NORTHERN VIRGINIA TRANSPORTATION COMMISSION

Zero-Emission Bus (ZEB) Technical Assistance

Lithium-ion Battery Safety and Hazard Mitigation Strategies

Technical Memorandum

Prepared by:

AECOM

Revised October 13, 2026

AECOM Quality Information

Prepared by	Checked by	Verified by	Approved by
Jon Scheer	Cole Pouliot	Chris Fike, PE	Patrick Gough, AICP

Revision History

Revision	Revision date	Authorized by	Position
1	28 August 2026	Patrick Gough	Project Manager
2	13 October 2026	Patrick Gough	Project Manager

Contents

1. Introduction 3
1.1. Context 3
2. BEB Deployment Trends and Fire Safety 4
2.1. BEB Fires 5
2.2. Lithium-Ion Battery Fires 7
3. BEB Fire Protection: Key Safety Principles 8
3.1. Standard Operating Procedures 9
3.2. Vehicle Battery Health Monitoring via Telematics 12
3.3. Handling Damaged and Defective Batteries 13
3.4. Coordination with Fire Responders 15
3.5. Building Codes and Standards 16
3.5.3.1 Buildings 19
3.5.3.2 Vehicles 20
4. Best Practices: Checklist 20
Appendix A – Details on Recent Battery-Electric Bus Fires in the U.S. 22
Appendix B – TCRP ZEB Safety Training Structure 23
Appendix C – Loudoun County Guidance for Lithium-Ion Battery Safety 25

Tables

Table 1. Estimated Battery-Electric Buses in the United States over the Next 30 Years 4
Table 2. Battery-Electric Bus Fires: Locations and Manufacturers 6
Table 3. Average Passenger Vehicle Peak Heat Release Rate (PHRR) from Recent Studies 8
Table 4. VCC S-1 Occupancy Sprinkler Requirements 18
Table 5. NFPA 13 Design Criteria 19
Table 6. Checklist for Enhancing BEB Fire Safety 21

Figures

Figure 1. Car Fires by Vehicle Type in the United States 5

1. Introduction

NVTC has contracted with AECOM to provide technical support to Northern Virginia agencies that can help transit operators make a smooth transition to zero-emission buses. Through Working Group meetings, NVTC and AECOM learned that one of the areas that agencies would like to know more about is safety issues relating to the lithium-ion batteries that power battery-electric buses (BEBs).

The objective of this technical memorandum is to give Northern Virginia agencies useful information about BEB fire protection. It begins with the national context for BEB deployments and safety concerns that are unique to lithium-ion batteries. The memo then addresses important considerations regarding BEBs and facilities, including building codes and standards, standard operating procedures in a BEB fire, monitoring the health of BEB batteries, handling damaged and defective batteries, and coordinating with fire responders. The memo ends with a checklist that agency staff members can use to enhance BEB safety measures at their facilities.

1.1. Context

In Northern Virginia, agencies are at varying stages in their transition to zero-emission fleets, leading to differing levels of exposure to safety and hazard mitigation strategies related to Battery Electric Buses (BEBs). To support these agencies in their journey, NVTC and AECOM have provided practical guidance in this document regarding BEBs and lithium-ion battery fire safety.

To address the risks associated with lithium-ion battery technology, this technical memorandum focuses on five key areas of safety consideration:

1. Standard operating procedures
2. Vehicle battery health monitoring
3. Defective battery handling
4. Coordination with fire responders
5. Building codes and standards

These topics are informed by current studies on lithium-ion battery safety and best practices from other transit agencies. The memorandum is designed to be adaptable, allowing transit agencies to integrate future technological advancements and changes in codes within these safety frameworks.

2. BEB Deployment Trends and Fire Safety

U.S. transit agencies have proposed a substantial increase in the number of new BEBs that will be used to electrify fleets and reduce emissions over the next several decades. Although local agencies anticipate a shift in bus type distribution in the coming 10 to 30 years, they are limited by the number of buses that manufacturers can produce.

Manufacturers produce an estimated 5,000 to 6,000 buses of all types every year. With many transit authorities aiming for complete fleet electrification, manufacturers likely won't be able to keep up with demand for BEBs in the estimated time frame. According to the Federal Transit Administration, 1,548[1] BEBs were reported to be in use in the U.S. in 2021, and in CALSTART's inventory report of zero-emission buses, more than 7,200 BEBs were reported on U.S. roads in 2025[2].

Bearing in mind the production limitations of bus manufacturers, the estimated number of BEBs in the U.S. over the next 30 years was calculated considering the percent of total bus production (Table 1). The percentage of electric bus production is expected to increase as transit agencies move to order BEBs. The removal of older buses from service was also considered in the estimation.

Table 1. Estimated Battery-Electric Buses in the United States over the Next 30 Years

Years	BEB Percent of Total Production by Year	Buses aging out of service	Estimated BEBs in the United States
10	50% years 1 to 10	0	32,000
20	65% years 11 to 20	24,000	47,000
30	75% years 21 to 30	30,700	61,300

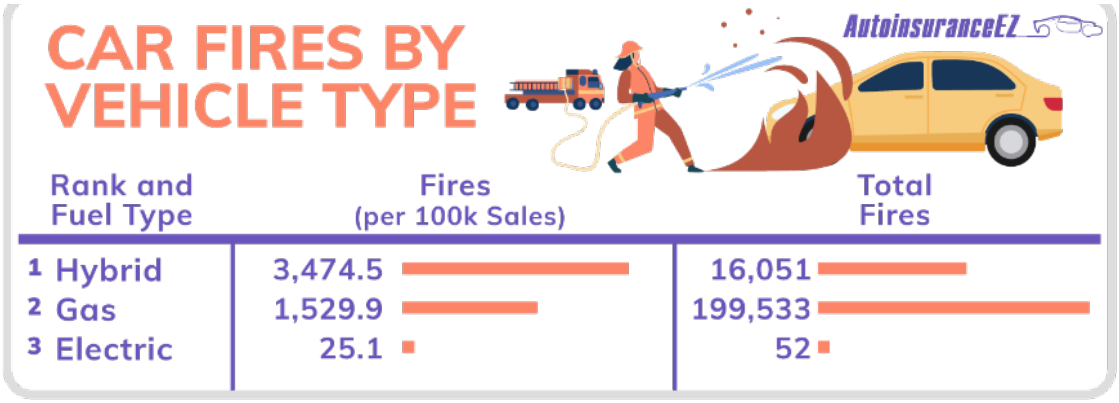
With the deployment of BEBs expected to increase by tens of thousands over the next few decades, there is a growing concern about the safety of BEBs, specifically regarding the fire risk of lithium-based batteries. BEB fires are different than conventional vehicle fires and therefore need to be understood by the transit agencies and local fire stations in the event that a BEB fire takes place to decrease risk of damage to the vehicle and injury to drivers, riders, and other agency workers.

AutoinsuranceEZ[3] completed a comparative analysis of data provided by the National Transportation Safety Board (NTSB) and Bureau of Transportation Statistics (BTS) to identify the

[1] 2021 Annual Database Revenue Vehicle Inventory." FTA 2021 Annual Database Revenue Vehicle Inventory.
[2] Hynes, Mike and Ketelsen, Kaila. *Zeroing in on ZEBs*. CALSTART, 2025. https://calstart.org/zio-zebs/
[3] Bodine, Rachel. "Gas vs. Electric Car Fires, 2023 Findings." AutoinsuranceEZ.com, November 11, 2022. https://www.autoinsuranceez.com/gas-vs-electric-car-fires/.

risk of fires in electric versus hybrids and gasoline-powered vehicles (Figure 1). They concluded that internal combustion engine vehicles are 60 times more likely to have a fire than EVs. AutoinsuranceEZ's analysis of EVs in the U.S. further found that there are 25.1 fires per 100,000 electric vehicles sold: a .0251% chance of a fire occurring in an EV.

Figure 1. Car Fires by Vehicle Type in the United States



2.1. BEB Fires

Several recent BEB fires within the United States and across the globe are outlined in Table 2. Additional descriptions on events from Philadelphia, Connecticut, and San Jose are provided in Appendix A and lessons learned from the events are presented in Section 2.1.1.

Table 2. Battery-Electric Bus Fires: Locations and Manufacturers

Date	Agency	Location	Bus Manufacturer / Model	Battery Manufacturer
September 2016	Frederick County Transit	Frederick, MD [4]	Complete Coach Works 30-ft Refurbished bus	ZEPS Electric Battery
February 2021	Not specified	Changwon, Gyeongnam, South Korea [5]	Hyundai Elec City	LG Energy Solution / LG Chem
June 2021	Not specified	Guangxi Zhuang, China [6]	No information available	No information available
September 2021	City of Wiesbaden	Stuttgart, Germany [7]	Mercedes eCitaro	Akasol
April 2022	RATP	Paris, France [8]	Bluebus 5SE	Bolloré
July 2022	CTtransit	Hamden, CT [9] [10]	New Flyer Xcelsior	XALT Energy Battery
November 2022	SEPTA	Philadelphia, PA [11]	Proterra Catalyst	Proterra
September 2023	Valley Transportation Authority	San Jose, CA [12]	Proterra	Proterra
August 2025	SEPTA	Philadelphia, PA [13]	Proterra	Proterra

[4] **Marshal, Ryan. "Report Confirms Sensor Failure Caused Electric Bus Fire." Post, November 4, 2016.** https://www.fredericknewspost.com/news/politics_and_government/levels_of_government/county/report-confirms-sensor-failure-caused-electric-bus-fire/article_7689d9d5-7ded-5586-b6d9-b2b2519ca568.html.

[5] **Lee, Jin-Woong. "Hyundai Motor's electric bus catches fire in South Korea"** ***Reuters*** *https://www.reuters.com/world/asia-pacific/hyundai-motors-electric-bus-catches-fire-south-korea-2021-02-16/*

[6] **Anderson, Brad. "Electric Bus in China Erupts in Fire That Spreads to Four Others." Carscoops, June 8, 2021.** https://www.carscoops.com/2021/06/electric-bus-in-china-erupts-in-fire-that-spreads-to-four-others/.

[7] **Manthey, Nora. "Daimler Recalls eCitaro Buses with Solid-State Batteries." electrive.com, March 8, 2021.** https://www.electrive.com/2021/03/08/daimler-recalls-ecitaro-buses-with-solid-state-batteries/.

[8] **"Paris withdraws Bollore's electric buses after two catch fire"** ***Reuters,*** **April 29, 2022.** https://www.reuters.com/business/autos-transportation/paris-public-transport-network-suspends-bollore-e-buses-after-fire-incidents-2022-04-29/

[9] **National Transportation Safety Board Hamden Investigation HWY22FH011** NTSB Investigation Docket HWY22FH011

[10] **Skahill, Patrick. "CTtransit Fleet of Electric Buses Remains out of Service after Summer Battery Fire." Connecticut Public, November 14, 2022.** https://www.ctpublic.org/news/2022-11-02/cttransit-fleet-of-electric-buses-remains-out-of-service-following-summer-battery-fire

[11] **Briggs, R and Fitzgerald, T (2022, Nov 11). A Proterra electric bus battery exploded in a South Philly SEPTA depot** ***Inquirer.*** https://www.inquirer.com/transportation/septa-proterra-electric-bus-battery-fire-philadelphia-20221111.html

[12] **CBS News San Francisco;** https://www.cbsnews.com/sanfrancisco/news/electric-vta-bus-fire-san-jose-cerone-yard-2-mechanics-injured-zanker-road/

[13] **ABC A6 Action News;** https://6abc.com/post/several-septa-buses-fire-philadelphias-nicetown-tioga-section/16663970/

2.1.1 Lessons Learned

Lessons learned from the information available related to these fires are as follows:

- **Battery Enclosure Risks**: One fire originated from battery enclosures in an enclosed bus facility, highlighting the need for better monitoring and safety measures around battery storage.
- **Decommissioned Bus Storage**: A fire at an outdoor storage yard for decommissioned buses involved 40 out of 100 buses, traced back to a battery issue. Regular inspections and maintenance protocols must be strictly followed to prevent such incidents.
- **Out-of-Service Bus Protocol**: A bus that had been out of service for two days due to charging failure later began smoking. The fire department was called, but the bus eventually caught fire outside the facility. This underscores the importance of thorough inspections and monitoring of out-of-service vehicles.
- **Recall Awareness**: The incident with the out-of-service bus may be linked to a recall concerning battery coolant leaks, indicating the necessity for awareness and adherence to recall notices.
- **High-Voltage Battery Safety**: In another fire, the investigation revealed that the cause was not related to high-voltage battery packs, suggesting that other factors need to be considered in fire investigations and safety protocols.

2.2. Lithium-Ion Battery Fires

Incidents involving fires in electric vehicles (EVs) and BEBs, along with fires caused by lithium-ion batteries in portable electronics, have raised public concerns about battery-operated equipment. Visual accounts of fires in bus depots abroad, which engulf multiple vehicles and produce large fireballs, may lead to the perception that EVs are more hazardous than conventional vehicles. However, data[14,15,16] over the last several years' worth of EV fires indicates that EVs are statistically less likely to experience fire events and present a comparable risk to conventional and hybrid vehicles.

These studies also recognize that the high-voltage battery component presents additional challenges in fire suppression and firefighting operations. While small scale tests and studies on small battery fires have been performed, there have been no full-scale fire sprinkler tests on battery vehicles.

[14] **P. Sun, R. Bisschop, H. Niu, X. Huang* (2020) A Review of Battery Fires in Electric Vehicles.**
[15] **P. Sun, R. Bisschop, H. Niu, X. Huang* (2020) A Review of Battery Fires in Electric Vehicles, Page 56 of Source, Footnote 15.**
[16] **Dorsz, A.; Lewandowski, M. Analysis of Fire Hazards Associated with the Operation of Electric Vehicles in Enclosed Structures. Energies 2022, 15, 11.**

In 2013, the NFPA Research Foundation[17] performed testing with firefighters on manually suppressing and extinguishing Battery Electric Vehicles (BEV) fires and found that the test fires were controlled more quickly after groups became more familiar with the location and access means to the battery compartments. The report also indicated that the greatest tool to combating vehicle fires is better training, including hands-on training and system familiarization. In addition, Table 3 demonstrates that BEB fires burn only marginally hotter than those of hybrid and conventional vehicles.

Table 3. Average Passenger Vehicle Peak Heat Release Rate (PHRR) from Recent Studies

Vehicle Type	Average Battery / Fuel Capacity	Average PHRR
Battery-Electric Vehicles	At least 80% charge	7.3 MW
Hybrid	At least 85% charge	6.9 MW
Conventional	Full tank	6.5 MW

No live-fire tests or studies have been performed on BEBs, as the technology is new enough that no transit agency can afford to burn a bus that it needs to provide transit service, and no BEB in service has yet reached the end of its lifespan. However, the BEB data that does exist can be used to make informed decisions on how to protect new investments. The safety principles used in mitigating BEB fire risk are described in Section 3.

3. BEB Fire Protection: Key Safety Principles

As new vehicle technologies emerge, building codes and safety standards evolve along with them to reduce the risks introduced by these changes. Some relevant examples include alternative fuels like compressed natural gas (CNG), liquid propane gas (LPG), and hydrogen fuel cells (H2). NFPA 30A, the standard for vehicle fueling facilities and repair garages, has existed since 1987; however, it was not until 2000 that it began to address requirements for CNG and LNG fueled vehicles and fueling sites. NFPA 2, the standard for hydrogen technologies, has existed since 2011; but it did not gain widespread adoption until hydrogen fuel cell technology became more feasible in recent years.

One of the challenges when considering lithium-ion and general battery safety is that the existing codes are focused on the stationary energy storage systems (SESS) and bulk storage of battery cells, and not as much on electric vehicles. While progress is being made to adjust these codes and standards on both a state and national level, transit agencies are often left to determine the right means and methods to mitigate these risks on their own.

[17] **Long, R. T., Blum, A. F., Bress, T. J., & Cotts,, B. R. T. (2013). (tech.).** ***Best Practices for Emergency Response to Incidents involving Electric Vehicle Battery Hazards*****. Bowie, MD: Exponent Inc.**

The objective of this section is to provide context, considerations and key takeaways (which are provided at the end of each section).

3.1. Standard Operating Procedures

Question from agency interviews: What content should be included when an agency is drafting or updating their Standard Operating Procedures?

While a BEB is functionally not much different from any other transportation bus, there are components and systems in BEBs that require new training, maintenance schedules, and safety considerations. Standard operating procedures should include content related to isolation areas, the roles and responsibilities of key staff, thermal runaway and fire incidents, and training.

3.1.1 Isolation Areas

Agencies should review their properties where BEBs will be stored and maintained to establish pre-determined areas to isolate buses that have been identified as hazardous until they can be properly addressed. These areas would ideally already be readily open and available, and remote from other structures and property to prevent fire spread and damage. Approximately 20 to 30 feet of clear space on all sides should be provided to prevent fire spread and give fire department and maintenance personnel ample space to perform their duties.

However, unused outdoor space is understandably rare for most transit agencies, especially in urban locations. Where ample clear space and separation from other combustibles cannot be maintained, agencies should consider providing means to either relocate vehicles (via "tugs" or drivers) or establish a constructed isolation zone. Constructed isolation zones should be designed to provide protection where amble clear space cannot be provided; this may typically become a three-sided free-standing structure.

Constructed isolation zones should be tall enough to prevent any resulting bus fire from impinging on that adjacent structure and utilize listed fire rated wall assemblies to ensure structural integrity for the duration of any subsequent fire event. The size and shape of any constructed isolation structures should consider both bus operator egress as well as firefighting access for both ladder-truck operated hoses as well as ground operated hoses.

Regardless of how isolation areas are implemented, agencies should include the local fire department in planning and locating them with respect to fire department operations. Access to fire hydrants in isolation areas will be a key factor in fire department planning, as any battery-related fire will require large amounts of water. General fire truck access within the property will also dictate how a fire department responds and what operational tactics they can use; ideally, any isolation area would be readily accessible to the fire department apparatus for ease of operations.

3.1.2 Key Staff Roles and Responsibilities

It is strongly recommended that agencies develop internal guidelines for training and identifying subject matter experts (SMEs) for general BEB operation, BEB charging, the battery systems specific to owner's BEBs, and other pertinent proprietary systems that the fire department may require additional information about when responding to emergencies at BEB facilities. While factory training may be provided by the bus manufacturer, owners should seek additional training and knowledge for related bus systems, such as operating on high-voltage equipment.

Similar to the IFC Section 1207.1.6.1 requirements for BESS facilities, the goal of the SME for BEB systems is to provide informational assistance to the fire department and be available on site during and after fire emergencies. While BEB systems may not be as functionally complex or chemically hazardous as energy storage systems (ESS) and stationary energy storage systems (SESS), they do present unique challenges to the fire service that can be mitigated by providing a liaison to the fire service during a fire event and during post-fire event work.

It is recommended that at least one individual be available as the facility SME for any battery bus systems; if a SESS SME is provided, they should also not be the BEB SME to reduce the informational burden on SMEs. At 24/7 operated facilities, a SME should be available at all times and where employees operate in shifts there should be at least one SME per shift. For facilities that do not operate 24/7, there should be at least two SMEs available at all times, one as the primary and one as a redundant SME should the primary be unavailable. One employee should not be the same SME for multiple physical locations; each facility should have their own SME(s) to ensure that someone is available at all times if there are fire events at multiple locations.

However, SME staffing and response will be correlated to the size and location of BEB fleets and evaluated as part of an agency's operating procedures and emergency response plans. Agencies should also have one BEB SME at the administrative level to develop training and learning standards and develop enterprise-level materials.

3.1.3 Thermal Runaway and Fire Incidents

Thermal and fire events involving BEB batteries will be long-duration events requiring coordination from multiple stakeholders, including bus maintenance personnel, agency BEB SMEs, fire department command staff, regional emergency management teams, and bus and battery manufacturers. To help these events flow seamlessly and so that the involved parties understand their roles and responsibilities, it is imperative that agencies work with these pertinent stakeholders to establish written procedures for potential thermal and fire events.

Agencies should develop both a thermal event and fire response plan outlining responsible parties, tiered actions list, and other key metrics. It is possible that existing fire response standard operating procedures (SOPs) can be modified to address BEB-specific concerns; however, new SOPs should be developed to respond and address thermal events that have not escalated to fire events.

Fire departments should be involved in developing emergency response plans and SOPs, including access to the property, locations of BEBs and charging equipment, identifying liaisons and BEB SMEs. Fire responders should also have familiarity and hands-on training with BEBs and BEB equipment.

BEB and battery manufacturers should assist agencies with the development of their emergency response plans, including post-incident clean-up and disposal procedures. The procedures to properly clean up and dispose of a disabled or damaged battery can be a long and difficult process (as discussed further in Section 3.3 *Handling Damaged and Defective Batteries*); however, if the process is known and personnel charged with initiating the process do so at the inception of the thermal or fire event, agency downtime may be reduced significantly.

3.1.4 Training

While the obvious training needs for routine service and maintenance may be facilitated through bus and battery manufacturers, other training may be less obvious and overlooked. When dealing with the disposal of damaged battery packs, bus technicians need training and equipment to work on high-voltage systems that would typically be reserved for electricians working on switchgear equipment. Please see Appendix B for high-level training recommendations for staff working on BEBs.

Transit agencies should consider the level of maintenance work they plan to perform on BEBs and provide that at least two technicians per shift per location are trained for all levels of planned maintenance activities. Agencies should provide training for all BEB maintenance personnel to identify and respond to battery-related incidents. Agencies should also procure personal protective equipment (PPE) and safety equipment for each trained technician, as battery disposal events may require multiple technicians to work at the same time. Manufacturers may not be capable of providing generic high-voltage safety training as part of delivery close-out, so agencies should engage with local providers to ensure that employees receive that training. Larger agencies that plan for a full-fleet transition may benefit from having in-house personnel certified to give this training.

Training opportunities for first responders should include review of manufacturer-provided emergency response guides (ERGs) and emergency shut-down procedures. Training should

also include how to identify BEBs in a mixed fleet. Agencies should consider providing distinctive branding on BEBs to assist in identifying BEBs and ensure that areas or components used during emergency events are clearly identifiable. Quick identification of a given hazard allows for an equally quick response by the fire department.

Training modules for first responders should include take-home materials with pertinent information that can be used at later dates for informal training with other crews and shifts. On-site training should also be provided to help first responders familiarize themselves with the site to plan not just for BEB related emergency responses, but any fire event that could occur on agency property. These training opportunities should be provided for agency employees, fire department personnel, and other relevant stakeholders. Training should be tailored to the role and work performed by individuals but maintained and updated annually.

3.1.5 Key Takeaways for Standard Operating Procedures

- **Establish isolation areas for BEBs undergoing thermal runaway or fire.**
- **Develop and update SOPs for dealing with BEB thermal runaway and fire events.**
- **Identify / train dedicated multiple SMEs re: BEBs, BESS, and lithium-ion batteries.**
- **Ensure that crews are trained in high-voltage systems.**
- **Provide training modules that give both hands-on experience and take-home materials.**
- **Review and update manufacturer emergency response guides (ERGs).**
- **Provide bus branding that enables easy identification of BEBs.**
- **Make adequate PPE and safety gear available for all crews working with BEBs.**

3.2. Vehicle Battery Health Monitoring via Telematics

Question from agency interviews: What steps should agencies take during the procurement process to ensure there is effective telematic monitoring and early fire detection for BEBs?

While battery manufacturers state that there are many internal designs and battery management processes that help prevent thermal events from occurring, there is still a possibility that they can happen. While building-level fire protection systems can detect and respond to a fire, BEB on-board telematic systems may be able to help identify when a battery is about to undergo a thermal event and give agency staff members time to respond before it transitions to a fire event.

It is strongly recommended, as part of the procurement process, that agencies outline their need to access as much data as possible from the bus. In turn, manufacturers must help agencies identify which telematic data would indicate a fire, damaged battery, or thermal runaway event. Manufacturers should further provide assistance in identifying telematic

datapoints that help agencies establish criteria for identifying buses or batteries that may be damaged and at risk of failure. State of charge, temperature, voltage, and other similar metrics may be obvious indicators of potential thermal or fire events, however a multi-criteria alerting procedure should be used to prevent false-alarm events should a single metric present a false positive.

Because a transit agency may have electric buses from multiple manufacturers, it may elect to a deploy a third-party charge management solution to eliminate the need of working with multiple, OEM specific software. In fact, many agencies select their charge management solution before a bus solicitation and make compliance with this software a requirement. This clarifies which data inputs are required across the fleet to ensure battery monitoring and related SOPs are consistent. Agencies may request assistance and direction from bus and charger manufacturers, or third-party charge management solutions like Chargepoint/ViriCiti or BetterFleet, in determining how best to achieve the agency's telematics goals.

Many bus manufacturers and third-party telematics companies use a web-based portal and offer email and cellphone alerts if one or more vehicles reaches a pre-set telematic threshold. To best use bus telematics as a means of early fire detection, a dedicated computer or console should be provided at each facility where a person is able to monitor for alerts and take appropriate action based on the alert. Staff assigned to receive email or text notifications should be those who, according to the agency's mitigation procedures, are able to make actionable decisions based on those alerts to ensure there is little time delay in enacting emergency response procedures.

3.2.1 Key Takeaways for Vehicle Battery Health Monitoring via Telematics

- **Describe in detail all data needed from telematics companies / manufacturers.**
- **Build telematics / data collection into procurements with manufacturers.**
- **Require third-party telematics providers to allow agencies to obtain BEB data easily.**
- **Establish a dedicated telematics console and staff member to monitor BEB health.**
- **Allow staff monitoring BEBs to make actionable decisions when there is a problem.**

3.3. Handling Damaged and Defective Batteries

Question from agency interviews: What are the recommended disposal practices for damaged or defective batteries?

Unlike conventional and alternative fuel vehicle batteries, EV and BEB batteries that have become damaged or obsolete cannot go to municipal waste facilities; they must be disposed of differently. Lithium-ion batteries are currently categorized under the EPA's "universal waste"

standards along with other battery technologies; however, in 2021, the EPA provided additional specific guidance and best practices on the disposal of lithium-ion batteries[18].

The EPA recommends coordinating with the vehicle or battery manufacturer to remove and dispose of the battery. While removal procedures require direct coordination or assistance from the bus or battery manufacturer, the transportation of the battery to an approved recycling facility requires direct coordination with the specific facility vendor and US Department of Transportation regulations[19] for transporting damaged batteries.

In December 2024, a Fairfax County BEB was involved in an accident that damaged the batteries on the vehicle. The agency soon learned that disposal of the damaged equipment was an intense process that the agency had to lead and own. The agency learned that the bus OEM could not take these batteries, in fact, only two venders existed that could. The process to ship them to a vendor required special containers, task-specific procedures to deenergize the units, coordination with the vendor to accept the units, and an intense amount of paperwork to register the disposal with the EPA. Fairfax County was able to utilize their relationship with the bus manufacture to help guide this process, and the county had to account for the unexpected cost for equipment and labor hours related to the disposal. Having proper procedures and plans in place for disposing of these batteries before the need arises would make this process easier for any agency in its BEB journey.

The 2024 IFC Chapter 1207 has robust requirements for supporting documentation for BESS, including decommissioning, which could be used voluntarily by transit agencies that operate BEBs. While not entirely applicable, there is overlap between BESS and BEBs, as both use lithium-ion battery packs to operate. The requirements include:

- A designated "fire mitigation" person(s) to be established by the transit agency to be trained in BESS incidents to be on site or dispatchable within 15 minutes of any fire event to assist in fire department response, coordinating with system manufacturer on response procedures, and other incident related functions for the duration of the emergency incident.

- Written plans for system commissioning, maintenance, and decommissioning of BEBs and high-voltage electrical systems. While commissioning and maintenance procedures for transit vehicles are already robust, it is unlikely that there are equally exacting decommissioning procedures already established for batteries. Agencies should, as part of the development of procurement plans, require manufacturers to assist agencies in developing decommissioning plans for BEB batteries.

[18] https://www.epa.gov/recycle/used-lithium-ion-batteries
[19] https://www.phmsa.dot.gov/training/hazmat/safety-advisory-notice-transportation-lithium-batteries-disposal-or-recycling

3.3.1 Key Takeaways for Handling Damaged and Defective Batteries

- **Coordinate with vehicle / battery manufacturer on proper disposal of batteries**
- **Build battery disposal into procurement contracts with manufacturers**

3.4. Coordination with Fire Responders

Question from agency interviews: How can agencies collaborate with fire departments to enhance emergency preparedness and safety for incidents involving BEBs?

Fire departments respond to numerous calls for service that may involve interaction with BEBs, ranging from fires to vehicle extrication, collisions and hazardous material response. To enhance the safety of first responders and facilitate the actions they need to take, it is imperative that agencies work closely with their emergency response partners.

Many vehicle manufacturers produce documents called emergency response guides (ERG) to assist fire departments with emergencies involving motor vehicles. Historically, they have focused on cutting locations for patient extrication; however, they have begun to be regulated by the NTSB and include other pertinent information regarding fire events and locations of hazardous systems (such as high-voltage power lines and gas system safety features).

Agencies should consider, as part of the bus procurement process, requiring manufacturers to provide training hours with first responders to both review ERG materials and perform hands-on training with a bus. A study on the firefighting of EVs by the NFPA Fire Protection Research Foundation[20] found that repetitive, hands-on training greatly increased confidence and success in fighting EV fires. Agencies should support this approach as much as possible to ensure that their fire department partners are knowledgeable about each type of vehicle agencies operate. Refer to Appendix C, Loudoun County's circular for lithium-ion battery device fires, for an example of what could be prepared.

As agencies develop infrastructure to support BEB maintenance, charging, and storage, agencies should involve fire department partners to provide input regarding access and strategies for fighting potential fires. While the building codes and standards take fire department operations into account in many respects, firefighting strategies and operations can be regional and differ from one jurisdiction to the next.

---

[20] **Long, R. T., Blum, A. F., Bress, T. J., & Cotts,, B. R. T. (2013). (tech.).** ***Best Practices for Emergency Response to Incidents involving Electric Vehicle Battery Hazards*****. Bowie, MD: Exponent Inc. https://www.nfpa.org/education-and-research/research/fire-protection-research-foundation/projects-and-reports/emergency-response-to-incident-involving-electric-vehicle-battery-hazards**

Additional consideration should be given to those responsible with towing or moving BEBs that have been identified as "hazardous" are require interventions, otherwise known as "secondary responders." Whether they are direct employees, contractors or third-parties, they should also receive training on BEB emergencies and the steps necessary to protect themselves when handing hazardous BEBs.

3.4.1 Key Takeaways for Coordination with Fire Responders

- **Involve fire department in establishing BEB isolation areas.**
- **Work closely with fire department on all ERGs, SOPs, and staff training.**
- **Update fire department whenever there are changes to the fleet and facilities.**

3.5. Building Codes and Standards

Question from agency interviews: What are the current code requirements for building and fire safety?

As of 2024, the Virginia Construction Code (VCC) and Virginia Statewide Fire Prevention Code (VSFPC) are based on the 2021 International Building Code (IBC) and International Fire Code (IFC); the most recent editions of the IBC and IFC are the 2024 editions but not applicable until adopted by the state of Virginia. This also applies to the editions of other codes and standards such as NFPA 13 for fire sprinkler systems; the 2021 VCC and IBC adopt the 2019 edition, the 2024 IBC adopts the 2022 edition, however the most recent edition published by NFPA is from 2025.

While all buildings must comply with the adopted editions, designers and building owners are permitted to use recent codes and standards to apply equal or greater levels of protection to their buildings. This section outlines the current code requirements but will identify newer codes and standards that provide meaningful updates or relevant changes.

3.5.1 Occupancy Classification, Fire Separation, and Storage

The 2024 IFC introduced Section 320 to begin addressing bulk battery storage (batteries in boxes, piles, on shelves, etc.), citing additional protections for this specific use. However, it states that batteries installed within vehicles do not need to comply with the new section[21]; the IFC recognizes that batteries stored with or within the equipment they are meant to power pose less of a risk than bulk battery storage and currently do not require the protections outlined in this new section.

[21] **2024 IFC Section 320.1 Exception 1, 2 and 5.**

Per the current IBC and VCC, the presence of BEBs does not change the occupancy classification of vehicle maintenance areas from its S-1 designation or vehicle parking structures from S-2. NFPA 2 stipulates that where quantities of LH2 or GH2 exceed the maximum permitted quantities the area is treated as a Group H hazardous occupancy, which has more stringent protection requirements. While NFPA 30A Chapter 7.8 does not change the occupancy classification, it does recognize that reducing the on-board fuel capacity reduces the overall hazard level and only permits the "minor repair" designation in minor repair maintenance facilities where fuel pressure is below 500 psi gauge. A similar approach could be taken by reducing the state of charge of BEBs prior to servicing them or removing batteries where service work doesn't require them; agencies should seek guidance from bus and battery manufacturers if this is a recommended practice and if so how to store the batteries safely temporarily.

NFPA 30A and NFPA 2 both also require areas used for the repair of CNG, LPG and H2 buses be separated from other areas of the building by at least 1-hour fire rated construction regardless of on-board fuel capacities or the level of work being performed; this is not a base code requirement for gas or diesel vehicle maintenance garages. The codes recognize that gaseous fuels present a greater hazard to the non-repair areas that may exist in a mixed-use maintenance facility (such as multi-story buildings with adjoining offices and conference spaces) and require additional protections for non-repair areas. This approach could be applied to any vehicle maintenance or storage use area in a mixed-use building as a general best-practice to provide an additional degree of safety.

Further, a recent APTA report recommends proper storage of out-of-service high-voltage vehicles with lithium-ion batteries, including procedures for short-term, long-term, and decommissioned vehicle storage to minimize fire risks. Reducing state of charge and monitoring environmental conditions is critical for promoting safety at facilities.[22]

3.5.2 Fire Suppression

Although most vehicle storage and maintenance facilities are provided with a full building automatic sprinkler system, the requirements by the VCC and IBC are based on the fire area of the building and maintenance areas (Table 4). As of the 2024 edition of the IBC, a new requirement was added addressing the storage of lithium metal-powered vehicles; while it is in the repair garage section, it specifically refers to vehicle storage as the trigger rather than vehicle maintenance. The code commentary for this addition states the new requirement was added "to acknowledge the increased fire risk in garages used for the repair of vehicles powered by lithium-ion or lithium metal batteries."

[22] **APTA BTS-BS-RP-007-26 - APTA**

Table 4. VCC S-1 Occupancy Sprinkler Requirements

Two or more stories tall with fire area containing repair garage greater than 10,000 sqft
Single story building with fire area containing repair garage greater than 12,000 sqft
Vehicle service performed in a basement
Areas used to repair commercial motor vehicles with a fire area greater than 5,000 sqft
Areas used to store lithium-ion or lithium metal power vehicles where the fire area is greater than 500 sqft

Where provided, whether required or provided voluntarily, sprinkler systems protecting vehicle maintenance occupancies are required to meet the NFPA 13 requirements of the assigned hazard classification. Similar to occupancy classifications in the IBC and VCC, NFPA 13 has hazard classifications used to define required protections based on the use and contents of a space. For vehicle maintenance and storage occupancies, Ordinary Hazard 2 is the assigned classification (see Table 5 for a comparison of several NFPA 13 hazard classification requirements).

This requirement for vehicle maintenance areas had not changed for several decades; but in 2022, NFPA 13 increased the hazard classification for vehicle parking from Ordinary Hazard 1 to Ordinary Hazard 2. While the appendix language states that the additional combustible materials associated with modern cars and recent large parking structure fires, it does not indicate that this is with respect to an increase in electric vehicles or battery contents. Despite the recent change in hazard classification for vehicle parking, NFPA 13 treats all vehicle propulsion types the same regarding hazard classifications.

Throughout the fire protection industry, many groups agree that the requirements for vehicle-related occupancies requires further evaluation to address the hazards posed by all modern vehicles. But, until prescriptive requirements are provided, any increase from the code required minimums are at the discretion of individual building owners and operators.

Several fire hazard analyses have been performed and published for BEBs with varying recommendations for voluntary increases from the code required Ordinary Hazard (OH-2) classification; recommendations range from Extra Hazard (EH-1) systems (double the minimum required fire water) to non-code required systems with a density of 0.6 or 0.8 gpm/sqft (at least five-times the minimum required water). Each analysis has its own baseline assumptions that impact the end results but overall, most recommend a voluntary increase from OH-2 requirements.

Some analyses have recommended deluge systems in which all sprinklers in a given zone operate at once; however, those systems can be prohibitively demanding for water pressure and require large fire pumps where they would otherwise not be required for other sprinkler systems. When considering how to design safety mitigations to address gaps in code, transit agencies are encouraged to focus investments on improvements that efficiently increase the

level of safety relative to the targeted risk. One way to make this determination is to have a fire hazard analysis performed by a qualified firm to review the specific goals and needs of each owner and property.

Table 5. NFPA 13 Design Criteria

NFPA 13 Classification	Density (gpm/sqft)	Design Area (sqft)	Hose Stream Demand (gpm)	System Flow over Design Area – no hose stream (gpm)
OH-1	.15	1,500	250	225
OH-2	.2	1,500	250	300
EH-1	.3	2,500	500	750
EH-2	.4	2,500	500	1,000

3.5.3 Fire Detection

Relative to fire detection, codes generally do not mandate full building fire detection in vehicle maintenance or storage facilities, but targeted detection systems can enhance safety, especially where buses are left unattended. For vehicles, early warnings often come from onboard detection and telematics, as initial smoke may remain trapped in battery enclosures. It's important to choose detection technologies based on the area, considering coverage, integration, maintenance and cost.

3.5.3.1 Buildings

While most vehicle maintenance facilities are equipped with a fire suppression system, a full building fire detection is typically not provided. The IBC and VCC do not require vehicle maintenance or vehicle storage buildings to have a full building fire detection system but may require some means of fire detection to serve specific life safety functions, such as HVAC shut down, elevator recall or closing fire doors and shutters.

Smoke detection is a proven method of detecting fires in their early and more controllable stages and can prompt an automatic 911 response faster than sprinkler activations; however, the more confined a fire is the longer it takes to detect. In an occupied building, it is likely that an occupant will notice signs of a fire before a building fire detection system; providing non-required fire detection systems may provide a greater degree of safety in buildings or areas where buses are left unattended for prolonged periods of time.

Where fire detection is a desired level of protection, the most optimal technology to apply will vary based on the area being protected. For many indoor applications, traditional spot detectors are a familiar and affordable way to protect a given space and can be easily integrated into any existing fire alarm systems. Other technologies, such as aspirating smoke detection, may be beneficial for protecting large indoor spaces and reduce maintenance burdens for a higher installation cost.

Current codes and standards require forms of optical fire and radiant energy detection for many BESS installations and may be a viable option to detect fires in outdoor parking areas; however, this technology is limited by the field of view of the cameras, any consideration of use should include close coordination with the product manufacturer to ensure full coverage.

3.5.3.2 Vehicles

Although battery fires and thermal runaway events are known to produce large quantities of smoke, the initial quantities of smoke and gases produced by the event will likely be trapped inside the battery enclosure until the enclosure fails and releases smoke into the building. Onboard fire detection systems and monitoring bus telematic systems (discussed in Section 3.2) may likely provide the earliest warning of a battery thermal event before it happens; however, these systems cannot be monitored by building fire alarm systems and often only notify transit agencies via text or email alerts and require human action.

New products, such as the on-board battery gas detection offered by Amerex, have been developed to monitor BEB battery enclosures for the gases produced during thermal runaway events for on-board detection of thermal runaway events. Some bus telematics systems may provide a more reliable means of detecting thermal runaway events before they become fire events.

3.5.4 Key Takeaways for Building Codes and Standards

- **Reduce state of charge before servicing vehicles or storing unused BEBs.**
- **Focus sprinkler systems and other investments on increasing safety relative to risk.**
- **Provide non-required fire detection systems wherever BEBs are left unattended.**
- **Install radiant energy detection and aspirating smoke detection when feasible.**

4. Best Practices: Checklist

Table 6 summarizes the content of this technical memorandum in a checklist that Northern Virginia transit agencies can use to determine which activities they have completed or have underway to enhance BEB fire protection at their facilities.

Table 6. Checklist for Enhancing BEB Fire Safety

1. Standard Operating Procedures / Training	**Completed / In Progress**
a. Establish isolation areas for BEBs undergoing thermal runaway or fire	
b. Develop and update SOPs for dealing with BEB thermal runaway and fire events	
c. Identify / train dedicated multiple SMEs re: BEBs, BESS, and lithium-ion batteries	
d. Ensure that crews are trained in high-voltage systems	
e. Provide training modules with hands-on experience and take-home materials	
f. Review and update manufacturer emergency response guides (ERGs)	
g. Provide bus branding that enables easy identification of BEBs	
h. Make adequate PPE and safety gear available for all crews working with BEBs	
2. Vehicle Battery Health Monitoring via Telematics	**Completed / In Progress**
a. Describe in detail all data needed from telematics companies / manufacturers	
b. Build telematics / data collection into procurements with manufacturers	
c. Require third-party telematics providers to allow agencies to obtain BEB data easily	
d. Establish dedicated telematics console & staff member to monitor BEB health	
e. Allow staff monitoring BEBs to make decisions when there is a problem	
3. Handling Damaged and Defective Batteries	**Completed / In Progress**
a. Coordinate with vehicle / battery manufacturer on proper disposal of batteries	
b. Build battery disposal into procurement contracts with manufacturers	
4. Coordination with Fire Responders	**Completed / In Progress**
a. Involve fire department in establishing BEB isolation areas	
b. Work closely with fire department on all ERGs, SOPs, and staff training	
c. Update fire department whenever there are changes to the fleet and facilities	
5. Building Codes and Standards: Fire Mitigation Strategies at Facilities	**Completed / In Progress**
a. Reduce state of charge before servicing vehicles or storing unused BEBs	
b. Focus sprinkler systems & other investments on increasing safety relative to risk	
c. Provide non-required fire detection systems wherever BEBs are left unattended	
d. Install radiant energy detection and aspirating smoke detection when feasible	

Appendix A – Details on Recent Battery-Electric Bus Fires in the U.S.

Philadelphia

The 2022 Proterra bus fire in Philadelphia has limited available information, with no NTSB reports or investigations that could be found. However, according to news sources, initial investigations indicate that the fire in Philadelphia was traced back to the battery enclosures. The fire occurred in one of the enclosed bus facilities, and the bus was pushed outside. Proterra stated that it is working with SEPTA, the transit agency, to further investigate the fire. In 2025, SEPTA had a second fire at an outdoor storage yard for decommissioned buses. Of the 100 buses stored at that site, 40 were involved in the fire, including 15 electric Proterra buses. SEPTA confirmed in news reports that the source of the fire was a battery in one of the Proterras but provided no additional information as to what cause the battery fire. A SEPTA official stated the batteries were drained of coolant, disconnected from the bus as regularly inspected in accordance with manufacturer recommendations. No additional information has been provided by the NTSB, SEPTA, Proterra, or other parties.

Connecticut

The New Flyer BEB fire in Hamden, Connecticut, is covered in NTSB Report HIR-24/03. The bus had been placed out of service two days before the fire because it failed to charge and began smoking around 3 a.m. on July 23, 2022. Connecticut Transit employees evacuated the building and alerted the fire department, which instructed the maintenance crew to push the bus out of the facility. The fire department left shortly after due to the lack of fire and likely decreasing smoke emissions. The fire department was then called back to the scene around 7 a.m. when the bus began flaming outside of the facility. The incident commander elected to allow the bus to "free burn" since it was outside and isolated. After eight hours of fire department operations, the bus, including all six battery packs, were consumed in the fire. During this time, two transit agency personnel were transported to the hospital for smoke inhalation. The fire department was called out two days later to extinguish "hot spots" in the bus in the yard. While there is no direct link between this fire event and the NHTSA recall 23V-083 regarding a battery coolant leak in some New Flyer buses, the information in the fire report as well as the recall allude to a possible link between the two.

San Jose

In September of 2023, the Valley Transportation Authority (VTA) experienced a Proterra bus fire at their San Jose facility. The bus was a Proterra fully electric vehicle and initial reports from Proterra indicated that the fire was unrelated to the high-voltage battery packs. News reports further said that two mechanics were taken to the hospital and sustained injuries while pushing the bus out of the maintenance building. There was no reported damage to the maintenance building, and the fire department was able to control and extinguish the fire.

Appendix B – TCRP ZEB Safety Training Structure

The Transit Cooperative Research Program's (TCRP) *Research Report 219: Guidebook for Deploying Zero Emission Transit Buses (2021)* identifies three key best practices relating to personnel training and development:

- Ensuring adequate safety training related to high voltage hazards and hydrogen fuel
- Requiring OEMs to conduct first responder training (and follow up training as needed), and specify training materials, needs, and responsibilities in the procurement contract
- Careful coordination of training before or in conjunction with bus delivery

At a high level, workforce training should cover three phases:

- Phase 1: Foundational Electrical / Electronics Principles
- Phase 2: Zero emission Bus Systems and PPE
- Phase 3: OEM-Specific Training

Phase 1: Electrical / Electronics (E/E) Principles

Learning elements covered in the foundational phase of training include (but are not limited to) the following key elements identified by the International Transportation Learning Center (ITLC):

- **Foundational Skills**
  - Ability to read basic wiring diagrams
  - Safe handling of low-voltage batteries
  - Troubleshooting and repairing basic circuit faults
  - Inspecting and testing relays
  - Demonstrating proficient use of digital multi-meters
  - Repair wiring and terminals
- **Multiplexing**
  - Reading and interpreting ladder logic diagrams
  - Using LED indicator lights to troubleshoot the system
  - Identifying symbols used for input and output electrical systems
- **Electronics Skills**
  - Ability to inspect and test capacitors, diodes, and other electronic modules
  - Differentiate between analog and digital signals
  - Ability to describe the purpose of data communication protocols CAN/SAE J1939 and SAE J1708
  - Differentiate between direct current (DC) and alternating current (AC)
  - Demonstrate use of an oscilloscope and a graphing multimeter
  - Inspect and troubleshoot gateway modules

Phase 2: Zero emission Systems and Personal Protective Equipment

After establishing foundational skills, workforce development training should focus on familiarizing workers with the structure, major components, and functionality of both Battery Electric and the associated elements of Personal Protective Equipment (PPE), Safety, and High-Voltage Systems. This will focus on applying fundamental electronics skills for high-voltage bus systems to ensure safe and effective maintenance.

Phase 3: OEM Training

Once maintenance technicians have a solid foundation in E/E (Electrical or Electronic Equipment) components, ZEB systems, and safety protocol for working on high-voltage systems, the focus of training can shift to familiarizing technicians with the specific make and model of buses ordered by the agency.

At this stage in the process, it is expected that most of the workforce will need training in high-voltage systems and safety, and the new forms of diagnostic tools associated with ZEB maintenance. Implementing ZEB buses will require a shift to new diagnostic tools and methods. Familiarity with the new diagnostic procedures and troubleshooting techniques should be emphasized through the early stages of workforce training and before bus delivery; training material from OEM can aid in developing these procedures and techniques.

Appendix C – Loudoun County Guidance for Lithium-Ion Battery Safety

Jasen Dodson, Battalion Chief of Loudoun County Department of Fire and Rescue, provided the following circular to AECOM staff to illustrate the kind of training materials that transit agencies can develop for their respective staffs. Loudoun County and NVERS produced the circular in June 2025.

June 2025

NVERS

EV ACCIDENTS/ENTRAPMENT

One Pager Lithium-Ion Battery Series

Due to the frequency of these Lithium-Ion incidents, and the increased risks associated with these types of emergencies we have developed this document to provide consistent guidance to our personnel.

HAZARDS

FIRE/EXPLOSION

- **Thermal Runaway** is the chemical process that produces heat; the heat increases the rate of reaction and increases temperature and escalates the process. This causes a domino effect from one cell to another cell. The following are indicators of thermal runaway:
  - Heat Signature on battery
  - Jetting **(up to 75 feet)**
  - Smoke
  - Hissing
  - Popping
- **Stranded Energy** is the energy that remains inside undamaged battery modules and cells with no path to discharge it. The stranded energy can cause batteries to reignite (rekindle) and there is no way to isolate this power.

ELECTRIC SHOCK

- Battery Voltage can exceed 400+ Volts

INHALATION THREATS

- Hydrogen, Hydrogen Fluoride (HF), Carbon Monoxide, Carbon Dioxide (CO_2), Dimethyl Carbonate, Ethane, Ethylene, Methane

RECOMMENDED RESPONSE GUIDELINES

- The first arriving engine should perform a 360 to verify that all occupants are out of the vehicle and their status. During the 360, a four gas and thermal imager should be utilized to look for gases and heat signatures from the battery, leaking battery coolant (typically blue), signs of damage to the battery pack and identify exposure hazards.
- If available, an Emergency Plug should be placed in the charging port utilizing the proper plug type or adapter once the self-check and the green light turns on, this will either place the vehicle in neutral or park for most manufacturers. Blue indicates it is safe for you.
- Wheel chocks and cribbing should be placed to secure the vehicle.
- Secure the power per the EV ERG. Vehicles should be placed in park with the ignition turned off. The key should be removed and placed at least 25 feet away from the vehicle.
- A charged hoseline should be in place for vehicle extrication. If available, position an uncharged electric vehicle nozzle under the vehicle for potential thermal runaway.
- Specialty apparatus should utilize the EV ERG for vehicle specific hazards during shoring and extrication process. Special consideration should be given due to the extra weight of the electric vehicle.
- A Safety Plan should be developed to include a 360 of the incident along with a thermal scan, four-gas metering, verification that hoselines are in place and, if available, the emergency plug is in place and properly working. Battery packs should be constantly monitored throughout the incident.
- The Incident Commander should consider establishing a Unified Command with Law Enforcement and VDOT. Law Enforcement should be made aware that an electric car is involved to ensure that the proper tow company can handle the transportation and properly store it.
- **If the vehicle shows signs of going into thermal runaway and, if available, remove the Emergency Plug. Then the Incident Commander should consider additional resources for water supply, for hazmat and Fire Marshal for potential cleanup. Refer to the NVERS EV Fire One-Pager for additional guidance.**

ADDITIONAL RESPONSE GUIDELINES

Electric Vehicle Emergency Response Guides:

- Personnel should be familiar with the various EV ERG apps/websites to include NFPA, EV Rescue App, manufacture resource guides and others.
- **FUEL CELL EV's Pose Additional Hazard Considerations**
- Contact Hazmat Team or State EOC at (800) 468-8892 for additional resources
- It is recommended that the additional weight and location of the weight of the vehicle be considered during stabilization
- It is recommended that purchase points and cutting locations be verified utilizing the EV ERG.

June 2025

NVERS

ELECTRIC VEHICLE FIRES

One Pager Lithium-Ion Battery Series

HAZARDS

FIRE/EXPLOSION

- **Thermal Runaway** is the chemical process that produces heat; the heat increases the rate of reaction and increases temperature and escalates the process. This causes a domino effect from one cell to another cell. The following are indicators of thermal runaway:
  - Heat Signature on battery
  - Jetting (up to 75')
  - Smoke
  - Hissing
  - Popping
- **Stranded Energy** is the energy that remains inside an undamaged battery modules and cells with no path to discharge it. The stranded energy can cause batteries to reignite **(rekindle)** and there is no way to isolate this power.

ELECTRIC SHOCK

- Battery Voltage can exceed 400+ Volts

INHALATION THREATS

- Hydrogen, Hydrogen Fluoride (HF), Carbon Monoxide, Carbon Dioxide (CO_2), Dimethyl Carbonate, Ethane, Ethylene, Methane

RECOMMENDED RESPONSE GUIDELINES

- The first arriving engine should perform a 360 to verify that all occupants are out of the vehicle and verify their status. During the 360, a four gas and thermal imager should be utilized to look for gases and heat signatures from the battery, leaking battery coolant (typically blue), signs of damage to the battery pack and identify exposure hazards. **A 75-foot Hot Zone should be considered or 1/3 mile for tractor trailers with air monitoring.**
- **If there are no life safety hazards, exposures or other factors** to include road structures and traffic impacts, take a defensive attack "let it burn" and protect surroundings.
- **If there are no life safety hazards but exposure hazards**
  - **Prior to having an established hoseline**
    - If available, utilize an EV blanket, take a window out of the involved vehicle.
    - The EV blanket with a 50' tagline and should be deployed over the involved vehicle(s) and/or exposures.
    - Personnel should be cognizant of a deflagration due to gases building up under the EV blanket.
    - Prior to placing an EV nozzle (if available) in service, personnel should burp the built-up gases utilizing a rope attached to the EV blanket with a fog line for protection.
    - Prior to removing an EV blanket, exposures should be extinguished and the area should be ventilated and an established hoseline should be in place for personnel protection.
    - ***EV Blankets should be considered as an exposure protection but not an extinguishment tool**
  - **With an established hoseline**
    - Personnel should advance a charged hoseline protecting the exposure and knocking the bulk or the fire down in the vehicle.
    - If not already done so, personnel should take a window of the vehicle to release superheated gases.
    - If available, place an EV nozzle under the vehicle. An additional hoseline set to a wide fog should be utilized to protect personnel advancing the EV nozzle.
    - A second hoseline preferably with an additional EV nozzle/distributor nozzle should be placed to fill the interior of the vehicle.
    - If no EV nozzles are available, personnel should consider placing an additional unmanned hoseline (ex: Blitzfire) to protect exposures.
    - If there is a sufficient water supply and the scene allows for it, a deck gun may be a consideration in lieu of the handlines.
- **If there are life safety hazards (possible entrapment)**
  - Aggressive offensive attack in full PPE with handlines and place
  - If available, uncharged electric vehicle nozzle under the vehicle
  - Extrication crews should also don full PPE due to IDLH and Flame Jetting
    - Utilize manual door opener if the electric door locks fail
  - Review the EV ERG to locate the battery packs and quantify the air bags with the locations. The air bags may release violently in addition to the battery packs.
- Law Enforcement and VDOT should be notified if an extended road closure is needed.
- Once the fire has been knocked down and the thermal imager is no longer indicating heat signatures, personnel should evaluate the vehicle with a safety hoseline still in place.
- Personnel should work with law enforcement and the tow company to verify the transport. The vehicle should be stored 50' away from other objects or placed into a lot that has concrete barriers approved by the AHJ.
- If used, personnel should assist the tow company with the EV fire blanket as it is being loaded onto the tow truck to ensure that it is properly tucked prior to strapping the vehicle to the tow truck.
- In case of a propagation (rekindle), personnel should consider having an engine and law enforcement go with the tow truck to escort the vehicle to the storage lot. VDOT may assist with traffic light control.
- Personnel exposed to lithium-ion batteries that have gone into thermal runaway, should go through decon, document the exposure, and have their PPE cleaned per departmental procedures.

ADDITIONAL RESPONSE GUIDELINES

Electric Vehicle Emergency Response Guides:

- Personnel should be familiar with the various EV ERG apps/websites to include NFPA, EV Rescue App, manufacture resource guides and others resources.

Parking Garage Considerations: Water Supply, Blanket Deployment, Ventilation, Elevators, Additional Weight of EV's, Power Isolation to EV Charging Stations and the need for additional resources to include the Hazmat.

Residential Garages Considerations: EV and BESS, Power tools

- **EV fires in a residential garage** with the door closed can create a ventilation limited fire. The driveway should be considered a hot zone with the potential of the garage door becoming the vent port and becoming a projectile.
- The IC should work with the FMO to determine when the EV can be removed from the garage to prevent rekindling from propagation.
- Refer to your department's procedures in reference to removing the EV from the garage. **The secondary responder should not enter the hot zone to connect to the vehicle.**