Fire Fighter Safety and Emergency Response for Solar Power Systems

Final Report

A DHS/Assistance to Firefighter Grants (AFG) Funded Study

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FOREWORD

Today's emergency responders face unexpected challenges as new uses of alternative energy increase. These renewable power sources save on the use of conventional fuels such as petroleum and other fossil fuels, but they also introduce unfamiliar hazards that require new fire fighting strategies and procedures.

Among these alternative energy uses are buildings equipped with solar power systems, which can present a variety of significant hazards should a fire occur. This study focuses on structural fire fighting in buildings and structures involving solar power systems utilizing solar panels that generate thermal and/or electrical energy, with a particular focus on solar photovoltaic panels used for electric power generation.

The safety of fire fighters and other emergency first responder personnel depends on understanding and properly handling these hazards through adequate training and preparation. The goal of this project has been to assemble and widely disseminate core principle and best practice information for fire fighters, fire ground incident commanders, and other emergency first responders to assist in their decision making process at emergencies involving solar power systems on buildings. Methods used include collecting information and data from a wide range of credible sources, along with a one-day workshop of applicable subject matter experts that have provided their review and evaluation on the topic.

The Research Foundation expresses gratitude to the members of the Project Technical Panel, workshop participants, and all others who contributed to this research effort. Special thanks are expressed to the U.S. Department of Homeland Security, AFG Fire Prevention & Safety Grants, for providing the funding for this project through the National Fire Protection Association.

The content, opinions and conclusions contained in this report are solely those of the authors.

Note: This report was revised in October of 2013. Changes other than editorial are indicated by a vertical rule beside the paragraph, table or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. This report was issued in May 2010 and revised in October 2013. Changes have been made to the information on page 57 to address the hazards of PV at nighttime. The information described on page 57 for the electrical energy hazards of a PV system from other than sunlight (e.g., mobile lighting plant) were taken from citation 137 when this FPRF report was prepared in May 2010, which was the best information available at that time. Since then a subsequent separate study from Underwriters Laboratories has further clarified through empirical tests that a hazard may exist from non-sunlight sources, i.e., at nighttime. This UL report is “Firefighter Safety and Photovoltaic Systems” and was issued in November 2011, and is available through the UL website.

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FIRE FIGHTER SAFETY AND EMERGENCY RESPONSE FOR SOLAR POWER SYSTEMS

A U.S. Department of Homeland Security
(AFG Fire Prevention & Safety Grants)
Funded Project

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EXECUTIVE SUMMARY

As the use of alternative energy proliferates, the fire service has identified a number of areas of concern with hazard mitigation and emergency response. This includes solar power systems, which are introducing new and unexpected hazards to fire fighters and other emergency responders.

The goal of this report is to assemble and disseminate best practice information for fire fighters and fireground incident commanders to assist in their decision making process for handling fire incidents in buildings equipped with solar power systems or in the systems themselves. Specifically, this study focuses on structural fire fighting in buildings and structures involving solar power systems utilizing solar panels that generate thermal and/or electrical energy, with a particular focus on solar photovoltaic panels used for electric power generation. The project deliverables will be in the form of a written report, which will include best practices that can serve as the basis for training program development by others.

The deliverables for this project collectively review the available baseline information, identify the fundamental principles and key details involving fire/rescue tactics and strategy, provide a summary of core basics, and address and clarify related issues such as training needs, areas needing further research, revisions to codes/standards, and other applicable topics.

A companion study to this report focuses on electric and hybrid electric vehicles rather than solar power systems ("*Fire Fighter Safety and Emergency Response for Electric Drive and Hybrid Electric Vehicles*", FPRF). This has taken an identical approach and focuses on assembling and disseminating best practice information for fire fighters and fireground incident commanders to assist in their decision making process. This companion report addresses emergency events involving electric drive and hybrid electric vehicles, both near or within structures (e.g., residential garage).

This overall initiative (consisting of the reports *Solar Power Systems* and *Electric Drive and Hybrid Electric Vehicles*) is funded through a U.S. Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA) Assistance to Firefighters Grant (AFG).

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Amongst the new challenges facing the U.S. fire service is the changing nature of emergency response to incidents where alternative energy sources are in use. The term *alternative energy* describes any of the various renewable power sources that can be used in place of conventional fuels such as petroleum and other fossil fuels.[1]

The fire service has identified a number of areas of particular concern with respect to hazard mitigation and emergency response in these scenarios. As the use of alternative energy proliferates, it introduces new and unexpected hazards that confront and challenge responders in an emergency.

Some fire service organizations are in the process of developing recommended emergency response procedures and best practices on a local or regional basis; in other jurisdictions, basic information on the hazard and appropriate response is lacking or not currently available. This project will take a comprehensive national look at the needs of the fire service for credible information and best practices in order to address these topics for first responders and provide an overall coordinated perspective on this topic.

The goal of this report is to assemble and disseminate best practice information for fire fighters and fireground incident commanders to assist in their decision making process for handling fire incidents in buildings equipped with solar power systems or in the systems themselves. Specifically, this study focuses on structural fire fighting in buildings and structures involving solar power systems utilizing solar panels that generate thermal and/or electrical energy, with a particular focus on solar photovoltaic panels used for electric power generation (see Figure 1-1 for an example of a solar power system on a typical residential occupancy).

While this report addresses issues of concern on *solar power systems*, a separate companion report addresses electric drive and hybrid electric vehicles, and it specifically addresses those emergency events involving electric drive and hybrid electric vehicles either near or within structures (e.g., residential garage). The project deliverables will be in the form of a written report, which will include best practices that can serve as the basis for the development of training programs by others.

This report will focus on solar power systems through the following specific tasks:

(1) Collect and analyze applicable scientific studies, case study reports, and available operational and training guidance from various sources;
(2) Synthesize this information in the form of best practice guidance for emergency response;
(3) Make the project deliverables broadly available to the fire service through on-line and print methods, and generate awareness of its accessibility; and

(4) Determine if standardization of safety practices is feasible and if so disseminate information to those involved, including submittal of possible revisions to applicable codes and standards.

The first of these tasks is key, which is to collect and analyze all applicable scientific studies, training guidance, case study reports and loss data, and available emergency response guidance relating to solar power systems. This task includes an interactive one-day workshop involving experts on fire service and other subject matter..

The goal of the one-day workshop was to identify, review, and assemble best practice information for tactical and strategic decision making by fire fighters and fireground incident commanders, to assist in their decision making process when responding to fire and/or rescue emergency events involving solar power systems. The workshop will focus on the following objectives:

- Collectively review the available baseline information provided to participants prior to the workshop;
- Identify the fundamental principles and key details involving fire/rescue tactics and strategy, and provide a summary of core basics; and
- Address and clarify related issues such as training needs, areas needing further research, revisions to codes/standards, and other topics applicable to the overall workshop goal.

Figure 1-1: Example of Home with a Photovoltaic Solar Power System in Milton, MA
(Photo courtesy of NREL Photographic Information Exchange)

2. OVERVIEW OF SOLAR POWER SYSTEMS

Technology offers great advantages that generally make our world a better place. Yet when it fails it can introduce new and unusual challenges for emergency responders. As solar power systems proliferate, fire fighters and other emergency first responders need to be prepared to handle the hazards they present.

This section provides the baseline information necessary to understand and adequately address the technology used for solar power systems. This includes some brief historical information on the development of the technology, clarification of the basic solar panel types currently available and marketplace trends, discussion of available loss information, and a summary of applicable information resources.

Evolution of Technology for Harnessing Energy from the Sun

Life on planet Earth is fully dependent on the incredible energy of the Sun. As mankind has intellectually evolved, he has learned to directly harness this energy for practical everyday uses. Today, solar power has come into the mainstream and today is a practical and increasingly common alternative power source to conventional fossil fuels.

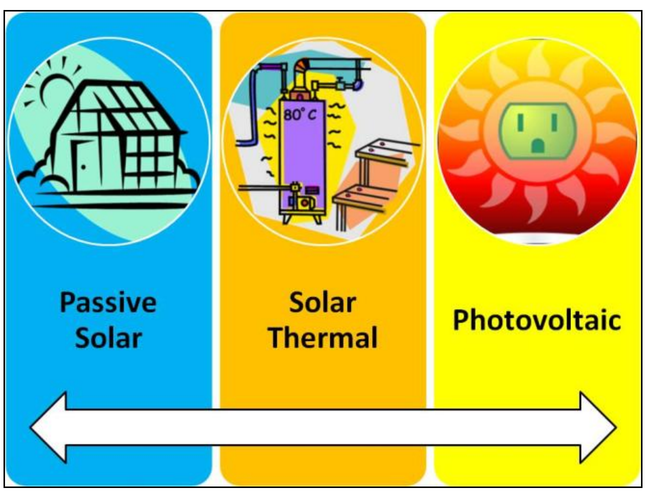

Figure 2-1: Basic Methods for Harnessing Solar Energy

The three basics means of capturing the sun's energy are: *passive solar* (i.e., capturing the Sun's energy in building design and construction); *solar thermal* (i.e., sunlight converted to heat); and *photovoltaics* (sunlight converted to electricity).[2] These basic methods for harnessing solar energy are illustrated in Figure 2-1. Generally, the evolution of the technology for harnessing the sun's energy occurred first with passive solar many centuries ago. In the last several centuries this has given way to the development of solar thermal technology and in more recent decades by photovoltaic technological advancements.

Mankind has been harnessing the energy of the sun for thousands of years. Since as early as the 7th century BC, building construction and structural positioning were done so as to take advantage of maximizing solar heating potential. Common techniques of construction included the use of south-facing windows to capture the sun's warmth.[3] Today, perhaps the most obvious direct application of passive solar concepts is with greenhouses used for agricultural or horticultural purposes.

The scientific advances of the last two and one half centuries have propelled solar technology into mainstream everyday applications. The concept of capturing the sun's thermal energy is credited to Swiss naturalist Horace de Saussure, who during the 1760s created a *hotbox* that effectively captured heat within multiple insulated boxes with plate glass windows.[4]

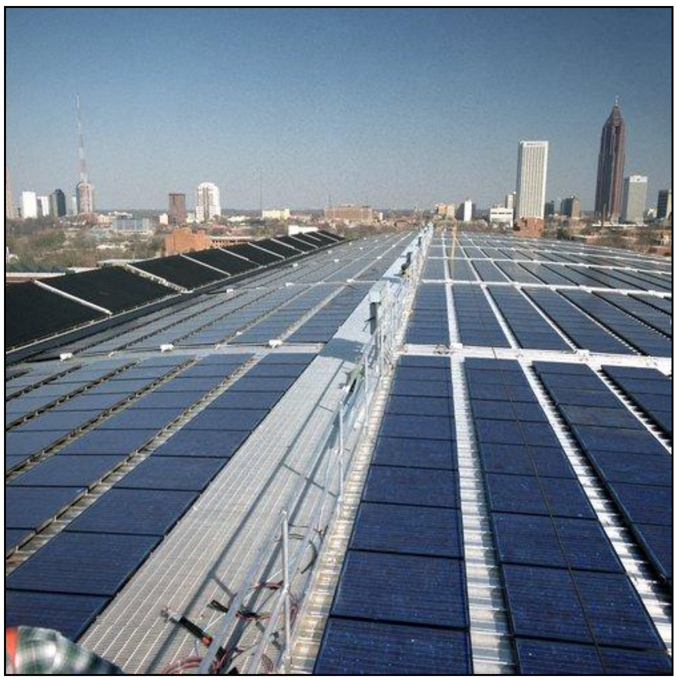

Figure 2-2: Rooftop Installation of Solar Thermal and PV Systems in Atlanta, GA
(Photo courtesy of NREL Photographic Information Exchange)

A century and a half later in the 1800s this application was expanded to metal water tanks painted black that would heat water when exposed to sunlight on rooftops. In 1891 Clarence Kemp of Baltimore received a patent for the first commercial solar water heater that was successfully marketed under the name *Climax*. This represented the world's first modern solar power system.[5]

Today, the use of solar panels for heating water are common in certain countries such as Australia, Israel, and Japan, and for certain application such as heating swimming pool water in the United States and elsewhere. Figure 2-2 shows a combination solar thermal system (on left) and photovoltaic system (on right) at the Georgia Tech Aquatic Center in Atlanta, Georgia. As shown in the illustration, the two types of systems have similar outward visual features, and it may not be immediately obvious to emergency responders which type of system they are handling.

While solar thermal power technology was under development, so too was solar electric power technology. In 1839, French scientist Edmond Becquerel discovered a way to convert light into an electric current using an electrolyte cell made up of copper oxide electrodes in an electrically conductive solution.[6] The photoconductivity of the element selenium was discovered by Willoughby Smith in 1873, and 10 years later American inventor Charles Fritts is credited with the design of the first practical solar cell using selenium wafers.[7]

The conversion of sunlight into electrical energy remained a scientific curiosity until the development of a crystal silicon cell. In the early 1940s, Russell Ohl at Bell Telephone Laboratories received a series of patents for thermoelectric-type devices using high purity fused silicon that paved the way for the development of the modern solar cell.[8] In 1954, a Bell Laboratories team led by Daryl Chapin, Calvin Fuller, and Gerald Pearson created a crystal silicon cell that had good conversion efficiency (~6% light-to-electricity). This resulted in the first commercial uses of photovoltaics in 1955 at remotely located telephone repeaters, and in the first communications satellites launched in 1958.[9]

Photovoltaics soon established itself as the power source of choice for satellites in space, and it has held this role ever since. The high cost of the early PV technology has steadily dropped over the years with increasing advancements in technology updates. Today, photovoltaics, commonly known as "PV", has firmly established itself as one of the premier methods of sustainable energy and as a realistic alternative to conventional fossil fuels.[10]

Types of Solar Power Systems

From a consumer's standpoint, the fire service has an interest in all methods of harnessing solar energy when it comes to their own fire stations and related facilities. However, from the standpoint of fireground operations at a structural fire, their focus on the topic of solar power is, for all practical purposes, entirely on solar panels for thermal systems (direct heating) and photovoltaic's (generating electricity). Accordingly, these two basic methods are the primary focus of this report, as illustrated in Figure 2-3, types of solar power systems of interest to the fire service.

Fire fighters engaged in fireground operations at a structural fire are most likely to encounter solar panels on the roof of the structure, since this is normally the area most exposed to sunlight. The scope of this report includes all thermal systems and photovoltaic systems that are directly supporting the energy use of a particular structure. In such a case the solar panels may be located on the structure (i.e., roof) or be immediately adjacent and directly supporting the building's energy use. This study does not intend to include independent solar power generating facilities. An example would be a large array of ground-mounted solar panels that are directing their combined electrical energy into the power grid for collective consumption by the community.

Thermal systems are generally less complicated than photovoltaic systems. The basic concept used by a thermal system is to use sunlight to directly heat a fluid that is used to transfer the thermal energy.[11] Often the fluid is water, and on a structure this may or may not be connected to an internal storage tank such as a conventional hot water heater. Fluids other than water may be used in certain closed-loop systems to avoid freezing and enhance the fluid's heat transfer characteristics.[12]

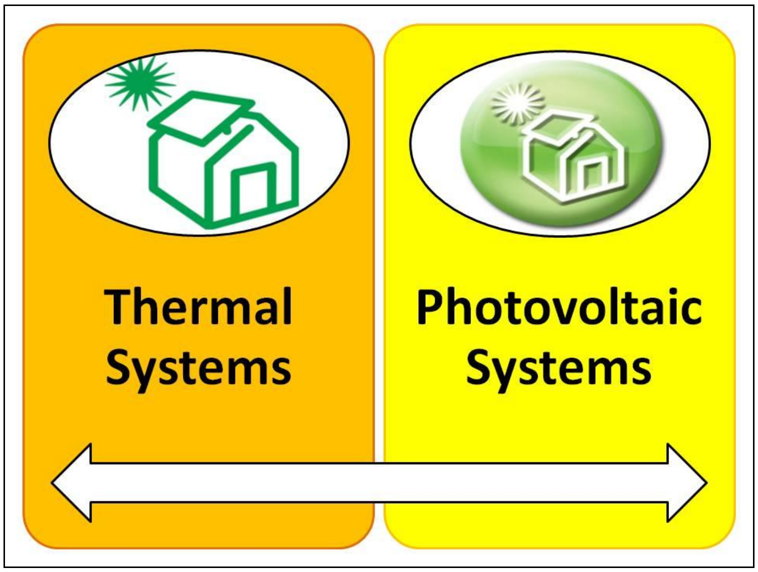

Figure 2-3: Types of Solar Power Systems of Interest to the Fire Service

Thermal systems are often further recognized as either passive thermal or active thermal systems, depending on whether or not they have a pump that actively circulates the fluid. A common application of a thermal system is to heat swimming pools, primarily because the fluid (swimming pool water) and pump (swimming pool filtration system) are already readily available. The four primary classifications of solar pool collector designs are: plastic panels, rubber mats, metal panels, and plastic pipe systems.[13] The overall risk from thermal systems presented to fire fighters involved with fireground operations is generally considered to be low.

Marketplace Trends

Solar power is an important source of sustainable alternate energy. The benefits of harnessing solar energy often outweigh the barriers, which most often is the initial installation cost. Most of the common solar energy applications available today are highly reliable, require little maintenance, have minimal operational costs, are sustainable with limited environmental impact, reduce our dependence on foreign energy sources, and provide a flexible and adaptable supply of power.[14] Figure 2-4 illustrates a typical residential solar power installation located in Maine.

Figure 2-4: Typical Residential Installation of a Solar Power System
(Photo courtesy of NREL Photographic Information Exchange)

The overall health of the solar power industry is strong. Worldwide solar heating capacity increased by 15 percent from 2007 to 2008, and for the first time ever more renewable energy than conventional power capacity was added in both United States and the European Union.[15] In the United States photovoltaics show strong promise for supporting our future electrical energy needs. Since early 2000 the production of photovoltaics had been doubling every two years until 2008 when it doubled in just one year.[16]

The solar power marketplace in the U.S. has experienced significant growth over the most recent decade. This is due to strong consumer demand, rising energy prices from conventional energy sources, and financial incentives from the federal government, states and utilities. These factors have resulted in the installed cost of consumer-sited PV systems declining substantially since 1998.[17]

The PV market is dominant in a small number of states led by California, but this is expanding as installations doubled in more than eleven states during 2008. The top states in 2008 based on installed megawatt (MW) capacity of PV installations were: (1) California - 178.7; (2) New Jersey – 22.5; (3) Colorado – 21.7; (4) Nevada – 14.9; (5) Hawaii – 8.6; (6) New York – 7.0; (7) Arizona – 6.4; (8) Connecticut – 5.3; (9) Oregon – 4.8; and (10) North Carolina – 4.0. The remaining states accounted for a cumulative capacity of 15.9 MW.[18]

Over 62,000 installations were completed in 2008, and the industry experienced a growth of 78 percent in 2008 with more than 5.4 gigawatts (GW) of capacity in shipments.[19] Similarly, the average size of PV system installations also increased during this time frame. Examples occurring in 2008 include a 12.6-MW installation in Nevada and a 3-MW installation in Pennsylvania, which together accounted for 5% of the annual installed capacity that year.[20] An example of a large commercial installation located in Boston, MA is shown in Figure 2-5.

Figure 2-5: Example of a Large Solar Power Commercial Installation
(Photo courtesy of NREL Photographic Information Exchange)

Each year in the last decade the manufacture and shipment of components for solar thermal and photovoltaic solar power systems has increased at a noteworthy rate. For solar thermal, Table 2-1 illustrates solar thermal collector shipments each year from 1998 to 2007, demonstrating the vibrant overall health of the solar thermal industry in the United States.[21] Similarly, the annual U.S. shipment of photovoltaic cells and modules remains strong and has increased sharply from 1998 through 2007. The increase in annual shipments of photovoltaic cells and modules in peak kilowatts over this time period is illustrated in Table2-2. At this time indications point to this growth continuing.

Table 2-1: Solar Thermal Collector Shipments Annually from 1998 to 2007[22]

Year	Import Shipments (1000 Sq Ft)	Export Shipments (1000 Sq Ft)	Total Shipments (1000 Sq Ft)	Number of Companies
1998	2,206	360	7,756	28
1999	2,352	537	8,583	29
2000	2,201	496	8,354	26
2001	3,502	840	11,189	26
2002	3,068	659	11,663	27
2003	2,986	518	11,444	26
2004	3,723	813	14,114	24
2005	4,546	1,361	16,041	25
2006	4,244	1,211	20,744	44
2007	3,891	1,376	15,153	60

Table 2-2: Photovoltaic Cell/Module Shipments Annually from 1998 to 2007[23]

Year	Import Shipments (Peak Kilowatt)	Export Shipments (Peak Kilowatt)	Total Shipments (Peak Kilowatt)	Number of Companies
1998	1,931	35,493	50,562	21
1999	4,784	55,585	76,787	19
2000	8,821	68,382	88,221	21
2001	10,204	61,356	97,666	19
2002	7,297	66,778	112,090	19
2003	9,731	60,693	109,357	20
2004	47,703	102,770	181,116	19
2005	90,981	92,451	226,916	29
2006	173,977	130,757	337,268	41
2007	238,018	237,209	517,684	46

The largest barrier to the proliferation of PV technology is its initial cost, and reducing this cost will further promote its widespread use. This obstacle hinges directly on the manufacturing process used to create the solar cells and related technology components. Intense research is under way that is focusing on improved processes to reasonably manufacture PV solar cells, and in the coming years it is anticipated that the affordability of PV solar systems will improve.[24]

The attractiveness of solar power is of course dependent on the available sunlight. However, the cost of purchasing electricity tends to be a greater marketplace influence, which is why some of the states with less than ideal optimum sunlight rank high on the list of states with the most installations. For example, New Jersey, New York, Connecticut, Oregon, and North Carolina all ranked in the top ten among states with the most installed MW capacity in 2008, despite ranking lower in terms of annual total sunshine. Further, certain states (e.g, California) and certain regions within states have aggressive legislation and active incentive programs promoting the use of solar and other sustainable forms of alternative energy. Therefore, fire fighters should not assume they won't encounter a solar power system simply because their jurisdiction is in an area of the U.S. lacking a reputation for abundant sunshine.

An example of a proactive state activity is the "California Solar Initiative Program", which provides significant rebate incentives through selected participating public utilities to promote the use of solar energy.[25] Table 2-3 illustrates the growth of solar energy systems in California from 1981 through 2008, and the impact of two major legislative initiatives to promote its use that were initiated in 1998 and 2007, respectively. In 2010, an estimated one percent of all buildings in California have some type of solar power system.[26] The program started in 1998 focused on incentives for stimulating utilities to broaden their use of solar energy, while the independent 2007 program additionally addresses consumer-based incentives.

Table 2-3: California Grid-Connected Photovoltaic Systems 1981–2008[27]

Year	Total Kilowatts	Year	Total Kilowatts
1981	37	**1995**	4,193
1982	75	**1996**	5,046
1983	86	1997	5,465
1984	1,231	1998	6,263
1985	1,245	1999	7,228
1986	2,217	2000	8,929
1987	2,217	2001	15,180
1988	2,221	2002	29,820
1989	2,280	2003	58,460
1990	2,295	2004	95,984
1991	2,312	2005	139,516
1992	2,801	2006	198,257
1993	4,064	2007	279,463
1994	4,606	2008	449,216

All corners of planet Earth have some number of sunny days, and thus this technology can be found virtually everywhere. The remoteness and ease of access to an area also provide a strong motivation for using solar power, and it is ideal where delivery of conventional fuels is very difficult. For this reason solar power has been the energy source of choice for the space exploration program, as well as isolated, difficult to access sites such as telephone repeater stations on mountain-tops and other remote locations.

As solar power technology is enhanced, it will reduce the complexities of installation and make system installation more readily available in the broad consumer marketplace. This raises the questions regarding non-OEM-type (OEM: Original Equipment Manufacturer) installations by unregulated consumers (i.e., purchase of self-install kits from a local hardware store). Additional monitoring by safety professionals may ultimately be required to assure safe and proper installations for occupants and emergency first responders. Unregulated private occupant installations raise questions that are not necessarily within the present regulatory infrastructure (e.g., via building and/or electrical permits). Further attention to this issue will likely be required as these self-installed systems become more common.

The convenience of an energy source that minimizes the need for replenishment is highly attractive. For example, solar power has already replaced small batteries in various convenience items such as wristwatches and calculators, thus greatly extending their lifespan without the need to replenish the power source (i.e., battery). Another example includes new motor vehicles that are considering solar energy collectors to supplement their electrical power system.[28]

Use of solar power for emergency preparedness and disaster planning is an obvious application of alternative energy independent of the electrical power grid. Numerous initiatives are underway to supplement disaster critical support functions. One example is an initiative to establish a PV back-up power supply in the City of Boston for evacuation routes out of the city for critical traffic controls, gas station pumps, emergency evacuation repeaters, etc.

Figure 2-6: Example of PV Systems Mounted on Fire Apparatus[29]
(Photo courtesy of San Rafael Fire Department)

The utilization of vehicle-mounted solar panels already exists within the fire service. In particular, an approach gaining traction in California is the installation of fire apparatus PV systems to address fire apparatus deployment over long periods of time (e.g., a wildfire event).[30] This provides them with a dependable electrical power supply for radio operation and other critical electrical equipment, and supplements the energy provided from conventional fuels that need periodic replenishment. Figure 2-6 illustrates PV panels mounted on the roof of fire apparatus in San Rafael, California.[31]

Figure 2-7: Example of Fire Station with a Photovoltaic Solar Power System in Missoula, MT
(Photo courtesy of NREL Photographic Information Exchange)

In addition to vehicle-mounted systems, fire stations are an integral part of almost all communities, and these civic structures are possible candidates for solar power system applications. Multiple examples exist over the last several decades of fire departments that have effectively installed solar power systems on their fire stations.[32,33] Figure 2-7 illustrates an example of a PV installation at Station Number 4 in Missoula, Montana.

Fire service facilities in remote areas utilize solar power systems more by necessity than for cost savings or similar reasons. This is not unusual for installations in the urban/wildland interface where commercial electric power from the local utility is simply not available. Figure 2-8 illustrates a PV installation on the Hawley Lookout Tower, which is operated by the U. S. Forest Service and located in the Boise National Forest in Idaho.

Figure 2-8: Example of PV System at a Remote Fire Lookout Tower in Idaho
(Photo courtesy of NREL Photographic Information Exchange)

The value of solar power systems as a source of sustainable energy is clear. While the fire service is obviously interested in clarifying fireground operations for structures equipped with solar panels, they also have a genuine interest in this technology as a general consumer.

Loss History and Data

Statistical data indicates that on average 40,270 fire fighters were injured during fireground operations in the United States annually from 2003 through 2006. Of these injuries, there were on average 215 fire fighters engaged in fireground operation at a building fire whose injuries were due to "electric shock." Further, 50 of these annual injuries were considered moderate or severe injuries.[34] Statistical data from present data collection efforts does not address whether or not photovoltaic power systems were involved with any of these occurrences.

The danger of electric shock on the fireground is a real hazard for fire fighters. Exemplifying this hazard is a report containing thirty-two specific incidents from the Fire Fighter Near Miss Database for the calendar years 2005 and 2006.[35] These incident reports provide anecdotal information on actual incidents involving fire fighters exposed to electric shock. While these are useful case studies, the level of detail in these reports does not always include the type or source of the specific electrical equipment involved, and none of these reports mentions the involvement of a solar power system.

To facilitate a review of loss information, structural fires involving solar power systems can be one of three basic types depending on the point of ignition. These are: (1) an external exposure fire to a building equipped with a solar power system; (2) a fire originating within a structure from other than the solar system; or (3) a fire originating in the solar power system as the point of ignition.

Detailed loss information to support each of these scenarios is lacking due to the relative newness of this technology. Traditional fire loss statistics such as NFIRS (National Fire Incident Reporting System) handled by the U.S. Fire Administration and FIDO (Fire Incident Data Organization) administered by the National Fire Protection Association, do not provide the necessary level of detail to distinguish the relatively recent technologies of solar power systems. A preliminary scan of the NFIRS data yields 44 incidents that involve "solar" in some manner, but a detailed review indicates that most are not applicable and involve fires that started with sunlight through glass, landscape lighting, are non-structural fires such as vehicles, vegetation, rubbish, etc. Further, proprietary information may exist with certain insurance companies and similar loss control organizations, but this is typically focused on their specific constituents and transparent data summaries are not known to be readily available.

In summary, statistical data involving solar power systems is not readily available to provide quantifiable data analysis of these systems. We do, however, have quantifiable data on the number of structure fires in the United States each year. For example, in 2007 there were 530,500 structure fires resulting in 3,000 deaths, 15,350 injuries, and $10.6 billion in direct property loss. Of these fires, one- and two-family homes accounted for 399,000 fires, 2,865 deaths, 13,600 injuries, and $7.4 billion in direct property loss.[36] While the actual percentage of overall buildings with solar power systems and those involved with fire remains a quantifiably mystery, we have a general expectation of how the data will likely trend in the future. As solar power systems continue to proliferate, the likelihood of fire fighters encountering them at a structural fire will similarly increase.

Fire service emergencies will more likely be responding to smaller installations commonly found on residences and similar occupancies since they comprise most of today's installations. However, large commercial systems will be equally noteworthy since even though they will be encountered much less frequently (due to fewer overall installations), they present unique fire fighting challenges that will require special tactical and strategic considerations.

Several Individual fire reports of specific events are able to supplement our understanding of fires involving solar power systems. Comparatively, there are very few incidents of fires originating with or directly involving solar power systems. This implies that the solar power industry has a relatively good record when it comes to their equipment and components contributing to the source of ignition. The following seven reported incidents provide information on distinctly different fire emergency scenarios.

The first of these incidents involved a residential structure fire in Colorado during May 1980. This involved a solar thermal system on a new unoccupied home with a small fire starting in a solar module due to faulty insulation materials. The fire resulted in minimal damage, but it did raise concern about this particular module design and its ability to properly endure the anticipated heat and weather conditions.[37,38,39] This fire occurred in 1980 and in the three decades since, significant advances have been made with the components and materials in this type of application.

Figure 2-9: Type of Arrays Involved in May 2008 CA Incident[40]
(Photo courtesy of Matt Paiss, San Jose CA)

The second incident involved photovoltaic panels in May 2008 on a structure at the University of San Francisco. Figure 2-9 provides an illustration of the type of arrays involved in this event, which was a relatively extensive installation and had the potential for significant fire spread. However, the building engineers on site were certified to handle high voltage, and the local electrical utility crew also arrived early in the event, and they took multiple steps to isolate energized conductors and power down the system, allowing responding fire fighters to extinguish the fire in one of the combiner boxes using portable extinguishers and a blanket of foam. Property damage was kept to the components of the solar power system involved in the fire, with minimal damage to the host building.[41]

The third fire of interest occurred in February 2009 at a California residence equipped with a newly installed photovoltaic system. The system was tied to the grid and was installed under cloudy conditions, and turned on prior to receiving a final electrical inspection. The system remained in an underpowered mode of operation for an extended stretch of rainy days. Ten days after the installation when exposed to full sunlight conditions, the system caught fire due to an electrical malfunction. Damage was limited to the roof-top system components.

A fourth fire occurred in a PV solar module installed on the roof of a home in California during March 2009. Unlike the residential fire in Colorado that involved a solar thermal system, this fire involved electrical arcing with a photovoltaic module that initiated the fire. This fire resulted in minimal damage to the residence, but portions of the solar system required replacement.[42]

The fifth fire occurred in California during April 2009 and involved a large PV solar array comprised of 166 strings of 11 modules each on the roof of a department store.[43] Figure 2-10 illustrates the solar power system involved in this event.

Figure 2-10: Solar Power System involved in April 2009 CA Incident[44]

A diagram of the rooftop installation is shown in Figure 2-11, and this illustrates how "strings of arrays" in terms of the physical configuration are not necessarily consistent with the "strings of electrically connected arrays." Explained in another way, the separate strings of 11 modules each is based on their electrical interconnections, and these do not directly equate to physical strings of 11 modules in a single individual row. This can cause confusion as emergency responders attempt to work with electrical system experts to isolate the system.

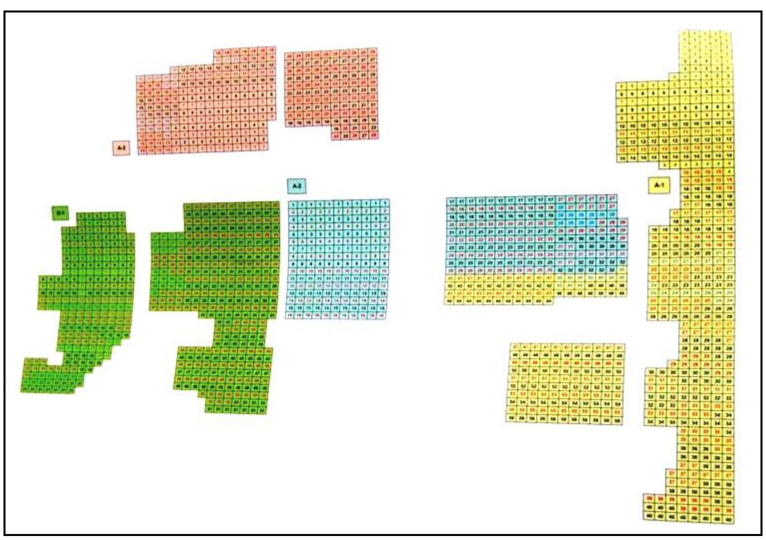

Figure 2-11: Diagram of Rooftop System in April 2009 CA Incident[45]

Two separate electrical fires broke out remote from each other, and were caused by electrical arcing. One of these fires consumed a complete string of solar modules. The resulting two-alarm fire was confined to the solar modules and was kept from penetrating the store's roofing materials. The arcing occurred when metal electrical conduits separated at their couplings due to significant contraction and expansion from sunlight, which exposed wiring that ultimately shorted. Figure 2-12 illustrates one of the arrays damaged by fire.

Figure 2-12: Fire-Damaged Array in April 2009 CA Incident[46]

The fire department was challenged by the lack of accessible means to readily isolate the modules on fire. This fire occurred on a bright sunny day, and the modules continued to generate electricity throughout the event with no means available to isolate them or de-power them. The electrical energy generated at the time of the fire by the system was appreciable and dangerous, and fortunately no injuries occurred. Although the installation met the requirements of the applicable electrical code, this event indicates a need to revise code requirements to provide emergency responders with appropriate measures to readily isolate solar modules.

A sixth fire incident occurred in March 2010 and involved a PV system at a residential occupancy in Maryland.[47] First arriving units reported that they had smoke and fire venting through the roof, but they soon realized the fire was confined only to the rooftop solar panels, after finding no smoke or fire within the structure. The fire was effectively controlled with a hose stream from the ground. Indications are that leaves and similar debris around and underneath the solar panels contributed to the fire's ignition. Figure 2-13 provides an illustration of the fire scene.

Figure 2-13: Residential PV Fire in March 2010 MD Incident[48]

The seventh fire occurred in a photovoltaic solar power system located on a residential occupancy in Southern California during April 2010. This fire was the result of an electrical fault within the inverter unit, and it resulted in an estimated $4,000 in damage and no injuries.[49] Despite relatively minimal damage, the event gained attention due to the challenge to the fire department to fully extinguish the fire while they attempted to safely remove electrical power that was generated by sunlight powering the photovoltaic panels. The fire department kept the small fire effectively contained within the inverter unit for several hours, and eventually fully extinguished the fire after locating and obtaining the assistance of a properly credentialed and equipped electrician to assist with removing the electrical power.

One issue not yet addressed and included in the identified loss data, is the potential future impact of solar power systems on the spread of wildland/urban interface fires. In recent decades these large-scale fires have increased in frequency and their loss magnitude has been enormous, dwarfing other traditional fire events. Some of these incidents have involved vast areas of vegetation and included the loss of hundreds of structures.

Concern exists on the ability of structures to withstand the onslaught of a wildland fire in these interface areas, which is testimony to the requirements of NFPA 1144, *Standard for Reducing Structure Ignition Hazards from Wildland Fire* that was originally issued in 1935.[50] The ability of a structure to resist an encroaching wildfire (including flying brands) is a critical defense for the wildland/urban interface fires, and how solar panels resist or fail to resist the fire attack is important. At this time, however, no data has been compiled nor any specific known losses recorded that indicate the impact of rooftop solar power systems for wildland/urban interface events.

More specifically it is unknown how rooftop solar panels perform when exposed to radiant heat or flying brands of an approaching wildland fire. Fire protection professionals have for many decades fought to prohibit building construction that uses certain types of roofing materials (e.g., untreated wood shingles) unable to resist building-to-building conflagrations. This has led to roofing material standards to protect from exposure fires such as ASTM E 108, *Standard Test Methods for Fire Tests of Roof Coverings*.[51]

Certain questions remain unanswered about the performance characteristics of roofs equipped with solar power systems and their ability to withstand external fire exposure. One recent research project through Underwriters Laboratories has further explored this topic, but this work is still in progress and the results are currently pending.

Information Resources

Solar power system installations have steadily grown in numbers in the first full decade of the 21st century. Factors contributing to this growth include strong consumer demand, rising energy prices from conventional energy sources, and financial incentives from the federal government, states, and utilities.[52] This has resulted in the development of multiple resources available from government entities, independent membership associations, and other similar broad-based organizations.

A useful resource addressing PV installations is the Open PV Project administered by the National Renewable Energy Laboratory (NREL), which provides updates of current PV market trends as well as specific details on existing U.S. photovoltaic installations.[53] The Open PV Project is a collaborative effort between government, industry, and the public that provides a community-driven database of PV installations. It utilizes a comprehensive web-based data collection process focusing on PV installation data for the United States. Its goal is to collect, organize, and distribute knowledge addressing the location, size, cost, and commissioning date of all U.S. PV installations.

The Open PV Project utilizes an active data-collection approach that is continually gathering input from contributing sources. Trend information starts in the year 2000, and NREL administrators bolster the collection efforts by using data from organizations such as large utilities and state-run incentive programs. The ongoing data compilation process includes multiple features to enhance quality and screen duplicates, although they acknowledge that statistics, rankings, and other estimates are only estimates and do not represent the actual current market status. Figure 2-14 illustrates information from the Open PV Project located at openpv.nrel.gov. In the future it is hoped that other private and government databases that track permits and similar information (i.e., through building departments and fire departments) will be able to directly contribute to the Open PV Project and other on-line tracking efforts focused on this topic.

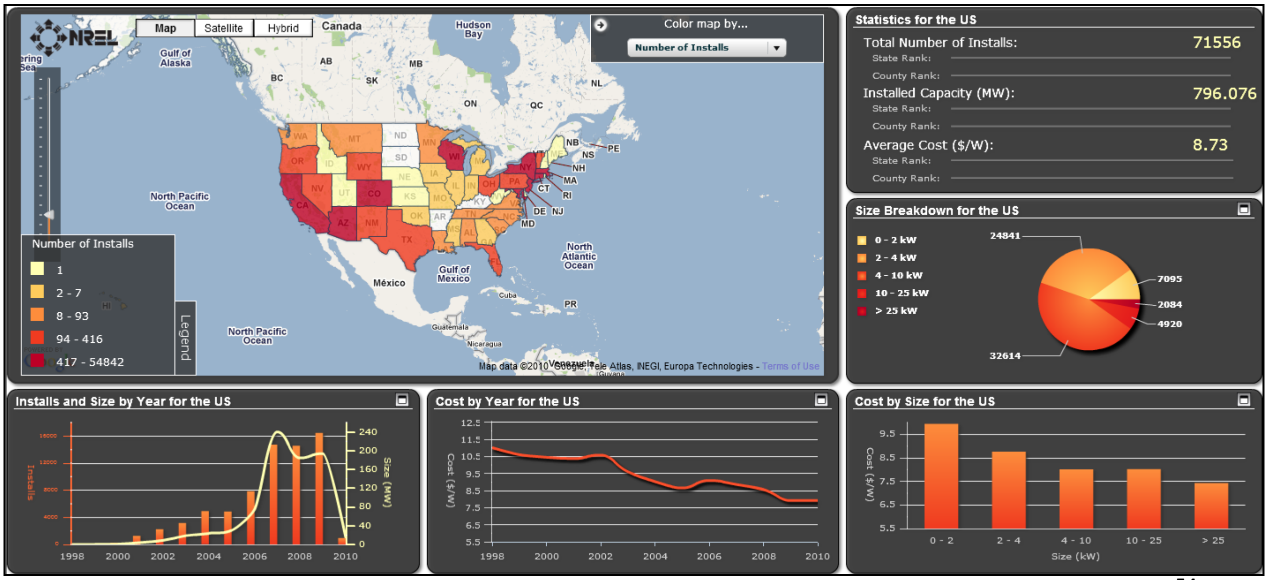

Figure 2-14: Example of Information from the "Open PV Project" (at openpv.nrel.gov).[54]

A few local jurisdictions track the solar power systems installations within their domain, and this provides useful information for emergency responders with their fire emergency pre-planning efforts. An example of one such jurisdiction is the Building Department in the City of San Francisco. They provide useful information on the installations located throughout the city, including detailed case studies of selected solar power systems. This information is readily available on a website (sf.solarmap.org), and Figure 2-15 provides an example of this particular web-based resource.[55] Other cities have similar web-based inventories, such as San Diego, which is considered to have the most Megawatt capacity among U.S City based jurisdictions.

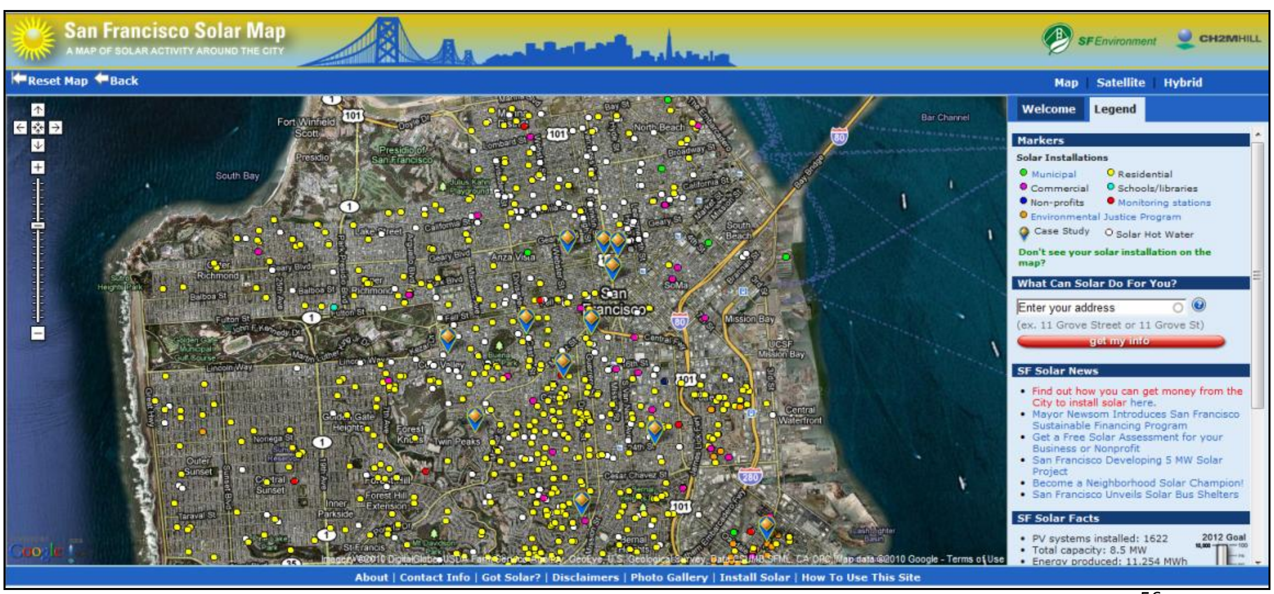

Figure 2-15: Website Example for Local Solar Power Systems (at sf.solarmap.org)[56]

Illustrations are a critical aspect of training programs for emergency responders, and a valuable source of useful pictures on a wide range of alternative energy related topics including solar power systems is the NREL PIX (National Renewable Energy Laboratory Picture Information Exchange). This website is located at www.nrel.gov/data/pix/ and offers a substantial library of illustrations that can be freely downloaded and used, and also provides a service for obtaining high resolution pictures if needed.

The growth in recent years of solar power industry has led to multiple national organizations that provide a supporting infrastructure for the use of solar power. Some of these organizations are focused on industry lobbying efforts or activities of interest to industry constituent groups. Their applicability to emergency responders may, in some cases, be arguably limited, but understanding them is nevertheless important to gain a full appreciation of the solar power industry. The following provides a summary of the key membership and resource organizations addressing solar power in the United States:

American Solar Energy Society (ASES)
The American Solar Energy Society (ASES) is a membership organization with approximately 13,000 energy professionals and grassroots supporters, dedicated to advancing the use of solar energy for the benefit of U.S. citizens and the global environment. ASES promotes the widespread near-term and long-term use of solar energy, has regional chapters in 40 states, and is the U.S. section of the International Solar Energy Society.[57]

Database of State Incentives for Renewables & Efficiency (DSIRE)
The Database of State Incentives for Renewables & Efficiency (DSIRE) was established in 1995 is a consortium of multiple government and non-government organizations that provides a comprehensive source of readily accessible information on state, local, utility, and federal incentives that promote renewable energy and energy efficiency. Funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), the database is administered by the National Renewable Energy Laboratory (NREL) and is an ongoing project of the North Carolina Solar Center and the Interstate Renewable Energy Council (IREC).[58]

Interstate Renewable Energy Council (IREC)
The Interstate Renewable Energy Council (IREC) is a nonprofit organization that addresses renewable energy programs and policies, and is a premier resource for current information, education, credentialing, and best practices regarding renewable energy. IREC was founded in 1982 and has been focused on rulemaking initiatives for connecting distributed power to the utility grid, workforce development, consumer protection, and stakeholder coordination.[59]

National Renewable Energy Laboratory (NREL)
The National Renewable Energy Laboratory (NREL) is the nation's primary laboratory for renewable energy and energy efficiency research and development. In 1977 NREL began operating as the Solar Energy Research Institute, and in 1991 was designated a U.S. Department of Energy national laboratory and its name changed to NREL.[60]

Solar America Board of Codes and Standards (Solar ABCs)
The Solar America Board for Codes and Standards (Solar ABCs) is funded by the U.S. Department

of Energy to help facilitate widespread adoption of safe, reliable, and cost-effective solar technologies, primarily through the development, implementation, and dissemination of codes and standards addressing solar power. Solar ABCs coordinates recommendations to codes and standards making bodies as a collaborative effort of affected stakeholders.[61]

Solar Energy Industries Association (SEIA)

The Solar Energy Industries Association (SEIA) was established in 1974 and functions as the national trade association of solar energy industry. SEIA accomplishes its mission by expanding markets, removing market barriers, strengthening the industry and educating the public on the benefits of solar energy. SEIA also administers a separate nonprofit organization called the Solar Energy Research and Education Foundation (SEREF) that oversees policy-driven research and develops education outreach programs to promote solar as a mainstream and significant energy source.[62]

Solar Energy International (SEI)

Solar Energy International (SEI) was founded in 1991 and is a nonprofit educational organization that provides education and training to decision makers, technicians and users of renewable energy sources. The SEI mission is to empower people around the world through the education of sustainable practices, and they work cooperatively with grassroots and development organizations in the Americas, Africa, Micronesia, and the Caribbean.[63]

Solar Living Institute (SLI)

The Solar Living Institute (SLI) is a nonprofit educational organization that promotes sustainable living through inspirational environmental education. SLI was founded in 1998 and has its headquarters in Hopedale, California.[64]

Other national organizations address solar power and directly address its virtues, but tend to represent the interests of system consumers, the general public, or other broad-based general interest group. The following is a summary of these organizations:

International Solar Energy Society (ISES)

The International Solar Energy Society (ISES) was founded in 1954 as the "Association for Applied Solar Energy". The organization revised their name in 1963 to the "Solar Energy Society" and again to the "International Solar Energy Society" in 1971. ISES is a global, nonprofit, non-governmental membership organization serving the needs of the renewable energy community. With world headquarters in Freiburg, Germany, ISES is a UN-accredited organization with a presence in more than 50 countries.[65]

Solar Alliance

The Solar Alliance is a U.S. oriented, state-focused alliance of solar manufacturers, integrators, and financiers dedicated to facilitating photovoltaic energy. The Alliance works closely with corporations, state-level trade associations, grass roots organizations, academic institutions, and local governments to advocate the virtues of solar energy.[66]

Solar Electric Power Association (SEPA)
Solar Electric Power Association is a nonprofit membership organization focusing on electric utility use and integration of solar electric power. SEPA is a business-to-business utility-focused activity that provides customized, localized and practical advice, research and events that are of specific interest to the electric utility industry. Funding comes from membership dues, individual and corporate donations, event revenue, and support from the U.S. Department of Energy.[67]

Solar Nation
Solar Nation is a program of the American Solar Energy Society that is a national grassroots campaign working to harness and facilitate public support for solar energy. Their focus is to positively affect state and federal policy and to enable solar power to become a significant part of America's energy future. Solar Nation promotes networking for advocacy groups with similar interests to build alliances and support long-term mutual goals linked to specific policy actions.[68]

Vote Solar
The Vote Solar Initiative is headquartered in San Francisco and works to resolve regulatory roadblocks impeding solar adoption. Established in 2001, Vote Solar operates at the local, state, and federal level to implement programs and policies that promote a strong solar market.[69]

In addition to the national organizations, various regional organizations have also found their way into various levels of mainstream recognition. Some of their work has had noteworthy impact and serves as a model for others with interest on these topics. Virtually every state and/or region has some organization that is supporting the local interest of solar power. These are summarized in multiple listings, such as the Action Partners section maintained by Solar Nation that provides a summary of their fifty-two Action Partner organizations.[70] Some examples are summarized in Table 2-4, Regional Organizations Addressing Solar Power.

Table 2-4: Regional Organizations Addressing Solar Power.[71,72,73,74,75]

Organizations	Website
Arizona Solar Energy Industries Association (AriSEIA)	www.arizonasolarindustry.org,
California Solar Energy Industries Association (CALSEIA)	calseia.org
Florida Solar Energy Resource Center (FSEC)	www.fsec.ucf.edu
Northeast Sustainable Energy Association (NESEA)	www.nesea.org,
Texas Renewable Energy Industries Association (TREIA)	www.treia.org

When compared to other energy technologies, solar power is relatively new and its usage has become more mainstream in the last several decades. Consequently, the model codes and standards arena is actively engaged in addressing the latest technologies and application methods.

Consensus-based model codes and standards provide the baseline for the design, installation, operation, maintenance, and other important aspects of solar power systems. A key organization providing support in this topic is the aforementioned Solar America Board of Codes and Standards, also popularly known by their acronym Solar ABCs.[76] Funded by the U.S. Department of Energy, their charter is to support efforts towards development, implementation, and dissemination of codes and standards addressing solar power, with the intent of facilitating widespread adoption of safe, reliable, and cost-effective solar technologies. There role is particularly important to help address safety and other concerns from the emergency response community, as they coordinate recommendations to codes- and standards-making bodies as a collaborative effort of affected stakeholders.

Several internationally recognized codes and standards directly address solar power systems, either within the entire document or in part. Included are certain emergency responder concerns for solar power systems, such as certain features that assist them during an emergency such as component labeling or electrical isolation switches. The following technical documents are directly applicable documents in the codes and standards arena:

- IEC/TS 61836:2007, *Solar Photovoltaic Energy Systems – Terms, Definitions, and Symbols*
- IEC 60364-7-712 (2002-05), *Electric Installations of Building*s – Part 7-712: Requirements for Special Installations or Locations – Solar Photovoltaic (PV) Power Supply Systems
- ISO 9488:1999, *Solar Energy* – Vocabulary
- NFPA 70, *National Electrical Code*, 2008 edition (Article 690, Solar Photovoltaic Systems)

These documents provide detailed requirements, but the relatively rapid introduction of this technology has required them to be continually updated. For example, NFPA 70, *National Electrical Code* is presently undergoing revisions for the upcoming 2011 edition of the NEC, and multiple enhancements are proposed in Article 690 to address additional safety details for PV installations. This includes routing PV source and output conductors, directories for remote multiple inverters, and qualification requirements for installers.[77]

Other model codes address the topic of solar as part of their overall scope, such as the various model building codes, fire codes, and other related documents. Model codes continue to be updated to include the latest requirements and guidance information, some of which pertains to the design and installation of solar power systems for buildings. This is especially important for new and unusual technologies and configurations (e.g., flame spread characteristics of vertically mounted solar panels rather than horizontal rooftop panels). Examples of applicable model codes include:

- *NFPA 5000, Building Construction and Safety Code*, 2009 edition
- *ICC International Building Code*, 2009 edition
- NFPA 1, *Fire Code*, 2009 edition
- *ICC International Fire Code*
- *ICC-700, National Green Building Standard*
- *ICC International Energy Conservation Code*
- *ICC International Residential Code*

Individual states typically utilize the model codes to provide direction and approach for their own legislation. Some state-based requirements are already well established, and in other locations it is under development. Examples include:

- *2008 Building Energy Efficiency Standards for Residential and Nonresidential Building*s, (California Energy Commission, effective 1 Jan 2010).[78]
- *Oregon Solar Energy Code*, Draft Document dated September 2009.[79]
- *Guidelines for Fire Safety Elements of Solar Photovoltaic Systems* (Orange County Fire Chiefs' Association, California, December 1, 2008).[80]

Both the model codes as well as the specific state-applied local codes are typically oriented as overarching documents focused on basic design, installation, and maintenance as they relate to the use of solar power in buildings and structures. They normally refer to other more specific standards often by mandatory reference (administered by organizations such as ASTM International, Underwriters Laboratories, etc.), for the particular details important to maintain safe and reliable construction of the solar power systems and components. In addition to assuring safety, these documents also provide useful consumer marketplace conformity to facilitate interoperability in the solar power infrastructure and marketplace (i.e., matching thread sizes for component interconnections.

Two aspects of regulatory oversight that have not been resolved for the solar power industry are reliable methods for assuring qualified installations, and ongoing maintenance and long-term service. From the vantage point of building officials, electrical inspectors and fire inspectors, solar power systems arguably should be addressed similar to other building systems that present potential hazards to the occupants or emergency responders. These other systems have requirements to assure quality installations and proper ongoing service. The present oversight of solar power systems is not as robust as with other similar building systems.

As a comparative example, in France a report was issued that one in three photovoltaic systems are not meeting the required safety standards, this being related to inadequate installation, maintenance, and/or enforcement oversight.[81] This study is based on installations in France and not the United States, and a similar analysis for the U.S. is not readily available. Nevertheless it raises the question of the status of these characteristics, and how best to address these topics in the future.

The fire service literature includes multiple published articles that specifically address emergency situations and emergency responder interests involving solar power systems. A summary of the readily available literature addressing fire service interests and concerns is provided by Table 2-5, Literature Review Summary for Solar Power Systems and the Fire Service.

Table 2-5: Literature Review Summary for Solar Power Systems and the Fire Service

	Title	Publication	Author(s)	Year	Vol/Iss	Pg(s)	Format	Comment
1	Solar Energy Units and Fire Safety	Fire Engineering	Bare, W.K.	1978 Jun	131/6	51-52	Article	Fire safety & building code concerns with solar power systems
2	Fire Experiments and Flash Point Criteria for Solar Heat Transfer Liquids	NBSIR 79-1931	Lee, B.T., Walton, W.D.	1979			Report	NIST BFRL Publication on characteristics of solar heat transfer fluids
3	Fire Occurs Within Solar Panel	Fire Command	Harvey, C.S.	1980 Sept	47/9	40-41	Article	Case study of solar panel fire in Boulder CO in May 1980
4	Fire in a Residential Solar Panel: A Potential National Problem	International Fire Chief	Harvey, C.S.	1980 Sept	46/9	55-57	Article	Case study of solar panel fire in Boulder CO in May 1980
5	Fire Within A Residential Solar Panel	Fire Chief	Harvey, C.S.	1980 Sept	24/9	31-33	Article	Case study of solar panel fire in Boulder CO in May 1980
6	Solar Collector Fire Incident Investigation	NBSIR 81-2326	Walton, W.D.	1981 Aug			Report	NIST BFRL Publication on 1980 case study fire in Boulder CO
7	Fire Testing of Roof-Mounted Solar Collectors by ASTM E 108	NBSIR 81-2344	Walton, W.D.	1981 Aug			Report	NIST BFRL Publication on roof covering fire tests per ASTM E108 with solar panels
8	Fire Testing of Solar Collectors by ASTM E 108	Fire Technology	Waksman, D., Walton, W.D.	1982 May	18/2	174-186	Article	Roof covering fire tests per ASTM E108 with solar panels
9	Rooftop Photovoltaic Arrays: Electric Shock and Fire Health Hazards	Solar Cells	Moskowitz, P.D., et al.	1983	9	1-10	Article	Review of health hazards of solar cells exposed to fire
10	Toxic Materials Released from Photovoltaic Modules During Fires	Solar Cells	Moskowitz, P.D., et al.	1990	29	63-71	Article	Review of health risks from solar cells exposed to fire
11	Here comes the sun: Solar Energy for Emergency Medical and Disaster Use	Emergency	Ross, C.	1993 Dec	25/12	34-37	Article	

	Title	Publication	Author(s)	Year	Vol/Iss	Pg(s)	Format	Comment
12	Inspecting Solar Electric Systems For Code-Compliance	Building Standards	Brooks, B.	2000 Sep Oct	69/5	22-25	Article	Safety concerns of PV for building, fire and electrical inspectors
13	Photovoltaic Power Systems	NEC Digest	Wiles, J.	2002 Nov	1	26-34	Article	Review of NEC Article 690 criteria for PV
14	2005 Code Revisions: Proposed Changes to Article 690	NEC Digest	Brown, J.M.	2003 Fall		70-75	Article	Review of revisions to NEC Article 690 criteria for PV
15	Photovoltaic and 2005 NEC	IAEI News	Wiles, J.	2005 Mar Apr		80-84	Article	Review of revisions to NEC Article 690 criteria for PV
16	Solar power: A Hot New Trend in the Fire Service	Firehouse	May, B.	2005 Apr		134	Article	Review of solar power systems installed for fire station
17	Solar systems: Strategies for Neutralizing Solar-Powered Homes	Fire Rescue Magazine	Nadel, S.	2005 Oct	23/9	88-89	Article	Review of hazards at residential properties using solar power
18	Fundamentals of Photovoltaics for the Fire Service	California Solar Energy Industries Association	Slaughter, R.	2006 Sep			CDRom	
19	Tips for Firefighters Facing "Green" Photovoltaic Electric Systems	WNYF	Woznica, Joseph	2008	3	26-27	Article	
20	Growth Strategy	Reason		2009	2	36-39	Article	Review of hazards with green roofs and solar power systems
21	The Impact of Solar Energy on Firefighting	Fire Engineering	Kreis, T.	2009 Jan	162/1	79-80	Article	Review of basic PV hazards to firefighters
22	Simi Solar Panel Fire Raises Safety Issue	Ventura County Star	Gregory, K.L.	2009 Mar 14			Article	Online newspaper article describing residential fire at www.vcstar.com/news/2009/mar/14/

	Title	Publication	Author(s)	Year	Vol/Iss	Pg(s)	Format	Comment
23	Solar Panel Dangers	MCAFDSO Newsletter	Leechan, J.	2009 Mar-Apr	IV/2	4	Article	Monroe County Association of Fire Dept. Safety Officers, Spencerport NY
24	Roof PV Fire of 4-5-09	City Memo	P. Jackson to P. Burns	29 Apr 2009			Memo Fire Report	Fire report on PV roof fire at dept store in Bakersfield CA
25	Solar Electric Systems and Firefighter Safety	Fire Engineering	Paiss, M.	2009 May	162/5	83-88	Article	Review of multiple fire fighter concerns with solar panels
26	PV Safety & Engineering	Home Power	Paiss, M.	2009 Jun / Jul	131	88-92	Article	Overview of fire fighter concerns with solar panels
27	Building Construction: Solar Energy Systems	Coffee Break Training – Fire Protection Series	USFA National Fire Academy	2009 Sep 29	FP-2009-39		One-Page Flyer	Review of potential hazards from solar energy collection systems

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3. PHOTOVOLTAIC SOLAR POWER

Photovoltaic systems are based on fundamentally different technology from thermal systems. This section provides additional background information on photovoltaic technology and the systems that use this technology, including details on the materials and methods used and how this relates to emergency first responders required to handle them during an emergency. Photovoltaic systems present certain special concerns to fire service personnel through electric shock, and thus this section provides additional information on this particular type of solar power.

Photovoltaic Basics

The photovoltaic process converts light to electricity, as indicated by the root words *photo* meaning “light” and *voltaic* meaning “electricity”, and often represented by the acronym PV. The process involves no moving parts or fluids, consumes no materials, utilizes solid-state technology, and is completely self-contained.[82] The primary concern for emergency responders with these systems is the presence of electrical components and circuitry that present an electrical shock hazard.

The basic components of a photovoltaic system include the photovoltaic unit that captures the sun’s energy, and inverter that converts the electrical power from DC to AC, electrical conduit and other electrical system components, and in some cases a storage battery. At the heart of the system is the unit that is actually capturing the sun’s electromagnetic energy in the form of light. Figure 3-1, illustrates the basic photovoltaic components used to capture solar energy.

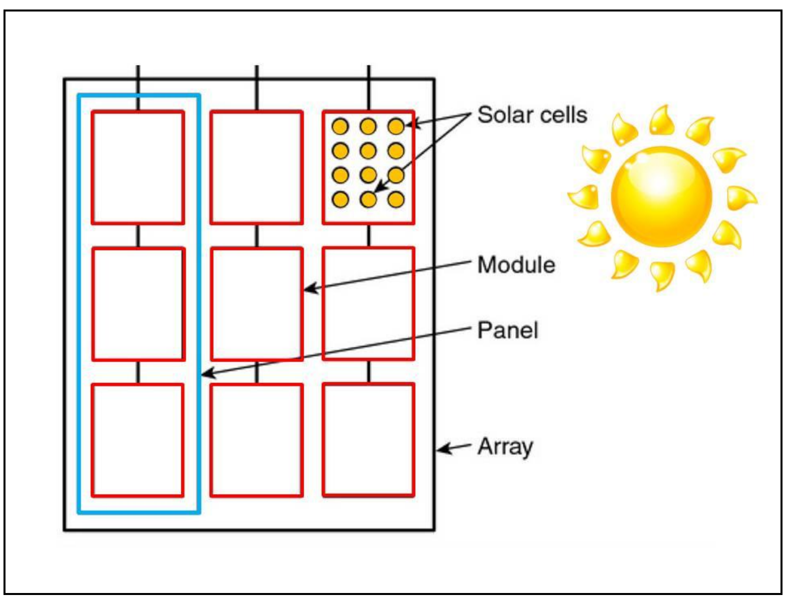

Figure 3-1: Basic Photovoltaic Components Used to Capture Solar Energy

A photovoltaic unit includes one or more solar ce*ll* or *photovoltaic cell* components that convert the sun's electromagnetic rays into electricity. These are the most elementary photovoltaic devices or components in the system.[83] An environmentally protected assembly of interconnected photovoltaic cells is referred to as a *module*, *solar module,* or photovoltaic module.[84] Modules are mechanically integrated, preassembled and electrically interconnected units called a *panel*, *solar panel*, or *photovoltaic panel*.[85] In the solar industry these are also referred to as *strings*.

Figure 3-2: Configurations of Solar Modules, Including Framed, Flexible, and Rolled
(Photo courtesy of NREL Photographic Information Exchange)

Common configurations of modules include framed, flexible and rolled. Figure 3-2 illustrates these basic types of solar modules. Multiple modules (in panels or strings) are often mechanically integrated with a support structure and foundation, tracker, and other components to form a direct-current power-producing unit, and these are termed an *array* or *photovoltaic array*.[86]

Solar Cell Technology and Photovoltaic Systems

From the perspective of fire fighters on the fireground, the photovoltaic modules are the fundamental components within the photovoltaic system that converts the sunlight to electricity. These have physical dimensions in the general range of 2½ feet by 4 feet by ½ foot, and large systems might have hundreds of modules arranged in strings as part of the solar array.[87]

A typical PV module includes not only the solar cells, but several other important components including the concentrators that focus the sunlight onto the solar cell modules, array frame and associated protective components, electrical connections, and mounting stanchions. Figure 3-3 provides a relatively detailed illustration of the primary components of a PV solar power system, and Figure 3-4 illustrates the fundamental electrical interrelationship for photovoltaic systems that are stand-alone, hybrid, or interactive with the building's conventional electrical system.[88]

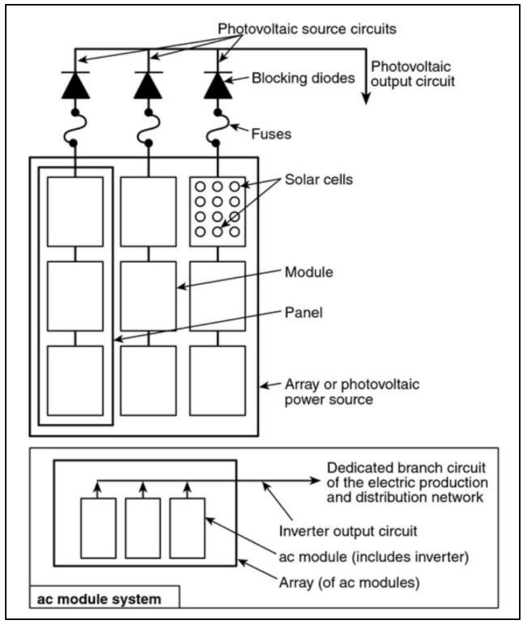

Figure 3-3: Basic Components of a Photovoltaic Solar Power System.[90]

All of these components are designed with significant attention given to their endurance, recognizing that a typical solar panel will be exposed to ongoing harsh weather conditions that will promote degradation. Some of the materials used might have excellent weather endurance characteristics, but not necessarily be resistant to exposure fires. Today, the lifespan of a typical solar array is typically in the 20 to 25 year range, and component endurance is an important performance characteristic of the overall solar energy system.[89]

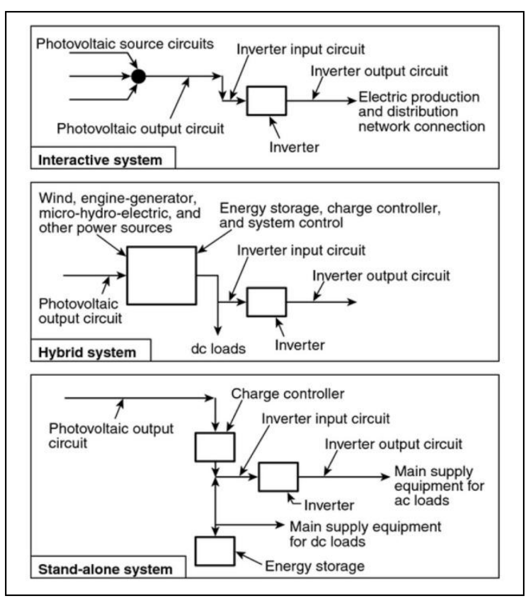

Figure 3-4: Photovoltaic System Interrelationship with Conventional Electrical Systems.[91]

In addition to the solar module, the other key components of the PV system are the inverters, disconnects, conduit, and sometimes an electrical storage device (i.e., batteries). The electricity generated by PV modules and solar arrays is dc (direct current), and an inverter is required to convert this to ac (alternating current). As with any electrical equipment that is tied into a building's electrical circuitry, disconnect switches are required for purposes of isolation. Some systems also include batteries to store the additional energy created during sunlight hours for use at a later time.

Present PV technology is based on the use of solar cells, which are the primary subcomponent within the system that converts light to electricity. Most often this is done through the use of high purity silicon wafers. Solar cells are interconnected in series and parallel to achieve a predetermined output voltage when operating at capacity. Current technologies allow new and unusual geometric configurations, such as films that adhere to a roof or vertical building surfaces. An example is a system using building-integrated photovoltaics, which are photovoltaic cells, devices, modules, or modular materials that are integrated into the outer surface or structure of a building and serve as the outer protective surface of that building.[92] As an example, Figure 3-5 illustrates a PV panel shaped like a roof shingle.

Figure 3-5: Example of PV Roof Panels Shaped Like Conventional Roofing Shingles
(Photo courtesy of NREL Photographic Information Exchange)

Several new technologies are under development for solar cells that have promise for future applications. Examples include gallium-arsenide cell technology and multijunction cell technology. Other new methods and approaches are experiencing rapid proliferation, such as thin-film cadmium telluride cell technology. From the standpoint of the fire service, these new technologies will likely result in greater solar panel performance and greater proliferation of installations, but likely will not result in additional or unusual hazard characteristics from what they are already facing with the current solar cell technologies.[93] Figure 3-6 shows a thin film PV system on a large commercial building in Detroit, Michigan, and exemplifies how this technology allows the PV system to blend with other building components (e.g., roof assembly).

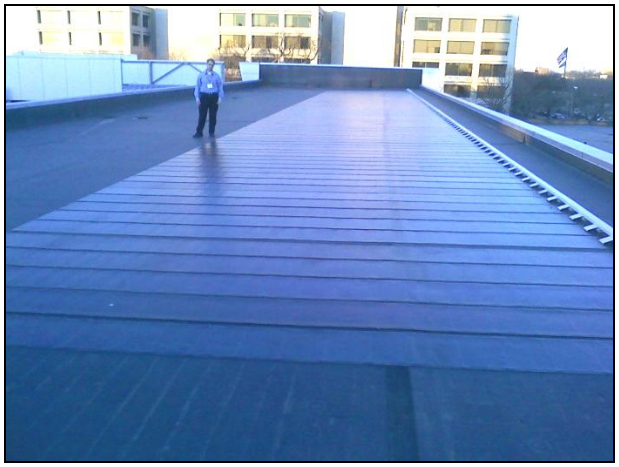

Figure 3-6: Example of Thin Film PV System on a Commercial Building in Detroit, MI

Photovoltaic modules that are integrated into the building's components are generally referred to as *Building Integrated Photovoltaic* (BIPV) modules. These are allowing new and unusual applications of PV systems, including expansive vertical configurations. Among the most widely recognized recent BIPV installations using a vertical configuration is the Condé Nast Building in Times Square, New York City. This 48-story skyscraper is considered to be one of the first major commercial applications of vertically configured BIPV in the United States. The PV skin extends from the 37th through the 43rd floor on the south and east facades over the glass components, and blends in seamlessly with the building's exterior. Figure 3-7 provides an illustration of the Condé Nast Building.

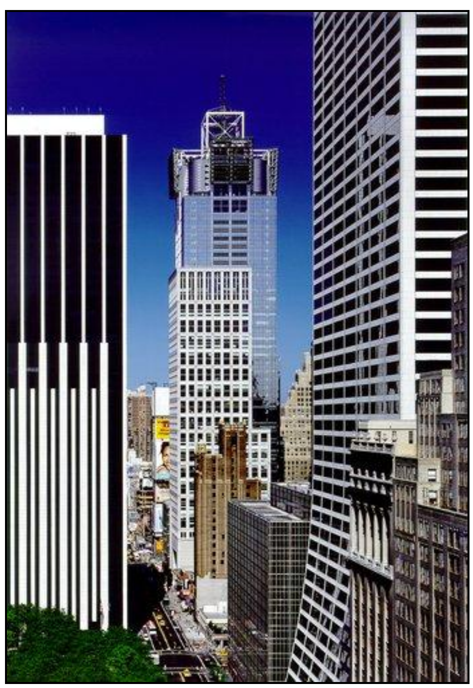

Figure 3-7: BIPV System Using a Vertical Module Configuration in New York City
(Photo courtesy of NREL Photographic Information Exchange)

New York City is addressing the needs of solar panel installation in the same fashion as other jurisdictions, but the numerous variations utilized is a challenge for the regulatory approval agencies that require variances from their building code. In a recent report by the NYC Green Codes Task Force, their findings included the recommendation to "clarify standards for Attaching Rooftop Solar Panels." This addresses the issue that the NYC Building Code does not specify acceptable criteria for the attachment of solar panels to rooftops, which inhibits the installation of solar energy systems. It further includes a recommendation that the Department of Buildings develop detailed criteria for roof attachment of solar panels.[94]

Background on Fireground Electrical Hazards

Electrical shock while extinguishing a building fire is a realistic fireground hazard. A critical task during fireground operations at any building fire is to shutdown the utilities, including the electrical utilities to remove the electrical shock hazard. This is a relatively straightforward one-step process for a building receiving electrical power from the local communities' power grid. However, it becomes considerably more challenging when multiple sources provide electrical power (i.e,. distributed power generation) such as with a building equipped with a photovoltaic power system.

How much electrical energy is required to cause harm to the human body? Electricity and electrical equipment is widespread in today's modern civilization. Each year in the U.S. among all industry sectors there are approximately 30,000 nonfatal electrical shock accidents.[95] Data from a 1998 CDC/NIOSH summarizing electrocution fatalities in their data surveillance system indicates that during the decade of the 1980s approximately 7% of the average 6,359 annual traumatic work-related deaths were due to electrocution. This report also indicates that during the period from 1982 to 1994, twice as many fatal work-related electrocutions occurred with voltage levels greater than 600 volts.[96]

Understanding the dangers of electricity requires clarifying the terminology used to describe this danger. We often describe the magnitude of an electrical system in terms of *voltage* or *amperage*, and it is important to have a limited understanding of these terms. From a fire fighters perspective, the following describes these two terms:[97]

- Voltage—the electromotive force or potential difference, measured in volts. Voltage is the "pressure" that pushes an electrical charge through a conductor.
- Amperage or Current—The amount of electrical charge flowing past a given point per unit of time, measured in amperes or amps. Amperage is the measure of electrical current flow.

The flow of electrical energy in electrical wiring is analogous to the flow of water in a closed circuit of pipes. Hydraulics and the movement of water is a fundamental field of knowledge used by the fire service, and this visualization is useful to better comprehend the dangers of electricity. Instead of the transfer of water, electricity involves the transfer of electrons or other charge carriers. The voltage difference between two points corresponds to the water pressure difference between two points. If there is a difference between these two points, then flow will occur. Voltage is a convenient way of measuring the ability to do work.

The basic relationship between voltage and amperage is defined by Ohm's Law. This tells us that Volts x Amps = Watts, where wattage is the rate at which an appliance uses electrical energy. Wattage is considered the amount of work done when one amp at one volt flows through one ohm of resistance. The power generation of a photovoltaic system is normally described in terms of watts or kilowatts (1000 watts).[98]

The term *high-voltage* is defined differently depending on the particular application. This understandably can create confusion among emergency responders who are faced with handling emergencies with electrical equipment. For example, voltage ratings for buildings and structures in the built infrastructure treat high voltage as being any voltage exceeding 600 volts, based on Article 490 of the National Electrical Code.[99] Voltage ratings for electrical equipment generally conform to the ANSI C84.1 standard, which considers low voltage as 600 volts and below.[100] In addition, levels of voltage (i.e., high, medium, low) are defined differently with non-building applications, such as motor vehicles. Despite the lack of universal definitions of high, medium, and low voltage; from the perspective of emergency responders, any voltage level that can cause injury or worse is a direct safety concern.

It is common to speak about the dangers of electricity in terms of voltage, but the amperage or current is the key measurement parameter of danger to humans. An electrical shock involving high voltage but very low current would be less dangerous than low voltage and high current. Table 3-1 provides some examples of the observable effects of electricity on the human body. The current required to light a 7½ watt, 120 volt lamp, if passed across the chest, is enough to cause a fatality.[101]

Table 3-1: Estimated Effect of 60 Hz AC Current on Humans.[102,103]

Milliamperes	Observable Effect
15K/20K*	*Common fuse or circuit breaker opens*
1000	*Current used by a 100-watt light bulb*
900	Severe burns
300	Breathing stops
100	Heart stops beating (ventricular fibrillation threshold)
30	Suffocation possible
20	Muscle contraction (paralysis of respiratory muscles)
16	Maximum current an average man can release "grasp"
5	GFCI will trip
2	Mild shock
1	Threshold of sensation (barely perceptible)

*Note: 15 to 20 Amps (15,000 to 20,000 Milliamperes) is current required to open a common residential fuse or circuit breaker.

These electricity effects are also described in Figure 3-8, human body reaction to shock hazards. Nearly all materials will conduct electrical current to some degree, and this includes the human body. Each situation involving an individual receiving an electrical shock is unique, and will depend on multiple factors that alter the manner in which the electricity passes through the human body and the detrimental effect that results. Variables affecting the physiological impact include: amount of current flowing through the body; length of contact time; travel path through the body; area of contact; pressure of contact; moisture of contact; body size and shape; and type of skin.[104]

Shock Hazard Levels

Reaction of Human Body to Electric Current

Effect of Current	AC Current in Amps–Men	AC Current in Amps–Women
Perception threshold (tingling sensation)	0.0010	0.0007
Slight shock–not painful (no loss of muscle control)	0.0018	0.0012
Shock– painful (no loss of muscle control)	0.0090	0.0060
Shock–severe (muscle control loss, breathing difficulty–onset of “let-go” threshold	0.0230	0.0150
Possible ventricular fibrillation (3-second shock)	0.1000	0.1000
Possible ventricular fibrillation (1-second shock)	0.2000	0.2000
Heart muscle activity ceases	0.5000	0.5000
Tissue and organs burn	1.5000	1.5000

Figure 3-8: Human Body Reaction to Shock Hazards.[105]

4. Overview of Fire Service Operational Material

Training and education are important for preparing fire fighters to properly perform their assigned tasks. Arguably of greater importance, however, are the operational guidelines and operational procedures used by fire departments to perform their duties to mitigate an emergency situation. Standard Operating Procedures (SOPs) and Standard Operating Guidelines (SOGs) are widely used in today's fire service.

The terms *Procedure*s and *Guidelines* are sometimes used interchangeably. However, in fire service parlance they are considered to be different. Procedures imply relatively inflexible instructions, prescriptive task steps, and appreciable detail. In contrast, guidelines are more performance oriented and imply discretion in performing the required tasks.[106]

There is significant overlap with the interpretation and final implementation of these descriptors, and ultimately it can sometimes be hard to distinguish the difference between them. Multiple precise definitions can be found in the fire service literature. As one example, the following definitions are from the 2008 edition of NFPA 1521, *Standard for Fire Department Safety Officer*:

> *Standard Operating Guideline: A written organizational directive that establishes or prescribes specific operational or administrative methods to be followed routinely, which can be varied due to operational need in the performance of designated operations or actions. (Note: Standard operating guidelines allow flexibility in application.)*[107]
>
> *Standard Operating Procedure: A written organizational directive that establishes or prescribes specific operational or administrative methods to be followed routinely for the performance of designated operations or actions. (Note: The intent of standard operating procedures is to establish directives that must be followed.)*[108]

The wide range of possible unpredictable emergency scenarios requires a degree of flexibility in terms of written procedures, but conversely too much flexibility and discretion reduces control and increases the likelihood of mistakes. Litigation sometimes provides the basis for interpreting the difference between procedures and guidelines, but the courts tend to ignore actual terminology and focus on content. They tend to consider liability based on factors such as: national standards and other recognized regulatory requirements, adequacy of training activities; demonstration of training competence; procedures for monitoring performance; unique needs of the fire department; and procedures for ensuring compliance.[109]

Actual fire service education and training materials can be obtained from a number of sources. General emergency responder operational materials are readily available, and these can be adapted and used directly by members of the fire service. These include, for example, the training manuals provided by the International Fire Service Training Association (since 1932), fire service training materials provided by Jones and Bartlett Publishers, and various books and publications provided through Delmar Learning.[110,111,112] Specific details of these organizations include the following:

International Fire Service Training Association (IFSTA)

The mission of IFSTA is to identify areas of need for training materials and foster the development and validation of training materials for the fire service and related areas. With origins that are traced back to 1934, this association of fire service personnel provides oversight and validation of the manuals, curricula, training videos, CD-ROMs, and other materials developed by Fire Protection Publications (FPP). FPP is a department of Oklahoma State University and serves as the headquarters for IFSTA in Stillwater, Oklahoma.[113]

Jones and Bartlett Publishing (J&B)

J&B publishes an extensive line of training materials for the fire service, including comprehensive online resources for fire service students and instructors. As an independent publisher headquartered in Sudbury, MA, they are the seventh largest college publisher in the United States, publishing training materials as professional and reference books as well as a variety of multimedia and online products. The content for their training materials is developed in collaboration with the International Association of Fire Chiefs and the National Fire Protection Association.[114]

Delmar Learning

Delmar is a sub-group within Cengage Learning and they offer a portfolio of emergency services educational and training materials. Headquartered in Clifton Park, NJ, there products include printed books, multimedia, online solutions, certification tests, reference products, instructor teaching and preparation tools.[115]

A key federal government organization serving as an external training source for fire departments is the National Fire Academy (NFA) of the USFA.[116] The NFA is the Fire Administration's training delivery arm and is located in Emmitsburg, Maryland. The creation of the NFA has its genesis in the landmark report *America Burning* written in 1973, which recommended the establishment of a "National Fire Academy for the advanced education of fire service officers and for assistance to state and local training programs".[117]

With more than three decades of operation, the NFA has earned the respect of the fire service and provides an important stabilizing influence that helps to unite the fire service on the myriad of specific training topics. As a central focus point for the development and refining of fire service training materials, the NFA works closely with not only the vast range of local and regional fire departments throughout the country, but equally with the various national organizations that administer important sub-components of the training infrastructure. At the state level the NFA works closely with the state fire training directors through their association, the "North American Fire Training Directors" (NAFTD).

The NFA provides an important forum for the centralized development, refinement, and dissemination of fire service training materials on specific topics. An alternative to the training courses delivered on-site at the NFA is to build special topic curricula, which are then made available for internal fire department training activities through NFA "Endorsed Courses".[118] The NFA also provides hand-off training programs for individual training academies that are usually based on two days worth of content.

These Endorsed Courses at NFA provide a mechanism for outside organizations to cultivate and promote the development of applicable, state-of-the-art, accurate, useful and timely training information. As a specific example worthy of consideration, the training information contained in U.S. DOE online training packages such as "Hydrogen Safety for First Responders" and "Introduction to Hydrogen for Code Officials" may be candidates for material used in NFA endorsed courses.[119,120]

One NFA activity that serves a critical role in disseminating training information to the various state and local training agencies is the *Training Resources and Data Exchange (TRADE)* program.[121] This is a network of the state fire service training systems, along with the senior executive training officers from the Nation's largest fire departments protecting populations greater than 200,000 and/or who have more than 400 uniformed personnel. As a regionally based network established in 1984, TRADE facilitates the exchange of fire-related training information and resources among government organizations at the local, state, and federal levels.

The TRADE system operates using geographic regions that correspond to the ten FEMA regions, with coordinated networking within the respective regions and between regions. The National Fire Academy works closely with TRADE on various training details, and refers to them for functions such as the review of NFA Endorsed Courses. Specifically, TRADE serves their mission through the following:

- Identifying regional fire, rescue, and emergency medical services training needs;
- Identifying applicable fire-related training and education national trends;
- Exchanging and replicating training programs and resources within regions; and
- Provide annual regional assessments of fire training resource needs to NFA.

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5. ASSEMBLY OF BEST PRACTICE GUIDANCE FOR EMERGENCY RESPONSE

Every emergency incident to which a fire department responds is unique. Despite the differences, however, there are common characteristics that allow fire service personnel to better understand the tasks that need to be performed and to prepare for their duties. This section provides a review of the common elements of most interest to fire fighters when handling emergencies involving solar power systems.

Identification of Common Themes and Principals

Based on today's proliferation of solar power system technology, a fire-related emergency incident involving a structure with one or more solar panels would not be considered an unlikely or rare occurrence. Structure fires are relatively common for any particular municipality, on the order of several significant events per year per station and/or department. The rapid growth of the solar power industry is increasing the likelihood that some of these structures are presently or soon will be utilizing some type of solar power.

<u>Solar Thermal Hazards Versus Photovoltaic Hazards</u>

From a fire service perspective, the comparable hazards between thermal systems and photovoltaic system are similar with two noteworthy exceptions: a photovoltaic system includes an electric shock hazard, while a thermal system includes potential scalding from hot fluid. Figure 5-1 summarizes the primary hazards of solar power systems for emergency responders, and illustrates a side-by-side comparison of the fire fighter hazards for these types of solar power systems.[122]

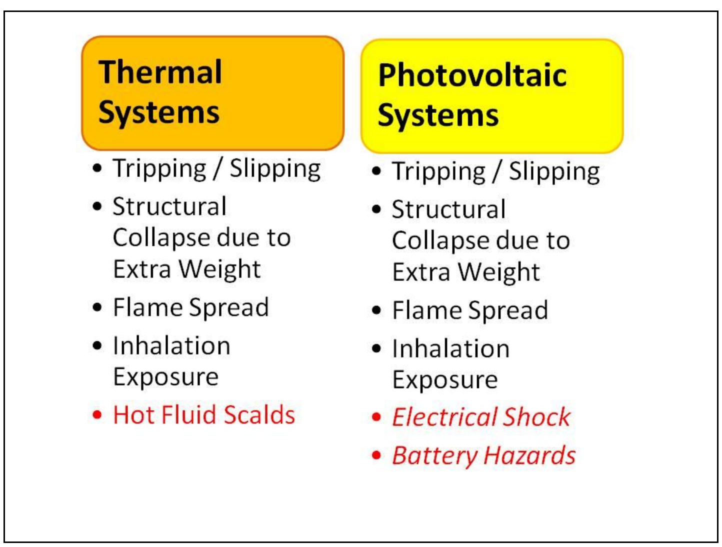

Figure 5-1: Primary Hazards of Solar Power Systems for Emergency Responders.[123]

As with any structural fire attack, size-up is a key step. The knowledge that the building has a solar power system should be immediately conveyed to the incident commander (IC), and the type of system should be immediately identified, that is, whether it is a solar thermal system or photovoltaic system. This will determine subsequent steps to minimize the hazards unique to both types of systems. Sometimes this is not readily obvious, such as with solar components that are blended in with the building construction. Figure 5-2 provides an example of a residential occupancy with a PV system that is an integral part of the roof assembly.

Figure 5-2: Residential Occupancy with a PV System Integral to the Roof Assembly
(Photo courtesy of NREL Photographic Information Exchange)

Arguably, the additional hazard characteristic of electric shock of a photovoltaic system makes it a greater concern than a solar thermal system, since it can remain energized and not be readily apparent during fireground operations. Thus, identifying and clarifying the type of solar power system is a critical first step for fire fighters and the IC on the fireground.

One concept for quickly identifying a solar power system and its specific components is the development and implementation of an equipment identification system, to assist with pre-planning and rapid identification on response. This would require clarifying the information critical to emergency responders, working with industry to incorporate this information, and enabling access to it by emergency first responders during an emergency.

This approach already exists in a general sense, such as, for example, through the "Fire Fighter Safety Building Marking System" (FFSBMS) described in Annex Q of NFPA 1, *Fire Code*, 2009 edition.[124] The FFSBMS provides a fire fighter safety building marking system with basic building information for fire fighters responding to the building or structure. Figure 5-3 illustrates a sample sign for the FFSBMS, which reserves the center of the Maltese cross for indication of special hazards, and could be used to indicate special concerns associated with the building's utilities.

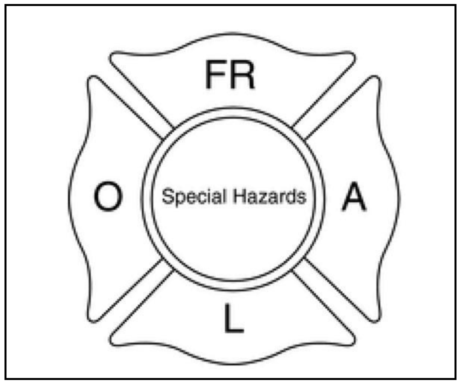

Figure 5-3: Sample Sign for Fire Fighter Safety Building Marking System.[125]

Rooftop Fire Fighting Operations

Several hazard concerns are common to either type of solar power system. Perhaps most obvious is tripping or slipping that may occur on a rooftop in dark or smoky conditions. Certain types of solar power systems that are integral with the roof structure and membrane might minimize tripping hazards, but not necessarily slipping. However, the inherent dangers to fire fighters on the roof of a burning structure, with or without a solar power system, are appreciable and always deserve special attention. Figure 5-4 illustrates townhouses in Bowie, MD, equipped with a PV system based on a standing seam roof design, and this demonstrates the challenges of roof operations confronting fire fighters in certain cases.

Figure 5-4: Townhouse with PV Systems in Maryland
(Photo courtesy of NREL Photographic Information Exchange)

During roof operations fire fighters will need to consider the additional weight of the PV array on a roof structure that may be weakened by the fire. A rooftop solar array may also prevent direct access to the section of roof providing the optimum point of ventilation. Under no circumstances should solar panels be damaged or compromised to perform vertical ventilation. To do so introduces serious potential risk to the fire fighters performing the task.

Solar power adds another component to possible rooftop dangers already faced by fire fighters. Multiple research initiatives are under way exploring the use of positive pressure ventilation (PPV) as a more integrated tool in the fire fighters tactical arsenal.[126,127] Approaches to better controlling the products of combustion in a building fire are being examined that will hopefully provide some relief from the need for fire fighter rooftop exposure. This would be additionally advantageous as solar power systems proliferate and appear on more and more rooftops.

Other Rooftop Concerns

Another common hazard regardless of the type of solar power system is the potential flame spread characteristics of the modules, such as from an adjacent exposing building fire or an approaching wildland fire. The components exposed to sunshine and other exterior elements of weather need to have highly durable characteristics, and certain materials that have traditionally performed well in this regard (i.e., certain types of plastics), do not necessarily have good fire-resistant characteristics. Further work is needed to clarify the fire resistance and fire spread characteristics of these panels.

If a photovoltaic solar array becomes engulfed in fire, care should be exercised in fighting the fire, and it should be attacked similarly to any piece of electrically energized equipment. Normally this would involve shutting down the power and applying water in a fog pattern on the photovoltaic array, but it is critical to be aware that a solar panel exposed to sunlight is always "on" and energized. Further, the electrical energy produced by multiple series connected panels or large solar systems are normally very dangerous.

One additional secondary concern that should always be considered when approaching rooftop solar power systems is that the module frame and junction boxes provide ideal nesting locations for biting and stinging insects. This could introduce an additional layer of difficulty for on scene fire fighters, enhancing other hazard concerns such as tripping or slipping.

The added rooftop weight may be a concern in some cases, although most of today's modern solar panel modules do not contribute an appreciable additional dead load on the roof. For a photovoltaic system, a typical panel weighs less than 50 pounds, and this is distributed over a relatively wide surface area that results in a cumulatively low additional roof load. A noteworthy exception, however, is when a solar thermal system includes a roof-mounted fluid storage unit. This could add a significant load at a specific localized position.

Electrical Shock Considerations

For solar thermal systems, the hazards facing fire fighters during fireground operations are not usually considered a serious additional concern, and they can be readily addressed in their normal tactical and strategic approaches. In contrast, however, the electrical shock hazard of photovoltaic systems presents an additional challenge, although it is one that fire fighters can readily handle once equipped with the proper operational knowledge. Thus, the need to identify and determine the type of solar power system is a critical step for emergency responders.

A photovoltaic system generates electricity when the sun is shining, and when it is receiving sunlight it is operational and generating electricity. This creates additional challenges for the fireground task of shutting off the utilities and the electrical power in the structure that could be a dangerous source of electric shock. Even with known shutdown steps taken to isolate electrical current, fire fighters should always treat all wiring and solar power components as if they are electrically energized.[128]

The inability to de-energize individual photovoltaic panels exposed to sunlight cannot be overemphasized. It is absolutely imperative that emergency responders always treat the systems and all its components as energized. This includes after the emergency event is stabilized, as the system will continue to be energized while exposed to sunlight, possibly with damaged system components that could present serious shock hazards or even cause a rekindling of a fire. Operational approaches for fire fighters in situations involving live electrical systems is well established, and constant attention needs to be given to the threat of live electrical wiring and components.[129]

Because a photovoltaic module and their respective solar cells within the modules will continue to generate electricity when exposed to light, any conduit or components between the modules and disconnect/isolation switches remain energized. Care should be taken throughout fireground operations never to cut or damage any conduit or any electrical equipment, and they should be treated as energized at all times. One tactic for minimizing or eliminating the electrical output from a solar module is to cover it with a 100% light-blocking material such as certain types of tarpaulin. However, this is a difficult tactic to implement, since many tarpaulins are not 100% light-blocking, often the solar system is too large for this to be realistically applied, and wind or other external influences (e.g., hose streams) make it difficult to maintain coverage.

The number of photovoltaic panels in the solar power system provides an indication of the magnitude of the electrical energy being generated. A smaller system such as on a residential occupancy might include only a few modules; however, the electricity generated is still appreciable and can be lethal. In contrast, large systems that are now being installed on roofs of commercial buildings (e.g., department stores) sometimes have hundreds of panels, and the electrical current they generate is very significant.

The inability to shut down the power on these large systems exemplifies the challenge facing fire fighters, since every panel is still generating electricity and thus the wiring and components are always “live” when the sun is shining. The presence of rooftop disconnects are primarily for maintenance of the system. Fire fighters should be wary of utilizing these as a secure method of power isolation. If not all disconnects to an inverter are opened, there still exists the possibility of voltage throughout the system. Additionally, large capacitors in the inverters will provide voltage in daylight hours for several minutes on both sides of the disconnect even when opened. Figure 5-5 illustrates a typical large PV installation on a commercial building located in Chicago, Illinois.

Figure 5-5: Example of a Large Photovoltaic Solar Power System on a Commercial Building
(Photo courtesy of NREL Photographic Information Exchange)

Battery Storage Components

An additional electrical concern exists for systems that have an optional battery storage arrangement as part of the PV system. The batteries can maintain electrical current at nighttime and when the rest of the system has been isolated, thus presenting an additional electric shock hazard. Further, depending on the types of batteries, they can present leakage and hazardous materials concerns, and special attention is required for any battery storage systems that have been damaged in a fire. Figure 5-6 illustrates a typical battery installation for a large commercial PV system.

Design requirements for batteries are already established and can be extrapolated to the battery systems used in a photovoltaic system, such the requirements for stationary storage battery systems addressed by Chapter 52 of NFPA 1, *Fire Code*, and Section 608 of the *International Fire Code*.[130,131] Technology commonly used for stationary storage batteries include: flooded lead-acid, flooded nickel cadmium (NI-CD); valve-regulated lead-acid; lithium-ion; and lithium metal polymer.[132]

Figure 5-6: Typical Battery Installation for a Photovoltaic Solar Power System
(Photo courtesy of NREL Photographic Information Exchange)

Batteries generally burn with difficulty, although plastic battery casings provide a limited contribution to the combustion process. However, batteries that do burn or are damaged in a fire generate fumes and gases that are extremely corrosive. Spilled electrolyte can react with other metals and produce toxic fumes, as well as potentially flammable or explosive gases. Full protective clothing and respiratory protection is imperative in such incidents, and special care and maintenance may be required during cleanup. Dry chemical, CO_2, and foam are the preferred methods for extinguishing a fire involving batteries, and water is normally not the extinguishing agent of choice.[133]

Overhaul and Post Fire Concerns

Proper respiratory protection should be used during all fireground operations that involve a potentially hazardous atmosphere. Similarly, these protective measures apply during post-fire activities such as overhaul or fire investigations. Care should be taken during all fireground operations to protect against respiratory exposure from products of combustion involving PV systems. Under normal conditions the materials used for solar cells and modules are relatively inert and safe, but they can become dangerous when exposed to fire.

If solar power components are involved in a fire, care should be taken to avoid exposure to the products of combustion due to the somewhat unusual materials involved. In addition to inhalation concerns, dermal exposure from solar power system materials damaged by fire should also be handled with caution regardless of the type of solar power system. For large solar systems involved in a fire, additional precautions should be considered to protect downwind populations from respiratory exposure.

Some of the materials used in solar power components are known to be a problem when they decompose in a fire, and although stable under normal conditions, they exhibit adverse effects if released as a vapor of fluid. For example, cadmium telluride is among the most promising photovoltaic technologies, but when damaged by fire it introduces potentially dangerous levels of materials such as cadmium, a known carcinogen.[134] Some solar power systems are integral to other building components and may not be immediately obvious in a post-fire situation. Figure 5-7 illustrates the installation of PV shingle design whose presence may be difficult to detect by emergency first responders following a fire event.

Figure 5-7: An Example of PV System Integral with Building Components
(Photo courtesy of NREL Photographic Information Exchange)

Examples of other materials of concern that may be involved in solar power components include gallium arsenide and phosphorous.[135] Emergency responders are required to wear full respiratory protection (e.g., self-contained breathing apparatus) for any atmosphere that is possibly IDLH (immediately dangerous to life or health), and this should be the case when handling damaged solar modules involved in fire unless proven otherwise.[136]

An important delayed hazard occurs when a nighttime building fire damages a photovoltaic system and compromises system integrity at a time when no energy is being generated by the system. If the system wiring sustains short circuits and damaged components, exposed live wiring and components may suddenly appear once the sunlight returns. Solar arrays will resume generating electrical power through circuitry that was unpowered during the fire event, but becomes energized during the post-fire event when exposed to sunlight.

General Safety Precautions

Certain basic safety precautions should be taken into account by all fire fighters on the fireground. Determining the presence of a PV system is key to preventing fireground injuries. The following six points of safe operation are offered for fire fighters:[137]

- Daytime = Danger; Nighttime = Less Hazard
- Inform the IC that a PV system is present
- Securing the main electrical does not shut down the PV modules
- At night apparatus-mounted scene lighting may produce enough light to generate an electrical hazard in the PV system
- Cover all PV modules with 100 percent light-blocking materials to stop electrical generation
- Do not break, remove, or walk on PV modules, and stay away from modules, components, and conduit

A photovoltaic array will always generate electricity when the sun shines. These units do not turn "off" like conventional electrical equipment. Fire fighters on the fireground should always treat all wiring and components as energized. Breaking or compromising a photovoltaic module is extremely dangerous and could immediately release all the electrical energy in the system.

Without light, photovoltaic panels do not generate electricity, and thus nighttime operations provide less of a hazard. Emergency scene lighting during a nighttime fireground operation, such as from a mobile lighting plant unit, or sources other than direct sunlight, may be bright enough for the photovoltaic system to generate a dangerous level of electricity.

In summary, there are several fundamental points of consideration for fire fighters and incident commanders when handling any building fire equipped with a solar power system:[138]

- Identify the existence of a solar power system
    - locate rooftop panels
    - clarify electrical disconnects
    - obtain system information
- Identify the type of solar power system
    - Solar Thermal System
    - Photovoltaic System
- Isolate and shutdown as much of the system as possible
    - Lock-out and tag-out all electrical disconnects
    - Isolate the photovoltaic system at the inverter using reliable methods
- Work around all solar power system components

For an overview of revisions to this page, see the NOTE at the end of the report foreword.

While salvage covers can be used to block sunlight, some electricity will still be generated unless they are made of material that is 100 percent light blocking. Care is needed to make sure that wind does not suddenly blow off any salvage covers covering panels. Foam is not effective in blocking sunlight, and will slide off the solar array.

Target Applications Workshops

Solar power systems are experiencing widespread popularity in recent years, and they are one of the new challenges facing the U.S. fire service. Some fire service organizations are in the process of developing recommended emergency response procedures and best practices on a local or regional basis; in other jurisdictions, basic information on the hazard and appropriate response is lacking or not readily available.

One of the ways this project addresses these concerns is to collect and analyze all applicable scientific studies, training guidance, case study reports and loss data, and available emergency response guidance relating to solar power systems. To assist in accomplishing this task, an interactive one-day workshop was held, "Fire Service Workshop on Solar Power Systems." This workshop involved experts on the fire service and other subject matter and took place on Wednesday, 17 March 2010 at the Next Energy facility in Detroit, Michigan. The workshop was attended by approximately two dozen subject matter experts knowledgeable on fire service issues relating to solar power systems, and a summary of workshop attendance is included in Annex D, Attendees at Fire Service Workshop on Solar Power Systems.

The goal of the workshop was to identify, review, and assemble best practice information for tactical and strategic decision making by fire fighters and fireground incident commanders, to assist in their decision making process when responding to fire and/or rescue emergency events involving solar power systems. This goal was accomplished using an interactive approach involving subject matter experts that focused on the following workshop objectives:

- Collectively review the available baseline information (provided to participants prior to the workshop);
- Identify the fundamental principles and key details involving fire/rescue tactics and strategy, and provide a summary of core basics; and
- Address and clarify related issues such as training needs, areas needing further research, revisions to codes/standards, and other topics applicable to the overall workshop goal.

Final Evaluation of Best Practice Guidance

The workshop included a detailed review of the baseline information represented by the balance of content contained within this report. Two working groups were established among the attendees who, as part of the workshop, separately addressed a set of ten similar questions.

These ten questions were grouped into three sets according to: (1) current practice, (2) future trends and (3) other issues. Each working group reported their individual results to the entire workshop to support a collective discussion among all attendees. Based on the collective discussion of all attendees, the responses from each working group were subsequently consolidated and harmonized into a single set of responses for each question. This consolidated response is summarized in Figure 5-8, Workshop Working Group Summary.

FIRE SERVICE WORKSHOP ON SOLAR POWER SYSTEMS

Detroit, MI
17 March 2010

Working Group Summary

The following set of ten questions was addressed independently by two separate working groups at this workshop. This consolidated "Working Group Summary" provides their collective responses, and for each question is provided in a non-prioritized, harmonized summary-format.

I. CURRENT PRACTICE

A. In terms of prioritized hazards, how should this topic be scoped?

1. Solar Thermal vs. Photovoltaic
2. Solar Power System Types
    - 2.1. Residential (small in-grid systems, numerous)
    - 2.2. Commercial (large in-grid systems, less common)
    - 2.3. Utility scale power generation sites (very large systems, rare)
    - 2.4. Standalone off-grid systems
    - 2.5. Existing systems vs. new systems (for regulatory oversight)
3. Solar Power System Characteristics
    - 3.1. Hazard identification and labeling
    - 3.2. High voltage hazards (arcing, shock)
        - 3.2.1. Electrical component isolation (disconnects, how many?)
        - 3.2.2. Electrical conduit routing and location
        - 3.2.3. Batteries (integration, containment, isolation, etc.)
    - 3.3. System Responsibility/Accountability (installation, maintenance, etc.)
    - 3.4. Separate panels vs. integrated solar components (with structure)
4. Building Attributes
    - 4.1. Flammability hazard concerns
        - 4.1.1. Ignition
        - 4.1.2. Flame spread
        - 4.1.3. Products of combustion
    - 4.2. Building and roof assembly construction types
    - 4.3. Structural loads and related concerns (dead load, snow, wind, etc.)
    - 4.4. Integration with building electrical system
    - 4.5. Personnel access

5. Event Characteristics
    5.1. Fire in solar array vs. structure fire not yet involving array
    5.2. Support of site personnel not fully trained on system
    5.3. Hazards related to configuration (trip, slip, fall, etc.)
    5.4. Fire fighting ventilation tactics
    5.5. Products of combustion exposure (inhalation, air quality, etc.)
    5.6. Older systems vs. newer systems
    5.7. Low frequency occurrence, but with potential high severity

B. What are the prioritized core basics for emergency responders to address the topic?

1. Identification
    1.1. Common identification and labeling format (solar panel, rooftop conduits, disconnects, etc.)
    1.2. Common location of control panels and disconnects
    1.3. Establish and coordinate interface with local AHJ and fire department
2. Responder Guidance and Pre-Planning
    2.1. Provide universal fundamental set of tactics
    2.2. Develop emergency response plan
    2.3. Prepare to handle without outside support (e.g., utilities for shutdown)
3. Training
    3.1. Avoid complex training programs (instead promote inherent system design corrections)
    3.2. Concisely clarify what fire fighters can and can't do
4. Regulatory
    4.1. Establish an ongoing operation and maintenance process
    4.2. Consider regulatory oversight comparable with equivalent building systems (e.g., sprinklers, fire alarms, electrical, mechanical)

C. What is specifically needed for operational procedures and training materials?

1. Operational Materials
    1.1. Need standardization to set baseline requirements for operational materials
    1.2. Clarify offensive vs. defensive tactics
    1.3. Clearly indicate what can and can't be done
    1.4. Stress need for awareness and identification
    1.5. Indicate personnel access requirements to components (e.g., PPE)
    1.6. Identify options when in trouble (e.g., Rapid Intervention Teams)
2. Training Materials
    2.1. Need standardization to set baseline requirements for training materials
    2.2. Focus on state fire training academies
    2.3. Develop audience specific materials (e.g., fire personnel, incident commanders, fire instructors, investigators, etc)
    2.4. Include non-fire service groups in developing training materials
        2.4.1. Building owners and occupants
        2.4.2. Industry

D. What are the known or potential topics of technical debate?

1. NEC Related

1.1. Controllers and disconnects
   1.1.1. String level disconnects
   1.1.2. Module level controllers
1.2. Electrical conductor features and location
   1.2.1. Wiring that is grounded vs. ungrounded
   1.2.2. Ground indicators
1.3. Allowing DC power into building envelope
1.4. Number and size of access points
1.5. Effect of exterior conditions on system and components (e.g., contraction and expansion due to ambient roof temperatures, etc)

2. Fire Fighting Tactics
   2.1. Tactics for large commercial systems
   2.2. Firefighting with water vs. other agents
   2.3. Products of combustion and implications of letting it burn during daytime fire
   2.4. Support and response of system installer
   2.5. Overhaul and post-fire situation
   2.6. Myth vs. reality (inherent dangerous characteristics)
3. Regulatory
   3.1. Flammability (as well as electrical) (e.g., fire resistance ratings)
   3.2. Building construction and roof classifications
   3.3. Non-OEM installations (e.g., non-listed products)

I. FUTURE TRENDS

A. Based on current technological trends, what are the greatest anticipated future hazards?

1. System Operating Features
   1.1. Inability to power down system
   1.2. Securing the system in post-fire
   1.3. Micro-inverters and AC panels
   1.4. Systems with integrated components, or integrated with building
   1.5. Module level control (mitigation)
   1.6. Issues involving arc fault
2. Material Properties and Configurations
   2.1. Solar panels installed vertically
   2.2. Solar powered shingles
   2.3. Vertical surfaces (e.g., curtain walls, thin films)
   2.4. Tempered vs. non-tempered glass
   2.5. Solar concentrators and hot thermal fluids
3. Other System Concerns
   3.1. After-market and non-OEM installations
   3.2. Maintenance and upkeep requirements
   3.3. Solar power use with vehicle
   3.4. Mobile or portable equipment used to back feed building
   3.5. Roof configurations with "green" buildings

B. How should fire service be addressing this topic in 5 years? 10 years?

1. Standardization
   1.1. Isolate systems through module level controllers
   1.2. Ventilation tactics (horizontal vs. vertical)

1.3. Building and system labeling

2. Data Collection
   2.1. Establish better data collection process
3. Other Issues
   3.1. Sharp increase in solar
   3.2. Increase in distributed power supply

C. What constituent groups and/or organizations need to be involved?

1. Public Organizations
   1.1. Emergency responder representatives
      1.1.1. Fire service
         1.1.1.1. Membership organizations (e.g., IAFC, IAFF, NVFC, etc.)
         1.1.1.2. Training organizations (e.g., NAFTD, NFA, etc.)
      1.1.2. EMS and law enforcement
   1.2. Federal government
      1.2.1. DOE and NREL (and other DOE related organizations)
      1.2.2. OSHA
   1.3. Authorities Having Jurisdiction (AHJs)
      1.3.1. Building officials
      1.3.2. Electrical inspectors (e.g., IAEI, etc.)
      1.3.3. Fire Marshals (IFAM, NASFM, etc)
2. Private Organizations
   2.1. Conformity assessment and product approval organizations (e.g., UL, etc.)
   2.2. Industry
      2.2.1. Associations and membership organizations (e.g., Solar ABCs, etc.)
      2.2.2. Manufacturer representatives (e.g., NEMA)
      2.2.3. Integrator representatives (e.g., NEMA, IECI, etc.)
   2.3. Building users/owners
   2.4. Insurance
   2.5. Architects
3. Others
   3.1. Utility representation (e.g., EEI, etc.)
   3.2. Labor union groups (e.g., IBEW, etc.)
   3.3. International representation
   3.4. Codes and standard developing organizations (NFPA, ICC, ISO, IEC, etc.)

I. OTHER ISSUES

A. What other case study events have not already mentioned, and what are lessons learned?

1. Investigation process
   1.1. Clarify cause and origin information for investigators
   1.2. Establish investigation team process (for noteworthy incidents)
2. Data Collection Methods
   2.1. Better utilize industry organizations (e.g., Solar ABCs, etc.)
   2.2. Better define data elements with existing data collections (e.g., NFIRS, FIDO, etc)
3. Other Issues
   3.1. Clarify possible approaches with non disclosure agreements

B. What specific updates/additions/changes need to be addressed in codes and standards?

1. Electrical Codes
    1.1. String level disconnects
    1.2. Module level controllers
    1.3. Electrical conductor location
    1.4. Ground fault indicators
    1.5. Non grounded system
2. Building and Fire Prevention Codes
    2.1. Building markings and pre-incident planning info (in standardized format)
    2.2. Operation and maintenance for the upkeep of building marking
    2.3. Address flammability characteristics for exposure fires (e.g., NFPA 1144 Reducing Structure Ignition Hazards from Wildland Fire, etc.)
    2.4. System commissioning (NFPA 3, etc.)
3. Fire Service Standards
    3.1. Fireground tactics and strategy
        3.1.1. Residential
        3.1.2. Commercial and other large systems
    3.2. Overhaul and post-fire situations
    3.3. Update emergency responder professional qualification standards
4. Other Codes and Standards
    4.1. Data collection systems (e.g., NFIRS, FIDO, etc.)
    4.2. Fire investigations (e.g., NFPA 921, etc.)
5. Other Issues
    5.1. Aging and weathering
    5.2. Non-OEM installations (e.g., non-listed products)
    5.3. Proliferating use of applicable model code (e.g., Oregon, Cal Fire Guidelines, etc.)

C. What single message should the fire service express on this topic?

1. Fireground Tactics
    1.1. "Components are always hot!" (in daytime)
    1.2. Operate normally, but don't touch
    1.3. Size-up, identify and validate hazard
    1.4. Stress key message for tactical approach (especially large commercial systems)
    1.5. Leave the scene in a safe condition
2. Code Development
    2.1. Provide ability for electrical system isolation for emergency responders
    2.2. Create consistent placarding and labeling for emergency responders
    2.3. Address on-going maintenance oversight of installed systems (especially commercial)
    2.4. Require system contact information for emergencies
3. Education and Training
    3.1. This is energized electrical equipment like other equipment, but with inability to power down. Otherwise not much different.
    3.2. Systems are widespread: You probably have these systems in your 1st due jurisdiction
    3.3. Don't underestimate electrical hazard; don't be complacent

Figure 5-8: Workshop Working Group Summary

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6. Summary Observations

This report assembles best practice information for fire fighters and fireground incident commanders to assist in their decision making process with emergency events involving solar power systems. This is focused on structural fire fighting in buildings and structures having solar power systems that generate thermal and/or electrical energy, with a particular focus on solar photovoltaic panels used for electric power generation

This report collects and analyzes applicable scientific studies, training guidance, case study reports and loss data, and available emergency response guidance relating to solar power systems. The project deliverables are intended to serve as the basis for training program development by others.

A critical task in this project was the interactive one-day workshop involving fire service and other subject matter experts. This provided a detailed review and assessment of the information collected and generated a summary of the fundamental principles and key details relating to issues such as training needs, areas needing further research, revisions to codes and standards, and other applicable topics. The complete results are summarized in Figure 5-8 shown in the previous section.

The workshop review was coordinated around ten basic questions, and the collective response to these ten questions focuses on the core basics of this issue. Of particular interest is the tenth and final question that asked each break-out session: "What single message should the fire service express on this topic?" This question helped to clarify and highlight the most important issues arising throughout the entire project (as well as during the workshop review).

The following is a summary of the most important issues for emergency responders that need to considered and/or addressed for emergency events involving solar power systems:

Fireground Tactics

- "Components are always hot!" The single most critical message of emergency response personnel is to always consider photovoltaic systems and all their components as electrically energized. The inability to power-down photovoltaic panels exposed to sunlight makes this an obvious hazard during the daytime, but it is also a potential concern at nighttime for systems equipped with battery storage.

- Operate normally, but don't touch. Fire service personnel should follow their normal tactics and strategies at structure fires involving solar power systems, but do so with awareness and understanding of exposure to energized electrical equipment. Emergency response personnel should operate normally, and approach this subject area with awareness, caution, and understanding to assure that conditions are maintained as safely as possible.

- Size-up, identify and validate hazard. Accurate knowledge of the hazards present on the fireground is essential for minimizing personnel injuries. Identifying the type and extent of a solar power system during the emergency event size-up is critical to properly addressing the hazards they present. In particular, it is important to distinguish between a solar thermal system and a photovoltaic system, and the hazards presented by each type of system.

- Stress key message for tactical approach (especially large commercial systems). The tactical approach to solar power equipment in a building with a structure fire needs to be stressed with all fireground personnel (i.e., stay clear). Serious injury can occur with equipment such as photovoltaics on a sunny day, and the danger to fire service personnel is real and deserves attention. Of paramount concern are large commercial photovoltaic systems that generate significant levels of electricity and can create daunting strategic challenges for fire fighters as they are trying to address a building fire.

- Leave the scene in a safe condition. Emergency response personnel address and mitigate hazards, and turn the scene back over the owners and/or occupants after the scene is stabilized. They need to be aware of unanticipated dangers and leave the scene in a safe condition. An example would be a photovoltaic solar power system damaged during a nighttime fire, which once exposed to sunlight, begins to generate electricity and creates a shock hazard or re-kindling of the fire.

Code Development

- Provide ability for electrical system isolation for emergency responders. A key task handled by emergency response personnel at a building fire is the isolation or shutdown of the building's electrical power. For current photovoltaic solar power systems this may be difficult and/or impossible. Without delay code-making bodies need to explicitly address this problem, and provide adequate methods for emergency shutdown of this electrical equipment. This is especially important for large commercial systems that generate high levels of electricity and pose significant fire fighting challenges.

- Create consistent placarding and labeling for emergency responders. Standardized approaches to provide consistent identification of solar power systems and their components would greatly assist emergency responders in safely completing their job performance tasks. In particular, clearly and consistently identify system components that require special attention during an emergency, such as the color-coding of electrical conduit that is normally energized for a PV system. The more universal the identification protocol, the more likely for it to be embraced by the mainstream fire service.

- Address on-going maintenance oversight of installed systems (especially commercial). On-going operation and maintenance concerns for solar power systems must be addressed. These systems are normally exposed to outdoor weather conditions that enhance the aging process, and the infrastructure needs to be in place for the on-going maintenance of these systems to assure their safe operation.

- Require system contact information for emergencies. Consideration needs to be given to establishing responsible points of contacts that emergency responders can reliably depend on during an emergency situation. They currently have such contacts for other building systems they must handle, such as a building's electrical connection from the local power grid, or an automatic sprinkler system. In similar fashion, they should know who they can reliably use as an additional resource during an emergency, and who can readily assist with stabilizing the system. This is especially important for large commercial photovoltaic systems.

Education and Training

- This is energized electrical equipment like other equipment, but with an inability to power down; otherwise it's not much different. This topic is yet another new and evolving safety-related issue that requires attention from the emergency response community, and while it is important and deserves attention, there is no reason to create a sense of unfounded fear. While recognizing the key concern of not being able to power down energized electrical equipment, emergency response personnel should approach this overall subject area as yet another topic that they need to address with awareness, caution, and understanding to assure that conditions are maintained as safely as possible for all involved.

- Systems are widespread: You probably have these systems in your first due jurisdiction. Solar power systems represent a technology whose time has come. They are proliferating and it is likely that the first due response area for any particular emergency response unit includes this technology. It is also being utilized for direct use by the fire service on fire station facilities as well as fire apparatus.

- Don't underestimate electrical hazard; don't be complacent. Education and training materials needs to be clear on the hazards of solar power systems, and emphasize the importance of fire service personnel not becoming complacent about these hazards.
  The single most critical message of emergency response personnel is to always consider photovoltaic systems and all their components as electrically energized when exposed to sunlight.

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7. Bibliography

The following reference sources are cited throughout this report:

1) "Alternative Energy", Encyclopedia Britannica, website: www.britannica.com/EBchecked/topic/17668/renewable-energy, cited: 17 November 2009
2) "Solar Hot Water Heating", Solar Evolution, California Solar Center, website: www.californiasolarcenter.org/history_solarthermal.html, cited: 30 Dec 2009
3) "The History of Solar", National Renewable Energy Laboratory, U.S. Dept of Energy, website: www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf, cited: 29 Dec 2009
4) Gevorkian, P., "Solar Power in Building Design: The Engineer's Complete Design Resource", McGraw Hill, New York NY, 2008, pg. 411
5) Kemp, C.M., "Apparatus for Utilizing the Sun's Rays for Heating Water", United States Patent Office, Washington DC, patent No. 451384, issued 28 Apr 1891, website: www.google.com/patents/about?id=4QRIAAAAEBAJ&dq=clarence+kemp+1891, cited: 30 Dec 2009
6) Davidson, J., Orner, F., "The New Solar Electric Home: The Complete Guide to Photovoltaics for You Home", Aatec Publications, Ann Arbor MI, 2008, pg. 2
7) Perlin, J., "From Space to Earth: The Story of Solar Electricity", Aatec Publications, Ann Arbor MI, 1999, pg. 16
8) Ohl, R.S., "Thermoelectric Device", United States Patent Office, Washington DC, patent No. 438645, issued 11 Apr 1942, website: www.google.com/patents/about?id=HtxtAAAAEBAJ&dq=russell+ohl+1941, cited: 30 Dec 2009
9) Perlin, J., "From Space to Earth: The Story of Solar Electricity", Aatec Publications, Ann Arbor MI, 1999, pgs. 41-46
10) Davidson, J., Orner, F., "The New Solar Electric Home: The Complete Guide to Photovoltaics for You Home", Aatec Publications, Ann Arbor MI, 2008, pg. 3
11) "Solar Thermal Systems: Solar Heating R&D", Sandia National Laboratories, National Renewable Energy Laboratories, U.S. Dept of Energy, website: www.nrel.gov/docs/gen/fy04/36831m.pdf, cited: 29 Dec 2009
12) Thuman, A., Mehta, D.P., "Handbook of Energy Engineering", Fairmont Press, Lilburn GA, 2001, pgs. 361-365
13) Gevorkian, P., "Solar Power in Building Design: The Engineer's Complete Design Resource", McGraw Hill, New York NY, 2008, pgs. 267-272
14) Why PV is Important", Solar Energies Technologies Program, U.S. Dept of Energy, website: www1.eere.energy.gov/solar/pv_important.html, cited: 29 Dec 2009
15) "Renewables Global Status Report: Energy Transformation Continues Despite Economic Slowdown", REN21, Renewable Energy Policy Network for the 21st Century, Paris France 13 May 2009, website: www.ren21.net/globalstatusreport/g2009.asp, cited: 29 Dec 2009
16) Welch, B., "Photovoltaics: The Future of Solar Power", Mother Earth News, Ogden Publications, Topeka KS, 3 Dec 2009, website: www.motherearthnews.com/Rancho-Cappuccino/Photovoltaic-Solar-Power.aspx, cited: 29 Dec 2009
17) Wiser R., Barbose G., Peterman C., Darghouth N., "Tracking the Sun II: The Installed Cost of Photovoltaics in the U.S. from 1998-2008", Lawrence Berkeley National Laboratory, October 2009, Website: eetd.lbl.gov/ea/emp/reports/lbnl-2674e.pdf, cited: 26 March 2010

18) Sherwood, L., Table 1: Top Ten States by 2008 Capacity, “U.S. Solar Market Trends 2008”, Interstate Renewable Energy Council, July 2009, Website: irecusa.org/fileadmin/user_upload/NationalOutreachDocs/SolarTrendsReports/IREC_Solar_Market_Trends_Report_2008.pdf, cited: 26 March 2010
19) “Solar Outlook”, Bimonthly Photovoltaic Industry Update, Navigant Consulting, Issue SO2009-1, 23 Feb 2009, Website: navigant.designreactor.com/downloads/SO2009-1website.pdf, cited: 31 Mar 2010
20) Sherwood, L., “U.S. Solar Market Trends 2008”, Interstate Renewable Energy Council, July 2009, Website: irecusa.org/fileadmin/user_upload/NationalOutreachDocs/SolarTrendsReports/IREC_Solar_Market_Trends_Report_2008.pdf, cited: 26 March 2010
21) “Solar Thermal”, Table 2.1 Annual Shipments of Solar Thermal Collectors 1998-2007, Independent Statistics and Analysis, EIA: U.S. Energy Information Administration, website: www.eia.doe.gov/cneaf/solar.renewables/page/solarthermal/solarthermal.html, cited: 29 Dec 2009
22) “Solar Thermal”, Table 2.1 Annual Shipments of Solar Thermal Collectors 1998-2007, Independent Statistics and Analysis, EIA: U.S. Energy Information Administration, website: www.eia.doe.gov/cneaf/solar.renewables/page/solarthermal/solarthermal.html, cited: 29 Dec 2009
23) “Solar Thermal”, Table 3.1 Annual Shipments of Photovoltaic Cells and Modules 1998-2007, Independent Statistics and Analysis, EIA: U.S. Energy Information Administration, website: www.eia.doe.gov/cneaf/solar.renewables/page/solarphotv/solarpv.html, cited: 29 Dec 2009
24) Davidson, J., Orner, F., “The New Solar Electric Home: The Complete Guide to Photovoltaics for You Home”, Aatec Publications, Ann Arbor MI, 2008, pgs. 9-13
25) Gevorkian, P., “Solar Power in Building Design: The Engineer’s Complete Design Resource”, McGraw Hill, New York NY, 2008, pgs. 213-247
26) “California Solar Photovoltaic Statistics and Data”, CA.Gov Energy Almanac, website: energyalmanac.ca.gov/renewables/solar/pv.html, cited: 29 Dec 2009
27) “California Solar Photovoltaic Statistics and Data”, CA.Gov Energy Almanac, website: energyalmanac.ca.gov/renewables/solar/pv.html, cited: 29 Dec 2009
28) Shugar, D.S., Dinwoodle, T.L., Slavsky, S.T., “Electric Vehicle with Photovoltaic Roof Assembly”, United States Patent Office, Washington DC, patent No. 6586668, issued 1 Jul 2003, website: www.google.com/patents/about?id=kScOAAAAEBAJ&dq=6586668, cited: 30 Dec 2009
29) “San Rafael Fire Engine 52 Online”, E-52, San Rafael Fire Department, California, June 2008
30) Markley R., “Electricity On The Go”, Fire Chief, May 2008, Pgs 64 – 67
31) “San Rafael Fire Engine 52 Online”, E-52, San Rafael Fire Department, California, June 2008
32) Ross, C, “Here Comes the Sun: Solar Energy for Emergency Medical and Disaster Use”, Emergency, Volume 25, Issue 12, December 1993, pgs. 34-37
33) May, B., “Solar Power: a Hot New Trend in the Fire Service”, Firehouse, April 2005, Pg 134
34) Karter, M., Table 2, Fireground Injuries by Primary Apparent Symptom for Total Injuries and by Severity 2001-2006 Annual Average, “Patterns of Firefighter Fireground Injuries”, National Fire Protection Association, Quincy MA, May 2009
35) “Grouped Reports: Electrical / Power Lines”, website: www.firefighternearmiss.com, cited: 29 Jan 2010
36) “The U.S. Fire Problem”, National Fire Protection Association, Quincy MA, website: www.nfpa.org/categoryList.asp?categoryID=953&URL=Research/Fire%20statistics/The%20U.S.%20fire%20problem, cited: 29 Dec 2009
37) Harvey, C.S., “Fire Occurs within Solar Panel”, Fire Command, Volume 47, Issue 9, pgs 40-41, Sept 1980

38) Harvey, C.S., “Fire in a Residential Solar Panel: a Potential National Problem”, International Fire Chief, Volume 46, Issue 9, pgs 55-57, Sept 1980
39) Harvey, C.S., “Fire within a Residential Solar Panel”, Fire Chief, Volume 24, Issue 9, pgs 31-33, Sept 1980
40) NFIRS# 08044739 Fire Report, San Francisco Fire Dept, California, May 2008
41) NFIRS# 08044739 Fire Report, San Francisco Fire Dept, California, May 2008
42) Gregory, K.L., “Simi Solar Panel Fire Raises Safety Issue”, Ventura County Star, 14 March 2009
43) “Roof PV Fire of 4-5-09”, City Memorandum, P. Jackson to P. Burns, Bakersfield CA, 29 Apr 2009
44) “Roof PV Fire of 4-5-09”, City Memorandum, P. Jackson to P. Burns, Bakersfield CA, 29 Apr 2009
45) Lindsey T., “Roof PV Fire”, PowerPoint Presentation, Solar Power Workshop, Detroit MI, 17 March 2010
46) “Roof PV Fire of 4-5-09”, City Memorandum, P. Jackson to P. Burns, Bakersfield CA, 29 Apr 2009
47) Davis J., “Greenbelt House Fire”, Branchville 11 Volunteers, 20 March 2010, Website: www.bvfco11.com/index.cfm?fs=news.newsView&News_ID=535, cited: 27 March 2010
48) Davis J., “Greenbelt House Fire”, Branchville 11 Volunteers, 20 March 2010, Website: www.bvfco11.com/index.cfm?fs=news.newsView&News_ID=535, cited: 27 March 2010
49) Wolff E., “Energy: Solar Fire Raises Questions About Panel Safety”, North County Times, 10 April 2010; Website: www.nctimes.com/business/article_8a32fb03-9e3f-58ca-b860-9c7fe1e28c7e.html, cited: 11 April 2010
50) NFPA 1144, Standard for Reducing Structure Hazards from Wildland Fire, National Fire Protection Association, Quincy MA, 2008 edition
51) ASTM E 108, Standard Test Methods for Fire Tests of Roof Coverings, American Society of Testing and Materials, West Conshohocken PA, 2007
52) Sherwood, L., “U.S. Solar Market Trends 2008”, Interstate Renewable Energy Council, July 2009, Website: irecusa.org/fileadmin/user_upload/NationalOutreachDocs/SolarTrendsReports/IREC_Solar_Market_Trends_Report_2008.pdf, cited: 26 March 2010
53) "Open PV Project", National Renewable Energy Laboratory, Website: openpv.nrel.gov, cited: 25 March 2010
54) "Open PV Project", National Renewable Energy Laboratory, Website: openpv.nrel.gov, cited: 25 March 2010
55) “San Francisco Solar Map”, San Francisco Department of the Environment, Website: sf.solarmap.org, cited: 25 March 2010
56) “San Francisco Solar Map”, San Francisco Department of the Environment, Website: sf.solarmap.org, cited: 25 March 2010
57) “About ASES”, American Solar Energy Society, Boulder CO, website: http://www.ases.org/index.php?option=com_content&view=article&id=1&Itemid=2, cited: 28 Dec 2009
58) “About Us”, Database of State Incentives for Renewables & Efficiency, Raleigh NC, website: http://www.dsireusa.org/about/, cited: 28 Dec 2009
59) “About IREC”, Interstate Renewable Energy Council, website: irecusa.org/about-irec/, cited: 29 Dec 2009
60) “Solar Research”, National Renewable Energy Laboratory, Golden CO, website: http://www.nrel.gov/solar/, cited: 29 Dec 2009
61) “What is Solar ABCs?”, Solar America Board for Codes and Standards, website: http://www.solarabcs.org/index.php?option=com_content&view=article&id=44&Itemid=28, cited: 28 Dec 2009
62) “About SEIA”, Solar Energy Industries Association, Washington DC, website: http://www.seia.org/cs/about_SEIA, cited: 28 Dec 2009

63) "About SEI", Solar Energy International, Carbondale CO, website: http://www.solarenergy.org/about-sei, cited: 28 Dec 2009
64) History of SLI", The Solar Living Institute, Hopedale CA, website: www.solarliving.org/display.asp?catid=49&pageid=6, cited: 29 Dec 2009
65) "About Us", ISES: International Solar Energy Society, Freiburg Germany, website: www.ises.org/ises.nsf!Open, cited: 29 Dec 2009
66) "Who We Are", The Solar Alliance, website: http://www.solaralliance.org/about-us/who-we-are.html, cited: 29 Dec 2009
67) "About SEPA", Solar Electric Power Association, Washington DC, website: http://www.solarelectricpower.org/about/about-sepa.aspx, cited: 28 Dec 2009
68) "Solar Nation", ASES, website: www.solar-nation.org, cited 29 Dec 2009
69) "Who We Are", The Vote Solar Initiative, San Francisco CA, website: http://votesolar.org/who-we-are/, cited: 29 Dec 2009
70) "Action Partners", Solar Nation, website: www.solar-nation.org/about-solar-nation/action-partners/, cited 30 Dec 2009
71) "AriSEIA: Arizona Solar Energy Industries Association, website: www.arizonasolarindustry.org, cited: 30 Dec 2009
72) "CALSEIA: California Solar Energy Industries Association", website: calseia.org, cited: 30 Dec 2009
73) "FSEC: Florida Solar Energy Resource Center", website: www.fsec.ucf.edu, cited: 30 Dec 2009
74) "NESEA: Northeast Sustainable Energy Association", website: www.nesea.org, cited: 30 Dec 2009
75) "TREIA: Texas Renewable Energy Industries Association", website: www.treia.org, cited: 30 Dec 2009
76) "What is Solar ABCs?", Solar America Board for Codes and Standards, website: www.solarabcs.org/index.php?option=com_content&view=article&id=44&Itemid=28, cited: 28 Dec 2009
77) Johnston M., "2011 NEC Changes Around the Corner", NFPA Journal, National Fire Protection Association, May/June 2010
78) "2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings", California Energy Commission, 1 Jan 2010, website: www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF, cited: 30 Dec 2009
79) Oregon Solar Energy Code, Draft Document dated September 2009, website: www.cbs.state.or.us/bcd/committees/10sec/102209_Draft_Solar_Code.pdf, cited: 30 Dec 2009
80) "Guideline for Fire Safety Elements of Solar Photovoltaic Systems", Orange County Fire Chiefs Association, 1 December 2008, Website: www.ocfa.org/_uploads/pdf/PhotovoltaicGuideline.pdf, cited: 19 March 2010
81) "A Third of Photovoltaic Installations are At Risk", Le Monde Economie, 10 March 2010, Website: http://www.lemonde.fr/economie/article/2010/03/19/un-tiers-des-installations-photovoltaiques-sont-a-risque_1321546_3234.html, cited: 30 March 2010
82) Davidson, J., Orner, F., "The New Solar Electric Home: The Complete Guide to Photovoltaics for You Home", Aatec Publications, Ann Arbor MI, 2008, pgs. 4-5
83) Section 3.1.43a, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007
84) Section 3.1.43f, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007

85) Section 3.3.56e, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007
86) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
87) Paiss, M., "Solar Electric Systems and Firefighter Safety", Fire Engineering, May 2009, pg. 84
88) Article 690, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
89) Luque, A., Hegedus, S., "Handbook of Photovoltaic Science and Engineering", John Wiley & Sons, Hoboken NJ, 2003, pgs 3-5
90) Article 690, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
91) Article 690, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
92) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
93) Gevorkian, P., "Solar Power in Building Design: The Engineer's Complete Design Resource", McGraw Hill, New York NY, 2008, pgs. 12-13
94) "EF 13: Clarify Standards for Attaching Rooftop Solar Panels", NYC Green Codes Task Force, Executive Summary, Urban Green Council, New York Chapter of the U.S. Green Building Council, February 2010, pg 30
95) Section K.2, Electric Shock, NFPA 70E®, Standard for Electrical Safety in the Workplace®, National Fire Protection Association , Quincy MA, 2009 edition
96) "Worker Death by Electrocution", A Summary of NIOSH Surveillance and Investigative Findings, CDC/NIOSH, May 1998, website: /www.cdc.gov/niosh/docs/98-131/, cited: 26 Feb 2010
97) Steiner, W., "The Fire Fighter's Guide to Electrical Safety", University of Missouri – Columbia, 1981, pg. 8
98) Slaughter, R., "Fundamentals of Photovoltaics for the Fire Service", Sept 2006, website: www.osfm.fire.ca.gov/training/photovoltaics.php, cited: 28 Dec 2009
99) Article 690, National Electrical Code, National Fire Protection Association, Quincy MA, 2009 edition
100) ANSI C84.1, *American National Standard for Electric Power Systems and Equipment – Voltage Ratings (60 Hertz)*, National Electrical Manufacturers Association, Rosslyn VA, 2006 edition
101) Section K.2, Electric Shock, NFPA 70E®, Standard for Electrical Safety in the Workplace®, National Fire Protection Association , Quincy MA, 2009 edition
102) IAEI Data, International Association of Electrical Inspectors, Richardson TX, 2008
103) "Worker Death by Electrocution", A Summary of NIOSH Surveillance and Investigative Findings, CDC/NIOSH, May 1998, website: /www.cdc.gov/niosh/docs/98-131/, cited: 26 Feb 2010
104) Slaughter, R., "Fundamentals of Photovoltaics for the Fire Service", Sept 2006, website: www.osfm.fire.ca.gov/training/photovoltaics.php, cited: 28 Dec 2009
105) NEC Training Curriculum, National Fire Protection Association, Quincy MA, 2004
106) "Developing Standard Operating Procedures", FA-197, U.S. Fire Administration, Federal Emergency Management Agency, Washington DC, Dec. 1999, Chap. 1, pg. 2, website: www.usfa.dhs.gov/downloads/pdf/publications/fa-197-508.pdf, cited: 23 Dec 2009
107) NFPA 1521, "Standard for Fire Department Safety Officer", National Fire Protection Association, Quincy MA, sections 3.3.47 & A3.3.48, 2008 Ed.
108) NFPA 1521, "Standard for Fire Department Safety Officer", National Fire Protection Association, Quincy MA, sections 3.3.48 & A.3.3.48, 2008 Ed.

109) "Developing Standard Operating Procedures", FA-197, U.S. Fire Administration, Federal Emergency Management Agency, Washington DC, Dec. 1999, Chap. 1, pg. 2, website: www.usfa.dhs.gov/downloads/pdf/publications/fa-197-508.pdf, cited: 23 Dec 2009
110) "About Us", International Fire Service Training Association", Stillwater OK, Website: imis-ext.osufpp.org/imispublic/Content/NavigationMenu/AboutUs/Our75YearHistory/default.htm, cited: 17 Nov 2009
111) Jones and Bartlett Publishing, Sudbury MA, Website: Fire.jbpub.com, cited: 17 Nov 2009
112) DELMAR CENGAGE Learning, Florence KY, Website: www.delmarlearning.com, cited: 17 Nov 2009
113) "About Us", International Fire Service Training Association, Stillwater OK, website: www.ifsta.org, cited:17 Nov 2009
114) Jones and Bartlett Publishing, Sudbury MA, Website: Fire.jbpub.com, cited: 17 Nov 2009
115) DELMAR CENGAGE Learning, Florence KY, Website: www.delmarlearning.com, cited: 17 Nov 2009
116) National Fire Academy, Emmitsburg MD, US Fire Administration, website: www.usfa.dhs.gov/nfa/, cited: 4 August 2009
117) "America Burning: The Report of the National Commission on Fire Prevention and Control", The National Commission on Fire Prevention and Control, U.S. Government Printing Office, pg. xi, 1973
118) "Endorsed Courses", USFA National Fire Academy, Emmitsburg MD, website: www.usfa.dhs.gov/nfa/endorsed/, cited: 5 August 2009
119) "Hydrogen Safety for First Responders", U.S. Department of Energy, Washington DC, website: www.hydrogen.energy.gov/firstresponders.html, cited: 4 August 2009
120) "Introduction to Hydrogen for Code Officials", U.S. Department of Energy, Washington DC, website: www.hydrogen.energy.gov/code_official_training.html, cited: 4 August 2009
121) TRADE, National Fire Academy, U.S. Fire Administration, website: www.usfa.dhs.gov/nfa/trade/index.shtm, cited: 24 July 2009
122) "Building Construction: Solar Energy Systems", Coffee Break Training – Fire Protection Series, USFA National Fire Academy, No. FP-2009-39, 29 Sept 2009
123) "Building Construction: Solar Energy Systems", Coffee Break Training – Fire Protection Series, USFA National Fire Academy, No. FP-2009-39, 29 Sept 2009
124) Figure Q.1.2.3, NFPA 1®, Fire Code, National Fire Protection Association, Quincy MA, 2009 edition
125) Figure Q.1.2.3, NFPA 1®, Fire Code, National Fire Protection Association, Quincy MA, 2009 edition
126) Ezekoye, D.K., "Positive Pressure Ventilation", University of Texas-Austin, and Austin Fire Department, website: www.me.utexas.edu/~ezekoye/rsch.dir/PPV.html, cited: 28 Dec 2009
127) Kerber, S.; Walton, W. D., "Effect of Positive Pressure Ventilation on a Room Fire", NISTIR 7213; March 2005, website: www.fire.gov, cited: 28 Dec 2009
128) Steiner, W., "The Fire Fighter's Guide to Electrical Safety", University of Missouri – Columbia, 1981, pg. 8
129) NIOSH Hazard ID 15, "Fire Fighters Exposed to Electrical Hazards During Wildland Fire Operations", National Institute for Occupational Safety and Health, May 2002, website: www.cdc.gov/niosh/hid15.html, cited: 28 Dec 2009
130) Chapter 52, Stationary Storage Battery Systems, NFPA 1, "Fire Code", National Fire Protection Association, Quincy MA, 2009
131) Section 608, IFC, International Fire Code, International Code Council, Country Club Hills IL, 2006 edition
132) Table 52.1, Stationary Storage Battery Systems, NFPA 1, "Fire Code", National Fire Protection Association, Quincy MA, 2009
133) Slaughter, R., "Fundamentals of Photovoltaics for the Fire Service", Sept 2006, website: www.osfm.fire.ca.gov/training/photovoltaics.php, cited: 28 Dec 2009

134) Moskowitz, P.D., Coveney, E.A., Rabinowitz, S., Barancik, J.I., “Rooftop Photovoltaic Arrays: Electric Shock and Fire Health Hazards”, Solar Cells, Volume 9, pgs. 1-10, 1983
135) Slaughter, R., “Fundamentals of Photovoltaics for the Fire Service”, Sept 2006, website: www.osfm.fire.ca.gov/training/photovoltaics.php, cited: 28 Dec 2009
136) Moskowitz, P; Fthenakis, V., "Toxic Materials Released from Photovoltaic Modules during Fires: Health Risks" Solar Cells, Volume 29, pgs. 63-71, 1990
137) Paiss, M., “Solar Electric Systems and Firefighter Safety”, Fire Engineering, pg. 88, May 2009
138) Slaughter, R., “Fundamentals of Photovoltaics for the Fire Service”, Sept 2006, website: www.osfm.fire.ca.gov/training/photovoltaics.php, cited: 28 Dec 2009
139) Section 8.1, ISO 9488:1999, *Solar Energy – Vocabulary*, International Organization for Standardization, Genève Switzerland, 1999
140) Section 8.5, ISO 9488:1999, *Solar Energy – Vocabulary*, International Organization for Standardization, Genève Switzerland, 1999
141) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
142) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
143) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
144) Section 7.6, ISO 9488:1999, *Solar Energy – Vocabulary*, International Organization for Standardization, Genève Switzerland, 1999
145) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
146) Section 11.4, ISO 9488:1999, *Solar Energy – Vocabulary*, International Organization for Standardization, Genève Switzerland, 1999
147) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
148) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
149) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
150) Section 3.2.15, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007
151) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
152) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
153) Section 3.3.56a, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007
154) Section 3.3.56c, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007
155) Section 3.1.43a, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007

156) Section 3.1.43f, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007
157) Section 3.3.56e, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007
158) Section 3.3.62, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007
159) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
160) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
161) Section 7.1, ISO 9488:1999, *Solar Energy – Vocabulary*, International Organization for Standardization, Genève Switzerland, 1999
162) Section 3.14, ISO 9488:1999, *Solar Energy – Vocabulary*, International Organization for Standardization, Genève Switzerland, 1999
163) Section 9.1, ISO 9488:1999, *Solar Energy – Vocabulary*, International Organization for Standardization, Genève Switzerland, 1999
164) Section 3.1.61, IEC/TS 61836, *Technical Specification – Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*, International Electrotechnical Commission, Genève Switzerland, 2007
165) Article 690.2, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2008 edition
166) Karter, M.J., Stein, G.P., "U.S. Fire Department Profile Through 2007", National Fire Protection Association, Quincy MA, Nov 2008, pg. 1
167) Nolan, D.P., Encyclopedia of Fire Protection", Thompson Delmar Learning, Clifton Park NY, 2nd edition, 2006, pg. 91
168) "Origin and Development", NFPA 1961, Standard for Fire Hose, National Fire Protection Association, Quincy MA, 2007 edition
169) "Origin and Development", NFPA 1410, Standard on Training for Initial Emergency Scene Operations, National Fire Protection Association, Quincy MA, 2005 edition
170) "2008 State & Provincial List of Certifications to NFPA Professional Qualifications Standards", NFPA Public Fire Protection Division, National Fire Protection Association, Quincy MA, July 2009
171) "DHS adopts NFPA standards for responders to hazardous materials/weapons of mass destruction incidents", News Release, National Fire Protection Association, Quincy MA, 3 Sep 2008, website: www.nfpa.org/newsReleaseDetails.asp?categoryID=488&itemID=40386, cited: 18 Dec 2009
172) Grant, C.C., "Research Renaissance", NFPA Journal, National Fire Protection Association, Mar/Apr 2009, pg. 54
173) Laughlin, J., "Training Programs for Fire and Emergency Service Personnel", Fire Protection Handbook, 20th edition, Section 12, Chapter 10, National Fire Protection Association, Quincy MA, 2008, pg 12-166
174) "About Us", International Fire Service Training Association", Stillwater OK, Website: imis-ext.osufpp.org/imispublic/Content/NavigationMenu/AboutUs/Our75YearHistory/default.htm, cited: 3 August 2009
175) Jones and Bartlett Publishing, Sudbury MA, Website: Fire.jbpub.com, cited: 17 August 2009

176) DELMAR CENGAGE Learning, Florence KY, Website: www.delmarlearning.com, cited: 17 August 2009
177) Laughlin, J., "Training Programs for Fire and Emergency Service Personnel", Fire Protection Handbook, 20th edition, Section 12, Chapter 10, National Fire Protection Association, Quincy MA, 2008, pg 12-169
178) NFPA 1000, Standard for Fire Service Professional Qualifications Accreditation and Certification Systems, National Fire Protection Association, Quincy MA, section 3.3.2 through 3.3.6, 2006 edition
179) NFPA 1000, Standard for Fire Service Professional Qualifications Accreditation and Certification Systems, National Fire Protection Association, Quincy MA, section 3.3.1 through 3.3.5, 2006 edition
180) NFPA 1000, Standard for Fire Service Professional Qualifications Accreditation and Certification Systems, National Fire Protection Association, Quincy MA, section 3.3.1, 2006 edition
181) NFPA 1000, Standard for Fire Service Professional Qualifications Accreditation and Certification Systems, National Fire Protection Association, Quincy MA, section 3.3.3, 2006 edition
182) NFPA 1000, Standard for Fire Service Professional Qualifications Accreditation and Certification Systems, National Fire Protection Association, Quincy MA, section 3.3.5, 2006 edition

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Annex A: Solar Power–Related Definitions

The following are terms relating to solar power that are used throughout this report and/or are commonly used relative to the subject matter applicable to this report.

In some cases multiple definitions are found in the common literature. Where multiple defined terms exist, preference is given to federal or state publications and widely recognized consensus-developed codes and standards. In some cases multiple definitions of the same term are provided.

Absorber. Component of a solar collector for absorbing radiant energy and transferring this energy as heat into a fluid.[139]

Aperture. Solar collector opening through which unconcentrated solar radiation is admitted.[140]

Array. A mechanically integrated assembly of modules or panels with a support structure and foundation, tracker, and other components, as required, to form a direct-current power-producing unit. See also "Photovoltaic Array".[141]

Building Integrated Photovoltaics. Photovoltaic cells, devices, modules, or modular materials that are integrated into the outer surface or structure of a building and serve as the outer protective surface of that building.[142]

Charge Controller. Equipment that controls dc voltage or dc current, or both, used to charge a battery.[143]

Concentrating Collector. Solar collector that uses reflectors, lenses or other optical elements to redirect and concentrate the solar radiation passing through the aperture onto an absorber. See also "Solar Collector".[144]

Electrical Production and Distribution Network. A power production, distribution, and utilization system, such as a utility system and connected loads, that is external to and not controlled by the photovoltaic power system.[145]

Heat Transfer Fluid. Fluid that is used to transfer thermal energy between components in a system.[146]

Hybrid System. A system comprised of multiple power sources. These power sources may include photovoltaic, wind, micro-hydro generators, engine-driven generators, and others, but do not include electrical production and distribution network systems. Energy storage systems, such as batteries, do not constitute a power source for the purpose of this definition.[147]

Interactive System. A solar photovoltaic system that operates in parallel with and may deliver power to an electrical production and distribution network. For the purpose of this definition, an energy storage subsystem of a solar photovoltaic system, such as a battery, is not another electrical production source.[148]

Inverter. Equipment that is used to change voltage level or waveform, or both, of electrical energy. Commonly, an inverter [also known as a power conditioning unit (PCU) or power conversion system (PCS)] is a device that changes dc input to an ac output. Inverters may also function as battery chargers that use alternating current from another source and convert it into direct current for charging batteries.[149]

Inverter. Electric energy converter that changes direct electric current to single-phase or polyphase alternating currents.[150]

Module. A complete, environmentally protected unit consisting of solar cells, optics, and other components, exclusive of tracker, designed to generate dc power when exposed to sunlight. See also “Photovoltaic Module” .[151]

Panel. A collection of modules mechanically fastened together, wired, and designed to provide a field-installable unit. See also “Photovoltaic Panel”.[152]

Photovoltaic Array. Assembly of mechanically integrated and electrically interconnected PV modules, PV panels or PV sub-arrays and its support structure. Note: a PV array does not include its foundation, tracking apparatus, thermal control, and other such components. See also “Array” .[153]

Photovoltaic Assembly. PV components that are installed outdoors and remote from its loads, including modules, support structures, foundation, wiring, tracking apparatus, and thermal control (where specified), and including junction boxes, charge controllers and inverters depending on the assembly’s installed configuration.[154]

Photovoltaic Cell. Most elementary photovoltaic device. See also “Solar Cell”.[155]

Photovoltaic Module. Complete and environmentally protected assembly of interconnected photovoltaic cells. See also “Module”.[156]

Photovoltaic Panel. PV modules mechanically integrated, pre-assembled and electrically interconnected. See also “Panel”.[157]

Photovoltaic System. Assembly of components that produce and supply electricity by the conversion of solar energy.[158]

Photovoltaic System Voltage. The direct current (dc) voltage of any photovoltaic source or photovoltaic output circuit. For multiwire installations, the photovoltaic system voltage is the highest voltage between any two dc conductors.[159]

Solar Cell. The basic photovoltaic device that generates electricity when exposed to light. See also "Photovoltaic Cell".[160]

Solar Collector. Device designed to absorb solar radiation and to transfer the thermal energy so produced to a fluid passing through it. See also "Concentrating Collector".[161]

Solar Energy. Energy emitted by the sun in the form of electromagnetic energy. Note: solar energy is generally understood to mean any energy made available by the capture and conversion of solar radiation.[162]

Solar Heating System. System composed of solar collectors and other components for the delivery of thermal energy.[163]

Solar Photovoltaics. Pertaining to PV devices under the influence of sunlight.[164]

Solar Photovoltaic System. The total components and subsystems that, in combination, convert solar energy into electric energy suitable for connection to a utilization load.[165]

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Annex B:
Example of Fire Service Training Program on Solar Power Systems

This annex provides a specific example of a fire service training program addressing solar power systems, and in particular photovoltaics. While multiple programs are available from various qualified sources, the following summarizes one comprehensive program as an example. This is posted on the website of the California State Fire Marshal's Office, and is available at the following URL: www.osfm.fire.ca.gov/training/photovoltaics.php

The information contained on their website includes student manuals, lesson plans, student handouts, and instructor information. Interested parties should directly access their website and download the applicable materials of interest. This following is the outline of this particular program:

I. Introduction
II. Cells and Components
III. PV Performance
IV. PV Applications
V. PV Codes
VI. Emergency Response

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Annex C: Overview of Fire Service Training and Education

There are an estimated 1.1 million fire fighters in the United States today.[166] This estimate is based on a sample survey with a confidence level associated with each estimate, and does not include certain fire fighter constituency groups such as industrial fire departments and federal fire departments.

Approximately 75 percent of these fire fighters serve as volunteers with the remainder serving as career fire fighters. As expected, the more populated jurisdictions are protected primarily by career fire fighters while rural areas are protected primarily by volunteer fire fighters. Some fire departments are a mix of career and volunteer fire fighters in what are considered combination fire departments.

This section covers the preparation and process infrastructure utilized by fire fighters to perform their duties. A review is provided on what is typically included in fire service training and education programs, as well as an overview of fire service standard operating procedures and guidelines commonly used by fire fighters.

Defining the Profession of Fire Fighting

Fire fighters face a bewildering spectrum of possible emergency events. As a result they are generalists in their core knowledge and acquire specialized additional skills to handle certain duties.

Fire service personnel require skills that are already adequately learned and ready to be used before an emergency occurs. Beyond the obvious hazards associated with fireground operations, the duties of a fire fighter include the need for training on additional topics commonly shared with other professions. Examples include biohazards associated with handling of victims requiring emergency medical services, and transportation safety relating to the hazards of large mobile fire apparatus.

Fire service training and education is a critical part of the activities addressed by fire fighters. It is not uncommon for fire fighters to be in a situation where their own personal survival depends on this training and education, and they are continually subjected to learning on a wide range of important topics. For all topics of interest to fire service emergency responders, an on-going need exists for updated, accurate, consistent, readily understandable training information.

What distinguishes a fire fighter from someone who is not a fire fighter? Most obvious is an individual's formal relationship (e.g., employment or membership) with a recognized fire service organization. Equally important, however, is the individual's training and education that qualifies them to adequately perform the tasks expected of a fire fighter.

To be "*qualified by training and examination*" are critical defining characteristics for today's fire service. Among the various definitions of "fire fighter" in the common literature, the following reflects the baseline importance of qualification by training and examination:

> *"Fire Fighter: An individual qualified by training and examination to perform activities for the control and suppression of unwanted fires and related events"*[167]

Fire fighter professional qualifications are key to defining the profession of fire fighting. Standards that set baseline requirements have been subject to ongoing enhancements for decades (as exemplified by documents such as NFPA 1961, *Standard on Fire Hose*, which was first issued in 1898, or NFPA 1410, *Standard on Training for Initial Emergency Scene Operations*, first issued in 1966).[168,169]

NFPA 1001	• Fire Fighter 2008 Edition
NFPA 1002	• Fire Apparatus Driver/Operator 2009 Edition
NFPA 1003	• Airport Fire Fighter 2005 Edition
NFPA 1005	• Marine Fire Fighting for Land-Based Fire Fighters 2007 Edition
NFPA 1006	• Technical Rescuer 2008 Edition
NFPA 1021	• Fire Officer 2009 Edition
NFPA 1026	• Incident Management Personnel 2009 Edition
NFPA 1031	• Fire Inspector and Plan Examiner 2009 Edition
NFPA 1033	• Fire Investigator 2009 Edition
NFPA 1035	• Public Fire and Life Safety Educator 2005 Edition
NFPA 1037	• Fire Marshal 2007 Edition
NFPA 1041	• Fire Service Instructor 2007 Edition
NFPA 1051	• Wildland Fire Fighter 2007 Edition
NFPA 1061	• Public Safety Telecommunicator 2007 Edition
NFPA 1071	• Emergency Vehicle Technician 2006 Edition
NFPA 1081	• Industrial Fire Brigade Member 2007 Edition

Figure C-1: Types of Fire Fighters, according to NFPA Professional Qualification Standards.

Of particular interest for addressing fire fighter performance is the set of 16 NFPA standards addressing fire fighter professional qualifications. These documents are summarized in Figure C-1, and they clarify fire fighting disciplines and establish required levels of knowledge that can be used for training and other purposes.

The fire service operates as a quasi-military type organization, with the need for potentially large numbers of fire service members to be quickly deployed to handle complicated emergencies. Further, efficient and effective handling of the event is necessary to minimize danger to life and property, which means that there is normally very little time to implement mitigating action.

Table C-1: Examples of Fire Fighting Disciplines and Training Levels.[170]

FIRE FIGHTING DISCIPLINE	EXAMPLES OF LEVELS	NFPA STANDARD
Airport Fire Fighter		1003
Driver/Operator	Pumper; Aerial, Tiller; ARFF; Mobile Water Supply; Wildland	1002
EMS HazMat	I, II	473
Fire Department Safety Officer	Health/Safety Officer; Incident Safety Officer; ISO-Fire Suppression; ISO – EMS Operations; ISO – HazMat Operations; ISO – Special Operations	1521
Fire Fighter	I; II	1001
Fire Inspector	I; II; III; Plans Examiner	1031
Fire Investigator		1033
Fire Officer	I; II; III; IV	1021
Fire Service Instructor	I; II; III	1041
Hazardous Materials	Awareness; Operations; Technician; Incident Commander; Branch Safety Officer; Private Sector Specialist A, B, C; Tech w/Tank Car Specialty, Tech w/Cargo Tank Specialty; Tech w/Intermodal Tank Specialty; Tech w/ Flammable Gases Bulk Storage Specialty; Tech w/ Flammable Liquids Bulk Storage Specialty	472
Industrial Fire Brigade	Incipient; Advanced Exterior; Interior Structural; Advanced Structural; Leader	1081
Marine Fire Fighter	I, II	1005
Public Fire & Life Safety Educator	I; II; III; Public Information Officer; Juvenile Firesetter Intervention Specialist	1035
Public Safety Telecommunicator	I; II	1061
Rescue Technician	Rope; Confined Space; Trench; Structural Collapse; Surface Water; Vehicle & Machinery	1006
Wildland Fire Fighter	I, II	1051

As a result, multiple specialized fire fighting disciplines have evolved to address certain tasks and duties as defined by the level of training and education they receive. Table C-1 summarizes examples of fire fighting disciplines and the standardized levels to which fire fighters can be qualified.

The last several years has seen a more widespread use of these standards, partly because five (NFPA 1000, 1001, 1002, 1006, and 1021) are among the 27 NFPA standards adopted as national preparedness standards by the U.S. Department of Homeland Security.[171] Each year DHS distributes millions of dollars in aid through their “Assistance to Firefighters Grant” (AFG) to U.S. fire departments, which is administered by the U.S. Federal Emergency Management Agency (FEMA). A prerequisite for applying for this support is conformance to these DHS national preparedness standards. The 19,791 applications requesting more than $3.1 billion in AFG grants in 2009 indicate the level of activity in this DHS/FEMA program.[172]

Training versus Education

In today's fire service the terms training and education are sometime used synonymously; however, they have different meanings.[173] While both refer to the transfer of information from a body of knowledge to a recipient, each has a different focus on the purpose and details of the information transfer methodology.

Training is an exercise in focused learning, and refers to the exchange of specific information intended to enhance the proficiency of a particular skill. An example of training is a fire fighter class that teaches the skills necessary for certification at the "Awareness Level" for a hazardous materials incident. Training is more applicable to specific emergency events such as handling a motor vehicle accident.

In contrast, education refers to broad-based learning, with the intent of providing a foundation of general knowledge that supports efficient analytical techniques for effective problem solving. An example is a college degree in business administration, which will provide a fire service officer with the skill set needed to manage a large city fire department.

In general, the technical content for fire service training is well-established and addresses a wide range of topics faced by fire fighters. Much of this is captured in the mainstream literature and national standards (e.g., NFPA standards) addressing a wide range of fire fighting tasks, equipment, and other fire service detail. Some of this information has been developed and refined in various arenas for decades.

Specifically, multiple sources of training materials are available that extensively address useful content on the topic of interest. These training materials can be readily adapted and used directly by members of the fire service and other emergency responders. A wide assortment of broadly developed training materials and guidance materials are available that provide support. This includes, for example, the training manuals provided by the International Fire Service Training Association (since 1932), fire service training materials provided by Jones and Bartlett Publishers, and various books and publications provided through Delmar Learning.[174,175,176]

The Fire Service Training Infrastructure

Fire departments are the basic organizations used by fire fighters to deliver their services. These can range from a small volunteer fire department in rural areas, to large fire departments with all career personnel protecting a major metropolitan city. Training will also depend on the specific hazards within the protected jurisdiction, such as the difference between an industrial district and a bedroom community.

Fire departments, regardless of their size or type, have two distinct sources for their training needs: (1) training programs that originate and operate internally within the organization, and (2) those that originate and operate externally. Figure C-2 illustrates the two basic sources of training information and materials for the fire service.

Figure C-2: Types of Training Sources

The extent of internal training sources depends on the available resources of the particular fire department, and as a result, these internal sources tend to be more extensive and sophisticated for larger fire departments (e.g., large city or county fire departments). These larger fire departments generally have their own dedicated training divisions as well as training facilities (i.e., training academy), and are able to effectively handle recruit training and in-service training. Specialized training may be offered for specific duties such as fire apparatus operators, incident commanders, or safety officers. They may also offer specialized courses for duties beyond those of front-line emergency responders, such as fire investigators, fire prevention and inspection personnel (i.e., permitting officials), and public fire and life safety educators.

Multiple external sources of training information and materials are available from a number of sources. These are available to directly support the many fire departments (and especially smaller departments) with limited resources for training. In addition, they also help to supplement and support larger fire departments with their own training departments, and while doing so promote general consistency throughout the fire service. In some cases, regional training centers fulfill internal training needs despite their external characteristics, and these may be operated at the county or state level, or simply by multiple fire service organizations joining together for this purpose. Figure C-3 provides an overview of fire service training, from the perspective of the external sources that directly influence today's fire service training.

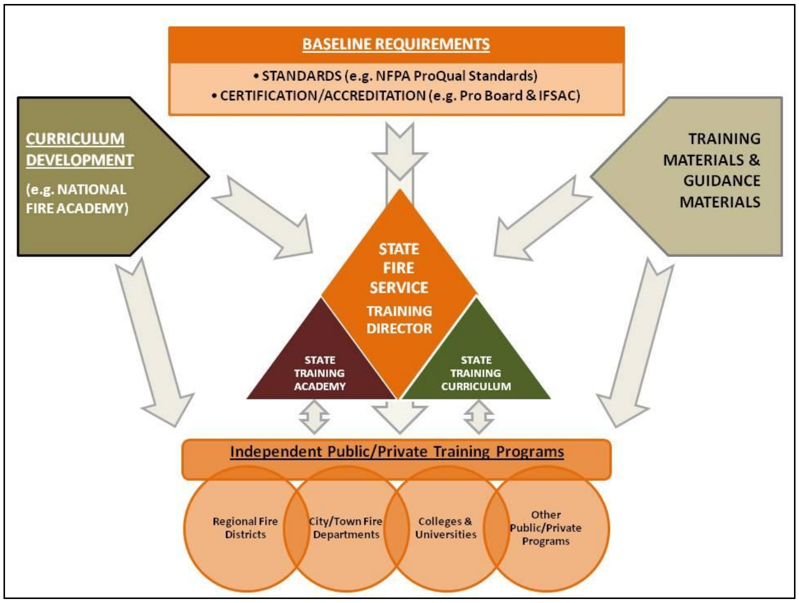

Figure C-3: Overview of the External Sources of Fire Service Training

State governments are a key external resource for fire departments, and many states have designated an official agency to provide state-wide training for fire and emergency personnel. Similarly but at a higher level, the federal government provides important support through the National Fire Academy and other resources. Depending on the legislative and funding arrangements in a particular state or region, certain colleges and universities may serve as centers for fire service training, with or without the involvement of their respective state agency. Supporting these training programs is a group of national fire service organizations and private training service organizations that provide valuable components for the fire service training infrastructure.

State training agencies and state training directors are central players in the fire service training infrastructure. Training directors sometimes report to the state fire marshal in each state, and many states operate a state-wide training academy. In addition, many also coordinate the training materials and curriculums used throughout the state. In some states, fire departments within the state are required to mandatorily use this information and material, and in others they can voluntarily utilize it as they deem appropriate.

Independent public and private training programs that exist within the state often work in coordination with state training programs. These may include the fire service training activities of regional fire districts, large city fire departments, colleges and universities, and other public or private fire service training programs. The relationships among these entities vary significantly from state to state. For example, one state may not have a dedicated state fire training academy and instead have multiple separate but similar training programs throughout the state in conjunction with the state community college system. Elsewhere there may be a state training academy, but the large city fire departments use their own training resources and do not participate in the state programs.

On a national level, several key programs, activities and initiatives feed into the multitude of fire service training activities found at the local and state levels. An example is the National Fire Academy that assists state and local organizations with curriculum development and the national promotion of technical training content. Important baseline requirements are set by the applicable standards that manage the training content and provide a level of agreement on the applicable professional qualifications. These baseline requirements are effectively implemented through accreditation and certification processes.

Administering Qualifications for the Fire Service

Fire fighting as a profession has been recognized for centuries among various civilizations. It was not until more recently, however, that its professional status has become more distinctly defined, with the development of standardized baseline requirements and the implementation and quality assurance process that supports the use of these requirements.

Starting in 1974, NFPA's professional qualifications standards began to appear, becoming increasingly used by state agencies responsible for fire service training in the years since. The use of national standards for fire fighter professional qualifications is a concept that political leaders have been able to widely support, and the appearance of these documents has independently coincided with a general rise in funding and recognition for state fire service training programs.[177]

As a result, most states utilize these standards as the defining measure of professional qualifications for fire fighters. However, certification programs in many states are voluntary, and states often do not have mandatory minimum qualifications requirements for fire service personnel.

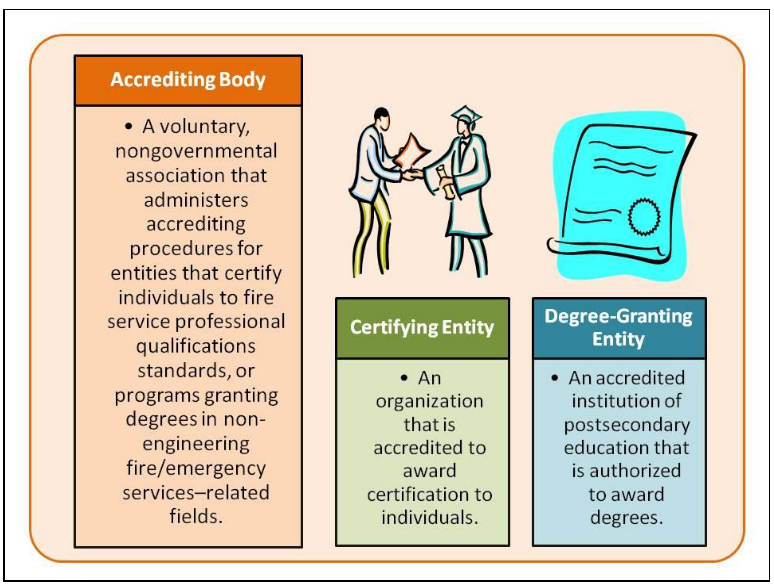

Figure C-4: Overview of Entities that Accredit, Certify, and Grant Degrees.[178]

The baseline requirements included in national standards provide a foundation for fire fighter professional qualifications, but how these are applied is equally important. To achieve consistent implementation, the processes of accreditation, certification, and degree-granting have evolved. The organizations that administer these training programs are known as accrediting bodies, certifying entities, and degree-granting entities, respectively. These are summarized in Figure C-4, which provides an overview of the entities that accredit, certify, and grant degrees.

As further explanation, accreditation refers to enabling oversight (within a recognized framework that measures and ensures quality implementation), bestowed upon another organization. Once accredited, that organization will in turn provide certifications and/or grants degrees to individuals. The following are definitions for accredit, certification, and degree:[179]

> *"Accredit. To give official authorization to or to approve a process or procedure to recognize as conforming to specific criteria, and to recognize an entity as maintaining standards appropriate to the provision of its services."*[180]
>
> *"Certification. An authoritative attestment; specifically, the issuance of a document that states that an individual has demonstrated the knowledge and skills necessary to function in a particular fire service professional field."*[181]
>
> *"Degree. A formal recognition of completion of a prescribed program of study at the postsecondary level."*[182]

Annex D: Attendees at Fire Service Workshop on Solar Power Systems

The following is a summary of the subject matter experts that attended and participated in the "Fire Service Workshop on Solar Power Systems", held in Detroit, Michigan on 17 March 2010.

Table D-1: Attendees at Fire Service Workshop on Solar Power Systems

Last Name	First Name	Organization	City, State	
Brooks	Bill	Brooks Engineering (SEIA, CMP-04)	Vacaville, CA	1
Croushore	Tim	Allegany Power (CMP-12 Chair)	Greensburg, PA	2
Dalton	James	Chicago Fire Dept.	Chicago, IL	3
Earley	Mark	NFPA	Quincy, MA	4
Frable	Dave	U.S. General Services Administration	Genera, IL	5
Grant	Casey	FPRF/NFPA	Quincy, MA	6
Groden	Walter	Chartis Insurance	New York, NY	7
Hollenstain	Tom	State Farm, ATR - Vehicle Research Facility	Bloomington, IL	8
Kerber	Stephen	Underwriters Laboratories	Northbrook, IL	9
Kreis	Timothy	Phoenix Fire Dept.	Phoenix, AZ	10
Layman	Jeff	BP Solar International	TN	11
Lindsey	Travis	Travis Lindsey Consulting Services	Las Vegas, NV	12
McCall	George	McCall & Son	Greenville, SC	13
Murchie	Colin	Solarcity	Washington, DC	14
Paiss	Matt	San Jose Fire Dept. (NGLB Training Group)	San Jose, CA	15
Peterson	Eric	FPRF/NFPA	Quincy, MA	16
Roper	Ed	SC State Training Academy, (NAFTD)	Columbia, SC	17
Sanfilippo	Tony	MI State Fire Marshal's Office	Lansing, MI	18
Sawyer	Steve	NFPA	Quincy, MA	19
Shaw	Ron	Extrication.Com	Plymouth MA	20
Stroud	Matt	MGS Tech	Shoreline, WA	21
Van de Velde	Marc	Global Asset Protection Services LLC	Frankfurt, Germany	22
Varone	Curt	NFPA	Quincy, MA	23
Willse	Pete	XL Global Asset Protection Services	Hartford, CT	24