July 2013

Solar PV Emergency & Resilience Planning

Key Messages

- **Solar PV systems can play an important role in the risk management, response and recovery of natural disasters.**
- **Solar PV systems can be applied for various uses in emergency operations, such as backup power for shelters, communications, lighting, transportation, or "all of the above" multi-use function on a smaller scale.**
- **Emergency preparedness planning should incorporate solar PV into integrated emergency, climate adaptation and resilience strategies for effective implementation.**
- **Public-private partnerships can increase rate of solar PV installation. Through partnerships with municipal governments, many private companies with solar PV technologies donate equipment for public use or provide support services during emergency operations.**
- **Solar PV applications with both off-grid and on-grid usability can be cost-effective as well as flexible.**
- **Cost, funding availability, multiple benefits, and ease of implementation may be considered as evaluation criteria prior to deciding which solar PV application to use.**

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MEISTER CONSULTANTS GROUP

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I. Introduction – Why Solar?

Natural disasters such as hurricanes, tornados, floods, and powerful storms often occur with little warning, and can be as destructive as Hurricane Katrina (2005), Hurricane Irene (2011) or Hurricane Sandy (2012). Sandy left 8.5 million people across the East Coast without power,[1] adding further challenges to disaster relief efforts such as providing medical support. Traffic controls, water purification, and hospitals are critical infrastructure systems during emergency situations and require backup electricity for continued operations.

A range of solar photovoltaic (PV) system applications are available and have the ability to meet critical power needs during emergency operations. If mobilized with technological solutions and policy change towards decentralized power generation, solar PV systems can offer a source of clean, flexible, reliable, pollution-free electrical power that can be used as on-grid systems during normal operations and as off-grid systems during emergencies or when the main grid connection is lost.

This brief provides a summary of solar PV applications for emergency planning, followed by an evaluation of criteria for choosing the right type of solar application for resilience. This brief concludes with examples of solar PV applications in municipal emergency and resilience planning in Boston (Massachusetts) and New York City (New York), followed by an introduction to various Florida Solar Energy Center initiatives (Florida).

II. Use and Applications

Solar PV systems can supply the electrical needs for a myriad of critical infrastructure systems. These systems can be grouped into five general types: backup power for emergency shelters, emergency lighting, communications, transportation, and small, portable systems for miscellaneous applications.

1. Backup power for emergency shelters - To sustain life and safety in emergencies, backup power for critical equipment should be available for a minimum of 3 days after a disaster has occurred.[2] Certain infrastructure systems such as hospitals may need to have more than 3 days of backup power.

- **Roof-top PV systems** can be used to generate electricity for emergency shelters and to provide backup power to augment other energy sources. For instance, gas station canopies can support solar installations that, when combined with battery storage, can provide the electricity needed to operate fuel pumps during an interruption in grid power at any time of day.
- **Solar-powered water pumps and purification systems** can be applied to a well connected to groundwater source and purify water for emergency shelters' critical water supply. For example, solar-powered water purifying pump unit, donated by WorldWater & Solar Technologies, Inc.,

[1] McCarthy, Tom, and Haroon Siddique. "Sandy: 'Major Disaster' in New York and New Jersey." The Guardian. Guardian News and Media, 30 Oct. 2012. Web. 10 June 2013. <http://www.guardian.co.uk/world/2012/oct/30/sandy-superstorm-flooding-power-cuts>.

[2] CH2MHILL. Solar America Cities Final Report Integration of Solar Energy in Emergency Preparedness. Rep. New York City Office of Emergency Management, Apr. 2009. Web. May 15. <http://www.nycedc.com/system/files/files/resource/SolarNYCReport.pdf>.

provided approximately 350,000 gallons of clean, potable water for hurricane victims in Waveland Mississippi for an 8-month period after Hurricane Katrina struck the Gulf Coast in 2005,[3] as shown in Figure 1.[4]

- In cases where an emergency shelter requires a significant up-front investment to be entirely supplied by a solar power system, creating a **hybrid system** that combines solar with a diesel or propane generator can improve efficiency and provide short-term backup power for critical operations.

Figure 1. Solar-powered Water Purifying Pump

2. Emergency lighting is crucial for emergency operations, including streetlights and traffic lights, as well as for portable personal lights. Solar-powered streetlights can be configured to illuminate evacuation routes during power outages. Streetlights in Florida, consisting of a pole-mounted fixture that contained a battery and controller enclosure, two PV modules and a fluorescent lamp, were donated by a local company (Solar Outdoor Lighting) and survived major hurricanes including Hurricane Andrew in 1992.[5] Solar-powered lighting can provide off-grid functionality to critical evacuation routes on highways and other roadways.

Figure 2. Solar-powered Speedometer

3. WiFi, communication repeaters[6] and variable message boards[7] can be used for roadside IP links, traffic management and other public communications. For instance, Florida Department of Transportation is equipped with solar-powered speedometers (See Figure 2),[8] traffic devices, changeable message signs, flashing arrow boards, emergency road repair, and highway advisory radio.[9]

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[3] See CH2MHILL New York Report, *supra* note 2.

[4] Solar-powered Water Purifying Pump. 2007. Photograph. WorldWater & Solar Technologies. 24 Aug. 2007. Web. 25 July 2013. <http://www.worldwatersolar.com/stand-alone-infrastructure/mobile-maxpure/>.

[5] Young, William R. Applying Photovoltaics to Disaster Relief. Florida Solar Energy Center, 1996. Web. 22 May 2013. <http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-294-96.pdf>.

[6] A radio repeater is a combination of a radio receiver and a radio transmitter linked together with a controller device that receives a weak or low-level signal and retransmits it at a higher level or higher power, so that the signal can cover longer distances without degradation. In emergency services communications, repeaters are used extensively to relay radio signals across a wider area. (see http://www2.hawaii.edu/~rtoyama/repeater.html)

[7] A variable message board is an electronic traffic sign often used on roadways to give drivers information about special events such as traffic congestion, accidents, adverse weather conditions, or emergencies. (see http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/guidelines_for_vms_on_state_highway.pdf)

[8] "Quality Construction Checklist." Florida Department of Transportation. Traffic Engineering and Operations Office, 2004. Web. 26 July 2013. <http://www.dot.state.fl.us/trafficoperations/ITS/Projects_Telecom/ITSFM/ITSFM-checklist.shtm>.

[9] Young, William R. Photovoltaics in Disaster Management. Tech. Florida Solar Energy Center, 2001. Web. 26 May 2013. <http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-1263-01.pdf>.

4. Solar arrays and laminates (such as those found on the roof of the Toyota Prius) can be used to power electronic devices in **emergency vehicles** such as police, fire, or emergency medical service (EMS) vehicles (See Figure 3). [10] For example, the Shawnee Fire Department in Kansas recently installed two solar panels, a charge controller, wiring and mounting parts on a fire truck to provide power for electronic devices.[11]

Figure 3. Vehicle rooftop array

5. Small portable systems

- **Portable solar generators** enable a flexible and versatile use of solar energy, as they are generally small in size and easy to transport. Generators are available in a variety of configurations and energy potentials, which can be as small as 100 W and as large as 4 kW. For example, a California-based solar installer, Mobile Solar, donated mobilized solar generators that were outfitted battery storage to support water purification systems and construction tools for the tsunami relief effort in Fukushima, Japan.[12]
- **Small PV systems packaged with batteries** can accommodate the power needs for air monitoring and remote sensing applications.
- **Fold-out panels** can support relatively small-scale emergency operations such as search and rescue, damage assessment, and GPS communications.[13]

III. Evaluation Criteria for Choosing the Right Solar PV Application[14]

Prior to deploying solar technologies for emergency preparedness, the following criteria or questions may be used to evaluate whether an application is appropriate for solar:

- **Provides Critical Service** – Is the service critical to the emergency response efforts? For example, back-up power for infrastructure such as hospitals would be necessary to emergency operations but WiFi systems for civilian communications may not be as important.
- **Multiple benefits** – Can a solar system be designed to provide multiple services or benefits? If it can be applied and used in other ways even outside of emergencies, it has more potential to add value. For example, Scripps Ranch Community Recreation Center in San Diego is also a community Emergency Command Center, with an existing roof-mounted solar array, inverters, advanced lithium-ion batteries, and a site controller.[15] The addition of the remote grid contactor allowed the

[10] Courtesy of Meister Consultants Group
[11] See CH2MHILL New York Report, supra note 2.
[12] OutBackPower. "Mobile Solar and OutBack Power Team Up To Provide Quick Solar Power Solutions For Japan's Tsunami Disaster Area." OutBackPower. N.p., 9 May 2011. Web. 1 July 2013. <http://www.outbackpower.com/news/article/65/>.
[13] See CH2MHILL New York Report, *supra* note 2.
[14] CH2MHILL. Solar America Cities Final Report Integration of Solar Energy in Emergency Preparedness. Rep. Boston: City of Boston Mayor's Office of Environmental and Energy Services and Mayor's Office of Emergency Preparedness, 2009. Web. 06 June 2013.
[15] Princeton Power. "City of San Diego Unveils Microgrid System Based on Princeton Power Technology." Princeton Power Systems Blog. Princeton Power, 26 Sept. 2012. Web. 26 June 2013. <http://www.princetonpower.com/blog/?p=746>.

building to disconnect from the grid as well as have it run as an islanded micro-grid in the case of blackouts caused by reoccurring wildfires in the San Diego area. This project is one of the nation's first to integrate solar with an innovative large-scale battery back-up system.[16]

- **Cost** – What is the potential return on investment, time horizon and resulting cost savings per unit of a given application? How much does it cost? If an application is very expensive but used infrequently only during emergencies for non-critical services, it may not be cost-effective to invest in such system. **Table 1** provides a brief overview of the application costs discussed in this factsheet.
- **Eligible for External Sources of Funding** – Is an application eligible for external sources of funding such as federal energy and/or homeland security grants? Various local, state, federal incentives can be applied to projects to lower the total installed costs.[17] A good resource is the Database of State Incentives for Renewables and Efficiency (DSIRE).
- **Ease of Implementation and Use** – How easy is it to install the systems? Does it require special technology? Some solar applications require installation by technical experts, and some products may have special technology that is difficult to use. It is important that users understand how to install, use, and maintain the applications, at least at a basic level.
- **Visibility to the Public** – How visible will the application be to the general public once implemented? A solar program may present a positive image to the public, but in some cases it may be seen as a negative barrier blocking other natural views such as trees.

Not all of the criteria have to be used for application selection. Depending on a city's needs and available resources, they can be weighted differently by importance, or only one criterion may be used. For example, the City of Boston chose a certain application based on three of the criteria that they considered most important.

Table 1. Application Cost[18]

PV System	Cost	Capacity	Notes
PV systems serving building loads	$5-$9 per Watt, $1 per amp hour for the battery bank		
Portable solar generators - Off-the-shelf PV trailer systems	Approx.$40,000 - $50,000	12 kWh/day & 24 kWh/day	
Water purification system	Approx. $95,000	A large unit configured for disaster response	
Water pumps	Costs vary by size, depth of a well, and		

[16] *Id.*
[17] See CH2MHILL Boston Report, *supra* note 14.
[18] See CH2MHILL New York Report, *supra* note 2.

PV System	Cost	Capacity	Notes
	power output		
Mounted solar panels on a fire truck	Around $1,000	2 solar panels	Does not include installation cost
Portable solar-powered repeaters	Min. $850	Varies per unit	
Solar-powered mobile communication units	$175 - $480	Varies per unit	
Message boards	Costs vary by size		
Semi-permanent wireless phone and radio towers	Up to $3,000	Varies per unit	
Solar-powered 3 X 11 W Compact fluorescent light (CFL)	$450	Varies per unit	Group discounts are available
Solar traffic signals	$2,000 to $8,000	Varies per unit	Depends on the complexity of unit
Fold-out solar panel Kit	$900 to $6,000	Varies per unit	Off-the-shelf configurations
Solar-powered remote sampling and monitoring	$1,000 to $15,000	Varies per unit	Depends on the type of monitoring equipment
Solar-powered vehicles	$21,000 for a transport model, $15,000 for a utility model, $9,000 for an all-terrain model	Varies per unit	Depends on the model
Solar conversion kits for vehicles	$1,500 to $2,500	Varies per unit	Depends on power needs

IV. Municipal Examples

1. Boston, MA

The City of Boston is making a range of efforts to build the city's emergency systems more resilient by utilizing solar energy. As one of the efforts, the city convened a workshop with various municipal stakeholders and conducted a cross-department emergency preparedness survey in 2009.[19] Workshop participants qualitatively prioritized potential solar power uses and identified criteria for evaluating solar applications.[20] Incorporating stakeholder input from the workshop, the city completed a study, "The Integration of Solar Energy in Emergency Preparedness," as part of the Department of Energy (DOE)

[19] See CH2MHILL Boston Report, *supra* note 14.
[20] *Id.*

Solar America Cities Program. The analysis prioritized solar applications for communications and variable message boards, fold-out panels for small scale/ad hoc use, PV arrays and laminates for vehicles, and lighting for evacuation and traffic control.[21] Based on these priorities, Boston established a PV backup power supply for critical traffic controls, emergency message boards, and radio repeaters along the city's evacuation route.[22] The flexible PV backup power can provide off-grid functionality to critical evacuation infrastructure as well as grid-connectivity during non-emergency operations.[23] Additionally, Massachusetts has funded innovative liquid metal battery technology for grid protection and is about to commence a study of district energy systems for outage protection.[24] The flexibility and variability of solar PV systems help build Boston's resilience and its emergency plans.

2. New York City, NY

New York City, the largest city in the East Coast with more than 600 rooftop PV systems, has been actively pursuing solar energy for its emergency planning with strong support from various stakeholders. In 2009, New York City held emergency preparedness workshops and completed a study under the same title as Boston, "The Integration of Solar Energy in Emergency Preparedness," as part of the Department of Energy (DOE) Solar America Cities Program. The workshops resulted in prioritizing solar applications including portable lighting, fold-out panels for small scale/ad hoc use, and PV arrays and laminates for vehicles.[25] Despite the planning efforts, the city experienced power outages after Hurricane Sandy, because the installed PV systems were not prepared or technically designed for emergency operations.[26,27] Recognizing the urgency and importance of emergency planning targeted for implementation, the city outlined a far-reaching resilience plan in 2013 with an initial budget of $20 billion.[28] The plan includes fortifying its power grid and improving hospital emergency power systems by 2030.[29] The plan also discusses developing best practices related to voluntary backup power generation and amending relevant codes to encourage buildings to comply with these best practices, such as utilization of building-mounted solar power systems.[30] Additionally, the city is preparing to install solar-powered streetlights, additional rescue boats, and a backup phone system in its evacuation zones.[31] The

[21] *Id.*

[22] Belden, Andrew. The Boston Solar Evacuation Route Pilot: Building Emergency and Transportation Systems Resiliency. Proc. of ICLEI Resilient Cities. ICLEI/Meister Consultants Group, 2010. Web. 05 May 2013. <http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/docs/H_Sessions/H1-Bonn2010-Belden.pdf>.

[23] USDOE. "Challenges and Successes on the Path toward a Solar-Powered Community Solar In Action Boston, Massachusetts." Solar in Action. US DOE EERE, Oct. 2011. Web. 7 June 2013. <http://www1.eere.energy.gov/solar/pdfs/50195_boston.pdf>.

[24] Milford, Lewis. "Resilient Power A New Business Case for Clean Energy." The Huffington Post. TheHuffingtonPost.com, 31 May 2013. Web. 20 June 2013. http://www.huffingtonpost.com/lewis-milford/resilient-power-a-new-bus_b_3367727.html.

[25] See CH2MHILL New York Report, *supra* note 2.

[26] Grid-independent solar PV systems require a device that cuts the electric flow from the grid, or a specially designed PV system which switches to backup battery power in the event of a grid outage.

[27] CUNY. "Sustainable CUNY." Smart DG Hub: Emergency Power. CUNY, 2013. Web. 27 May 2013. <http://www.cuny.edu/about/resources/sustainability/SmartDGHubEmergencyPower.html>.

[28] City of New York. PlaNYC A Stronger, More Resilient, New York. Rep. N.p., June 2013. Web. 30 June 2013. <http://nytelecom.vo.llnwd.net/o15/agencies/sirr/SIRR_singles_Lo_res.pdf>.

[29] *Id.*

[30] *Id.*

[31] Fermino, Jennifer. "Post-Hurricane Sandy Emergency Improvements Include Solar Street Lights, Better 311 Service." NY Daily News. N.p., 3 May 2013. Web. 26 June 2013. <http://www.nydailynews.com/new-york/post-sandy-emergency-plan-solar-street-lights-better-311-article-1.1334737>.

city's community members are envisioning a more resilient city that is powered by solar energy. The Manhattan Community Board has recently recommended solar-powered back-up systems for wastewater treatment plants.[32] The City University of New York (CUNY) is leading a push to integrate solar and distributed generation (DG) into emergency and resilience planning and has formed the Smart DG Hub.[33] CUNY is also mapping out the city's emergency solar potential by estimating kW capacity by each zip code in the city.[34] All of these efforts seek to strengthen New York City's resilience and emergency-preparedness.

3. Florida Solar Energy Center Initiatives

Through a number of hurricanes, disaster relief efforts in many towns and counties of Florida have benefited from the services provided by the Florida Solar Energy Center (FSEC) to integrate solar energy into emergency power systems. In addition to publishing various white papers[35] related to solar PV and disaster management, FSEC has been directly involved in installing and distributing a variety of emergency equipment using solar applications. For example, FSEC helped the Miami Emergency Management Office to use a portable standalone PV system to power an amateur radio system for emergency communication during Hurricane Andrew (1992). [36] In 2000, FSEC designed and built a PV Disaster Trailer to provide electricity for the Dade County disaster medical assistance team, a resource which has been used many times since then for other disasters.[37] Private companies such as Photocomm, Inc., Sovonics Solar System, and Solar Outdoor Lighting donated many of the PV systems used for emergency operations across Florida.[38] Across the State of Florida, there are 101 school emergency shelter systems[39] and 21 solar-powered community sirens (which serve as warnings for tornadoes), [40] as well as PV-powered meters that monitor river water levels for flooding.[41] According to the FSEC, most of these solar panels have survived numerous natural disasters. Only 4 out of 28 PV systems were damaged in Charlotte County after Hurricane Charlie (2004),[42] and all 33 streetlights in Miami-Dade County survived Hurricane Andrew (1992).[43] These well-established examples in Miami-Dade County

[32] City of New York Manhattan Community Board 1. Emergency Preparedness. NYC, 22 Jan. 2013. Web. 19 June 2013. <http://www.nyc.gov/html/mancb1/downloads/pdf/Home Page/Emergency Preparedness.pdf>.
[33] "Sustainable CUNY." NYC Solar Summit 2013. Web. 29 June 2013. <http://www.cuny.edu/about/resources/sustainability/solar-summit.html>.
[34] Case, Tria. "Solar for Emergency Preparedness." CUNY. N.p., Feb. 2013. Web. 25 May 2013. <http://www.cuny.edu/about/resources/sustainability/events/CUNYPVAmericaEastfinalforweb.pdf>.
[35] The main author is Bill Young, who has published five professional white papers listed in this factsheet and many others.
[36] Young. *Supra* note 5.
[37] Young, William R. Deploying Mobile PV Emergency Power System in A Disaster. Florida Solar Energy Center, 2008. Web. 24 May 2013. <http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-433-08.pdf>.
[38] Young. *Supra* note 9.
[39] CUNY. "OutBack Presentation." Proc. of NYC Resilient Inverter Workshop, CUNY, New York City. City University of New York, June 2013. Web. 29 June 2013. <http://www.cuny.edu/about/resources/sustainability/solar-summit/agenda2013/NYCResilientInvertersWorkshop/OutBack_Resiliency.pdf>.
[40] Young, William R. Emergency Power Systems for Disaster Relief. Solar America City Orlando, 2010. Web. 2 June 2013. <http://orlandorunsonsun.com/wp-content/uploads/2012/11/OC-Solar-Cities-Disaster-Relief-10-0630-Roundtable-Solar-Applications-071910.pdf>.
[41] *Id.*
[42] Young, William R. Renewable Energy and Disaster-Resistant Buildings. Florida Solar Energy Center, 2005. Web. 2 June 2013. <http://www4.eere.energy.gov/solar/sunshot/resource_center/sites/default/files/m-fsec-pf-385-05.pdf>.
[43] Young. *Supra* note 9.

and other cities in Florida are good precedents of emergency preparedness for other cities and counties to follow.

V. Useful Links

- SunShot Solar Outreach Partnership http://solaroutreach.org/
- DOE SunShot Initiative http://www1.eere.energy.gov/solar/sunshot/
- DSIRE Solar Portal http://www.dsireusa.org/solar/
- Florida Solar Energy Center http://www.fsec.ucf.edu/en/
- Sustainable CUNY NYC Solar http://www.cuny.edu/about/resources/sustainability/solar-america.html

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