow for the building as well as the hurricane protected area need to be addressed. By keeping energy demand in mind and constructing durable, energy efficient buildings, providing power to the facility can be more easily supplied by renewable energy technologies. By doing this, reliable power is provided to the facility during emergency situations. Because the building is energy efficient, during normal time, power use is greatly reduced. The deciding factor is the size of the shelter. Small shelters can be solar powered, but large ones may not be fully solar powered. What PV can do, is provide some power for critical loads giving the shelter manager time to have a generator installed or time for shelter people to be moved. This process keeps shelter inhabitants out of the dark and their medical equipment operating. As a reliable power supply for critical items, PV does the job.

8. ACKNOWLEDGEMENT

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