What the fire service wants you to know about your battery

Fire safety | While fire incidents involving lithium-ion batteries in energy storage systems are rare, they can have devastating consequences for the industry and pose a threat to safety. Tom Bensen, Nick Warner, Ryan Franks and Michael Bowes from energy storage and fire safety expert group Energy Safety Response Group (formerly Energy Storage Response Group) discuss some of the most important aspects of creating a safe battery storage industry.

Energy storage projects can range from a few hundred kilowatt-hours to multiple megawatt-hours in capacity. They can be located in arctic, desert, or tropical environments, in urban or rural settings and in a variety of property ownership situations from a solar development, to a utility substation, to a commercial or industrial facility. Each project has a variety of stakeholders present including potentially:

- Battery manfacturer
- Inverter, container/structure, HVAC, fire protection and other component manufacturers
- Engineering, procurement and construction (EPC) firm
- Authority Having Jurisdiction (AHJ), including permitting and inspection agencies
- Financiers, insurance entities and law firms
- Other professional advisory services (fire protection, communications, environmental services)

As a project is proposed, conceptualised and built, one entity is often overlooked – fire departments. While the circumstances and details surrounding an energy storage project can vary greatly, each one needs buy-in from first responders and public safety agencies. Energy storage projects have experienced opposition at public hearings, missed timelines, cost overruns and unrealised revenue from delayed operations in recent years. One remedy to these issues is engaging with the fire department from the outset.

It is Energy Safety Response Group's experience that forthright engagement with the fire department providing response for any planned energy storage system (ESS) instills a high level of goodwill between the fire professionals and the project team, eases friction at public hearings, and speeds up project deployment.

Credit: ESRG

All images show burn testing at ESRG's facilities.

Each of the stakeholders named above has a role and responsibility in the development of an energy storage system. The fire department does as well - it should be an integral member of the project team. Engagement with a fire department starts by understanding their concerns and addressing them and culminates in development of an emergency response plan and training. None of the stakeholders wishes an incident to occur in an ESS, but should one occur, the fire department wants you to know and explain certain pieces of information about the site, your system, and its operation.

Concerns of the fire department and how to address them

Energy storage is a relatively new technology to fire departments across the US. While different fire departments have differing levels of exposure to battery energy storage systems (or BESS for short), the primary concern of each is the same: the safety and well-being of their first responders.

Departments and local officials are, however, becoming increasingly aware of the hazards associated with battery storage and it is important that their concerns be properly addressed. Addressing these concerns in a complete and transparent manner has been seen not only to promote overall first responder safety but also to ensure project success. Perhaps the most defining characteristic of lithium-ion battery failures is a state known as "thermal runaway," in which a battery cell experiences uncontrollable overheating, often accompanied by the release of large quantities of flammable off-gases. Thermal propagation from the failing cell may lead to incipient thermal runaway of adjacent cells, thus creating a cascading failure across the system, resulting in tremendous amounts of heat and gas.

When these gases are allowed to accumulate in an enclosed space (such as a BESS container), an explosive atmosphere may develop, which, given an ignition source, may lead to a devastating deflagration (explosion) event. This blast wave can cause damage to nearby buildings and structures, as well as first responders who may be arriving on the scene, as was seen in the incident that unfolded in Arizona in 2019.

Deep-seated fires are also common in lithium-ion failure events. These fires are not easily extinguished and may continue for hours, fuelled by heat and gas from cascading cell failures. Even if suppressed by water, stranded energy within the cells often causes reignitions, thus perpetuating the event.

Concerns based on environmental risks are also often cited by fire departments across the country. Large quantities of smoke and gas are often released during battery fires, with high levels of carbon monoxide and hydrogen cyanide measured on-site in Arizona at the time of the incident. Contaminated runoff water may also affect the surrounding area. Electrical hazards also exist during and after battery failure events and should not be overlooked.

Industry is introducing measures to mitigate effects of battery failures

As the hazards associated with battery failures, such as those mentioned above, continue to be researched and more well understood, more effective protective measures are being utilised by industry to mitigate their effects. For instance, battery management systems (BMS), which can be thought of as the "brain" of the energy storage system, are becoming increasingly robust, providing granular thermal and electrical measurements at the cell level, as well as providing more effective system responses to abnormal battery conditions.

Even if suppressed by water, stranded energy within lithium battery cells can causes reignitions.

Deflagration vent panels are also emerging as a common solution for mitigating the effects of blast waves emanating from battery enclosures. These vent panels, which act as pressure relief points in the container, are used to direct the blast away from first responders and are thus often found on the roofs of the battery enclosures. Ideally, however, explosive atmospheres are never allowed to develop within an enclosure.

Exhaust systems, while less commonly utilised, are also finding use by battery system integrators to release flammable gases from the container before explosive limits are reached.

Gas-phase suppression systems such as Novec 1230, FM-200, inert gas or aerosolised gas-based agent have often been included in battery system enclosures to suppress electrical fires which may spread to nearby battery modules. It is important to note, however, that these types of systems are not effective for the extinguishment of battery-related fires, nor will they directly prevent thermal runaway from occurring. To date, water-based extinguishing methods remain the most effective means of providing thermal cooling to battery fires and preventing thermal propagation to adjacent units.

Smoke and gas detectors are widely employed by battery systems and depending on various factors may be effective in identifying an incipient failure event, though they have not proven to be reliable for extracting critical real-time data after an event has occurred. New detection technologies designed specifically for lithium-ion off-gases, however, are beginning to emerge, though are still in relatively adolescent stages of production and have not yet seen widespread adoption within the industry.

Credit: ESRG

The shift towards safety

Recent incidents involving lithium-ion battery storage, such as those in Arizona, South Korea and the UK, have gained the attention of industry, fire departments and code officials worldwide and have led to a noticeable shift towards safety within the industry. Fire departments across the US are beginning to look to recently developed codes and standards for the safe installation of energy storage systems.

For example, a chapter solely dedicated to energy storage was added in the 2018 edition of the International Fire Code (IFC), which is adopted by many states. The upcoming 2021 edition of the IFC contains the most robust ESS requirements. Additionally, the National Fire Protection Association (NFPA) has recently developed its own Standard for the Installation of Stationary Energy Storage Systems – NFPA 855 – which local jurisdictions across the country have begun pointing to for BESS deployment.

Updated requirements around energy storage have recently been adopted by California Fire Code (CFC) and New York State – both based on updated Sections 1206 of the International Fire Code. New York City, known for its historically conservative stance with regards to the permitting of battery storage, has played a particularly substantial role in the development of BESS requirements, having led many of the early conversations around safety.

To account for the densely-populated urban landscape unique to New York City, and to ensure the safety of its firefighters, the NYC Fire Department (FDNY) created its own set of requirements – 3RCNY 608-081: Outdoor Stationary Storage Battery Systems – published in October 2019.

In the US, UL 9540 battery safety certification is also becoming widely adopted by code officials, as is large-scale fire testing per UL 9540A. Test data from UL 9540A – a destructive battery test method conducted to determine properties of batteries undergoing thermal runaway – can be used to substantiate safety claims by battery manufacturers and integrators and is required by IFC and NFPA 855 when increasing maximum allowable quantities of storage or decreasing separation distances between units. UL 9540A has also found adoption by the NYC FDNY and Department of Buildings (DOB), who require testing be conducted for all lithium-ion battery systems looking to be installed in New York City.

Developing an Emergency Response Plan

Only recently have best practices around emergency response planning and firefighting tactics for battery storage systems begun emerging, guided largely by a deeper understanding of the dangers of BESS failures gained through research and recent battery incidents. Site-specific emergency response plans and comprehensive first responder training programs are quickly becoming the norm. Defensive firefighting tactics are also becoming more widely encouraged, as it has been seen that direct intervention with systems may have catastrophic consequences and in many cases may prove less effective than simply protecting the surrounding area and letting the system burn to completion.

Proper fire department training and more transparent communication by industry members have led not only to increased safety and awareness of the hazards associated with energy storage systems, but also led to the development of deeper relationships between parties. Trust building is an under-appreciated component of the project development process and is often overlooked by eager developers and battery companies. It is imperative that local fire departments and agencies, regardless of their size, are assured that their safety is the number one priority; in general, project success is quickly seen to follow.

The successful management of an incident begins long before any actual incident begins, including the reduction in risk and safety to human lives, property and environmental impact. This process should be started at the early stages of facility design and construction and be a continuation throughout its life span with an Emergency Response Plan (ERP). The emergency response plan is too often a document that is viewed as a box-checking document or is inadequate. Too often, entities ask that the emergency response plan be completed prior to the selection of the site, container type, fire protection/detection system or even batteries being utilised.

Credit: ESRG

UL 9540 A test data can be used to substantiate safety claims by battery manufacturers and integrators.

Throwing together an emergency response plan at a preliminary stage is setting up for failure and, frankly, a liability if an incident were to happen as there is no way the true hazards can be taken into consideration. If something goes amiss during an incident, the emergency response plan and implementation of the plan will be criticised. Some items that shall be contained are listed in Chapter 4 of NFPA 855 as well as 1910.38 (OSHA Emergency Action Plans). Considerations that should be covered with an ERP are equipment, roles, and responsibilities. Individuals should be placed into roles based on their availability and competency in the role. Many times, individuals are placed into a critical role, which they are not likely to be able to fulfil because of their normal work condition. This issue may even be more of a consideration in today's new norm of working remotely.

In short, if an individual is to meet the first responders on the scene, the individual fulfilling this role should not be located an hour away from the site location. The lack of local personnel will only leave the first responders to have to make hard decisions on their own and the basis of the rest of the ERP will be questionable in their minds. The issue of equipment in an Emergency Response Plan is often generalised, assuming either that first responders know what equipment they need or that the individuals preparing the emergency response plan do not know what equipment is needed and what the local first responders have on their apparatus.

One common mistake involving equipment specifications occurs when a statement such as "wear appropriate personal protective equipment (PPE)" is written into the plan. Such a statement begs the question to many, even in the fire service, as to what appropriate PPE is for the incident. Is proper PPE a hazmat suit, a duty uniform, or full firefighter turnout gear with self-contained breathing apparatus? The appropriate answer would be full firefighter turnout gear with self-contained breathing apparatus as a thermal event is the highest hazard that will likely be encountered. Further information should be obtained from the local public safety jurisdiction, including the availability and type of gas monitoring equipment, barriers to protect water runoff from streams, storm drains and other waterways and thermal cameras.

Information provided in an Emergency Response Plan supporting the main body of the plan may include maps of the facility which easily and readily identify key or critical features of the site. Key features may include water sources, water shuttle routes, identification of containers, safe zones, command posts, and identified hazards. Safety Data Sheets (SDS) of the material(s) shall be included at the end of the ERP. SDS aid in identifying the specific hazards of the incident relating to environmental concerns or in the event an individual sustains an exposure event. In the case of an exposure event, many times medical facilities will want to know what materials and substances the individual was potentially exposed to.

The ERP should cover types of incidents which have been identified through a detailed Hazard Mitigation Analysis (HMA). For example, appropriate consideration should be given regarding how to protect a system in a remote location where the property is bordered by trees, for example in California in relation to the threat of wildfires. However, this would not be necessarily be a valid threat in the a different location, for example in middle of the Arizona desert.

Without the complete HMA being performed, real hazards may be overlooked or missed altogether. Missing hazards may be catastrophic if and when that type of incident was to occur with not having the appropriate individuals, equipment, or plan of attack to manage the incident. The beginning stages of an Emergency Response Plan should start with having the proper competent individuals involved in the development and review of the document. These individuals should know the system being installed.

Knowing the system

Knowing the system means knowing what types of batteries are being utilised and how these batteries may react to different situations. Those situations may include overcharge, heat-related issues, or mechanical damage. Through hands-on experience with ESRG, we have had the privilege to test many different types and configurations of cells and modules.

One of the most significant learning points drawn from the experience of live fire testing is that a cell failure may not and often time does not react the same way once it is within a module. The same holds true when you take a module and place it within a rack and then racks within a container. Once you know what type of batteries are being utilised, you have to look and consider the type of container these are being placed in. Containers may look very similar with a quick glance, but oftentimes vary vastly in their design and concept. A walk-in container is vastly different from a container that only has exterior doors from a response and potential rescue standpoint.

Venting and pressure relief doors must be taken into consideration not only from the viewpoint of how the system may react but also form a life-safety standpoint as we always want responders at a safe distance but also do not want them standing in front of one of the pressure relief points or within the blast pressure wave. Many systems in the ground now do not include any type of pressure relief, meaning we must identify the weak points of the container which may become the pressure relief point. The fire protection system and how it is designed to operate must be known. A clean agent system will react drastically different from a system that would flood the interior of the container with water. The fire detection system and system monitoring (BMS/GEMS) system operations are imperative to understand. Personnel face increased risk without knowing what is being monitored, where the monitored equipment can be viewed, and how to interpret the data as this scenario leads to incompletely understanding what type of incident and the conditions within the container. The site location to include exposures, environmental concerns, access roads, the staging of response equipment, and prominent wind direction shall all be considered in the development of the emergency response plan as well.

Engage everyone involved and keep them informed

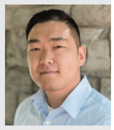
The development of the ERP shall include representatives of all entities which will be involved in an incident response at the facility. This list will include, at a minimum, representatives of the facility, the facility subject matter expert (SME) and public safety first responders (fire, law enforcement, and EMS). All these individuals shall be listed on the ERP with name, position, and phone number as well as their back-up in the event they are not available. It is critical to understand the staffing, capabilities and resources available to the first responders in the Emergency Response Plan. A large municipal public safety agency typically varies significantly in staffing, available resources, and response time from that of a rural volunteer agency. This information will affect how the public safety agency will approach incidents.

All parties should have input and be allowed to review and suggest changes to the plan. Once the ERP is reviewed and agreed upon, it should be signed off by all parties and made available to all parties for review at any time. Once the plan is finalised, that does not mean the work is done on it, however.

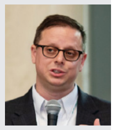
Training on the Emergency Response Plan for everyone involved must be conducted on a regular basis. Waiting until there is an incident to try to remember what the plan says under stress will not aid the situation. The ERP must be reviewed annually to see what changes may be needed. The changes could result from any of the entities that have interest in the response to the incident at the facility. The plan should be immediately amended if there is a change to the facility, operation of the system, or a change in personnel that is listed on the ERP. The plan should then be tested using either tabletop exercises or full-scale exercises which are independently evaluated and then debriefed on. These exercises will not only allow for training to make sure all parties involved understand their roles and responsibilities, but also allow for any deficiencies in the plan to be brought to light and corrected. ■

Authors

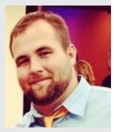
Thomas A. Bensen has been a full-time fire investigator since 2000, working both public and private fire investigations. Thomas holds a Bachelor of Science in Fire Protection Safety Engineering Technology from Oklahoma State University and has trained at the Georgia Fire Academy and the Ohio Basic Peace Officer Training Academy. Thomas also has experience as a firefighter and in law enforcement as well as with the Bureau of Alcohol, Tobacco, and Firearms. Tom has conducted numerous large-scale fire tests on lithium batteries. Tom is a current committee member of NFPA 855.



Michael Bowes holds a Bachelor of Science from Clarkson University and Data Analytics certification from Columbia University. His professional career has been concentrated in the advancement of the New York City energy storage landscape with a strong focus on battery safety and permitting. Previous roles have been at groups including the New York Power Authority (NYPA) and Sustainable CUNY of the City University of New York where he worked with stakeholders to streamline permitting of energy storage systems.



Ryan Franks graduated with a BS in Engineering Mechanics from the University of Illinois, an MBA from John Carroll University, and is the inventor on two patents. His industry experience includes serving as Global Energy Storage Business Manager at the Nationally Recognised Testing Laboratory (NRTL) CSA Group and led the development of that organisation's battery and energy storage business. Ryan has also led international and domestic standardisation projects for energy storage, microgrids, smart cities, and other strategic and emerging electrotechnical concepts at NEMA, the National Electrical Manufacturers Association, and the U.S. Green Building Council.



Nick Warner holds a holds a BS and MS in Mechanical Engineering from The Ohio State University. His professional career has focused primarily on safety topics related to battery storage integration and fire safety as well as failure analysis of energy storage systems. This includes supporting battery degradation and performance validation, failure analysis and the evaluation of materials and sensors for passive and active safety applications. Nick also works on due diligence and bankability studies, including hardware and safety reviews, and performs field inspections on ES systems and has become heavily involved in standards activities as well including all UL standards related to ESS as well as NFPA and ICC codes for fire safety and ESS deployment.