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## Impact of Solar Powered Disaster-Resistant Communities

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### ABSTRACT

Natural and man made disasters can destroy lives, homes, businesses, the economy and the environment. Disasters can happen with little or no warning, leaving hundreds or even thousands of people without medical services, potable water, sanitation, communications and electrical services for up to several weeks. This paper identifies the imperative for and value of creating disaster-resistant homes and communities. The use of renewables, the application of distributed generation, implementation of energy-efficient building designs and construction of disaster-resistant structures can minimize the destruction of property, cost of recovery and disruption of lives. Through enhanced construction practices and the use of solar energy, individuals and the communities in which they live can benefit from the implementation of disaster-resistant buildings that are functional and operational. The use of energy conservation practices and renewable power sources promotes energy assurance while allowing occupants to maintain some semblance of normal life after a disaster.

**KEYWORDS:** Disasters, conservation, energy-efficiency, renewables, photovoltaics, solar energy, critical items, distributed-generation, disaster-resistant.

### 1. INTRODUCTION

Hurricanes, floods, tsunamis, tornados and earthquakes can create natural disasters of mega proportions. In 1992, Hurricane Andrew came ashore in the United States with a vengeance, awakening concerns about potential destruction from storms. Andrew changed perspectives related to building design and building codes. Changes were made to structural performance standards for sustained winds over 120 mph. In 2004, the State of Florida was ravaged by four major hurricanes within a 6-week timeframe, causing 9 million people to evacuate their homes. Nearly all of the geographic area of the state was affected in some way. That year, Hurricanes Charlie, Frances, Ivan and Jeanne destroyed 25,000 homes, did major damage to 40,000 buildings and left over 8 million people without electricity. Consequently, standards were again upgraded requiring building designs to meet sustained winds of 150 mph.

Natural or man made disasters can destroy homes, businesses and the environment, creating high levels of stress for people, the economy and the natural

environment. Such disasters can happen with little or no warning, leaving hundreds or even thousands of people without medical services, potable water, sanitation, communications and electrical services for up to several weeks. The world's dependence on energy characterizes our daily lives through the use of lighting, computers, communications products, refrigerators, televisions, air conditioning and heaters. A loss of power can disrupt our daily routine and at worst, our health and financial welfare. The loss of utility service affects shelters, medical facilities, pumping stations, fire stations, emergency services and police stations needed in response and recovery. Emergency organizations, businesses and homeowners are hampered in the recovery process by the loss of power. Destroyed businesses can no-longer provide jobs or services to the community, creating economic crisis.

### 2. HOW ARE UTILITIES IMPACTED FOLLOWING A DISASTER?

The industrialized world has utilities with huge infrastructures designed to distribute reliable and cost

effective power. In the U.S., most buildings and homes are powered by utility companies that utilize a complex electric grid or pipeline to distribute energy across a wide geographic area. The utility industry is vulnerable to power outages due to systems failures caused by weather, physical failure, human error, market-based instability and intentional disruption of a power system (sabotage). Due to the vast size and complexity of the system, it is difficult to protect all utility facilities from possible attack or failure. Any type of power outage temporarily highlights the degree of importance of electricity in our lives, whether caused by a disaster or a minor weather-related event.

Disasters have varying impacts on utility resources. For example, a hurricane can tumble electric power lines but not impact natural gas lines underground. Utilities and regulators are developing “resilient” network architecture in order to provide energy assurance in spite of multiple disruptive events. Several factors effect energy assurance, such as proximity to load, fuel availability, facility protection, facility size, geographic location and vulnerability of technology. Options to improve energy security of the network include use of energy efficient practices, distributing energy sources and using renewable resources. Efficiency and conservation reduces the need for new generation. Use of distributed generation can provide multiple sources of energy and promote reliability. By using renewable energy resources, sustainability and energy security are enhanced.

Community growth poses a critical problem: as the population grows, so grows the load. This increase in demand will significantly increase energy consumption and a corresponding need to greatly increase generating capacity. It is quickly becoming incumbent upon each individual to become aware of energy security issues and to accept a shared accountability for meeting personal and collective energy needs. Just as utilities and regulators seek to improve energy system security, so too should the consumer implement the same measures to improve personal energy security. Consumers willing to take responsibility for generating part or all of their energy needs must learn to understand the energy requirements of their many appliances and electrical devices, whether connected to the grid or their own energy systems. Ideally, consumers would become “utility owners and operators” to enhance energy security by reducing overall and peak loads. Municipal utilities can be more responsive to consumers than corporate utilities in implementing distributed generation.

### 3. WHAT RESOURCES ARE AVAILABLE TO SUPPORT THE CONSTRUCTION OF DISASTER-RESISTANT BUILDINGS?

In the late 1990s, the U.S. government, through the Federal Emergency Management Agency (FEMA), began a new approach to mitigation by promoting disaster-resistant buildings for disaster resistant communities. A disaster-resistant building is built beyond conventional building methods and codes. This building method will likely cost more at the time of construction, but is positioned to deliver priceless life and property saving during and after a disaster. As an example, a disaster-resistant building would have extra nails in the roof decking, water barriers along the roof joints and wildfire buffers around the perimeter. The Federal Alliance for Safe Homes created the Blueprint for Safety program to provide a comprehensive set of disaster-resistant building techniques for protecting both new and existing homes from hurricanes, tornados, flooding and wildfires. The Institute for Business and Home safety created the Fortified Builders’ Guide to provide techniques for a higher level of protection against disasters. These and other programs are available to provide guidance to structurally enhance a building to save lives and reduce property damage. The U.S. DOE Energy Star, Rebuild America and Leadership in Efficiency and Environmental Design (LEED) programs provide many guidelines for efficiency, conservation and environmental measures. Preparedness and mitigation reduce damage and losses due to disasters, while reducing the amount of response and recovery effort potentially needed.

The U.S. Department of Energy, with support from the Florida Solar Energy Center (FSEC), added the concept of building functionality and operational capacity to the importance of creating structurally sound and safe buildings. Following a disaster, if a building is still standing, the building design should provide sustainable operational use. A disaster-resistant building should achieve the lowest energy consumption, applying a variety of possible conservation options. Energy consumption can be minimized to various degrees, with the ultimate being zero energy input from conventional grid utilities. Energy codes need to be changed to promote sustainability; this represents a step beyond minimum energy codes. From an energy security aspect, zero energy buildings would have energy production in close proximity to the load and would provide energy generation equal to consumption. Renewable energy sources should be used for on-site generation, providing consumers energy assurance in a disaster as well as in normal daily life. If excess generation is produced, it can be redistributed to the utility company or to other loads.

### 4. HOW CAN POWER BE MAINTAINED?

One way to maintain power is through the practice of distributed generation, which employs multiple sources of energy instead of depending on one large source like a utility plant. Solar systems can be designed and sized as a

renewable energy source for varying needs and applications. The Florida Solar Energy Center, Sandia National Laboratories and the National Renewable Energy Laboratory have jointly researched the application of photovoltaics (solar electric) in disasters. Photovoltaic (PV) is an environmentally benign, inexhaustible source of electrical energy. Solar-powered equipment requires no fuel, so the length of operation poses no problem when the solar power system is properly designed. Solar energy is a viable, cost effective resource for small portable and stand alone electrical power applications, since it offers lower operating costs than gasoline generators. PV modules are modular, allowing various outputs and the addition of battery storage to a PV system allows 24 hour operation.

PV-powered systems are a natural solution because they can be designed specifically for stand alone operation without utility power as a critical power supply. Some uses, like communications and applications in medical clinics, require quiet, non-polluting operation, which PV is capable of providing. A viable use for PV is to meet emergency demands in large-scale disasters, where power will be out for long periods of time and survivor support is difficult to provide due to the extensive area destroyed. If structures are still standing after a disaster, PV can serve as a critical power supply or back-up system when built to the latest codes.

By implementing an integrated approach to addressing critical energy issues, energy production and consumption can be balanced to assure an improved level of energy security and reliability. Distributed energy generation can be applied to building design using renewable energy sources where more than one energy source is used. The use of photovoltaics, solar thermal, wind and other renewables is needed to ensure sustainability. Solar thermal or hot water systems are cost effective and offset the need to generate electricity to produce hot water. Wind energy may be available at night when solar is not and enhances the energy mix. If one or more sources have failed, the other sources could supply the energy needed for the load.

## 5. HOW ARE ENERGY NEEDS PRIORITIZED AND MET?

The more energy conserved, the less energy that needs to be produced. Consumers, both homeowners and businesses, will benefit from evaluating their energy needs and operational activities. This study recommends that renewable energy can be applied at five levels, as shown in Table 1:

Table 1. Levels of renewable generation

Level	Item	Description	PV Power
1	selected items	outdoor lights, pump, gate control	0-200 W
2	critical items	refrigerator, light, radio, register	200-1000 W
3	backup power	lighting, kitchen, water supply, systems	500-2000 W
4	zero energy	production equals consumption	2000-20+Kw
5	producer	net generator beyond consumption	10-100+ kW

The first level of renewable generation could be a solar outdoor light in the drive way or other stand-alone device. The second level is geared to power critical energy needs in the home or commercial building to ensure needed power is available to maintain key operations. The third level of generation may be to power a kitchen, business computer system, water supply or other major system to generate as much power as you can afford, but not everything. The fourth level is to power the whole building and produce as much as is consumed. The fifth level is designed to become a power generator for the purpose of redistribution, and produces a set amount more than is consumed. With this level, a battery system for storage is critical for stand-alone operation when utility power is out and is usually supplied by batteries with a minimal storage capacity of 1 kW hr.

Levels 2 to 4 would be an advantage in disaster-resistant building design. Levels 2 and 3 use backup power systems that may be stand-alone or grid interactive and fitted to power small electrical and electronic devices or small systems. Of most interest is the critical power supply concept where critical energy needs are identified and incorporated into a power supply design to ensure needed power is available to maintain key operations and functions of a building. As an example, during a power outage, a homeowner will want to have electricity for operating a lamp, a refrigerator and a radio. A business may need a few lights for safety and a cash register to complete sales. Most consumers would consider these items critical to maintaining business operations, building functions and minimal personal lifestyle until utility power is restored. By incorporating even minimal building modifications, such as the addition of a small 1 kW photovoltaic array, the home or business owner can enhance energy security and realize long-term financial and environmental benefits.

Critical power supply can be achieved by connecting a sub panel to the main power panel of a building through a transfer switch for utility-connection. The sub panel would then be powered by an alternative energy source, such as a PV system, wind, small hydro, solar thermal, microturbines, geothermal or a hydrogen fuel cell generator. Emergency power transfer systems are available at local hardware suppliers. Utilities recommend their use to protect power line workers from backfeed from engine generators as shown in Figure 1 below. This design concept integrates a distributed energy source to a specific load, assuring energy security. The local utility could power from 1 to 99 percent of the building's energy needs and the building would have critical energy items powered by dual or multiple sources of energy.

Figure 1. Emergency Power Electrical Connection



## 6. WHAT ARE THE KEYS TO CREATING DISASTER-RESISTANT BUILDINGS AND LIFESTYLES?

Buildings and communities should be disaster-resistant, both structurally and with respect to energy resources. Ideally, the truly disaster-resistant building would be a zero energy home or building that ensures a high level of energy security. The first step is to conserve energy and reduce the energy load to near zero through passive building design, day lighting, energy efficient appliances, energy management systems, thermal mass, material selection and other practices. Conservation is not doing without, but to accomplish a similar or acceptable result using fewer resources. Heating water by a solar thermal water system or pool heating system instead of electricity or other energy source is one example. Another example would be to use wind energy to pump water. Once the load is minimized, renewable energy sources, such as PV, thermal or wind, are applied to match energy needs. Distributing energy resources by applying the right energy source to the right application and employing multiple sources of energy is key.

Energy analyses of various homeowners' needs suggest that a minimum of 2 kW photovoltaic array with a 2 kW inverter and adequate battery storage would continuously power most critical needs. The building may have 1 kW to 20 kW or more of PV based on a selected design criteria and electrical applications. The PV system can be ground or roof mounted or building integrated, depending on building design and orientation. The system may be utility interactive with battery back-up to power critical items during power outages. During normal times, the PV system would provide demand side management, offsetting energy consumption. During outages, the system would

power critical items required to survive. The energy sources need to be integrated into a comprehensive energy management system to provide a "smart building" energy mix.

Studies and experience have shown that PV plays an important role in response, recovery and mitigation following disasters. Portable systems under 1 kW meet many of the needs of disaster organizations in response efforts, where 1 to 5 kW systems provide critical stationary power. Small utility-interactive PV systems with battery backup increase the effectiveness of disaster-resistant buildings and ultimately support communities in the power mix for distributed generation. Inappropriate applications for photovoltaics are counterproductive. Builders, planners, homeowners and Emergency Management personnel need to understand their community's energy needs and photovoltaic technology to make appropriate application choices.

## 7. HOW HAVE PV SYSTEMS FARED DURING DISASTERS?

A damage assessment of buildings impacted during the 2004 Atlantic hurricane season found that the homes that originally had solar systems and whose roofs were still intact had a majority of the solar systems still attached. Rebuild America and Energy Star homes survived and owners were able to live in their homes during recovery. Some homes only had solar hot water and the owners could at least take hot showers until utility power returned. A few homes had PV, allowing refrigerators and other appliance to operate, and in some cases the whole building.

FSEC maintains a database of PV systems deployed through programs they manage. There are 61 buildings with PV

systems ranging from 500 to 10,000 watts of PV, of which, 31 have data collection systems that monitor them continuously. Only 11 systems were not within the path of the hurricanes. All impacted systems were operational after the storms hit; three systems reported minor damage and were still operational.

Oak Ridge National Laboratory and the Roofing Industry Committee on Weather Issues (RICOWI) conducted a roof damage assessment in Charlotte County, Florida, after Hurricane Charlie. Seven site evaluation teams assessed 428 buildings and found 14 solar systems, of which only three were damaged.

## 8. CONCLUSION

Because disasters can happen at any time with little or no warning, the creation of disaster-resistant buildings and communities can save lives and provide business continuity. There is a need to understand and apply disaster-resistant and fault-tolerant architectural concepts in equipment, buildings and communities to reduce losses and improve quality of life. Options to improve energy assurance should be integrated and implemented, such as conservation, energy efficient practices, distributed generation and use of renewable resources. Making modifications to homes and commercial buildings by incorporating even minimal changes, such as the addition of a small photovoltaic array, would enhance energy security and yield long-term financial and environmental benefits.

A true disaster-resistant building is structurally sound, functional and operational. Energy efficient buildings with fortified structural designs that use renewable energy systems attempt to mitigate the destructive forces of any disaster. This building method may cost more at the time of construction, but delivers priceless life and property saving after a disaster. Creating disaster-resistant buildings would reduce impact on shelters, emotional stress and recovery costs. Studies and experience have shown that PV plays an important role in response, recovery and mitigation in disasters.

The importance of electricity is temporarily highlighted with any type of power outage, whether caused by a natural or manmade disaster or a minor weather-related event. Significant changes in awareness, lifestyle habits

and economic priorities are required from people in the industrialized world who are dependent on utility energy providers to meet all their energy needs. It is the responsibility of each individual to become aware of energy security issues and to accept a level of accountability for meeting personal and collective energy needs.

## 9. ACKNOWLEDGEMENTS

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