Appendix O.3

Balance of Plant
Preliminary Fire Risk Assessment

Starlight Solar
Major Use Permit PDS2022-MUP-22-010
Balance of Plant
Preliminary NFPA 551 Fire Risk Assessment

20250320-SLS-AW0764-BOP-FRA-R1

Issued: 23 July 2025

AHJ Revision Note: This Balance of Plant (BOP) NFPA 551 Preliminary Fire Risk Assessment (FRA) is provided as a "Land Use Permit" approval analysis to support the initial permitting of the Starlight Solar Energy Storage Project in San Diego County California. This BOP NFPA 551 FRA was created using a theoretical technology agnostic ESS to characterize the failure modes that could result in fire, shock, explosion, or injury to personnel.

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Revision History

Revision	Date	Description
0	12 May 2025	Released to Client for Dissemination
1	23 July 2025	Redefinition of the intent of the document as preliminary at the client. Title page and appropriate verbiage changed as directed by client.

Executive Summary

This Preliminary NFPA 551 Balance of Plant (BOP) Fire Risk Assessment (FRA) was conducted to evaluate the external fire hazards and risks associated with a theoretically UL9540 compliant energy storage system for the Empire II LLC Starlight Project. The Empire II LLC Starlight Project is an eight-parcel project located in San Diego County, southeast of Manzanita CA in proximity of 32.66016162785173, -116.28052568720432.

This BOP FRA considers *external events* that if realized could result in the failure of an original equipment manufacturer (OEM) technology agnostic Lithium-Iron Phosphate (LFP) based energy storage system (ESS). This FRA considers both potential man-made and acts-of-God and determines if sufficient engineering controls exist to mitigate the likelihood of a failure requires results support of the San Diego County Fire Departments. In the event there are insufficient engineering controls, additional administrative controls (processes or procedures) may be necessary to reduce the potential threat of an event from occurring. In the scenario where acts-of-God events are realized, where identified, it is recommended Empire II, LLC evaluate the risk and evaluate if additional controls are necessary or if the risks are to be assumed.

The methodologies used in this FRA are based on the Occupational Safety and Health Administration (OSHA) Process Safety Management principles of reliance on recognized and generally accepted good engineering practices that employ numerous national consensus standards, peer-reviewed publications, and market sector testing to ensure the efficacy of the quantitative analysis [1, 2]. Specifically, the Society of Fire Protection Engineers (SFPE) Engineering Guide, *Fire Risk Assessments,* was utilized to frame the BOP Fire Risk Assessment format to be compliant with the requirements of the National Fire Protection Association (NFPA) Standard 551, *Guide for the Evaluation of Fire Risk Assessments* [3, 4]. Where necessary to compute the radiant heat at the adjacent Energy Storage Units and structure adjacencies, the *SFPE Handbook of Fire Protection Engineering [5]* and NFPA *Fire Protection Handbook* [6] as well as other peer-reviewed research and publications were relied upon to establish the technical basis for the applicable computations. The application of each standard and peer reviewed document is referenced throughout this report.

Presently, this BOP FRA has identified the following events that if unmitigated could result in a battery energy storage system fire [7]:

- Design Basis Flood
- Seismic Event
- Lightning Strike
- Wind and Tornado
- Vehicle Impact
- Vehicle Fire
- Wildland Fire
- Battery Energy Storage System Deflagration.

Scope

This BOP FRA identifies and quantifies the potential external fire hazards associated with the design, construction, commissioning, and operations of the Empire II, LLC Starlight Solar Battery Energy Storage based on a typical Lithium-Iron-Phosphate ESS design (Figure 1). The results of this FRA are intended to establish the technical basis for fire risk management decisions to mitigate the likelihood of initiating a fire within the BESS.

This Fire Risk Assessment was conducted in accordance with the requirements and guidelines of the:

- NFPA 551, *Guide for the Evaluation of Fire Risk Assessments* [8]
- SFPE G.04:2006 – *Engineering Guide: Fire Risk Assessment*; [4]
- NFPA No.: HFPE-01 - SFPE Handbook of Fire Protection Engineering [5]
- ISO 16732-1: 2012 – Fire Safety Engineering – Fire Risk Assessment, Part 1: General[9]
- ISO 16732-3: 2012 – Fire Safety Engineering – Fire Risk Assessment, Part 3: Example of an Industrial Property [10]

Purpose and Objectives

The use of Lithium-ion (Li-ion) battery-based energy storage systems (ESS) has grown significantly over the past few years. In the United States alone, Li-ion battery (LIB) use has gone from 1 MW to almost 35,000 MW by the end of 2025 (refer to Figure 2) [11]. Many of these systems are smaller installations located in commercial occupancies, such as office buildings or manufacturing facilities. Yet, there has been relatively little research conducted on large commercial or industrial systems that can be used to ensure that effective fire protection strategies are in place.

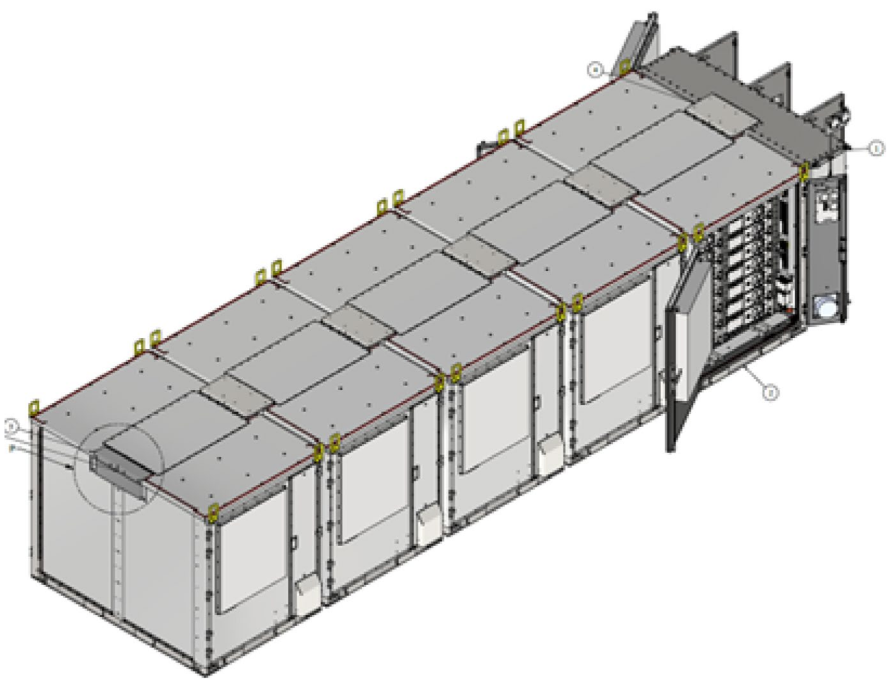

Figure 1: (ass. Typ.) OEM ESS Design

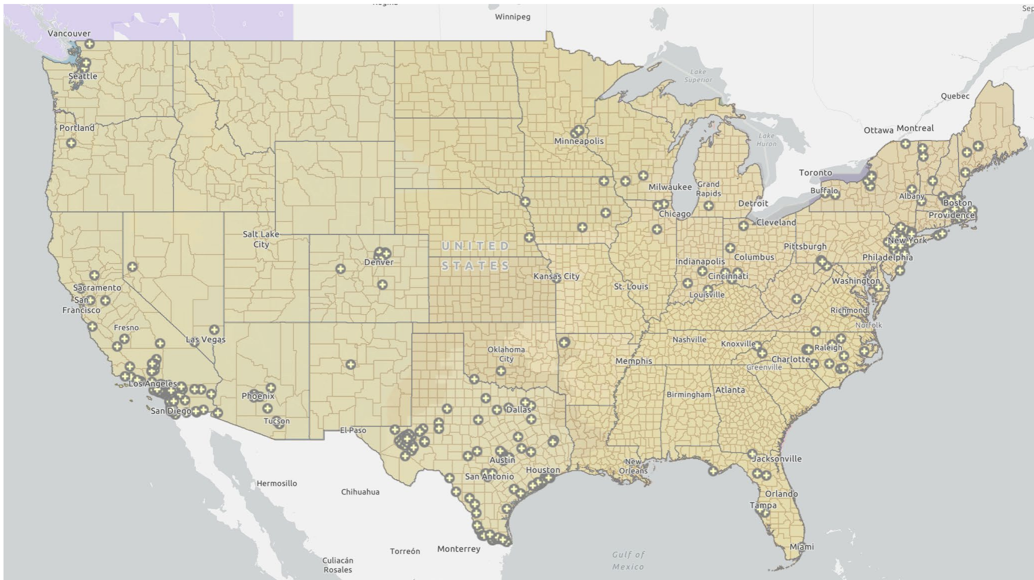

Figure 2: US Large Scale Battery Storage Installations by Region (2025) [12]

Many studies have addressed how failure of a single cell battery is affected by characteristics such as chemistry, electrolyte composition, state-of-charge (SOC), or format [2-8]. The subsequent propagation of thermal runaway to adjacent cells in a multiple cell battery module has also been studied and characterized.

From a fire protection and fire risk perspective, the overall fire hazard of any ESS is a combination of all the combustible system components, including battery chemistry, battery form factors (e.g., cylindrical, prismatic, polymer pouch), battery capacity and energy density, state of change (SoC), materials of construction, and component design (e.g., battery, module). To ensure confidence in the resulting fire protection guidance, the ESS was assumed to be operating under a normal electrical operation where electrical abuse may occur, such that any proprietary electronic protection systems, e.g., battery management system (BMS), were limited in mitigative response. Any benefit from these proprietary systems would further reduce the overall hazard, (e.g., the likelihood of ignition), but is not necessary or sufficient to ensure the adequacy of the fire protection or response measures [13, 14].

It is recognized that the assumed typical OEM *BESS* UL9540A Module test resulted in thermal runaway propagation from cell to cell without flaming [15-17]. However, sufficient flammable gas was emitted (~170 L) creating a highly flammable environment which is likely to be ignited due to the presence of non-intrinsically safe components [16]. This is based on a probabilistic initiating event of electrical abuse resulting in battery cell failure and subsequent cascading thermal runaway and the released flammable gas is ignited. This analysis is bound by the assumption of a single BESS fire and corresponding thermal energy released. This analysis assumes the fire and corresponding thermal energy released resulting in the heating of the upper third of the container as the heat radiator to the surrounding environment.

As part of this BOP FRA, the body of knowledge was researched, collected, reviewed, and summarized related to LIB ESSs to establish the technical basis for performance and any potential mitigation measures. The sources used include the Department of Energy (DOE) Safety Roadmap, relevant international consensus codes and standards, incident reports, related test plans, peer-reviewed research, and previous fire testing/research with the objective of identifying the inherent risks associated with the deployment of the LIB ESS technology to life (occupants or fire fighters) and for property (asset) protection.

Continuity of Operations is specifically excluded from this assessment as no administrative controls are assumed to limit the resultant hazard. Non-Safety Instrumented Systems (SIS) or components with a Safety Integrity Level (SIL) accreditation are assumed to have failed to create the bounding fire event.

The literature review conducted as part of this BOP FRA and is intended to identify documented research, knowledge, or technology gaps in the information currently available of the fire behavior and propagation of Lithium Iron Phosphate (LFP, $LiFePO_4$) based technologies as it applies to the Starlight Solar Project.

Assessment Methodology

This BOP FRA and the format of this report employs both qualitative and quantitative methods to determine the inherent risks of the LFP lithium-ion battery (LIB) energy storage system (ESS) technology and follows the guidance outlined in the SFPE Engineering Guide to *Application of Risk Assessment in Fire Protection Design* and the National Fire Protection Association (NFPA) Standard 551 *Guide for the Evaluation of Fire Risk Assessments* [4, 8].

The *SFPE Guide to Fire Risk Assessments* recommends the use of risk assessment methodologies in the design and assessment of building and/or process fire safety. This guide is a recognized and generally accepted and good engineering approach to fire risk assessments. The SFPE guide provides directions to practitioners in the selection and use of fire risk assessment methodologies used to determine adequacy of design for fire safety. It also provides guidance to project stakeholders in addressing fire risk acceptability. Furthermore, the SFPE guide establishes recommended processes to be considered for the use of risk assessment methodologies and provides references to available detailed sources of information on risk assessment methodologies, procedures, and data sources. However, the SFPE Guide to Fire Risk Assessments does not provide specific fire risk assessment methodologies or tools; nor does this guide provide specific data or acceptance criteria for use in the risk assessment process. Therefore, in the absence of specific quantification methodologies, the *SFPE Handbook of Fire Protection Engineering* [5] and the *Fire Protection Handbook* [6] as well as other peer-reviewed publications were used to identify the characteristic equations for calculating compartmental fires, heat release rates (HRRs), flammable gas temperatures, and surface temperatures.

The following figure outlines the process outlined in the SFPE Guide. The format of this report closely follows the recommendations of the SFPE Fire Risk Assessment Guide.

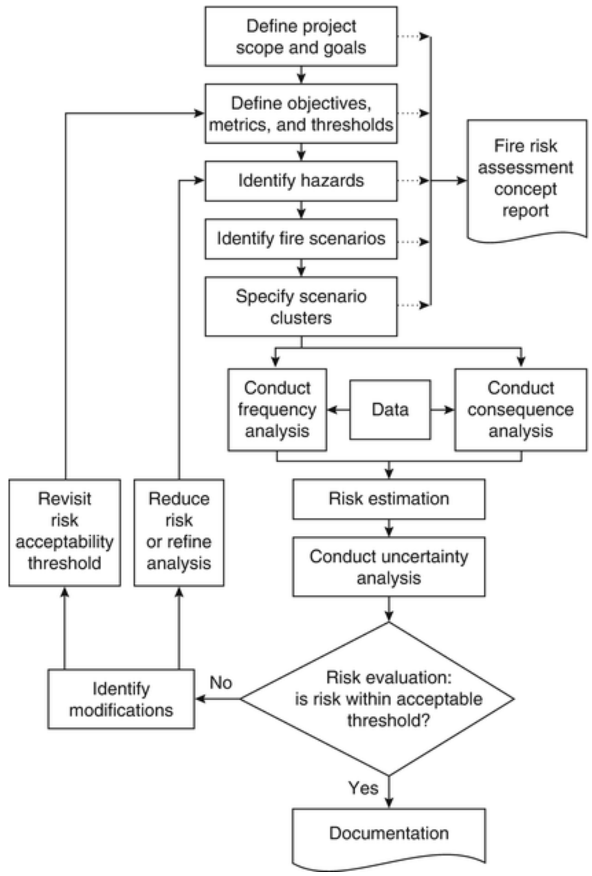

Figure 3: SFPE Fire Risk Assessment Process Flow Chart

Definition of the Project Scope

This quasi-quantitative FRA was developed for the Empire II, LLC containerized Battery Energy Storage System (ESS) was conducted to evaluate the external hazards and risks associated with a theoretical UL9540 compliant energy storage system (BESS) for the Empire II LLC Starlight Project. The Empire II LLC Starlight Project is an eight-parcel project located in San Diego County, southeast of Manzanita CA in proximity of 32.66016162785173, -116.28052568720432 as shown in Figure 4 and Figure 5.

This BOP FRA builds upon the Battery Energy Storage System (BESS) FRA to evaluate the external fire events that if realized could result in the creation of an unsuitable environment resulting in damage or BESS fire[18]. This BOP FRA evaluates natural/acts-of-God and limited man-made postulated events external to the Starlight Solar Project and assess the impact to ongoing operations that could result in fire, shock, explosion, or personal injury.

This steady-state BOP FRA leverages the quasi-quantitative information gained through an exhaustive literature review of the failure rates (the total number of failures within an item population, divided by the total time expended by that population, during a particular measurement interval under stated conditions) and consequences of LIB within the global ESS market sector, as well as estimates the heat flux generated from an external threat and its impact on a given ESS. When necessary to assist in the quantification of a creditable threat, in the absence of specific failure data of a manufacturer's part number, comparable and approximate reliability data presented in the Electronic Parts Reliability Database (EPRD), Non-electrical

Parts Reliability Database (NPRD) or Failure Modes/Mechanisms Database (FMD) was used.

This assessment does not quantify the increased pressures associated with system deflagrations of the vented flammable gases during LIB thermal runaway associated with the requirements of NFPA 69.

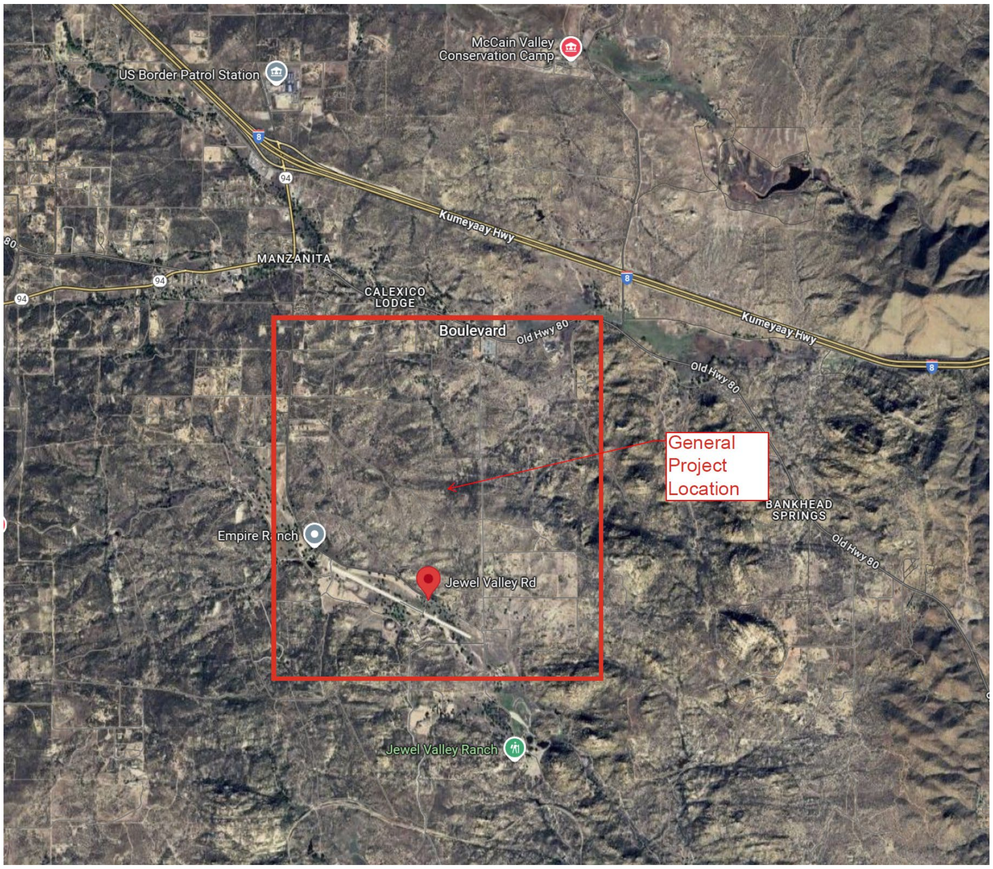

Figure 4: Starlight Solar Project Site

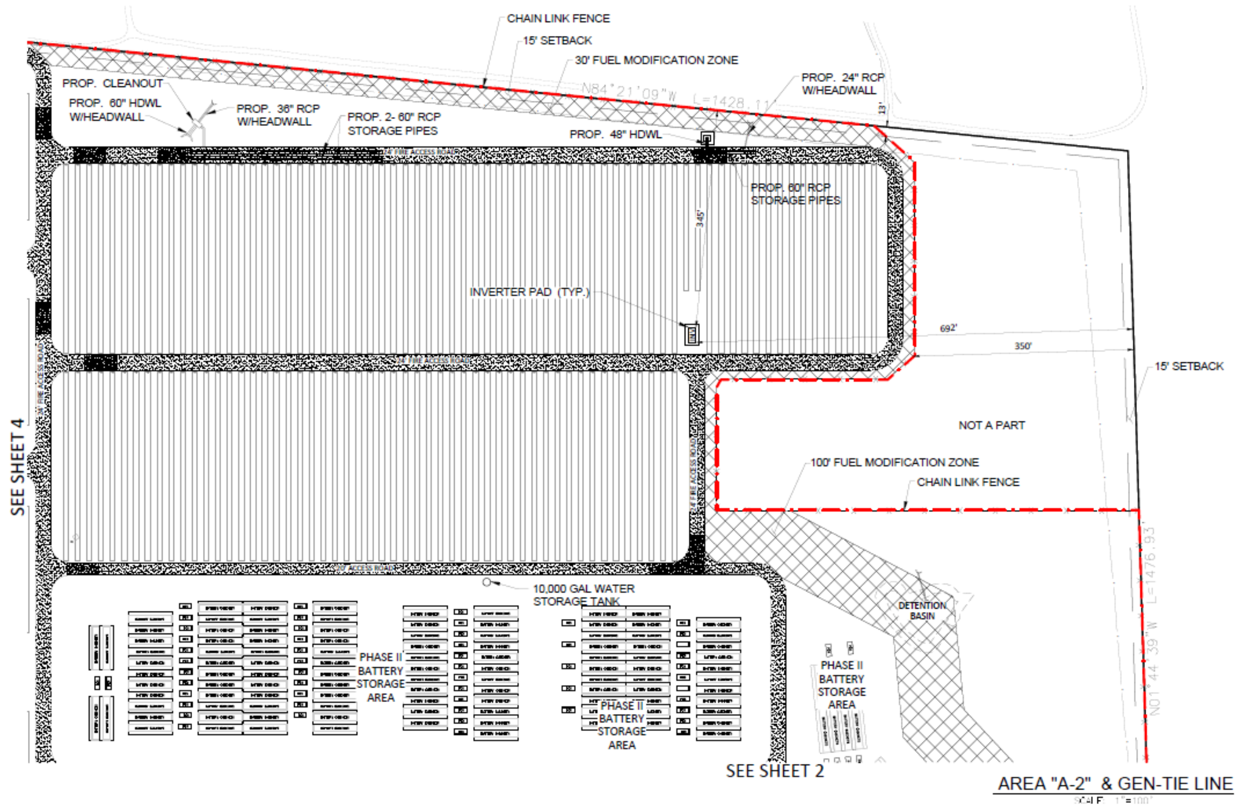

Figure 5: (typ.) Starlight Solar Project Layout

Analysis Enabling Assumptions

The general assumptions associated with this BOP FRA pertain to the accuracy of the documentation used to develop the FRA. The description and operation of the Empire II, LLC Starlight Solar Energy Storage System Project buildings and process as described in drawings, calculations, project documents and procedures were relied upon in developing this FRA. Fundamentally, it is assumed that the project and facility documents, drawings, calculations and procedures are complete and accurate and reflect the system design, operations and configuration. It is assumed the applicable data is under an appropriate engineering configuration control program. There are specific assumptions related to the design, operation, etc. that are important that are not identified here, but that are identified throughout this FRA when pertinent to the analysis at hand.

The following enabling assumptions were used to facilitate this Fire Risk Assessment to characterize a worst-case scenario:

- This NFPA 551 Fire Risk Assessment is technology agnostic and is provided solely as a basis for completing the requisite Hazard Mitigation Analysis. This FRA demonstrates the "typical" engineering rigor for evaluating both the internal and external risks associated with any LFP based ESS. The information presented in this FRA is for "information purposes only" and shall not be considered as bounding as numerous other considerations are required for the final technology selected.
- Full compliance with NFPA 70 is field verified and documented accordingly.
- The scope of the Empire II, LLC Starlight Solar Project work scope is bounded by the information

presented in the Starlight Solar Submittal Package.

- First Responders reaction time is assumed to be less than 60 minutes based on the assumption of notification 30 minutes into the thermal runaway event and distance from San Diego Fire Authority Boulevarde Fire Station #47, 39223 CA-94, Boulevard, CA 91905 to Starlight Project Site (~1.1 miles). Alternatively, the distance from CAL FIRE White Star Fire Station, 1684 Tierra Del Sol Rd, Boulevard, CA 91905 to the Starlight site (4 miles).
- Ambient conditions are assumed to be standard pressure temperature (STP). External environmental air conditions assume no wind movement. Ambient temperature is 295 K (22 °C/72 °F).
- Numerical/analytical methodologies employed are based on SFPE, NFPA Handbooks, or other peer-reviewed publications and are assumed to be adequate for characterizing the critical calculation variables and are cited herein.
- This FRA qualitatively evaluates natural and limited man-made postulated events external to the Starlight Solar Project and assess the impact to ongoing operations that could result in fire, shock, or personal injury.

Empire II, LLC Starlight Solar Project Construction Site Overview

The subject project covers numerous San Diego County Parcels including 612-082-12, 612-110-02, 612-110-04, 612-110-17, 612-110-18, 612-110-19, 612-120-01, 659-020-01, 659-020-02, 659-020-05, 659-020-06, 659-020-08, 659-080-02, 659-080-09.

The project would be served by the San Diego County Sheriff's Department Jacumba Substation, phone +16197664585, or the 378 Sheridan Rd, Campo, CA 91906, phone +16194785378.

Fire support is assumed to be provided by the San Diego Fire Authority Boulevarde Fire Station #47, 39223 CA-94, Boulevard, CA 91905 to Starlight Project Site (~1.1 miles). Alternatively, the distance from CAL FIRE White Star Fire Station, 1684 Tierra Del Sol Rd, Boulevard, CA 91905 to the Starlight site (4 miles).

The nearest hospital, Sharp Grossmont Hospital, is approximately 53 miles to the northwest of the project site at 5555 Grossmont Center Dr, La Mesa, CA 91942, phone +16197406000.

Primary site access via old Highway 80. The parcel falls under State Area Responsibility according to CALFIRE and is categorized as a "high fire hazard area as shown in Figure 6.

The Starlight Solar project fire hazard determination is presented in the San Diego County Wildland Urban Interface Plan. However, there is still a risk of wildfire. There is vegetation on-site and site maintenance would involve the removal of additional vegetation, although natural vegetation may be maintained if it does not interfere with project construction or the health and safety of on-site personnel. The site is not immediately adjacent to urbanized areas; however, there are isolated residences in proximity to the project site.

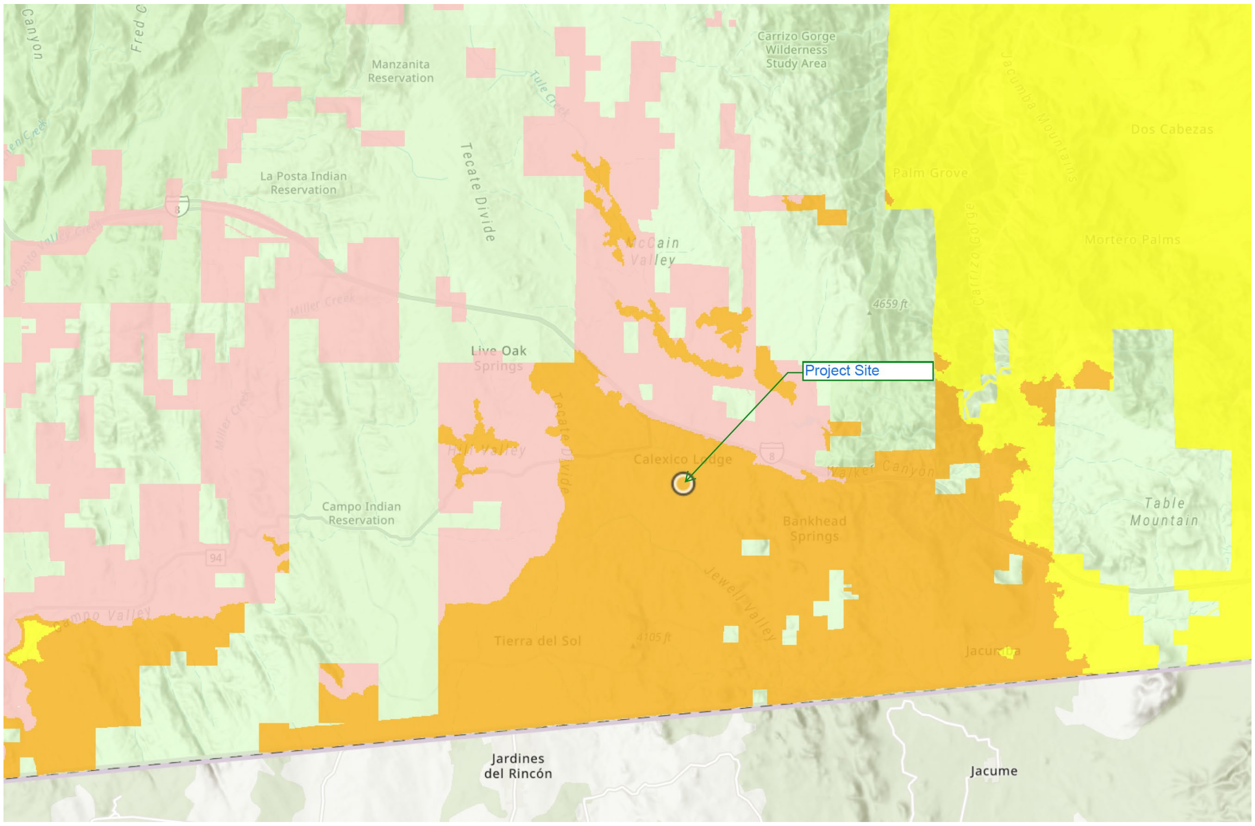

Figure 6: Project Site Wildfire Risk

Limitations

The theoretical fire hazards and potential fire scenarios identified and analyzed int this BOP FRA are based on documented process description summaries and information contained in related project drawings and documents. Subsequent changes in procedures, processes, combustible loads, or fire protection systems may require additional or new analyses to assess whether these changes affect the conclusions of the performed analyses and potentially the conclusions of the FRA.

Application of Industry Codes of Record and Standards

The project construction and building codes utilized for design during facility construction are referred to as the Code of Record (COR). The codes and standards used for installation of various required fire protection and life safety systems Starlight Solar Project Site are invoked by reference in the building COR and are also considered to be part of the COR. The CORs are the editions of the codes that were in place at the inception of the building construction are assumed to be based on the most current version at the time of this FRA. In the absence of defined CORs, it is assumed the current edition of the code or standard shall be applied with judgment in the assessment of the adequacy of fire protection. A COR may be established by the Burke County Authority Having Jurisdiction which may require further analysis to address additional fire risks not included in this BOP FRA.

The primary benefit of establishing the COR for a project is the establishment of facility components and systems (e.g., exit locations, stairs, hallways, fire suppression and detection systems) that were constructed or installed in compliance with the requirements of the applicable COR may not be required to comply with subsequent updates. Exceptions would include when there is a significant hazard that endangers building occupants or the public, or when a national code or standard, such as the *Life Safety Code*, specifically requires retroactive compliance. In such cases the specific requirements of the current code apply to mitigate the hazard.

Operational aspects for Empire II, LLC facilities shall comply with the most recent edition of the code. The CORs for a facility (or a portion thereof) are often revised when significant modifications occur. New construction/modification is regulated under the current revision (i.e., 2022 Edition of the California Fire Code (CFC)).

The COR concept shall not be applied to issues regulated by the *Fire Code*, *Life Safety Code* or to inspection, testing, and maintenance activities for required fire protection systems. Instead, issues regulated by the fire code shall be regulated by the currently adopted version of the fire code for Burke County and inspection and testing and maintenance shall be performed in accordance with the currently adopted code as defined by the AHJ. Maintenance of the required systems is performed in accordance with the currently adopted code set.

The normative requirements that define the safe design, construction, and installation of major assemblies associated with the Starlight Solar BESS Project include:

- 2024 California Fire Code (CFC) [19]
- NFPA 10:2022, *Standard for Portable Fire Extinguishers* [20]
- NFPA 13:2022, Standard for the Installation of Sprinkler Systems [21]
- NFPA 24:2022, *Standard for Installation of Private Fire Service Mains and Their Appurtenances* [22]
- NFPA 68:2023, *Standard on Explosion Protection by Deflagration Venting* [23]
- NFPA 69:2024, *Standard on Explosion Prevention Systems* [24]
- NFPA 70:2023, *National Electrical Code* [25]
- NFPA 72:2025, National Fire Alarm and Signaling Code [26]
- NFPA 101:2024*, Life Safety Code* [27]
- NFPA 855:2023, Standard for the Installation of Stationary Energy Storage Systems [28]
- NFPA 1144:2018, *Standard for Reducing Structure Ignition Hazards from Wildland Fire* [29]
- NFPA 1710:2020, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments* [30]

Alternate Approaches, Exemptions, Equivalencies, Variances and Interpretation/Clarifications

Alternate approaches to code compliance are available when strict compliance cannot be achieved and as approved by San Diego County AHJ. The San Diego County Fire Department Administration provides the requirements for the preparation and submittal of exemptions, equivalencies, and documentation for approval. Equivalencies and exemptions written to seek relief from the San Diego County AHJ directives and industry codes and standards can be approved by AHJ.

Emergency Response Time

The estimated response times to respond to fires and for emergency medical personnel to respond onscene cannot always meet the designated emergency response times and deployment objectives in National Fire Protection Association (NFPA) 1710, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*, for the Burke County Fire Department due to limiting factors including: the current number of fire stations, the locations of the fire stations on the Project Site, and the number of response personnel [30].

Also, there is not a fire station on the Project Site that can execute a full first alarm assignment at a fire suppression incident or medical incident within the NFPA 1710 designated response time objectives. Accounting for Project Site Facility location and design features includes the reliability and prevalence of fire detection alarms and suppression systems; the effectiveness of existing fire prevention programs; the Burke County low fire loss history; and the trained workforce extended first alarm response times may need to be considered.

As indicated above, Fire Support is assumed to be provided by the San Diego Fire Authority Boulevard Fire Station #47, 39223 CA-94, Boulevard, CA 91905 to Starlight Project Site (~1.1 miles). Alternatively, the distance from CAL FIRE White Star Fire Station, 1684 Tierra Del Sol Rd, Boulevard, CA 91905 to the Starlight site (4 miles). These stations are assumed to be the primary responder to a fire or emergency at the project site; however, in the event of a major fire, other resources would be called on to respond, as necessary as defined in the San Diego County Mutual Aid Agreement [31].

In the absence specific San Diego County delineation of the Code of References, it is assumed the National Fire Code set forth by the National Fire Protection Association and the San Diego County Ordinance Code to regulate fire safety.

Inherent Hazards

The current mission of Empire II, LLC Starlight Solar Project BESS Project is dynamic grid support through energy storage. Current work activities conducting construction and commissioning as well as routine facility surveillance and maintenance. Hazards inherent to the current primary mission energy storage are typical industrial hazards involving the use of mechanical and electrical equipment.

The inherent hazards associated with the use of lithium-ion battery energy storage present the primary hazards and include:

- Generation of flammable gases upon system degradation
- Deflagration
- Explosion
- Fire
- Electrical Shock
- Electrical Arc Flash

Hazardous Material Categorization

NFPA 1, *Fire Code*, and the International Fire Code (CFC) require that all hazardous materials present in a facility be categorized in accordance with fire code requirements. There are two threshold quantities defined in NFPA 1/CFC. The first level is referred to as “permit amount”, which is the quantity of hazardous materials for which a permit is needed in order to use, store or handle in quantities which exceed this value.

The upper threshold per NFPA 1/CFC is the Maximum Allowable Quantity (MAQ which if exceeded could require significant facility upgrades, fire system design requirements and other compensatory measures. For the Starlight Solar Project, the Lithium Iron Phosphate (LRP) is the only hazardous material identified to be present in the facility that could require regulation under NFPA 1/CFC. Any additional hazardous materials will require additional analyses [32, 33].

During construction, operation and maintenance, and decommissioning of the Starlight Solar Project, hazardous materials, such as petroleum products and maintenance chemicals, would be brought to and used on the Project site. Numerous federal, state, and local regulations exist that require strict adherence to specific guidelines regarding the use, transportation, and disposal of hazardous materials. Regulations that would be required of those transporting, using or disposing of hazardous materials will have to be complied with.

The primary hazards associated with LFP batteries are overheating, generation of flammable gases during degradation, and fire caused by thermal runaway. Thermal runaway is a temperature-triggered process that produces heat faster than the battery can cool, thus leading to temperature increases that can eventually lead to a fire. The release of lithium in the Starlight Solar BESS battery packs is unlikely due to the rigorous construction of the packs and regulations such as UL1642, UL1973, UL9540/9540A, and NFPA 855 safety standards [7, 34-37].

LFP batteries include a stable cathode chemistry that substantially reduces the possibility of thermal runaway and provides for a reduced reaction from any sort of abuse such as short-circuiting, overcharging, introduction of nails, or being crushed. In addition, the Starlight Solar battery storage system includes the following monitoring and safety components:

- Modular battery racks designed for monitoring and safety
- Integrated heat and fire detection
- Explosive gas monitoring
- Exhaust/ventilation systems
- Integrated air conditioning system
- Integrated battery management system

Critical information from the battery system and inverters would be monitored by the battery monitoring system inside the containers, at the metering at the inverter cabinets and at the SCADA/Energy Storage Management System (ESMS) control system. The battery management system within each container would track the performance, voltage and current, and state of charge of the batteries. The system would proactively search for changes in performance that could indicate impending battery cell failure, and power down and isolate those battery strings.

The Starlight Solar BESS Project should not include any other on-site storage, use, or transport of hazardous materials as a part of normal operations in quantities equal to or greater than 55 gallons, 500 pounds, or 200 cubic feet of substances classified as hazardous materials. All storage, handling, transport, emission, and disposal of hazardous substances shall be in full compliance with federal, state, and local regulations.

Battery Energy Storage System Fire and Heat Hazard

Based on our research, and the subsequent numerical analysis, we have determined there is not an increased probability that with unmitigated thermal and electrical abuse an exothermic reaction and thermal runaway could occur for a theoretical International based stationary energy storage system utilizing the OEM *BESS*. The calculated radiation and convection heat flux values were extrapolated from the BESS ESS Large Scale Fire Test Report. This Fire Risk Assessment is intended to represent the typical heat flux associated with a standard installation; it is not representative of all installations. Therefore, specific fire risk assessments are required for each installation associated with the ESS [18].

While unlikely, the bounding design basis accident assumes all uncertified Safety protection measures are assumed to fail or fail to operate upon demand. In the event and to characterize the container level risks, it is assumed the embedded design features associated with controlling the potential failure of the OEM 280 Ah LFP cells within each module will not be able to support an uncontrolled, unmitigated cascading exothermic reactions and thermal runaway consuming the contents of the container[15-17]. The analysis is based on the UL9540A Module Level Test is assumed. The calculated peak heat release rate of a fully engaged OEM BESS due to the ignition of the flammable gases is approximately 16.4 MW as function of the percentage of lithium consumed during a fire event [18]

The corresponding temperature of the internal compartmental gas layer due to the natural convection flow rates within the energy segment may reach approximately 910K (637 ^{o}C) after 3000 seconds (50 minutes). Due to internal gas temperatures and sustained degradation of the OEM battery Modules, the average internal wall temperature will approximately be 893K (620^{o}C). Due to the natural physics of the internal upper heated gas layer of a compartmental fire, it is assumed the upper 30% of the container is the primary radiated heat source. The theoretical centerline temperature of the associated smoke plume could reach approximately 917K (644^{o}C) at a height of 11 meters [18].

In this theoretical scenario, the worst case theoretical total radiant and convection heat flux on the target adjacent BESS located 10 feet across the passageway, assuming the peak wind velocity (1.92 m/s, 4.3 mph) based on local wind rose data will be approximately 12.2 kW/m^2 [18]

While very unlikely based on the global ESS market sector of cascading fires between adjacent containerized battery energy storage systems, if a design basis fire event is realized and is unnoticed and unmitigated, an adjacent *ESS* Thermal Management System should be able to control the internal environment but could eventually shutdown when internal temperatures exceed pre-established setpoints (typically 90^{o}F/32 ^{o}C). Once the internal thermal management is no longer in operation, the heat transfer from the adjacent fully developed container fire could, as a function of the fire lifecycle and thermal insulation degradation, could exceed the thermal stability thresholds of the adjacent racks [38]. In the bounding scenario, and based on the best available information, the internal temperatures of the immediately adjacent BESS could experience a 160 ^{o}C increase [18].

Fire Hazards

Burning fuel packages can adversely impact the Starlight Solar BESS structures in a number of ways. Relevant controls that are in place or those that should be implemented are identified in the appropriate discussions below. Damage Potential uses the information presented in this section as a basis to assess damage potential for candidate maximum possible fire loss (MPFL) and maximum credible fire loss (MCFL) scenarios. The FRA identifies and evaluates a variety of potential fire hazardous conditions present in Starlight Solar BESS Project Site.

The fire hazards described are categorized as either general fire hazards or specific fire hazards. General hazards are those that are expected to be present at varying locations throughout any operating facility in support of the operations. Specific fire hazards are those unique to a facility or those that require a special analysis to address the threat to a particular component or area of a facility.

Acceptance Criteria and Analysis Methods

The development of facility-specific fire scenario acceptance criteria is critical to effective analysis of fire hazards in an energy storage facility. The fire scenarios identified for the Starlight Solar BOP Project Site were analyzed to determine if any of the following acceptance criteria are not met. While this section focuses on specialized acceptance criteria to be utilized in the various fire analyses in this FRA, there are two global criteria that are always applicable:

1. The first is compliance with applicable prescriptive codes (e.g., IBC, CFC, NFPA 1 etc.). Compliance with the applicable prescriptive codes for all facilities is also assessed in the Fire Protection Assessments.
2. The second is compliance with San Diego County Fire Department risk management requirements.

Deflagration Potential

The [TBD] deflagration potential analysis of the OEM BESS is presented in [TBD].

The Computational Fluid Dynamics model of the theoretical BESS that includes two 500 cfm fans, a 1500 cmh HVAC system, as well as a Li-ion Tamer gas detection system. Assuming that the fan and louvers are operational within 12 seconds of thermal runaway and assuming that the fan system can provide 1000 cfm, the system can maintain gas concentrations lower than 25% LFL to meet NFPA 69 8.3.1 requirements.

This analysis covers the performance of the system. Other requirements to comply with NFPA 69 such as inspections, maintenance, and reliability were not evaluated. This conclusion is based on the test data provided. It is possible that even when keeping the average flammable gas concentration below 25% LFL, there may be flammable pockets of gas that could ignite and cause a partial volume deflagration. The evaluation of partial volume deflagration hazards is beyond the scope of this analysis.

It is recommended that the Li-ion Tamer/fan exhaust system response time be tested when it is available to verify that the response time is less than 12 seconds. This would help to ensure the system behaves as well as what was modeled. It is also recommended that the flow rate of the fan system be tested to ensure that it achieves at least 500 cfm per fan when installed in the system. Finally, it is recommended that manufacturers, owners, and operators adhere to NFPA 69 Chapter 15 guidelines to meet other NFPA 69 requirements for documentation, commissioning, inspections, and maintenance.

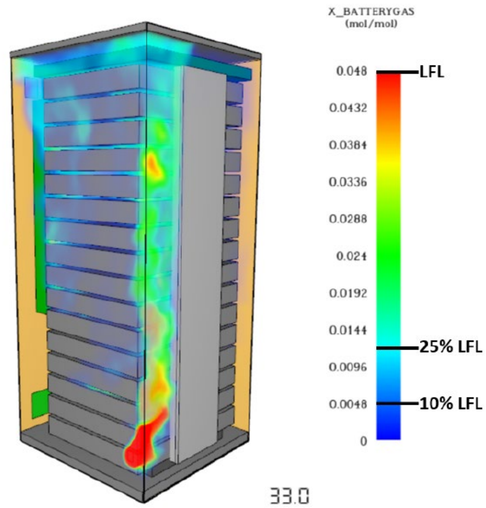

Figure 7; 30 Second Generation of Flammable Gas within the OEM BESS

General Fire Hazards

Combustible Control Program

Because the Starlight Solar BESS Project Site does not have sprinkler systems, it is recommended a strong combustible control program is implemented to mitigate the accumulation of fuels. The overall fire protection strategy should rely on control of combustibles as a key part of the overall risk management strategy.

Fire Involving a Miscellaneous Transient Fuel Package

Miscellaneous combustible materials include trash bags, wood packaging and pallets, personnel protective equipment (e.g., general combustible materials, plastic wrapping and other miscellaneous combustible fuel packages). These fuel packages could be located throughout the Starlight Solar BESS Project Site and could act as fuel for an external BESS fire event. This section evaluates the heat release rate that could occur from the selected fuel packages and provides separation distances between different fuel packages, container structural steel, and equipment to prevent multiple/cascading ignitions, structural failure, and failure of the safety equipment. The fuel packages considered in this section are considered typical for the construction, operation, and maintenance of a BESS site. Others may be found in the areas considered but are expected to be bound by those presented here.

Trash Bag Fires

A trash bag fire is assumed to burn with a unit heat release rate of 400 kW/m2, the maximum observed heat release rate from mail bags and cotton bags (NFPA 72 *National Fire Alarm Code* and NBSIR 79-1910, *Purely Buoyant Diffusion Flames: Some Experimental Results, Final Report*). It was also assumed that a typical trash bag would have a maximum floor area of 0.78 m^2, which corresponds to a bag diameter of 1 m. The peak heat release rate, (kW), was calculated using the following equation:

$$\dot{Q}_p = A_f \dot{q}'$$

Where
A_f is the floor area
$\dot{q}'$ is the unit heat release rate

The resulting maximum heat release rate expected from a trash bag is 310 kW (2.9 Btu/s). The fire duration was estimated using the following equation:

$$t_d = \frac{M_t \Delta H_c}{\dot{Q}_p}$$

The heat of combustion is assumed to be a mass average assuming the trash was 50 percent cellulosic and 50 percent plastic, which is 21,000 kJ/kg. Assuming that a single trash bag would not exceed 22.8 kg, the total duration of the trash bag fire would be 1,540 s. The continuous flame height was calculated using the following equation (Beyler, 1986):

$$F_h = 0.11\dot{Q}_p^{0.4}$$

where:
F_h is the flame height (m).

The flame height for a single trash bag fire would be 1.1 m, which is too low to expose the Starlight Solar BESS Containers to temperatures high enough to cause structural failure. However, it is recommended separation distances should be maintained. Fuel package separation requirements are determined at the end of this section. The smoke layer effects to the facility of a trash fire are predicted to be minimal.

Wood Packaging (Plywood Shipping Crate/Pallet Fires)

This section is retained to bound potential fires involving miscellaneous wood shipping crates, pallets, trash bags or similar items that may be present adjacent to the Starlight Solar BESS Container. A plywood crate fire was evaluated assuming that a typical plywood crate measures 1.2 m by 1.2 m by 2.4 m. The plywood was also assumed to be 0.019 m-thick. The peak heat release rate was calculated using the following equation:

$$\dot{Q}_p = A_f \dot{q}''$$

As is the exposed surface area (m^2) and the unit heat release rate for plywood was conservatively assumed to be 250 kW/m^2 [5].

Using the assumed dimensions of a single plywood crate and the equation above, the peak heat release rate from a single burning plywood crate was predicted to be 2,600 kW. Using the equations above, the fire duration was estimated to be 975 s. The total mass of plywood in a crate was determined to be 170 kg assuming a wood density of 640 kg/m^3 and a heat of combustion of 14,000 kJ/kg [39]. The flame height was calculated to be 2.6 m.

The smoke layer effects of a plywood crate fire are predicted to be minimal in the areas adjacent to the BESS Containers. The amount and duration of the heat released cannot cause the internal temperature of the BESS to reach auto-thermal runaway temperatures.

Plastic Wrap Fires

A fire in a single roll of plastic wrap material was evaluated assuming that the wrap material was polyethylene. Plastic wrap material is assumed to be used throughout the facility for routine operations and maintenance. Typical rolls are 0.15m in diameter and are about 1.2m long. The fire development in the rolls was determined by assuming that all the material would melt then ignite. This result was compared to the heat release rate calculated if no material melted and the surface area of the roll was used. Because the plastic probably would melt to an extent that would depend on the exposed surface area of the roll, the calculated heat release rate curves should be bounding.

The peak heat release rate for the plastic wrap fire was calculated. The heat release rate per unit area for fire retardant polyethylene is 416 kW/m^2 [40]. The depth of the pool was assumed to be 0.0064 m because this would bound in terms of heat release rate while providing sufficient duration to expose steel and combustibles. The surface area of the pool was determined using the following equation:

$$A_f = \frac{\pi D_r^2 L_4}{4\delta_p}$$

where:
Dr is the diameter of the roll of plastic wrap (m),
Lr is the length of the roll (m), and
δ_p is the depth of the pool (0.00064 m).

The Pool Surface Area was thus calculated to be 4.0 m^2 and the resulting peak heat release rate would be 1,670 kW. The fire duration was calculated to be 600 s, assuming a density of 951.5 kg/m^3 and a heat of combustion of 46,400 kJ/kg. The flame height from this size fire was determined to be 2.1 m. The flame height is below the elevation of the structural steel and would not cause it to fail.

The peak heat release rate assuming that none of the material pools is based on the surface area of the roll only. For a 0.15 m diameter roll that is 1.2 m long, the surface area is 1.9 m^2. The resulting peak heat release rate would be 790 kW and the fire duration would be 1,350 s. The actual peak heat release rate is expected to be between 790 kW and 1,670 kW. To be conservative, all separation calculations were based on the larger fire.

External Fire

A fire external to the Starlight Solar BESS Project, such as a range fire, ignition of windblown vegetation, or a vehicle fire, has the potential to interrupt normal operations and cause a site or area evacuation. Vegetation control is recommended within the BESS Area Fence line to establish adequate defensible space.

The smoke from a local range fire could enter the BESS and inadvertently create false-positive confirmatory signals of the internal smoke detection sensors. Compensatory measures may have to be considered.

Miscellaneous Combustibles

It is anticipated that routine operations and maintenance activities will require the use of miscellaneous combustible items, not individually or collectively considered fuel packages by this FRA. These items include tape rolls, paper pads, spare latex, nitrile and leather gloves, notebooks, three-ring binders of procedures, etc. Limiting these supplies to specific quantities with specific separation distances from each other or to other targets is not realistic. That being said, it is expected that the principles of as low as reasonably achievable (ALARA) be considered to limit the accumulation of these materials in the Project Site. Control of these items through the principles of ALARA will ensure that the potential fire hazards associated with these materials are bound by the various specific fuel package analyses provided in the FRA and will not pose additional unanalyzed threats to the safe operations processes or BESS structures.

Direct Exposure to BESS Structural Integrity

A temperature of 538°C is typically used as a basis for maximum allowable temperatures in fire-safe steel design, (e.g., as in the ASTM E-119), criteria for the maximum acceptable steel temperature. These latter criteria include the requirements that the average temperature of a fire-exposed section of a steel structure during an ASTM E-119 test evaluation never exceeds 538°C, and that the temperature at a single point never exceeds 649°C (ASTM E-119).

The ASTM E-119 criteria are less severe for wall/roof/floor assemblies, i.e., never exceed 593°C for average temperatures and 704°C for single points. (AISC 1978, *Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings* limits the maximum permissible design stress of structural steel to approximately 60 percent of the room temperature yield strength). At 538°C, the yield strength of structural steel is reduced to approximately 60 percent of the value at normal room temperature.

A sustained pool fire from a spilled or leaking (without a berm) source of a flammable or combustible liquid could be assumed to completely surround and engulf one container. Near the base of such a pool fire, the external floor and wall surfaces would be exposed directly to the part of the pool fire environment with the highest temperature, the continuous flaming region, where temperatures as a function of elevation/time are relatively uniform at approximately 1,690°F above the ambient temperature [41].

The threat from direct flame impingement of a relatively large, pool-like, burning fuel source that is immediately adjacent to and flows around the BESS Containers, but does not engulf the column is also a potential failure mechanism that may result in causing the internal temperatures of the BESS to exceed the auto-thermal runaway temperature of 200ºC.

Fuel Trucks and other Fueled Vehicles

It is envisioned that as part of ongoing operations and maintenance there will be the intermittent need for a fuel supply for the diesel-powered equipment that will need to be replenished as needed. During refueling activities, it is assumed a fuel delivery vehicle bounds the accident analysis scenario of a fuel spill or vehicle fire. The bounding fire scenario is postulated to involve the total contents of a fuel truck with a maximum capacity of 10,788 L in 3 independent fuel tanks.

Given that this bounding quantity is significantly higher than 1,500 L separation distance requirements from the containerized BESS's are required. It is recommended that all refueling activities occur externally to the BESS fence line with a limiting distance of 15.25 m.

Activities involving the use and operation of fuel delivery trucks and fueled vehicles including the use of portable engine-powered equipment and use and operation of other vehicles or equipment containing flammable and combustible liquid fuels are an integral component of activities at the Starlight Solar BESS Area.

An accident involving a fuel delivery truck in transit, or parked during refueling operations, with a resulting spill of flammable or combustible liquids, could result in an uncontained pool that is ignited. The fire could transfer to Starlight Solar BESS's and potentially increase the internal operating temperatures above the auto-thermal runaway temperature of 200ºC. Spill and ignition of flammable or combustible liquids also could contribute to the intensity of a fire from other causes (e.g., hot work, overheated equipment, electrical). To address these threats, analyses to evaluate the varying spilled fuel fire scenarios are warranted. The allowance of fuel delivery trucks and other fueled vehicles should be considered as part of the Combustible Control Program to minimize the likelihood of a fire event.

Vehicle Separation Distance

A potential fire event outside the Starlight Solar BESS Containers is a fire involving a fueled vehicle. A fire involving a fueled vehicle with less than 380 L of fuel is unlikely to have a significant impact on the BESS Container exterior walls, however for multiple parked cars, trucks, and other small vehicles that are routinely in the vicinity of the BESS Container should be permitted when a minimum parking distance from the exterior walls is enforced.

It is not anticipated that vehicles having routine access to the Starlight Solar BESS Project Site will contain more than 380 L of fuel. The minimum separation distance for vehicles containing 380 L gal or less fuel is 4 m. For vehicles having fuel capacities greater than 380 L that are needed for routine refueling of equipment or required for operations near the facility, it is recommended that all refueling activities be implemented outside of the Starlight Solar BESS fence line.

Emergency vehicles have no access restrictions.

Fuel Vehicle Spill Conclusions

This BOP FRA has analyzed fuel spills to determine the impact from fuel pool fires. The FRA concluded that direct flame impingement and thermal weakening of BESS can be minimized to acceptable levels by providing barriers to prevent migration of fuel within a 1 m area external to the BESS surfaces. Analysis of external fire exposures to the BESS exterior walls from a fuel and/or other flammable/combustible liquid spill used this conclusion to determine minimum acceptable distances for separation of fuel trucks and other vehicles or equipment from the exterior walls.

This analysis assumed a 2.54 cm depth for the spilled fuel pool. The area of an anticipated pool was determined based upon anticipated volume of the fuel(s) involved.

Separation distances were established based upon the assumed radius of a fuel spill pool plus 1 m to provide separation from exterior walls of the Starlight Solar BESS.

Controls are recommended to govern access of fuel trucks and other vehicles or equipment containing large quantities of fuels and other flammable and combustible liquids in the vicinity of the BESS Containers. The established controls are conservative and include the following:

- Vehicles with >380 be maintained outside of the Starlight Solar BESS Project fence line unless the Operations Manager documents that the controls are required to support operations or construction activities.

Chemical, Corrosive Agents, and Other Special Hazards

No routine chemical processes have been identified as part of the ongoing Starlight Solar BESS Operations. Some chemicals, such as those used for equipment maintenance, may be used occasionally. However, no chemical inventories of concern were identified for safety analysis considerations.

Process and Equipment Hazards (Special Hazards)

There is no additional special fire hazards associated with the Starlight Solar BESS Area and support facilities.

Assumptions, Fuel, Delivery Trucks and other Vehicles

Motor vehicles supporting Starlight Solar BESS activities include light, medium, and heavy-duty trucks and automobiles. The following assumptions about the operation and use of fuel trucks and fueled vehicles or equipment were identified to provide the bases for the evaluation performed for this FRA. The assumptions include the following:

- Fuel trucks transporting flammable and combustible liquids have a capacity of approximately 7,570 L of diesel fuel and approximately 3,028 L of gasoline in chassis-mounted tanks and an approximately 189 L diesel fuel tank supplying fuel to the truck itself. Fuel delivery trucks used on the Starlight Solar Site are equipped with ~45.72 m of hose. Fuel delivery truck assumes the total quantity of fuel ~10,788 L plus fuel remaining in any equipment being refueled would be available for involvement in a fire.
- Diesel fuel is classified as a Class II Combustible Liquid having a flash point ≥37.8°C, but <60 °C .
- Gasoline is classified as an NFPA Class IB Flammable Liquid having a flash point of <22.8°C and a boiling point of ≥37.8°C.
- Typically, lubricating oils and hydraulic oils are classified as NFPA Class III B Combustible Liquids having a flash point ≥93ºC. Note: Some hydraulic fluids, typically for process use, are classified as less flammable hydraulic fluids. Less flammable hydraulic fluids will burn under certain conditions, but the hazard has been reduced to an acceptable degree meeting the approval standards of FM Global.
- Motor vehicles and self-powered mobile equipment typically operate on paved and unpaved roadways around all buildings in the Starlight Solar BESS Area.
- Operation of mobile equipment (self-propelled) or engine-powered equipment (stationary, skid, or trailer-mounted) may occur at any location in the Starlight Solar BESS Container Area to support activities.
- Heavy equipment providing support at the Starlight Solar BESS Area includes cranes, loaders, backhoes, forklifts, etc. Quantities of fuel and flammable/combustible liquids vary depending on the equipment. An assumed 72.574 metric ton (80 ton) Grove Crane (Model TM 880) has an approximately 380 L diesel fuel tank with an additional approximately 1,155 L of hydraulic oil for a total of approximately 1,533 L of fuels and combustible liquids is assumed as a bounding vehicle.
- Miscellaneous fueled equipment supporting Starlight Solar BESS Area activities includes portable generators, light plants, air compressors, pumps, high-lifts, and other small engine powered construction equipment.
- A miscellaneous flammable or combustible liquid spill resulting from ≤ 19 L contained in hand-held containers under the control of one or more individuals is not within the scope

of this analysis. A fire of this nature is anticipated to have a small duration that does not inflict significant damage.

- Propane-fueled equipment may be used for handling containers or other purposes in the Starlight Solar BESS Areas. Use of propane-fueled equipment creates the possibility of propane release. A 38 L capacity propane container is a common size container used on forklifts and other industrial equipment. Propane-fueled equipment typically has tanks no larger than 151 L capacity (never filled to more than 80 percent full or 121 L).

Other Hazardous Materials

The following discussion presents the results of research conducted on the failure and subsequent combustion of BESS and provides a summary of the potential hazardous materials and toxicity of smoke plumes from a BESS fire.

Theoretical Toxic Composition of Smoke Plume

It is well documented that Lithium-ion battery fires generate intense heat and considerable amounts of gas and smoke [42-52]. Although the emission of toxic gases can be a larger threat than heat, the knowledge of such emissions is limited for large grid-connected energy storage systems. Therefore, the following discussion outlines the findings of research into peer-reviewed publications and government sources to identify the potential toxic gas constituents in a BESS fire.

The New York State Energy Research & Development Authority (NYSERDA) and Consolidated Edison, the New York City Fire Department (FDNY) and the New York City Department of Buildings (NY DOB), and DNV-GL were commissioned to address code and training updates required to accommodate deployment of energy storage in New York City. The research by NYSERDA concluded "that all batteries tested emitted toxic fumes, the toxicity is similar to a plastics fire and therefore a precedent exists"[44]. Several different manufacturer battery cells were tested and the typical gases emitted included:

- Carbon monoxide (CO)
- Hydrochloride (HCl)
- Hydrogen Fluoride (HF)
- Hydrogen Cyanide (HCN)

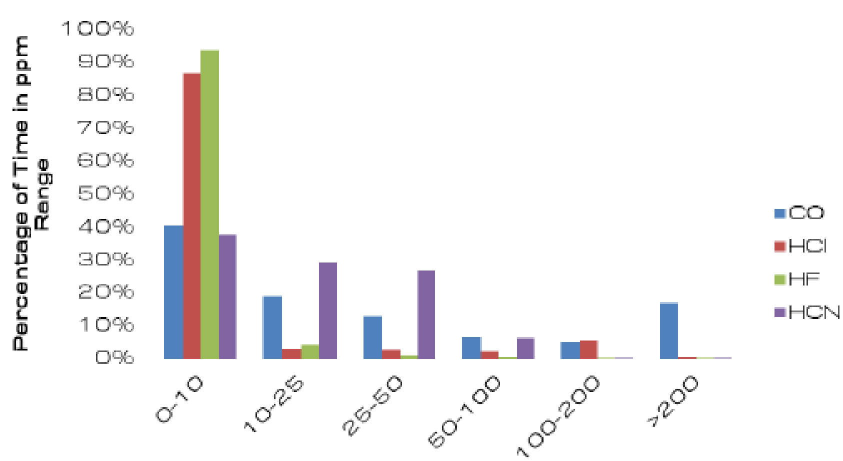

Figure 8: Representative emissions histogram from a Li-ion battery

DNV-GL concluded the "average emissions rate of a battery during a fire condition is lower per kilogram of material than a plastics fire"…."However, the peak emissions rate (during thermal runaway of a Li-ion battery, for example) is higher per kilogram of material than a plastics fire. This illustrates that a smoldering Li-ion battery on a per kilogram basis can be treated with the same precautions as something like a sofa, mattress, or office fire in terms of toxicity, but during the most intense moments of the fire (during the 2-3 minutes that cells are igniting exothermically) precautions for toxicity and ventilation should be taken. It should be noted that if Li-ion battery modules are equipped with cascading protection, the cell failure rate may be randomized and staggered. The randomized failure rate limits the toxicity and heat release rate of the fire"[44]. However, few studies have been published that report measurements of released HF amounts from commercial Li-ion battery cells during abuse and HF release during electrolyte fire tests [46, 47, 53].

Larsson et al. studied a broad range of commercial Li-ion battery cells with different chemistry, cell design and size and included large-sized automotive-classed cells, undergoing fire tests. Their objective was to evaluate fluoride gas emissions for a large variety of battery types and for various test setups. Based on their specialized results, they determined as a function of LIB design, a wide range of amounts of HF, ranging between 20 and 200 mg/Wh of nominal battery energy capacity, were detected from the burning Li-ion batteries [46, 53, 54].

Larsson determined the vented gases can contain evaporated solvents and decomposition products, e.g. CO, CO2, H2, CH4. Besides CO, a large number of different toxic compounds can be released including fluoride gases and most concerningly Hydrogen fluoride (HF). The fluorine in the cells comes from the Li-salt, e.g. LiPF6, but also from electrode binders, e.g. PVdF, electrode materials and coatings, e.g. fluorophosphates and AlF3-coated cathodes, as well as from fluorine containing additives, e.g. flame retardants [53]. PF5, POF3 and HF are of greatest concern but consideration should also be given to the fluorinated phosphoric acids since they will give HF and phosphoric acid when completely reacted with water [47].

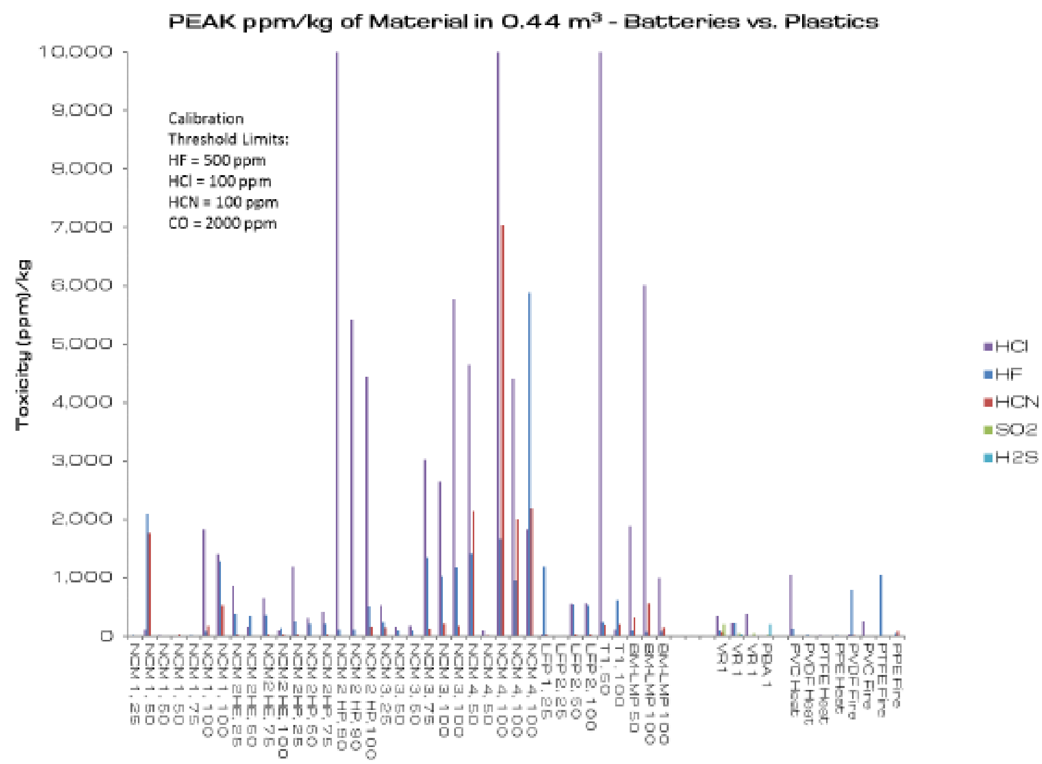

Figure 9: Peak ppm per kg (in a 0.44 m3 volume) for all batteries tested as compared to plastics [44]

The National Institute for Occupational Safety and Health (NIOSH) states that HF has a Immediately Dangerous to Life and Health (IDLH) value of 30 ppm as shown in Table 1 [55]. No exposure limits are given for Phosphorus pentafluoride (PF_5) and Phosphoryl fluoride (POF_3), however their chlorine analogues, Phosphorus pentachloride (PCl_5) and Phosphoryl chloride ($POCl_3$) have recommended exposure limits (REL) values of 0.1 ppm [55].

As it pertains to the OEM LFP OEM cells installed in the Starlight Solar BESS's, the work performed by the SP Technical Research Institute of Sweden when testing LiFePO4, lithium ion phosphate cells, determined the measured concentrations of HF were "generally quite low but well above the detection limits" [47].

The SP Technical Research Institute of Sweden concluded based on their research "POF_3 was detected in all the small-scale tests using pure electrolyte. However, no POF_3 was detected in the tests on cells. The detection limit for POF_3 was 6 ppm. Extrapolating from the small scale tests to the cells tests one ends up at concentrations below 6 ppm, which probably explains why no POF_3 was detected in these tests" [47]. "It is an important finding that POF_3 is emitted from a battery fire as this will increase the toxicity of the fire effluents. The amount of POF_3 is shown to be significant, 5-40 % of the HF emissions on a weight basis.

No PF5 could be detected in any of the tests" [47].

Table 1: NIOSH Chemical Listing for Hydrogen Fluoride (HF)

Hydrogen fluoride	Formula: HF	CAS#: 7664-39-3	RTECS#: MW7875000	IDLH: 30 ppm
Conversion: 1 ppm = 0.82 mg/m^3	DOT: 1052 125 (anhydrous); 1790 157 (solution)			
Synonyms/Trade Names: Anhydrous hydrogen fluoride; Aqueous hydrogen fluoride (i.e., Hydrofluoric acid); HF-A				
Exposure Limits: **NIOSH REL**: TWA 3 ppm (2.5 mg/m^3) C 6 ppm (5 mg/m^3) [15-minute] **OSHA PEL†**: TWA 3 ppm			Measurement Methods (see Table 1): **NIOSH** 3800, 7902, 7903, 7906 **OSHA** ID110	
Physical Description: Colorless gas or fuming liquid (below 67°F) with a strong, irritating odor. [**Note**: Shipped in cylinders.]				
Chemical & Physical Properties: **MW**: 20.0 **BP**: 67°F **Sol**: Miscible **Fl.P**: NA **IP**: 15.98 eV **RGasD**: 0.69 **Sp.Gr**: 1.00 (Liquid at 67°F) **VP**: 783 mmHg **FRZ**: -118°F **UEL**: NA **LEL**: NA Nonflammable Gas	Personal Protection/Sanitation (see Table 2): **Skin**: Prevent skin contact (liquid) **Eyes**: Prevent eye contact (liquid) **Wash skin**: When contam (liquid) **Remove**: When wet or contam (liquid) **Change**: N.R. **Provide**: Eyewash (liquid) Quick drench (liquid)	Respirator Recommendations (see Tables 3 and 4): **NIOSH/OSHA** **30 ppm**: CcrS*/PaprS*/GmFS/Sa*/ScbaF **§**: ScbaF:Pd,Pp/SaF:Pd,Pp:AScba **Escape**: GmFS/ScbaE		
	Incompatibilities and Reactivities: Metals, water or steam [**Note**: Corrosive to metals. Will attack glass and concrete.]			
Exposure Routes, Symptoms, Target Organs (see Table 5): **ER**: Inh, Abs (liquid), Ing (solution), Con **SY**: Irrit eyes, skin, nose, throat; pulm edema; eye, skin burns; rhinitis; bron; bone changes **TO**: Eyes, skin, resp sys, bones	First Aid (see Table 6): **Eye**: Irr immed (solution/liquid) **Skin**: Water flush immed (solution/liquid) **Breath**: Resp support **Swallow**: Medical attention immed (solution)			

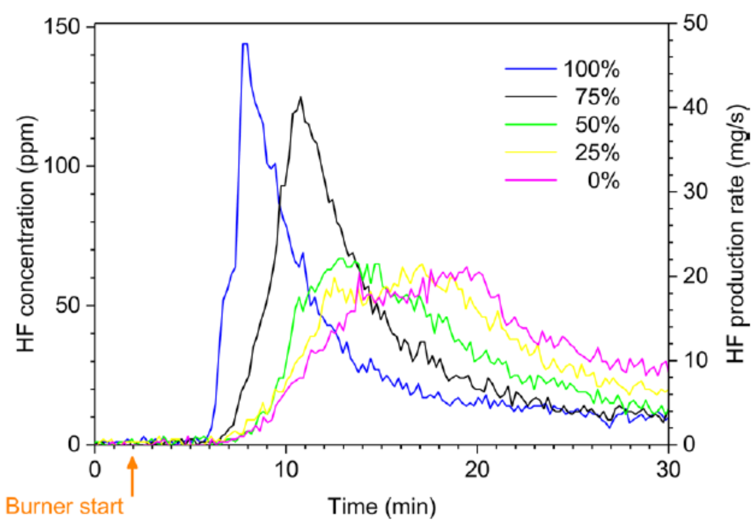

Figure 10: HF release both as the measured concentrations[46]

Lithium-Ion ESS Fire Smoke Plume Research Conclusion

Research has shown that the complex mixture of flammable and toxic gases emitted from the thermal decomposition of LIB is manufacturer and chemistry dependent. The composite breakdown of particles is a function of the size of the energy source and the inherent design chemistry that can only be estimated based on the research of others. To date, there is no readily identifiable performance data for the OEM batteries used in the OEM BESS applications. Therefore, the following list of potentially flammable and toxic gases is theoretical based on the cited works of [42-52]:

It is noted that while the DNV-GL/NYSERDA report lists only 4 emitted gases, UL9540A testing of the OEM 280 Ah batteries measured the following emitted gases:

Table 6 – Results of Gas Analysis			
Gas		Measured %	Component LFL
Carbon Monoxide	CO	11.191	10.9
Carbon Dioxide	CO_2	27.325	N/A
Hydrogen	H_2	48.013	4.0
Methane	CH_4	6.404	4.4
Acetylene	C_2H_2	0.107	2.3
Ethylene	C_2H_4	3.296	2.4
Ethane	C_2H_6	1.326	2.4
Propadiene (Allene)	C_3H_4	0.000	1.9
Propyne	C_3H_4	0.000	1.8
Propene	C_3H_6	0.948	1.8
Propane	C_3H_8	0.321	1.7
-	C4 (Total)	0.704	N/A
-	C5 (Total)	0.142	N/A
-	C6 (Total)	0.005	N/A
-	C7 (Total)	0.003	N/A
-	C8 (Total)	0.000	N/A
Benzene	C_6H_6	0.014	1.2
Toluene	C_7H_8	0.000	1.0
Dimethyl Carbonate	$C_3H_6O_3$	0.000	N/A
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.201	N/A
Diethyl Carbonate	$C_5H_{10}O_3$	0.000	N/A
Total	-	100	-

Figure 11: UL9540A Gas Constituents

Biological Hazards

No biological hazards have been identified as part of the Empire II, LLC Starlight Solar BESS Project.

Natural Hazards Having Potential Impact on Fire Safety

Earthquake

San Diego County is mot located in a low to moderate seismic and liquefaction area of the State of International with the high probability of >250 seismic events in 10,000 years resulting in damage or personal injury as shown in Figure 12.

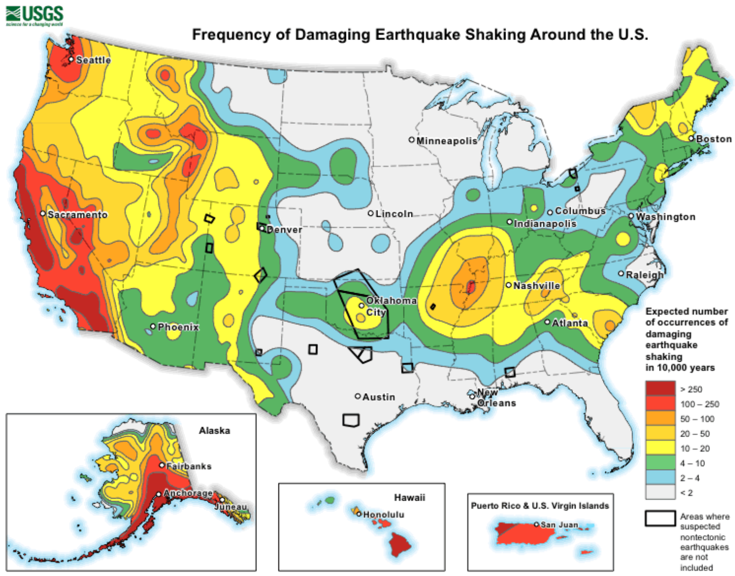

Figure 12: USGS Earthquake Hazard Map

There are no identified state-designated or United States Geological Survey (USGS) active fault on the Starlight Solar project site. The Starlight Solar BESS Project Site is approximately 10 miles west of the Fault as show in Figure 15.

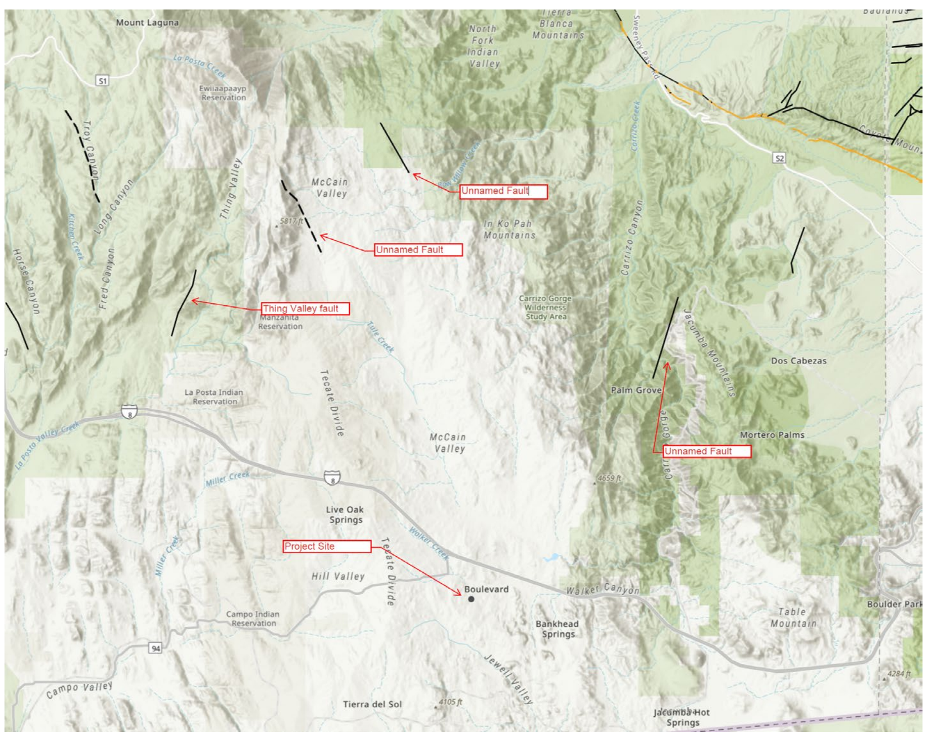

Figure 13: Mapped Faults within the Starlight Solar Project Area

Due to proximity to identified fault systems, and as classified by the USGS the project area and its vicinity is considered susceptible to seismic hazards and is classified as 4% to 20% chance of experiencing damage causing seismic events within 50 years. However, it is recommended the structural foundation of the OEM

BESS have been designed and certified by an California Professional Engineer as meeting the seismic requirements for installation.

Flood

Figure 16 presents the publicly available flood path information from the Federal Emergency Management Agency (FEMA). The Starlight Solar Project site is located in an unincorporated area San Diego County where the flood map details (FIRM Panels: 06073C2075F1) developed by FEMA. The San Diego County Flood Control Program Risk Map indicates there is presently no flood risk for the Starlight Solar Project Site.

Figure 14: Starlight Solar BESS Flood Risk

In the event there is a 500-year flooding event, there is the likelihood of flooding of the OEM BESS Containers based on the civil foundation drawings. If the design basis flood event occurs, flooding of the OEM BESS Containers would result in an electrical shock, arc flash and LFP battery cell failure.

Wind and Tornado Events

It is assumed the typical wind is represented by the Cameron National Guard Station Windrose as presented in Figure 15. Typical wind direction and velocity is primarily in the south-westerly direction which depending on the location of a BESS fire could adversely impact the recommended emergency egress routes of Construction, Operations, and Maintenance Personnel.

In the unlikely event of a battery energy storage fire, it is recommended the Incident Command be established in proximity to the Substation Control Building and Fire Control Panel.

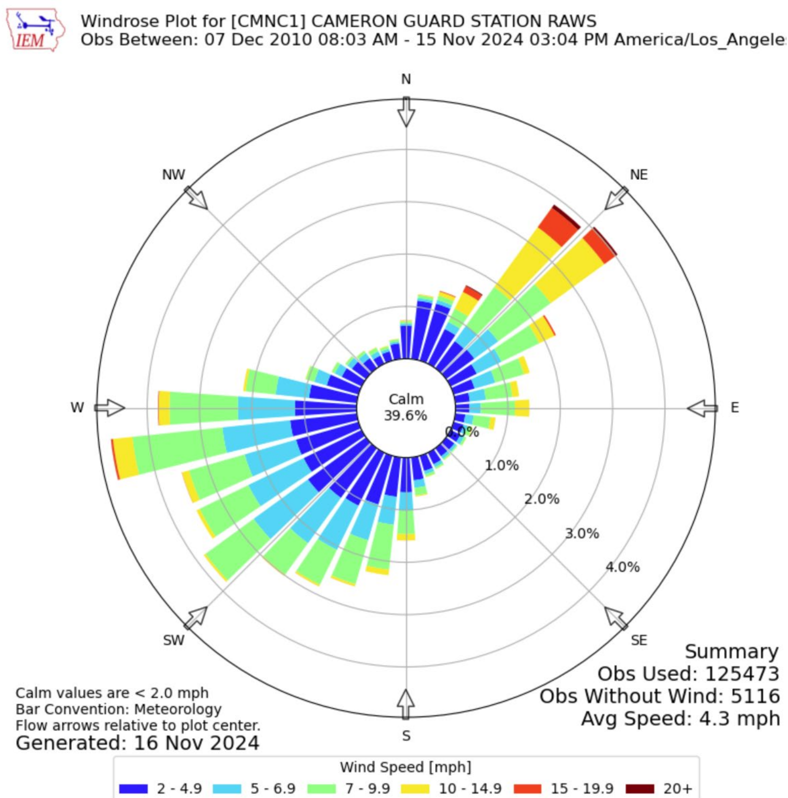

Figure 15: (ass. Typ) Cameron Guard Station Wind Rose

According to data from the National Oceanic and Atmospheric Administration, there have been 2 tornadoes within San Diego County from 1950 through 2024. While tornadoes occur on a rare occasion, there have been no recorded tornado in the proximity of the Starlight Solar Project Site.

In the event there is a greater than EF3 event, there is the likelihood of a tornado adversely impacting the safety of the OEM BESS Containers based on the civil foundation drawings.

Lightning

Under extreme fire weather conditions, the National Weather Service (NWS) issues Red Flag Warnings for all affected areas. A Red Flag Warning means that any ignition could result in large-scale damaging wildfire. The project site is located in the NWS Los Angeles/Oxnard region. Red Flag Warning criteria for the Los Angeles/Oxnard region are as follows

- Relative humidity 15 percent or less with sustained winds of 25 miles per hour (mph) or greater (for duration of eight hours or more);
- Widespread and/or significant dry lightning; and Other (forecaster discretion) - unusual but

significant meteorological and/or fuel conditions in coordination with the Geographic Area Coordination Center (GACC) or local agency. (NWS,2021).

Table 3 presents the NOAA 10-year lightning strike history in the measured area in the proximity of the Starlight Solar BESS Project Site. Figure 18 depicts the 2022 lightning strike locations closest to the Project Site. The average annual lightning strikes in the NOAA observation area are greater than 29.3 per year.

Table 2: NOAA 10 Year Lightning Strike History in the Proximity of the Starlight Solar BESS Project Site

Year	Number of Lightning Strikes at Starlight Solar BESS Project Site
2025	0
2024	24
2023	32
2022	70
2021	21
2020	4
2019	38
2018	13
2017	32
2016	7
2015	81

Each of the OEM BESS Containers are grounded in accordance with the requirements of NFPA 70, *National Electrical* Code. While unlikely to directly strike one or more of the OEM BESS Containers, review of the Empire II, LLC and Starlight Solar Project engineering drawings does not indicate the installation of lightning protection. A direct lightning strike with one of the OEM BESS Containers could result in the induction of a thermal-runaway event and cascading exothermic reactions resulting in a fire.

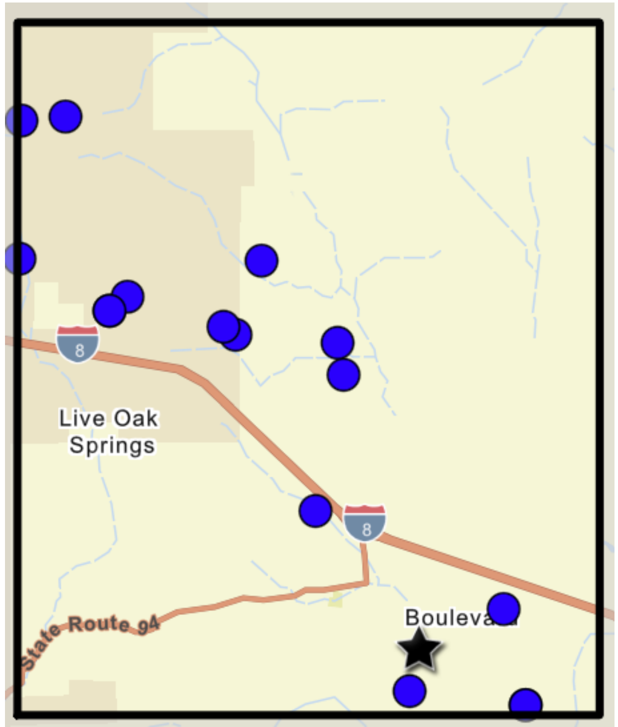

Figure 16: 15 July 2024 NOAA Electrical Storm History near Starlight Solar BESS Project Site

Wildland Fire

The Landscape-Scale Wildland Fire Risk/Hazard/Value Assessment San Diego County, California Forestry Service documents the assessment of wildland fire situations throughout the County. The Landscape-Scale Wildland Fire Risk/Hazard/Value Assessment San Diego County systematically assessing the existing levels of wildland protection services and identifying high-risk and high-value areas that are potential locations for costly and damaging wildfires. The goal of the plan is to reduce costs and losses from wildfire by protecting assets at risk through focused pre-fire management prescriptions and increasing initial attack success. Based on this assessment, preventive measures are implemented, including the creation of wildfire protection zones.

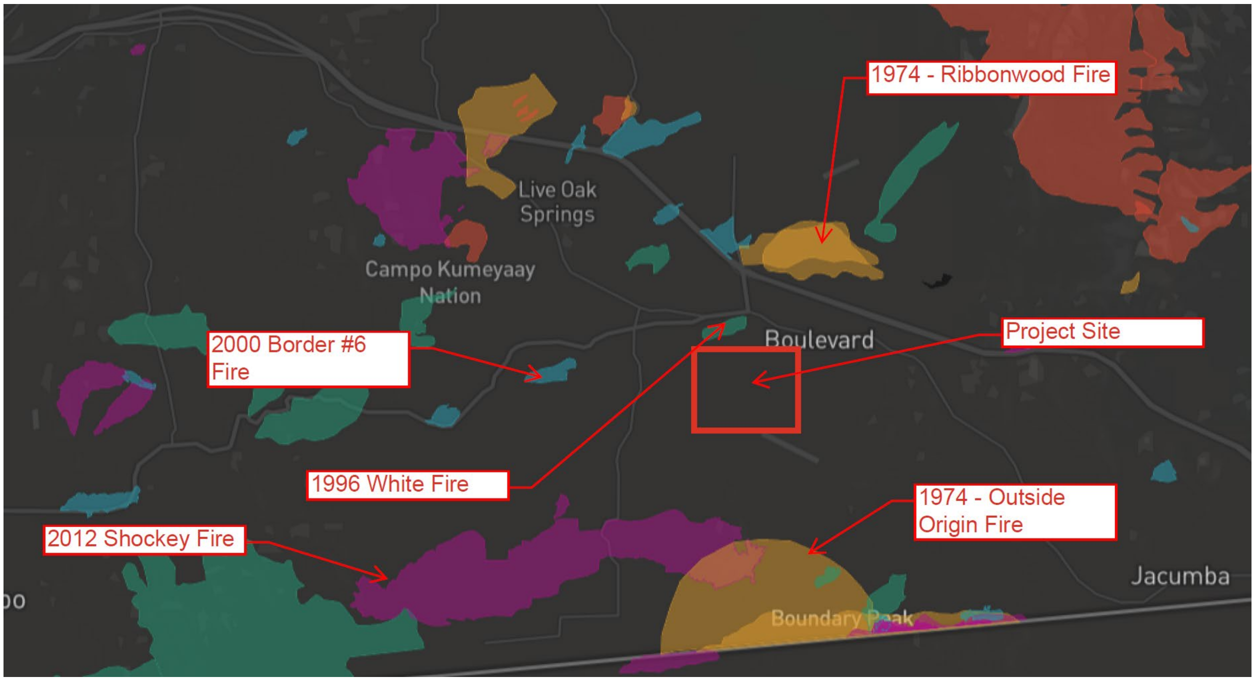

Figure 17: San Diego County CAHistorical Wildfire Map

Urban fire hazards may be influenced by a variety of factors, including building location and construction characteristics, access constraints, the storage of flammable and hazardous materials, inadequate supply of fire suppression water, and response time for fire protection personnel. Fire-related hazards in rural areas are generally the result of development within hillsides or other densely vegetated areas. Development that occurs in wildlands and wildland-urban interface (WUI) areas would be exposed to wildfire hazard. The Specific Plan Area is located within a WUI area.

As shown in Figure 6., the project site is classified as a High Wildfire Risk. The BESS Project area is protected by a permanent seven-foot-high chain fencing topped with three strands of barbed wire, for a total height of eight feet would be installed around the perimeter of each site, substations, and other areas requiring controlled access, in order to restrict public access during construction and operations. The surface within the confines of the perimeter fence line is composed of a 2" flex base and 4" of yard rock.

In the very unlikely event of a wildland fire, fire protection measures should be implemented to establish a safe state of the Starlight Solar project site. Vegetation control and maintenance is recommended to a minimum of 50' from the fence line.

Design Basis Fire Scenario

Hydrogen Explosion Hazards

The Starlight Solar BESS system contains numerous OEM BESS Containerized Battery Energy Storage Systems and are based on LFP batteries. Recent UL 9540A Cell, Module, and Unit Level performed on the LFP batteries did not result in fire, however cell-to-cell propagation was noted. Module-to-module propagation is assumed. The UL9540A tests identified the generation flammable gases containing measurable quantities of hydrogen. Deflagration analyses and flammable gas mitigation measures have also been conducted and design mitigation measures implemented.

No external hydrogen generating hazards have been identified.

Fire Protection Features

On-Site Water Supply and Distribution System

There are no planned on-site firewater sources for the Starlight Solar site.

Site Fire Hydrants

There are no known or identified fire hydrants within the Starlight Solar BESS Project Site.

External Fire Suppression

There is no external fire suppression system for the OEM BESS design.

Sprinkler System

There are no known or identified water-based sprinkler systems within the Starlight Solar BESS Project Site.

Portable Fire Extinguishers

Portable fire extinguishers should be available during routine maintenance efforts and maybe located within the Operations and Maintenance Offices.

Protective Signaling Systems

There are no known or identified proactive signaling systems within the Starlight Solar BESS Project Site.

Fire Detection and Alarm Systems

The BESS relies upon an integrated system for detection and alarm. The system was designed by OEM and is documented in the BESS drawing set. Hiller designed the external site level alarm system as shown in AW0763FC-1-1 Drawing Set.

Special Fire Protection Features

There are no known or identified special fire protection features within the Starlight Solar BESS Project Site.

Life Safety Analysis

Illumination and Marking Means of Egress

Construction of the Starlight Solar BESS Project would generally occur during daytime hours and could occur as late as 6:00 p.m. in order to meet the construction schedule. No overnight construction is assumed to occur. In the event that work is performed between dusk and 6:00 p.m., construction crews would use typical moveable “light plants” with minimal illumination in order to perform the work safely. All lighting would be directed downward and shielded to focus illumination on the desired work areas only, and to prevent light spillage onto adjacent areas. As applicable, work in the within the approved BESS construction area at night would be performed using battery or gas-powered light plants that would be directed to the active work area.

A site lighting plan is not included within the project documentation at this time. Therefore, there remains a risk to Operations and Maintenance personnel for nighttime emergency egress in the event of a fire, electrical shock or personal injury.

Analyzed Scenario Conclusions

Recommended Minimum Approach Distance

The Occupational Safety and Health Administration requires employers to establish minimum approach distance (MAD) as “the closest distance a qualified employee may approach an energized conductor or object” [56]. While directly applicable to energized circuits, the requirement of notifying employees of occupational hazards and risks and establishing both engineering and administrative controls is presented in 29CFR 1910. For the purposes of this analysis, the Minimum Approach Distance is defined as the closet distance a qualified employee may approach a known hazard.

While there are several different organizations (ACGIH, AIHA, OSHA, ISO, and NIOSH) that establish controls for hazard exposure, all require a job hazard analysis (JHA) to be conducted to identify the hazard controls. It is assumed the appropriate JHA will be performed for each scheduled task when operating and maintaining the OEM BESS energy storage systems.

Figure 21 presents the radiated heat flux as a function of distance from a fully engaged energy storage system as calculated by the BESS Level Fire Risk Assessment. Table 4 presents the physiological effects of thermal radiation and the time of exposure to extreme pain and 2nd degree burns.

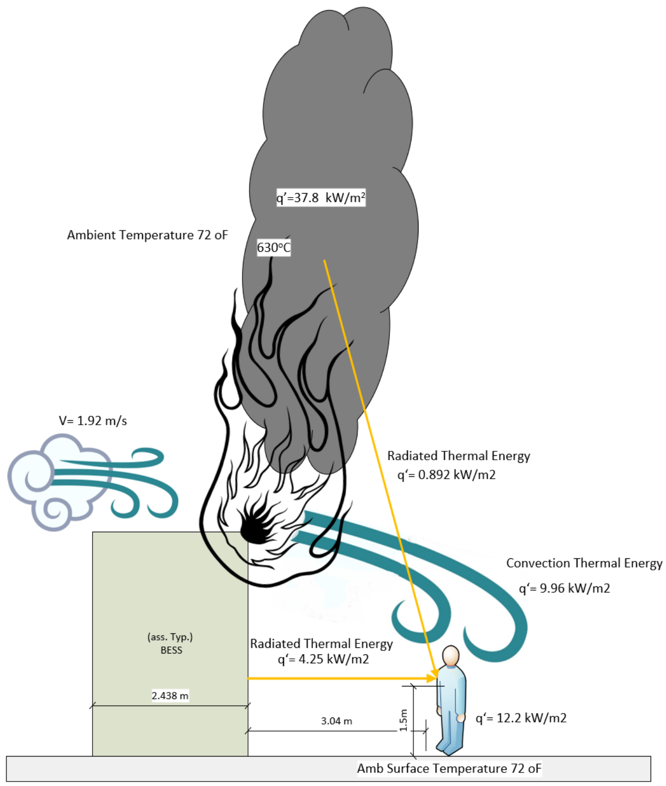

Figure 18: Maximum Theoretical Momentary Heat Flux Exposure at 3.04 m (10') at a height of 1.5m

Table 3:Physiological Effects of Thermal Radiation [78]

Time for Physiological Effects (on bare skin) to Occur Following Exposure to Specific Thermal Radiation Levels		
Radiation Intensity (kW/m2)	Time for Severe Pain (seconds)	Time for 2nd Degree Burn (seconds)
1	115	663
2	45	187
3	27	92
4	18	57
5	13	40
6	11	30
8	7	20
10	5	14
12	4	11

Therefore, it is recommended the Minimum Approach Distances for the Empire II, LLC ESS, be set at a conservative distance of 50 ft. when responding to a fire.

Scenarios

From a fire protection standpoint, the overall fire hazard of any ESS is a combination of all the combustible system components, including battery chemistry, battery format (e.g., cylindrical, prismatic, polymer pouch), battery capacity and energy density, materials of construction, and component design (e.g., battery, module). To ensure confidence in the conservative approach for this FRA, the ESS are assumed to be operating under a normal operating condition, such that proprietary electronic protection systems, e.g., battery management system (BMS), are active. It is recognized that any benefit from these proprietary systems would further reduce the overall hazard, e.g., the likelihood of ignition, but it is not necessary to ensure the adequacy of protection.

The enabling assumption of the fire scenario as a direct result of the aforementioned initiating events and based on the numerous published energy storage system fires, the calculated probability of occurrence of less than 1 %. Based on the UL9540A Cell, Module, and Unit Level Testing, and understanding the lack of propagation when heated to thermal runaway temperatures produced during a full-scale burn test, the likelihood of a sustained fire within the EMPIRE II, LLC Starlight Solar Project is reasonably less than 1%.

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