TEXAS A&M ENGINEERING
TEEX
EXTENSION SERVICE

Report from the TEEX Electric Vehicle/ Energy Storage Systems Summit

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Texas A&M Engineering Extension Service

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Introduction

Electric vehicles (EVs) and energy storage systems (ESS) are becoming increasingly prevalent in today's society. In the United States, there are approximately 2 million EVs on the road, and studies predict that by 2030, EVs will comprise 40% of new car sales. With this increase, EVs and charging stations are expanding into all areas of the country, including towns and rural areas. As of 2023, there were more than 140,000 EV charging stations across the United States, and this number will only continue to grow. Additionally, as the electric grid infrastructure ages and struggles to meet current demands, some companies have begun using solar and wind farms to harvest power, which use lithium-ion (Li-ion) batteries for energy storage. According to the U.S. Energy Information Administration, "the large amount of existing and planned solar and wind capacity in California and Texas presents a growing need for battery storage." Thus, ESS, including storage containers, warehouses, solar farms, wind farms and residential storage facilities, are expanding in urban, suburban and rural areas. As EVs, ESS and Li-ion batteries become increasingly ubiquitous, they present heightened challenges and safety concerns to first responders and public safety personnel.

In October 2023, Texas A&M Engineering Extension Service (TEEX) invited experienced professionals, policymakers and researchers to participate in a summit, during which they discussed concerns surrounding EV/ESS emergencies. TEEX identified the need for this initiative and recognized that one of the significant challenges surrounding this topic is the lack of information-sharing among experts. Therefore, TEEX hosted the summit in an effort to connect stakeholders, facilitate conversations, share resources and compile current practices to aid responders and governments. Subject matter professionals from fire, hazmat, law enforcement, city management, emergency services, technology, manufacturing, planning and code enforcement discussed regulations, facility design, response and prevention. As a thought leader in public safety training, TEEX is uniquely poised to gather experts in these fields.

Summit attendees came from agencies and organizations including the Texas A&M Transportation Institute, the Energy Security Agency, the International Association of Fire Fighters, Los Alamos National Laboratory, Shell, the Texas Commission on Fire Protection, the Texas Department of Insurance, the North Central Texas Council of Governments and the United States Department of Energy. Fire service professionals from fire departments in Houston, Frisco, San Marcos, Aldine, Arlington, Bryan, Cedar Hill, Irving, Denton, Flower Mound, Lewisville, Mesquite, Plano, Roanoke, Rockwall and Seattle participated in the summit, sharing their expertise and personal experiences with responding to EV/ESS emergencies.

The summit events included four keynote speakers with extensive experience responding to Li-ion fires, testing Li-ion batteries and developing transportation infrastructure.[1] In workshop sessions, participants discussed current field practices, shared concerns, identified gaps in knowledge and plannedways to move forward to address this evolving challenge.

Summit attendees developed best practices for local government officials and first responders. After the summit, TEEX published a list of current practices for responding to EV and ESS events for government officials and first responders. Additionally, TEEX compiled the following report, which presents summit discussion findings to aid responders and local governments in developing, implementing and improving prevention and response and establishing regulatory considerations.

[1] For more information on keynote speakers, see Appendix II at the end of this document.

Background

Purpose

The purpose of this report is to document the collaborative efforts from the October 2023 TEEX EV/ESS Summit and collect current practices to assist those responsible for EV and ESS prevention, response and policy creation.

Methodology

TEEX brought together nationally recognized experts with experience responding to and preventing Li-ion battery incidents. During the summit, experts:

1. Shared information about direct experiences responding to and testing tactics, techniques and procedures with Li-ion batteries and products.
2. Identified concerns surrounding Li-ion batteries.
3. Shared lessons learned and identified gaps in knowledge, current practices and possible solutions.
4. Collected additional information from subject matter experts.

Problem

Because Li-ion battery technology is relatively new, many first responders and policymakers have limited knowledge of and experience with Li-ion battery technology and incidents. The TEEX EV/ESS Summit identified issues and unique challenges that EV/ESS incidents pose. This section details some of those issues and additional considerations.[2]

One primary concern is the growing number and severity of EV/ESS incidents and the unique challenges they present to first responders. Summit participants described that although EVs are less likely to ignite than gas-powered and hybrid vehicles, the intense heat, high-voltage cables and hazardous materials make EV fires uniquely challenging for first responders. Moreover, there is currently no extinguishing agent that is fully effective on EV/ESS fires. Although a few products may be able to suppress small Li-ion fires, fires often reignite until stored energy dissipates.

All these issues are compounded by the increasing prevalence of Li-ion batteries. A report by the National Renewable Energy Laboratory predicts that by 2050, the energy storage capacity of the United States will grow by five-fold. Studies show that 45% of car sales in the United States could be EVs by 2035, making half of U.S. cars electric by 2050. In addition to the increases in EVs and ESS, Li-ion batteries are found in commonplace items such as laptops, phones, cameras, electric scooters, bikes, skateboards, power tools and other devices often found in homes and businesses. As Li-ion batteries are increasingly used in these devices, more items are being charged inside residences, businesses, residential garages and public parking garages, creating more potential hazards. Beyond increases in personal devices and electric vehicles using Li-ion batteries, many mass transportation fleets are converting to electric technology, increasing the

[2] For more information on how lithium-ion batteries work, see this overview by *The Conversation* or this description by UL Research Institutes.

potential size and number of incidents. As these numbers grow, so do the number of interactions between first responders and Li-ion batteries. Although some mistakenly believe that EV/ESS incidents are issues exclusive to big cities and urban areas, it has become more common to see EV/ESS incidents in small communities and on roads and highways passing through rural areas.

When responding to Li-ion incidents, first responders face additional hazards and must be aware of the unique dangers and concerns. However, in many cases, first responders do not know that incidents involve Li-ion batteries until they arrive on scene. Once on scene, they face Li-ion off-gassing and unique hazards, such as thermal runaway, electrical shock, fire, chemical exposure and structural failure. Thus, it is imperative that first responders treat each incident as one that could involve Li-ion batteries and that they are aware of the indicators of Li-ion battery fires. Summit participants identified the following as unique hazards presented by Li-ion battery fires:

- ***Thermal runaway:*** *In thermal runaway, the Li-ion battery overheats and can catch fire or explode. This can occur due to overcharging, overheating, physical damage or manufacturing defects and may result in extremely high temperatures, fire and the venting of gas or shrapnel.*

- ***Electrical shock:*** *Electric vehicles rely on high-voltage electrical systems (currently 300 to 400 volts, with 800-volt vehicles planned for future use), which pose a risk of electrical shock to occupants and first responders in the event of an accident.*

- ***Fire:*** *Battery fires may occur due to damage or defects in the battery or during charging or discharging. Li-ion battery fires are often difficult to extinguish and can reignite multiple times, as any stranded energy can cause reignition. Fires can also spread to other parts of the vehicle, storage system or surrounding areas.*

- ***Chemical exposure:*** *Li-ion batteries contain toxic chemicals and heavy metals that may harm responders, the public and the environment and pose a risk if the battery is damaged or improperly handled during maintenance or vehicle disposal. During thermal runaway and fires, flammable, explosive and toxic gases, including hydrogen, hydrogen fluoride, carbon monoxide and carbon dioxide, are released. Heavy metals, including cobalt, nickel, copper, chromium, lead, arsenic and cadmium, are also released.*

- ***Structural failure:*** *Summit participants discussed that Li-ion battery fires can burn at 3,000 to 4,000 degrees Fahrenheit, temperatures that can cause concrete and metal fatigue and failure. Structural damage or collapse are threats, especially to underpasses or parking garages.*

In addition to these physical dangers, the lack of government codes pertaining to Li-ion batteries exacerbates challenges in identifying these hazards. Many communities do not have code restrictions or signage regulations for charging systems, EV transportation or ESS sites, creating additional dangers. For example, batteries transported or stored in large quantities are not required to have specific signage other than “Hazardous,” and charging sites are not currently required to have well-labeled centralized emergency shutdown devices. Furthermore, National Fire Incident Reporting System (NFIRS) reports do not currently have an assigned reporting code.

Finally, some unique hazards and issues arise after a Li-ion battery becomes damaged. When an original manufacturer’s Li-ion batteries become damaged, users often replace them with unregulated, low-quality, incompatible batteries or charging units, increasing the risk of incident. Moreover, damaged EVs and batteries are often stored close to other vehicles in salvage yards and near other combustible materials in recycling and storage facilities. This creates additional hazards, as damaged batteries are more likely to combust.

Discussion

The following section includes current practices, recommendations and future areas of focus in preventing and responding to EV/ESS events, as identified at the summit.

Prevention: Recommendations and Future Areas of Focus

Signage, Code Enforcement and Regulations

- Identify regulations and code changes that can happen in the short term at the local or regional level. This should eventually lead to a coordinated state plan.
- The National Fire Protection Association (NFPA) and local communities should develop and enforce E-stop legislation and regulations for charging stations.
- Until specific testing and procedures are developed, follow current Occupational Safety and Health Administration (OSHA) standards regarding lockout/tagout of hazardous electricity events.
- Develop building codes and standards for EV charging and Li-ion storage in public and residential spaces.
- Establish local building codes for installing and operating charging stations, home energy systems, and the transportation, storage and disposal of Li-ion battery systems.
- Require manufacturers to consider input from subject matter experts and first responders in the EV/ESS development and design process.

Education, Training and Awareness

- Develop education and training for first responders, dispatchers and local officials about EV/ESS and their risks.
- In conjunction with first responders and elected officials, develop a comprehensive, coordinated EV/ESS public awareness campaign to educate the public about safe use, hazards and preventive actions regarding Li-ion batteries. Similarly, develop a holiday campaign warning the public about Li-ion battery hazards in toys, tools and other devices that are likely to be charged and used inside homes.
- As manufacturers research and develop new EV/ESS technologies, they should seek input from first responders and subject matter experts to address issues of concern and develop best practices for prevention and response.

Response: Current Practices

Prior to an Event

- Identify the locations of high-risk Li-ion hazards, such as ESS, solar farms, warehouses, manufacturing sites, recycling centers, large transport areas, windmill farms, wrecker yards, police impound yards, etc., and whether people typically occupy these locations.
- Ensure local law enforcement officers, paramedics and firefighters know how to identify, approach, and rescue from an EV/ESS incident. Plan and allocate proper first responder assets for EV/ESS emergencies,

including coordinating with neighboring departments.

- Be familiar with manufacturer guides and the guidance for various makes and models of EVs. Know where manual levers are for electric vehicle electronic door handles for common EVs and refer to emergency response guides for specific models.
- Develop preplan trigger points for cooling time or amount of water usage.
- Establish departmental Standard Operating Procedures and Standard Operating Guidelines for EV and Li-ion battery response.
- Establish departmental safety procedures for decontamination or disposal of gear and equipment used in Li-ion incident responses.
- Incorporate high-risk Li-ion sites into the computer-aided dispatch, such as warehouses, EV storage lots, recycling or manufacturing facilities, ESS and solar or wind energy sites.
- Develop a course of action for likely response scenarios involving Li-ion batteries.

During an Event

- Always wear full personal protective equipment (PPE) with face covering and self-contained breathing apparatus (SCBA), and establish an appropriate command structure.
- Upon arrival, assess the vehicle from a 50- to 75-foot distance and determine if an EV or internal combustion engine is involved.
- Position apparatus and teams up-wind if possible.
- When dealing with any type of fire, remove Li-ion battery devices from the area to avoid creating additional hazards.
- Never assume the vehicle is powered off. Keep key fobs and starting devices at least 25 feet from the vehicle to avoid unexpected movement of the vehicle. This may include cell phones that have remote start applications.
- When possible and safe, chock the wheels to prevent unintended movement, as EV motors are active unless disconnected.
- EV/ESS have power management systems that should shut down after impact or a crash.

  Do not reenergize these high-voltage systems.
  - If high-voltage damage is suspected, disconnect the low-voltage battery.
  - Use the vehicle response guide to find the battery package and high-voltage cable disconnect location.
- Determine the Li-ion battery's charge level and understand that a higher charge level means higher risk, a more prolonged incident and greater challenges to dissipating energy or containing a fire. Vehicle operators may have information about the vehicle's state of charge on their phones.
- Be aware that all Li-ion batteries contain common hazardous materials and heavy metals, but there may also be additional hazardous materials unique to the manufacturer.

In Case of Off-Gassing:

- Off-gassing is indicated by white smoke low to the ground.
- If a Li-ion device is off-gassing in a safe area and there are no signs of fire, contain it, monitor it and clear the surrounding area of flammables, but do not apply water, as this may short out additional cells.
- Use a thermal imaging camera to look for off-gassing and indications of thermal heating. Determine whether a thermal runaway event is occurring. Signs of this include a sweet electrical odor, visible smoke, fire, arcing or buzzing, popping or hissing sounds.

In Case of Fire:

- If a fire is present, apply water to the flames to contain the damage and cool the surrounding area. This will require a large, continuous, sustainable water supply from one or more fire hydrants or multiple tenders. Summit attendees described that past incidents have required between 3,000 and 8,000 gallons of water to contain the fire and allow energy to dissipate. However, this number depends on the battery's size, damage and charge level.
- If the vehicle is in a safe area, decide if it is best to contain the fire defensively and allow it to burn or attack it offensively.
- When attacking the vehicle fire, understand that once the contents of the fire are extinguished, sustained suppression on the battery pack may be necessary to cool the batteries.
- Expect probable secondary ignition. Damaged batteries may have stranded energy inside undamaged battery cells, which can cause multiple reignitions.

After an Event:

- Inform the towing company of hazards regarding Li-ion battery packs.
  - When moving a vehicle, there is a higher risk of battery thermal runaways, especially if the vehicle is damaged.
  - Be aware that energy is created when moving a vehicle with its wheels on the ground. This could cause a fire to reignite.
  - After an incident, EVs should be stored at least 50 feet away from other vehicles, buildings or flammable materials.
  - A fire engine may need to accompany the tow vehicle to the storage area.
- Fire and law enforcement departments should engage insurance companies to discuss reimbursement for time, equipment, PPE, recovery, cleanup and decontamination costs.
- Document Li-ion battery-related incidents in NFIRS software through plus-one coding. For example:
  - .2291 - battery, lithium-ion – personal mobility
  - .2292 - battery, lithium-ion – small electronics
  - .2293 - battery, lithium-ion – EVs and vehicle charging
  - .2294 - battery, lithium-ion – battery/ESS

Response: Recommendations and Future Areas of Focus

Signage, Code Enforcement and Regulations

- Require signage wherever there are Li-ion battery dangers. Ensure signs indicate Li-ion dangers, recharging stations and the typical occupancy of ESS locations. This information will aid first responders.
- Develop codes and regulations for Li-ion truck transport, including information on pallets, manifest listings, charge levels, damaged batteries and number of batteries.
- Develop codes and regulations for rapidly expanding ESS or home systems.
- Enforce regulations at Li-ion battery recycling centers and require permits and signage.
- Establish vehicle standards so first responders generally know how to respond to EV incidents without consulting individual manufacturers' guides.

Education, Training and Awareness

- Establish a web-based clearinghouse to consolidate and vet information and best practices and inform the public and first responder communities. This will aid first responders in planning for and managing EV/ESS incidents.
- Develop education and training for first responders and local government officials on EV/ESS incidents and their risks.
- Continue testing to determine best practices for decontaminating gear exposed to Li-ion battery incidents.

Conclusion

The TEEX Electric Vehicle/Energy Storage Systems Summit identified many of the challenges associated with Li-ion battery fires and incidents, including prevention, response and code enforcement issues. As this technology evolves and becomes increasingly prevalent, the challenges associated with EV/ESS emergencies are constantly changing and growing.

As part of the TEEX mission to provide training, develop practical solutions and save lives, TEEX is committed to remaining at the forefront of this issue. To this end, TEEX will continue to engage stakeholders, incorporate emerging EV/ESS incident response best practices into first responder training and share this information with the public. As TEEX completes testing and receives new information, **updates will be provided on the TEEX website.**

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Appendix I: Resources and Information

Energy Security Agency (ESA)

- Energy Security Agency serves manufacturers, public/private organizations, first responder communities and end-users with recommendations and training for safe battery handling.
- ESA houses the most extensive library of EV Emergency Response Guides provided by manufacturers.
- Risk Analysis and Guidance for First Responders
- Risk Analysis for Towing and Recovery Professionals
- Telephone: 855-ESA-Safe (855-372-7233)

European Environment Agency (EEA)

Report 13/2018: Electric Vehicles From Life Cycle and Circular Economy Perspectives

EV Rescue- Response Guide application

- Apple Store Application: EV Rescue-Electric Vehicles (EVR)

Fire Safety Research Institute (FSRI)

- Take Charge of Battery Safety

International Association of Fire Chiefs (IAFC)

- Lithium-Ion and Energy Storage Systems Resources

National Fire Protection Agency (NFPA)

- Emergency Response Guides from 35+ alternative
- fuel vehicle manufacturers for free download

National Transportation Safety Board (NTSB)

- Report on Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles

U.S. Fire Administration (USFA)

- Battery Fire Safety Tips

Appendix II: Summit Speakers

Dr. David Bierling
Senior Research Scientist
Texas A&M Transportation Institute

Sean DeCrane
Director of Fire Fighter Health and Safety Operational Services
International Association of Fire Fighters

Chris Greene
Captain, Retired
Seattle Fire Department

Dalan Zartman
Co-founder, Chief Operations Officer
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