Loss Control

Wildland Fire Hazard Risk Reduction for Solar Photovoltaic Sites

White Paper

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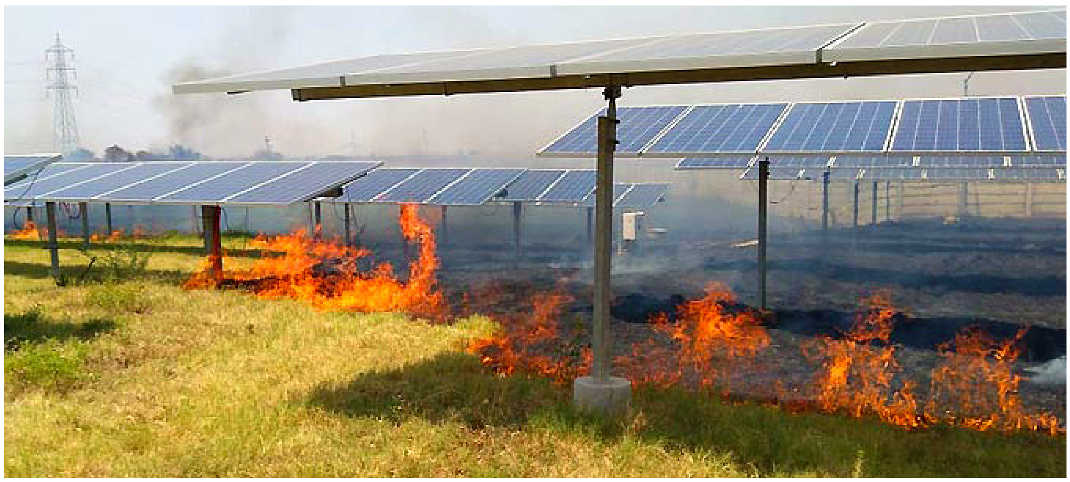

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I. Disclaimer

Wildland fires will continue to exist, either started by natural or human causes and we will need to address the inherit risk associated with their exposure to solar photovoltaic (PV) sites. The content in this document is not intended to be a review of applicable local, state or federal requirements, but rather guidance to our insureds to reduce risk. This document is not a substitute for expert advice, but is intended to help our insureds from an insurance perspective and nothing in this document should be interpreted as to not perform a Wildland Fire Hazards Mitigation Plan[1]. Neither the author nor AEGIS Insurance Services, Inc. endorses or guarantees that any particular practice or procedure stated herein is safe in all cases or meets any code or regulatory requirement. This document is provided without warranties of any kind. This document is not to be used or distributed in part or whole without the written consent of AEGIS Insurance Services, Inc.

II. Introduction

According to data from the Federal Energy Regulatory Commission (FERC), solar provided 49.3% of new domestic generating capacity in 2023 in the United States, more than any other energy source. Solar capacity additions in 2023 were 50% greater than the year before. Increases in the size and number of solar photovoltaic generating sites come with associated hazards which must be addressed. Specifically, the risk of loss due to wildland fire has also increased and can result in losses in the tens of millions of dollars. There are many variables that factor into the risk associated with wildland fire which include but are not limited to: location of the site, lightning activity, humidity, moisture content of fuel, type of fuel, fuel loading or depth of fuel, and wind speed.

Wildland fire exposures can occur from either exterior fires or interior fuel loading of the solar PV installation. Under the right conditions such as Red Flag Warning conditions as defined by the National Weather Service, wildland fires can grow from ignition point to several hundred acres in a matter of minutes. Red Flag Warnings are issued to inform the public, emergency responders, and other agencies that conditions are ideal for wildland fire combustion and rapid spread. The criteria used for determining warning conditions are a sustained wind speed in excess of 15 mph 20 feet above the ground, temperature greater than 75°F, and a relative humidity 25% or less. As these fires grow, flames can reach in excess of 10 feet high and flame fronts can easily stretch one-quarter mile wide. They can become large, fast-moving fires that create their own winds, produce flying brands, which are airborne burning embers, and preheat fuels far ahead of the actual fire. These conditions make them difficult to control and extinguish, thus increasing the risk of loss to solar PV installations.

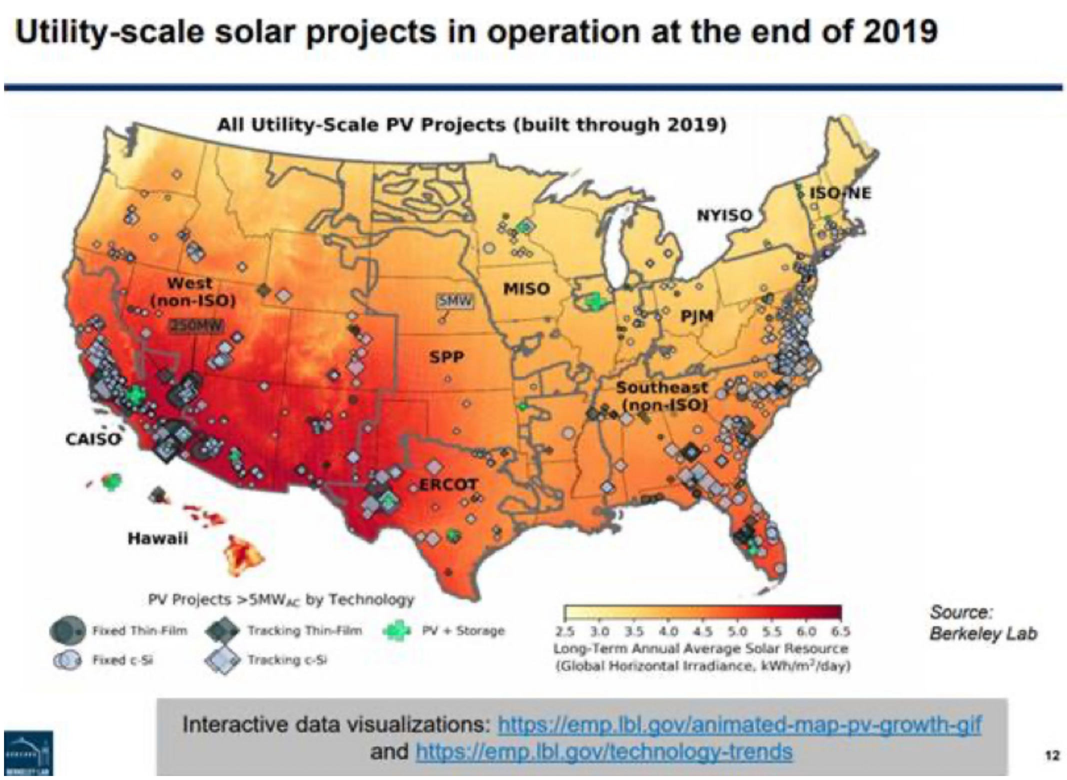
III. Background

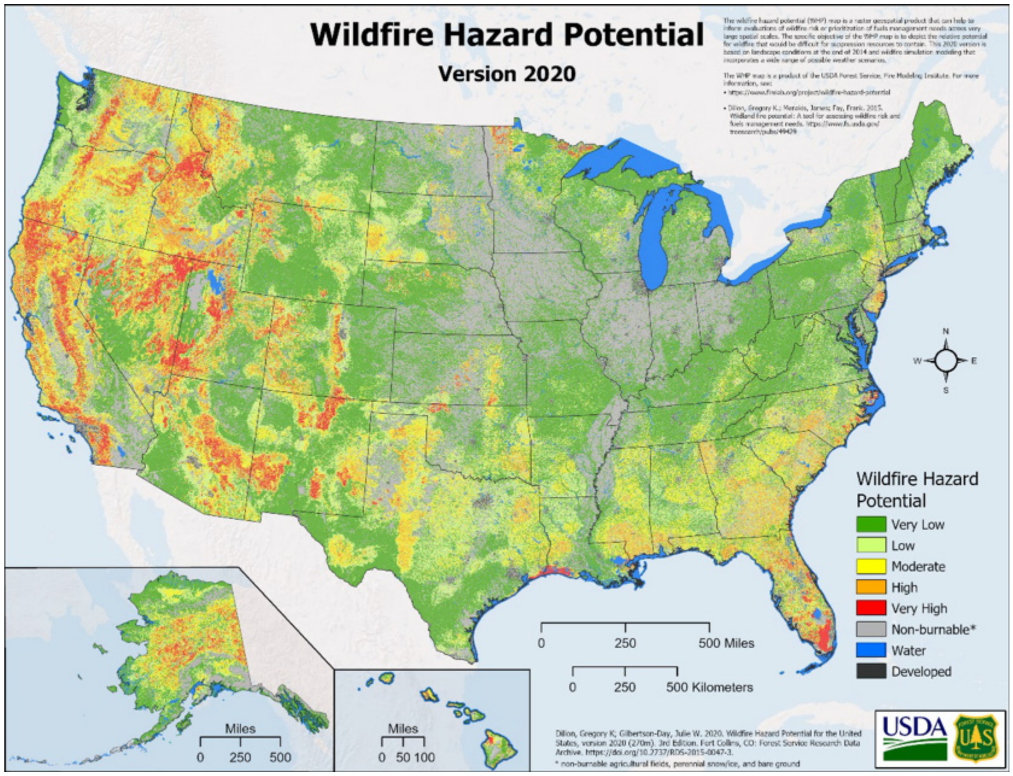
Wildland Fire History and Exposure Concerns

Data obtained from the National Interagency Fire Center (NIFC)[2] 2022 Annual Report indicates that 66,255 fires (12th least of all time) burned 7,534,403 acres (11th most of all time). Whereas the 2023 Annual Report indicates a decrease in both number of fires and acreage with 55,571 fires (3rd least) burning 2,633,636 acres (least). While the majority of the fires remain small and are contained to less than 10 acres, they can also grow to be many times larger.

In 2024, the Smokehouse Creek fire in the Texas Panhandle grew from ignition and traveled more than 30 miles in a single day. It grew to approximately 1 million acres in size in a little more than 48 hours. Dry conditions, high temperatures, and extremely high winds gusting up to 60 mph contributed to the rapid spread. As the acreage involved in wildland fires increases and with the rise in construction of solar PV sites, the risk of damage from wildland fire impacting PV sites is elevated.

The following maps further illustrate the risk of wildland fire to solar PV sites. The first depicts current and planned utility scale solar sites, and the second depicts the potential for wildland fire in specific areas.





FEMA National Risk Index

Controlling or eliminating vegetation within the solar PV site perimeter is a key factor in reducing a loss from a potential wildland fire.

As previously mentioned, flame heights can easily exceed 10 feet depending on the type of vegetation fueling the fire. Fire service information[4] indicates grazed grassland pasture with grass 3-4 inches in depth can generate flames up to 3 feet high under the right conditions. Computer modeling from the **US Department of Interior Interagency Fuels Treatment Decision Support System**[5] further illustrates a variety of wildland fire behaviors. The model supports approximately 58 different types of fuel environments and is used to illustrate the hazard presented by native vegetation regarding flame spread rate and flame height.

The following five fuel classes were chosen as examples of locations where solar PV installations may most likely be located. The model incorporates fuel factors, moisture content and wind speed to determine flame height on level ground. The most conservative parameters were selected for this exercise, and the 15 mph wind speed correlates to Red Flag Warning conditions.

Selected Fuel Classes and Flame Height (five of fifty-eight classes shown)


FM1

Fuel class FM1 – Short Grass – these are grasslands, savannah, grass tundra, shrub, and stubble.

FM1 – Flame height with 15 mph wind – **5.8 ft.**


GR1

Fuel class GR1 – Sparse Short Dry Climate Grass – sparse grass with fine amounts of dead fuel, may be sparse or discontinuous.

GR1 – Flame height with 15 mph wind – **2.5 ft.**


GR3

Fuel class GR3 – Low Load, Coarse Humid Climate Grass – continuous, coarse, humid climate grass. Low load fuel bed depth about 2 feet.

GR3 – Flame height with 15 mph wind – **11.07 ft.**


SH1

Fuel class SH1 – Low Load Dry Climate Shrub – woody shrub, some grass may be present. Fuel depth about 1 foot.

SH1 – Flame height with 15 mph wind – **4.01 ft.**

SH5

Fuel class SH5 – High Load Dry Climate Shrub – woody shrub and shrub litter. Heavy load with fuel depth 4-6 feet.

SH5 – Flame height with 15 mph wind – **23.70 ft.**

PV Panel Exposure

Short grasses such as fuel class FM1 and GR1 or grazed pasture land could represent a severe exposure to solar PV arrays either through direct flame impingement or radiant heat. The type of material on the back sheet of a solar panel is a critical factor in the maximum exposure to heat/flame that a panel can withstand. Many solar panels are constructed with plastic back sheets and exposed cabling, so even a short duration fire could cause a complete loss of the panel or array.

The back sheets on PV panels are the protective layer that prevents moisture infiltration into the panel. These back sheets are usually some type of either polyolefin plastic, polyethylene terephthalate (PET) or PCB material. Polyolefins, also known as polyalkenes, PET and PVC, are all thermoplastics, meaning that they melt and deform when exposed to heat.

These back sheets are typically very thin – about 300 microns or 0.012 inches thick, which equates to about 11.8 mils. In contrast, a heavy plastic trash bag is approximately 3 mils thick. The back sheet will be compromised from minimal heat even if treated with fire retardants to prevent ignition.

Flame temperatures in the 367°F range could be expected from free burn vegetative grassland matter, as found in some Canadian research.[6] Temperatures were higher when there was any woody mass as part of this vegetation. The melting temperature of a polyolefin back sheet will generally be in the mid 200°F range. PET has a higher melting temperature of 500°F, but becomes soft and pliable above 284°F. PVC, depending on how it is made has melting temperatures of 212°F to 500°F, but may begin to deform as low as 198°F. Once breached, deformed or compromised in any way, the panel will require replacement.

IV. Vegetation Management

Planning

Recognizing the importance of vegetation management, it should be addressed from the conceptual phase of the project through commercial operation as part of recurring costs in the annual Operation and Maintenance (O&M) budget. On average, vegetation management can amount up to 4% of the total O&M cost.

Mechanical Issues

In addition to the fire hazard exposure, uncontrolled vegetation growth within the site can lead to additional equipment related issues which can affect system performance leading to lost generation (output). Several of those issues are detailed as follows.

Shading – Vegetation growth partially covering or shading the panels can, in turn, decrease the panel's output.

Hot spot creation – If a part of the solar panel is shaded, the cell can heat up to such extreme temperatures that a module can burn out causing permanent damage.

Infestation – natural wildlife such as insects or snakes can cause a threat to the people working at the site.

Strategies for Control

Various methods are available for control and management of sites with established vegetation. With any method, there are advantages and disadvantages.

Chemical control is often easier to administer and less costly and time consuming when compared to other means of physical control. However, there are disadvantages to herbicide application. Chemicals may be harmful to the person applying the chemicals if exposed and the chemicals could have harmful environmental consequences.

Herbivore grazers are also an option. Consideration should be given to the particular animal selected. For example, goats may damage equipment by climbing on panels or eating wiring. Sheep are generally the preferred option since they are much more docile and tend to eat only the vegetation. Use of animals does have several drawbacks: Supervision is needed, the animal selected may not prefer the type of vegetation present, precautions should be taken with system components to prevent chewing/nibbling, and animals may inadvertently activate security systems.

Mowing is the most basic means of vegetation control. It must be done often and can be labor intensive although there are commercially available robotic mowers. Perhaps the biggest drawback to mowing is that it can also be an ignition source for wildland fires. Mechanical control such as mowing and especially use of a string or blade trimmer can also damage the panels, wiring, and particularly the more delicate plastic backing.

Physical means such as weed controlling fabrics or sheets or applications of an aggregate substrate is the most effective means of vegetation control. These methods require minimal periodic maintenance or vegetation removal, but they do come with a significant initial cost and may be difficult to implement for an established site. High winds, for example, may lift fabrics if they are not secured properly.

Agrivoltaic development is rapidly developing with approximately 6 GW of agrivoltaic generation capacity operating in the United States, ranging from solar panels on grazing pasture to crop fields.[7]

The **US Department of Agriculture** defines Agrivoltaics as the use of land for both agriculture and solar photovoltaic energy generation. It's also sometimes referred to as agrisolar, dual use solar, low impact solar.

The **US Department of Energy** defines Agrivoltaics as agricultural production, such as crop or livestock production or pollinator habitats, underneath solar panels or adjacent to solar panels.

In the case of crop related installations, additional fuel loading is being intentionally placed in proximity to solar panels. If agrivoltaic production is underneath the panels, this typically results in torque tubes being raised up to seven feet or higher off of the ground which aides in reducing the mechanical impacts of shading and hot spot creation.

Additionally, some European developers have begun using mounting structures made with organic materials. These structures weigh up to 90% less than steel and are comprised of flax, carbon, wood fiber, and other materials. Structural support made with organic material further increases the fire load and should be avoided.

V. Wildland Fire Hazards Mitigation Plan

Plan Overview

Both established sites and projects in development should have a Wildland Fire Hazards Mitigation Plan[1]. The plan should outline the overall strategies and responsibilities necessary to reduce or eliminate the exposure due to fire and heat. For a plan to be effective, an ignition risk assessment and fuel hazard assessment should be completed and utilized as part of plan development.

Assessments

An ignition risk assessment is an evaluation of potential ignition sources including but not limited to weather related sources, transportation roadways, railroads, utility corridors, nearby industrial operations, nearby recreational areas, and intentionally set fires.

Fuel hazards risk assessments encompass evaluations of the vegetation type, surrounding terrain and siting, weather conditions and effect on vegetation, direction of normal prevailing winds and fuel load in that direction, evaluation of fire behavior external to the facility, and fire history for the surrounding area.

Plan Development

Once risks and hazards are identified and evaluated, the mitigation plan can be written and implemented. Elements of the plan should include, at a minimum, mitigation activities, responsible party, priority for each activity, and a schedule. Activities may include fuel growth and ignition source monitoring, fuel treatment and control, and weather condition monitoring. Other elements to consider are the establishment of fire breaks, fire barriers, and clear spaces. Fuel growth monitoring and fuel treatment will be required activities from project inception through commercial operation.

The plan should also include preparedness and pre-planning activities with local emergency responders. In most cases, a wildland fire impacting or involving a solar PV generation facility will be part of a much larger overall event. Personnel should be designated to liaise with emergency response organizations and may need some level of Incident Command training in order to be incorporated into the Incident Management/Unified Command structure.

Once a plan has been developed it should be reviewed annually and updated as needed to address current conditions.

VI. Model Practices and Guidelines

Ultimately, complete vegetation removal within the site is the preferred method to reduce exposure to wildland fire. For those sites where vegetation has been removed, application of an aggregate substrate material (similar to what is found in an electric substation) aids in soil conservation. The external exposure remains but is significantly reduced due to the lack of fuel within the site. This method of mitigation is most easily accomplished during initial site construction.

For established locations, complete vegetation removal remains the best method, but may be difficult to achieve. For locations with established vegetation, the best overall strategy includes active and passive methods of fuel control. The active methods are managing and controlling vegetation growth, while passive methods include the creation of clear space fire breaks to prevent or minimize fire spread.

AEGIS Loss Control recommends that vegetation under or near solar PV panels not exceed 6 inches in height and may need to be reduced even more depending on seasonal conditions. Additionally, if any part of the panel (such as the bottom of a tilted panel) is within 12 inches of the ground, then vegetation should be cut as short as practical. Preferably all vegetation should be completely removed from below the panel. If vegetation is a mix of grass and short shrub similar to fuel class SH5, it must be removed completely regardless of panel height.

All sites should have a perimeter fire break which is vegetation free. Wildland fire exposure from an external fire can be mitigated by creating a defensible space around the site. The perimeter fire break should be bare ground or covered with an aggregate substrate for soil erosion control. The perimeter fire break should be clear of any vegetation, may be inside and/or outside of the perimeter fence, and should be at least 50 feet wide and potentially wider depending on site environmental conditions. It may be advantageous to have a meteorological analysis conducted to identify external environmental parameters which may have an impact on fire behavior and the site.

Additional fire breaks are necessary for locations with established vegetation to prevent or minimize fire spread within the site by interrupting the line of vegetation. The space between solar panel rows should be maintained free of vegetation and any space breaks in panel rows should be cleared of vegetation as well. A 10 feet wide clear space fire break should be established around transformers, electrical equipment, and any buildings, structures, or enclosures.

Due to increased fire load presented by **Agrivoltaic** sites, additional precautions to those previously discussed should be considered. The specific type of crop or vegetation chosen should be evaluated not only for the fire load impact, but potential for shading and hot spot creation. Lower growing crops should be considered. Once harvesting and the growing season are complete, dead vegetation should be removed. In order to further reduce the wildland fire hazard, any grasses or vegetation in the space between rows of panels should be maintained as low as capable or completely removed.

Refer to Appendix A for a summarized detailed list of potential actions.

VII. Conclusion

The content in this paper is suggested to help eliminate, mitigate, or reduce the risk of a complete loss of a solar PV site from internal and external factors, as well as minimize the impact from any fire related damage. With the shift to renewable generation and resulting increases in number and size of solar PV sites, the “Value at Risk” increases to both the insurer and the member.

VIII. References

[1] NFPA 1143 “Standard for Wildland Fire Management” 2018 Edition
[2] NFPA Research Brush, Grass, and Forest Fires, Marty Ahrens September 2018
[3] National Interagency Fire Center
[4] New South Wales Rural Fire Service
[5] US Department of Interior Interagency Fuels Treatment Decision Support System Fuel Modeling
[6] Arthur W. Bailey and Murray L. Anderson “Fire Temperatures in Grass, Shrub and Aspen Forest Communities of Central Alberta” Journal of Range Management 33, January 1980
[7] National Renewable Energy Laboratory

IX. Contributors

Tracy Browder, ARM CFPS – Property Loss Control Supervisor

Anthony Martin – Senior Loss Control Account Professional

Appendix A: Vegetation Management Strategies

The following are suggested actions to eliminate, mitigate or reduce the risk of wildland fire impacts to solar PV sites.

- Develop written plan outlining actions and responsibilities. Include annual budget for completing.
- As part of the plan, complete periodic fuel hazard assessments.
- Vegetation height should be maintained as low as possible.
- For certain areas and sites, this may mean continuous vegetation management operations during growing seasons.
- Select control options
- Complete vegetation removal within the site
- Application of an aggregate substrate material (similar to what is found in an electric substation) aids in soil conservation and prevents growth
- Active and passive methods of fuel control
- Mechanical control
- Chemical control
- Ensure all mobile equipment is equipped with a portable fire extinguisher.
- Do Not place any powered equipment directly on vegetation in order to prevent ignition of combustible vegetation by hot exhaust parts
- Vegetation under or near solar PV panels should not exceed 6 inches in height.
- If vegetation is a mix of grass and short shrub similar to fuel class SH5, it should be removed completely regardless of panel height.
- All sites should have a perimeter fire break at least 50 feet wide which is vegetation free.
- The perimeter fire break should be bare ground or covered with an aggregate substrate for soil erosion control.
- Additional fire breaks for locations with established vegetation to prevent or minimize fire spread within the site by interrupting the line of vegetation.
- The space between solar panel rows should be maintained free of vegetation and any space breaks in panel rows should be cleared of vegetation as well.
- A 10 feet wide clear space fire break should be established around transformers, electrical equipment, and any buildings, structures, or enclosures.
- For Agrivoltaic sites, the space between solar panel rows should be maintained free of vegetation at all times or maintained as low as possible if vegetation such as native grasses is required. Crop vegetation below panels should be removed immediately when harvest is complete or the growing season ends.

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