Incident Response: Engineering Safety, Tactical Resilience, and Environmental Responsibility for EVs and Battery-Related Incidents.

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(On behalf of Cervitas Solutions – Engineering Safety and Training for Modern Response)

Executive Summary

This white paper turns current research and real incidents (Surprise, Sacramento, Morris, Moss Landing, Los Angeles, Maryland) into street-ready tactics for firefighters, company officers, chiefs, trainers, policymakers, and industrial safety teams. Battery-powered everything is already here. It is not just outrunning the fire service, but also outpacing standards and regulations. EVs, BESS, e-bikes, portable power packs, battery-powered tools, and forklifts are driving incidents that result in high-toxicity plumes, stubborn re-ignition, structural compromise, and contaminated runoff. The need to act is immediate.

H.R. 973 (Abbreviations and Acronyms on Table 1) compels the CPSC to issue a binding federal rule within 180 days establishing UL 2271, UL 2849, and UL 2272 as the compliance baseline for e-bike and e-scooter batteries and systems. Future UL updates will auto-adopt and full CPSA enforcement (recalls/penalties) stand behind it. For industry, this shifts immediate responsibility to manufacturers, importers, and retailers to certify products and tighten charging, storage, and repair practices. Hence, directly reduces ignition risk, thermal propagation, and responder exposure. Standards for EVs are in the works as well.

Cervitas closes the gap between the lab, the street, and industry. We break complex battery science into digestible, practical plays by spotting off-gassing cues, deciding when to cool vs. contain, integrating air/water monitoring, controlling runoff, and using structured decision-making to protect crews, workers, and communities. We are working with medical clinicians to develop treatment plans for exposures. **The result: safer operations, fewer surprises, fewer injuries to responders, better environmental stewardship, expertise in navigating current and future regulatory guidelines, and faster recovery.** If your agency, department, or facility needs practical, evidence-based lithium-ion response training you can use tonight, Cervitas is the answer.

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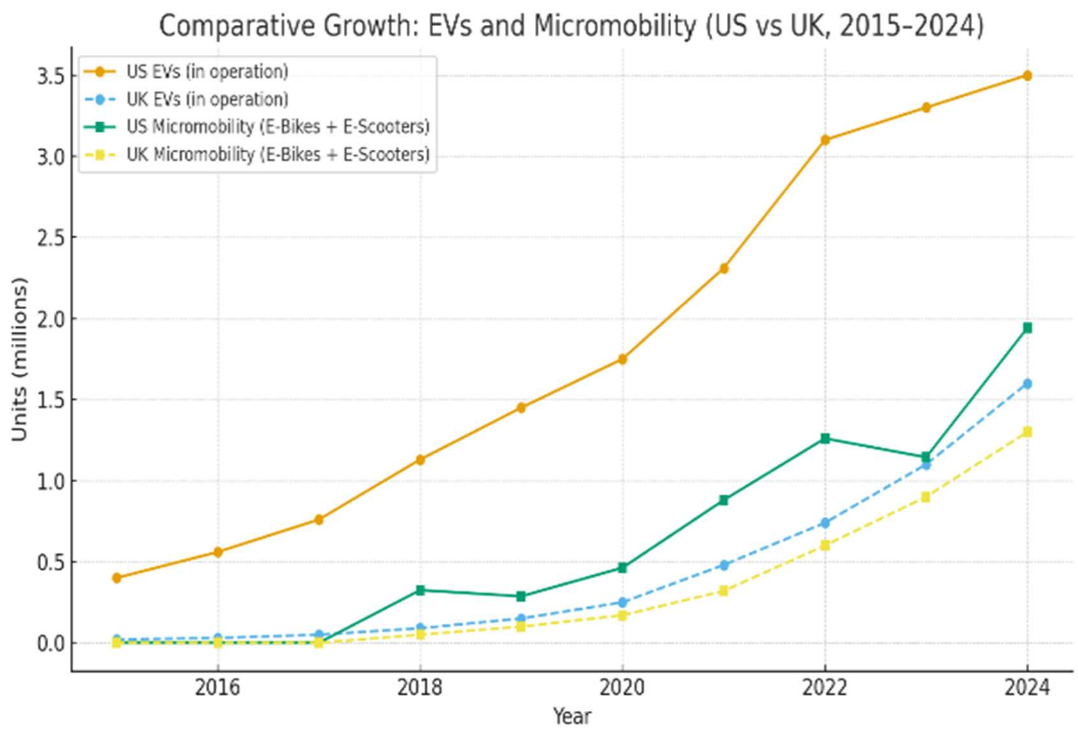
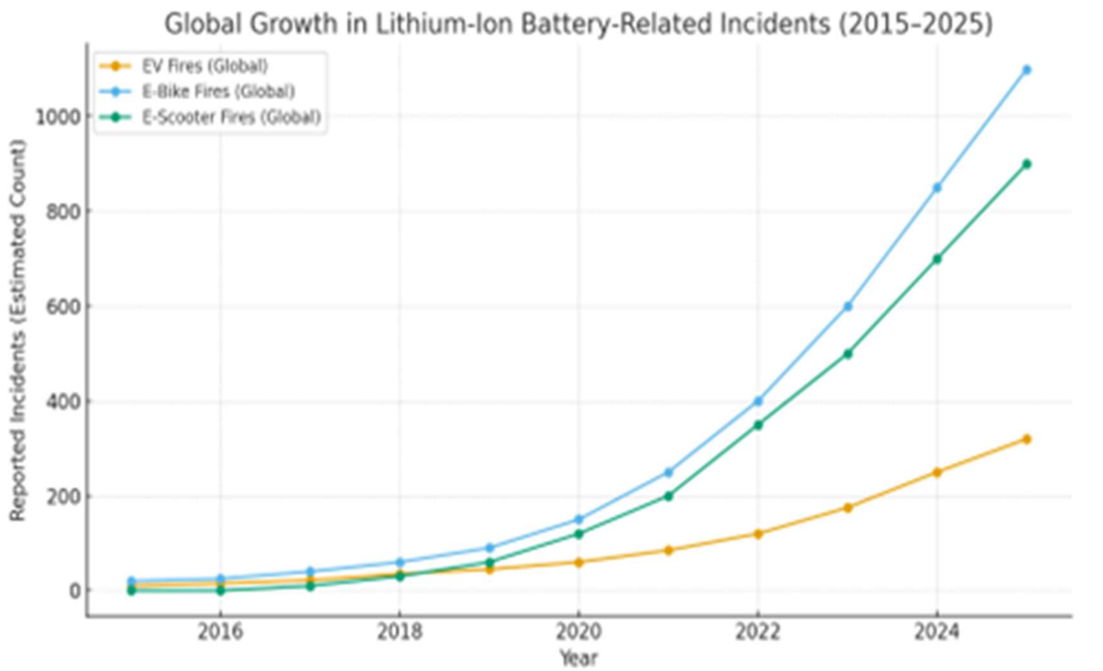
1. Introduction – The Global Electrification Paradox

By 2025, the world's roads carried approximately 58 million plug-in electric cars, with 2025 sales alone surpassing 17 million. That is over one-fifth of all new cars sold that year (IEA, 2025). At the same time, micromobility surged globally as cities adopted e-bikes and e-scooters at scale. With this rapid growth comes a parallel rise in battery-related incidents. Globally, researchers have verified roughly 511 traction-battery fires in passenger EVs between 2010 and mid-2024. This is rare compared with the overall fleet but operationally significant for responders (EV FireSafe, 2024). In the UK alone, 211 e-bike and e-scooter fires were recorded in 2024 (OPSS, 2025). New York City has reported more than 800 lithium-ion fires, resulting in over 30 deaths and 400 injuries since 2022 (FDNY, 2024). Every lithium-ion system, whether a sedan pack, a transit bus module, or a scooter battery, combines a flammable electrolyte, reactive materials, and a dense energy storage capacity. When damaged, defective, or overheated, these systems can release intense heat, and explosive and toxic off-gases. This turns the response environment into a combined thermal, chemical, and environmental hazard zone (FSRI, 2024). With battery technologies and deployment outpacing codes and standards, agencies worldwide must adopt a proactive stance built on targeted training, interagency collaboration, and engineering literacy (NFPA, 2024).



Sources: US DOE, Argonne, BTS, eCycleElectric, NABSA, SMMT, DfT, and Zap-Map (2025). UK micromobility values are indicative estimates from OPSS and DfT trends. Dashed lines denote UK data.



Sources: EV FireSafe Global Database (2024), OPSS (UK, 2025), IEA Global EV Outlook (2025), FDNY/US CPSC datasets. Values represent modeled estimates for global trend visualization.

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2. Chemistry and Thermal Runaway Mechanisms

Lithium-ion cells comprise an anode (usually graphite), cathode (lithium metal oxide), and a flammable electrolyte (often a mixture of ethylene carbonate with other carbonates). Ethylene carbonate is a waxy solid under operation of lithium batteries, so other carbonates are added to reduce viscosity. When a separator ruptures due to mechanical impact, overcharging, or an internal short, the exothermic reaction sequence known as **thermal runaway** begins (Gallagher, 2024).

The process unfolds in stages:

1. **Initiation:** Internal short raises cell temperature to ~120°C, decomposing the solid-electrolyte interface.
2. **Propagation:** Adjacent cells absorb the heat, reaching self-heating thresholds around 180–200°C.

3. **Gas and Flame Ejection:** Flammable gases and toxic vapors (HF, H_2, CO, HCN) are released; ignition follows if oxygen is available (FSRI, 2024).

Figure 1. CEP forensics image.

Recent UL studies reported hydrogen fluoride concentrations of 50–200 ppm in EV fires, well above the 30 ppm IDLH threshold (EPRI, 2025). These gases compound toxicity: CO binds to hemoglobin, reducing oxygen transport, while HF causes deep-tissue burns and systemic calcium depletion. This can lead to EKG changes and lung damage. (CTIF, 2023). Because HCN interrupts cellular oxygen use by binding to cytochrome c oxidase, victims may appear to have adequate arterial oxygen levels. At the same time, their tissues are effectively starved, a silent and insidious threat in a battery involved event. Exposure of first responders or civilians to the toxic gases results in a compounded interest of toxicity. This causes acute and long-term issues, many of which are still being discovered. The fire service and EMS services need to be ready to tackle not only fire but also exposure to these toxic gases for civilians, as well as their members.

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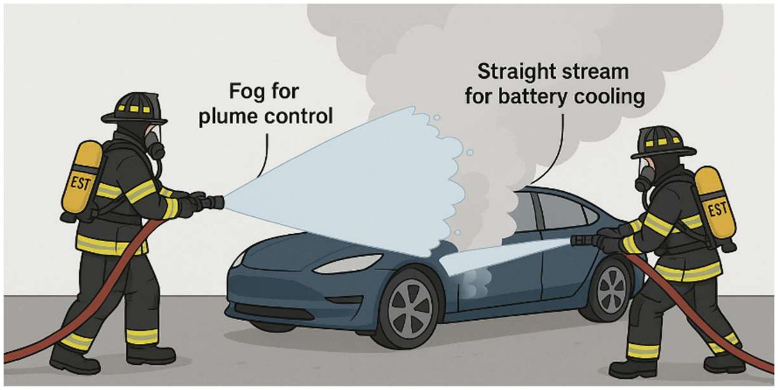
3. Tactical Complexity and the OODA Loop

Dynamic hazards require dynamic decision-making. The **OODA Loop**—Observe, Orient, Decide, Act provides a mental framework for adapting to rapid changes on scene (Boyd, 1987).

- **Observe:** Identify if batteries are involved; by observing the signs of audible venting, white vapor, off-gassing, loud pops, hissing, or deformation.
- **Orient:** Assess vehicle type, battery location, and SoC (if possible); establish wind direction and runoff paths.
- **Decide:** Determine whether suppression, isolation, or controlled burn is safest.
- **Act:** Implement a coordinated, multi-line approach while maintaining atmospheric monitoring.

Crews must remain on air throughout the incident and be ready to use SCBA immediately. If the EV's batteries are not involved and only the cabin is affected, crews should use standard tactics. This is what makes the OODA loop approach crucial to incident success. If batteries are involved, off-gassing often precedes deflagration by seconds or minutes, making readiness essential (FSRI, 2025). Given the gas's composition, the explosion risk is much higher than that of a combustion engine. Firefighters must recognize that, in these incidents, ‘white smoke’ is not always steam. The gases in the vapor cloud will often hang low to the ground, unlike steam, which rises. Another important change in thinking is that the gases are invisible, and some particulates are too small to see; therefore, ***clear air may not be clean air***.

Figure 2.



Runoff control should begin early. Tarps, booms, or vacuum systems can reduce contamination. The pollution concern stems from the cathode material in batteries, which can contain cobalt, manganese, and, far worse, nickel. When life risk is mitigated and infrastructure isolated, **allowing controlled burn** may be the most environmentally responsible option (EPA, 2025). When considering a controlled burn, assess critical infrastructure and exposure risks.

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4. State of Charge and Regulations

A battery's **State of Charge (SoC)** influences both volatility and the likelihood of re-ignition. Testing by Vora and Hogrefe (2024) showed that 90–100% SoC modules release up to 60% more energy than 50% SoC units. Fully charged packs sustain combustion longer, with higher HF concentrations during venting. They also have a more violent reaction and energy release. To combat this, most batteries are to be transported at <30% SoC. This reduces the risk of a violent reaction. There is a lower chance of thermal runaway at 50% or less SoC, but the risk of VCE increases if abuse occurs and the lithium-ion battery enters thermal runaway. Generally, the higher the SoC at the onset of thermal runaway, the greater the likelihood of ignition.

Responders should request telemetry data from manufacturers or fleet systems when possible. Understanding SoC informs cooling duration and post-incident observation time (EPRI, 2025).

Regulatory Snapshot: Strong on Fire, Thin on Toxic Plume

FAA/TSA/PHMSA policy does a good job of addressing the fire aspect of lithium-ion incidents: it mandates carry-on rules for spares, watt-hour limits, cargo-aircraft-only for cells at ≤30% SOC, and operator guidance that pairs halon for knockdown with aggressive water cooling to arrest thermal runaway. These frameworks do not fully address the toxic plume that accompanies venting cells: superheated aerosols and gases (e.g., HF, H2, CO, VOCs, metal oxides, ultrafine particulates) that can migrate through cabins, overhead bins, and ductwork, creating exposure risks long after the visible flame subsides. In practice, crew checklists emphasize suppression and containment but offer limited guidance on plume characterization, exposure thresholds, air-handling strategies, post-event monitoring, or medical follow-up for passengers/crew, and virtually no guidance for ground responders receiving the aircraft or handling a damaged pack during diversion/turnaround. The operational gap is clear: fire is controlled, exposure is assumed acceptable. Our recommendation: integrate plume-aware tactics (directed ventilation, time-weighted exposure controls, post-event air sampling, HF indicator protocols), PPE guidance for cabin/ARFF/EMS, effective PPE decontamination, and chain-of-custody packaging for hot/compromised batteries to align aviation practice with modern battery hazard science.

5. Environmental and Engineering Considerations

Environmental protection is now integral to tactical command. Lithium-ion fires produce runoff rich in **fluoride ions, cobalt, manganese, nickel, and organic solvents**. During the 2023 Luton Airport car park fire, UK environmental agencies recorded fluoride levels exceeding drinking water limits by a factor of 200. Although an EV did not start the fire, it caused numerous EVs to burn and be destroyed. There were also significantly high levels of heavy metals in firefighting runoff. (Bedfordshire FRS, 2024).

At **Moss Landing, California (2025)**, multiple BESS fires forced evacuations due to HF plumes and contaminated water discharge. The County of Monterey (2025) identified persistent fluoride ion contamination downstream.

The **Fire Research Authority (2024)** analysis of NFPA 855 recommends installing **Combustible Concentration Reduction (CCR)** systems and explosion-relief panels for BESS facilities. However, mobile applications (EVs, buses, RVs) lack equivalent requirements, necessitating local protocols for containment and runoff control.

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6. Case Studies and Lessons Learned

Surprise, Arizona (APS McMicken ESS Explosion, 2019)

Responder injuries following deflagration caused by accumulated hydrogen and toxic gases.

Crews who responded to this incident were alerted to a 'brush/ grass fire' by a civilian. What they encountered was far from that; a BESS had an incident. It is important that the crews operated tactfully and were the first to have this experience in the US. I applaud them for sharing their experiences to help us all learn. UL FSRI (2020) determined that off-gassed hydrogen and CO accumulated inside the BESS enclosure. Although gas-monitor readings were elevated, the decision to enter proceeded. The deflagration injured four firefighters. Key findings emphasized remote gas sampling, command-level standoff, and cross-agency communication with utilities.

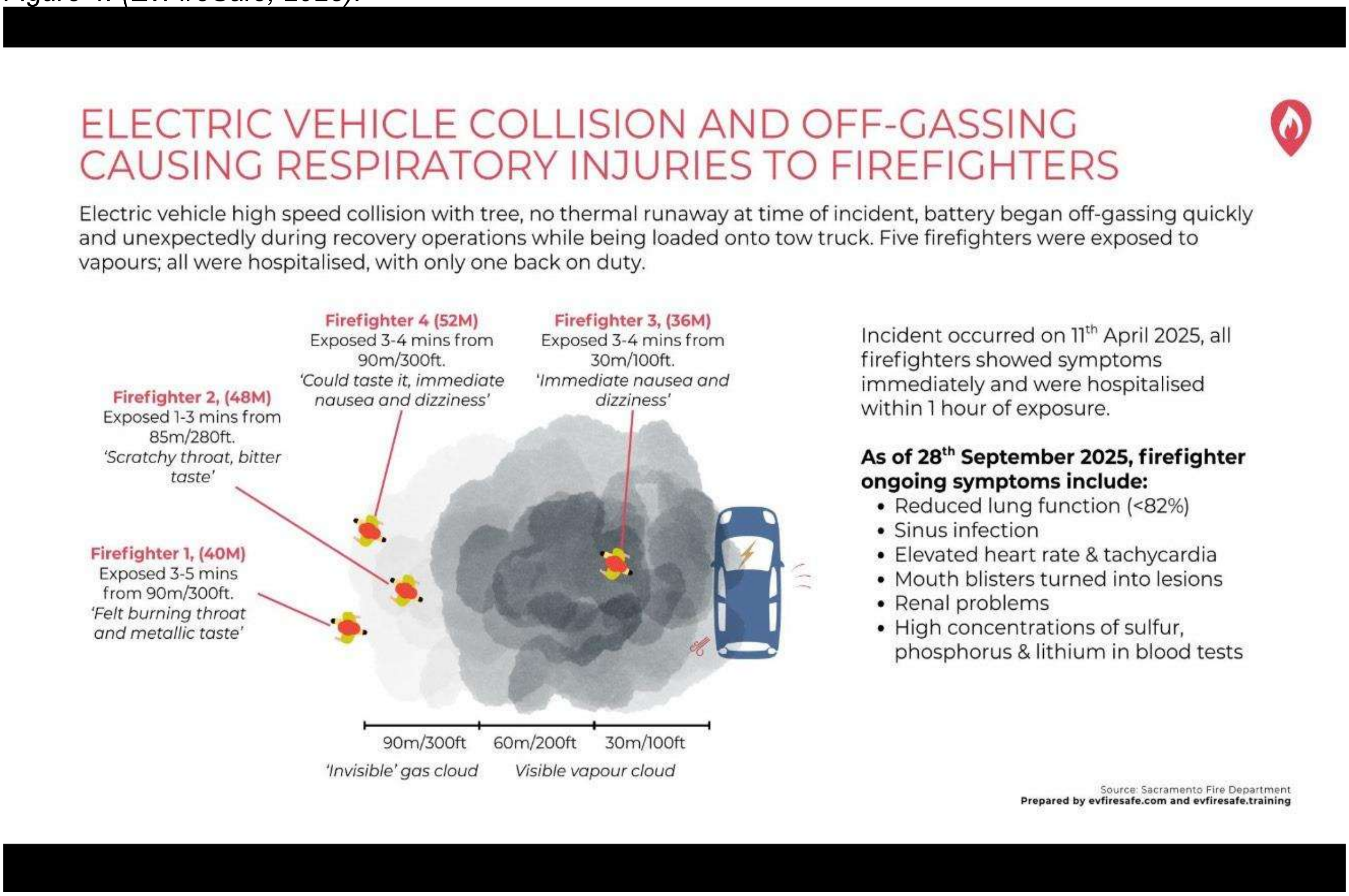
Sacramento, California (Tesla Crash and Battery Event, 2025)

Low-lying vapor exposure highlights the need for perimeter and SCBA discipline.

Following a crash involving a Tesla Model S versus a tree. The patient had to be extricated using hydraulic rescue tools. Post-incident, while the vehicle was being moved onto the tow truck, it began to exhibit signs of thermal runaway. The firefighters were no longer wearing their protective breathing apparatus and were immediately consumed by the vapor cloud. The firefighters observed a dense, white vapor drifting across the roadway. Four members experienced metallic taste and throat irritation; subsequent tests indicated exposure to HF, CO, and HCN due to off-gassing (KCRA, 2025). The department's internal report reiterated that

vapor does not equal steam and reinforced the use of SCBA until the atmosphere is confirmed safe.

Figure 4. (EvFireSafe, 2025).



Morris, Illinois (Lithium Battery Warehouse Fire, 2021)

EPA-managed HF monitoring underscores environmental coordination.

More than 100 tons of discarded batteries ignited in a warehouse. The EPA's On-Scene Coordinator deployed mobile HF monitors and coordinated public evacuation (EPA OSC, 2021). The incident became a national model for integrating environmental science into tactical operations.

Moss Landing, California (Vistra/PG&E BESS Fires, 2025)

Prolonged operations reveal long-term particulate and fluoride contamination risks.

Across three operational periods, responders addressed recurring thermal runaways at a 300-MW BESS facility, continuous HF monitoring and sample collection guided evacuation zones. Post-incident analysis confirmed runoff contamination, illustrating the importance of environmental liaisons within unified command (County of Monterey, 2025).

Los Angeles, California (7th Street Battery Fire Blue Sheet, 2025)

Overhaul contamination and PPE integrity—critical lessons for post-fire decontamination.

The Los Angeles City Fire Department (2025) documented persistent HF residue on PPE after overhaul. Despite gross decontamination, follow-up sampling detected fluorides within turnout fibers. Recommendations included double-washing, separate transport of contaminated gear, and tracking personnel exposure.

Maryland Incidents (DOD Contractor & RV Explosion, 2025)

Responder injuries and contamination emphasize persistent HF exposure risk.

A DOD contractor prototype battery fire released HF that affected a pump operator stationed outside and off-air, resulting in decreased lung capacity and prolonged recovery. Months later, a recreational vehicle equipped with aftermarket batteries exploded while crews were taking initial actions. Crews' PPE tested positive for HF residues. Both incidents reaffirm the need for **new tactics for these incidents, PPE testing, medical monitoring, and specialized decontamination** procedures (Cervitas Field Records, 2025).

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7. Responder Preparedness and Tactical Readiness

A modern response requires deliberate preparation across three domains: **training, equipment, and SOP integration**.

Training and Simulation

FSRI (2025) testing shows EV fires can reignite hours, days, weeks, or even months after extinguishment, with the longest interval being 8 months after the initial incident. Training evolutions must incorporate delayed re-ignition scenarios, air-monitoring practice, thermal imaging, and OODA-based tactical exercises. Cervitas programs emphasize multidisciplinary training that combines hazmat, suppression, and environmental units.

Equipment and PPE

Thermal imaging should be used continuously for hotspot monitoring, with the understanding that if you do not have a clear view of the battery, you could get a false 'cold' reading. Make sure you know the limitations of the TIC. Minimum flow rates of 400–600 gpm per line are recommended for battery pack cooling (UL FSRI, 2025). Crews must maintain SCBA use, including during EV or lithium-ion battery incidents. If there is an active fire or signs of thermal runway, crews must go on air within 300 ft of the incident, whether preparing for a rescue or executing firefighting tactics. SCBA should remain on and ready to use until monitoring confirms a safe atmosphere or crews are outside of the 300 ft hot zone. HF and HCN often linger after visible flameout. Remember, clear air is not clean air.

Extra cleaning protocols are essential: gross rinse, double wash, and isolation. Cervitas advocates annual PPE HF-residue testing for departments engaged in EV and battery responses.

Standard Operating Procedures

Departments should embed OODA-based decision trees into SOPs:

1. **Observe:** Identify off-gas color, components of gas, vapor behavior, and wind direction.
2. **Orient:** Determine battery location, SoC if possible, and access points. Exposure risk for toxic plumes and fire spread.
3. **Decide:** Choose suppression vs. isolation vs let it burn.
4. **Act:** Assign handlines, establish runoff control, and maintain monitoring.

Pre-plans should include tow-yard holding procedures, runoff containment methods, and debrief templates for sharing with JOIFF, IAFC, IAFF, and global networks.

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8. The Caution Against EV Fire Blankets

In recent years, electric vehicle (EV) fire blankets have been marketed as a means of containing lithium-ion fires. However, based on current field evidence, scientific data, and risk analysis, I do not recommend using EV fire blankets as a primary tactic in lithium-ion incidents. My own operational use of them is limited and increasingly cautious.

Fire blankets are often promoted for their ability to suppress flames and contain smoke, but in EV battery incidents, they may create more problems than they solve. Specifically, these blankets risk trapping flammable gases such as hydrogen, carbon monoxide (CO), hydrogen cyanide (HCN), and hydrogen fluoride (HF) beneath the surface of the blanket. If those gases reach explosive concentrations, responders could face a delayed deflagration or vapor cloud explosion (VCE), particularly during removal or venting efforts.

Furthermore, EV fire blankets may interfere with thermal imaging and delay recognition of hotspots or reignition events. Given that lithium-ion battery packs can reignite days or even months later (FSRI, 2025), maintaining visibility and access is critical. Covering an EV may compromise both firefighting tactics and atmospheric monitoring, hindering safety and situational awareness.

The International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) echo concerns regarding overreliance on unventilated containment tools. In its operational guidance, the IAFC stresses the importance of controlled ventilation, real-time gas monitoring, and fire-ground decision-making rooted in chemistry and risk modeling not product marketing (IAFC, 2024).

As of 2025, lithium-ion vehicle incidents remain high-risk but low-frequency. This may tempt municipalities and industry partners to pursue "quick fix" tools, such as EV fire blankets. However, the blankets may introduce new hazards rather than mitigate existing ones. In short, the risks of gas collection, potential ignition, reduced visibility, and a false sense of containment are too great.

Until further peer-reviewed field testing and incident data support their safe use, Cervitas Solutions does not recommend EV fire blankets as a standard tactic.

9. Information Sharing and Standardization

While NFPA 470, 800, and 855 establish foundational guidance, local implementation remains inconsistent. Departments often withhold after-action data, perpetuating knowledge silos. Cervitas addresses this gap by distributing quarterly **Safety Letters** to partner agencies and contributing to the **JOIFF Shared Learning Summit and Webinars**, ensuring that global lessons translate into local practice (Cervitas, 2025).

FSRI and USFA emphasize open-source AAR sharing as a leading indicator of safety culture (USFA, 2025). The success of international networks like JOIFF demonstrates that structured collaboration prevents repeated tragedies. Failure to share lessons learned will result in more responders getting injured or killed. Reporting all near-misses and eliminating silos will save lives and reduce injuries among responders.

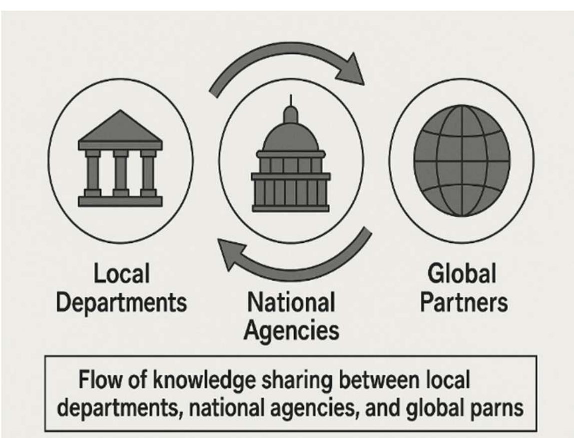

Figure 5. (Cervitas, 2025).

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10. Conclusions and Recommendations

Lithium-ion incidents pose a multidimensional hazard that requires engineering insight, tactical discipline, and continuous learning. Evidence from FSRI (2024-2025) and field incidents reveals recurring themes:

1. **Protocols and Preparedness** – Implement specific SOPs for EV/ Lithium-ion battery/BESS incidents, including OODA-loop integration, full SCBA use, and runoff control.

2. **Training and Exercises** – Incorporate re-ignition and toxic-vapor scenarios into hands-on evolutions. Practice pulling at least two handlines even with smaller crew sizes. Train for EVs to go into thermal runaway in rescue scenarios to have plans in place for when it happens.

3. **PPE and Health** – Mandate testing for metals, VOCs, and HF-specific in PPE, enhanced decontamination and cleaning. SOPs for immediate gross decontamination and proper bagging of gear after a fire. Implement additional post-cleaning testing of the gear beyond a wipe test, following traditional cleaning. This is to see what is released when gear is exposed to heat and flames after cleaning.

    a. Protocols for exposures to these toxins, working with toxicologists, pulmonologists, and other healthcare clinicians to help achieve the best outcomes for patients and first responders. Examples include not just first-line emergency treatments but also gathering baseline bloodwork for heavy metals, baseline EKGs, and lung function testing.

4. **Monitoring and Data Sharing** – Use of thermal imaging camera and gas detection for HF, CO, VOCs, and HCN. Share AAR data via JOIFF, IAFF, global partners, and IAFC.

5. **Environmental Stewardship** – Recognize when “let it burn” may minimize contamination, guided by EPA metrics.

The fire service stands at a crossroads between tradition and transformation. Tactical resilience demands humility and curiosity, qualities that drive Cervitas’ mission to bridge research and practice.

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11. Call to Action

I invite departments, industry partners, and government agencies to collaborate to advance readiness for lithium-ion and battery incidents. Through accredited training, JOIFF-aligned outreach, and custom scenario development, Cervitas delivers the expertise needed to **protect responders, preserve the environment, and prepare for the future**.

To connect with Cervitas or schedule training:
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Table 1:

	Abbreviations and Acronyms		
AHJ	**Authority Having Jurisdiction**	**HCN**	**Hydrogen Cyanide**
APS	**Arizona Public Service**	**HF**	**Hydrogen Fluoride**
ARFF	**Aircraft Rescue and Firefighting**	**IAFF**	**International Association of Fire Fighters**
BESS	**Battery Energy Storage System**	**IAFC**	**International Association of Fire Chiefs**
BMS	**Battery Management System**	**IDLH**	**Immediately Dangerous to Life or Health**
CO	**Carbon Monoxide**	**JOIFF**	**Joint Oil Industry Fire Forum**

CPSC	**Consumer Product Safety Commission**	**NFPA**	**National Fire Protection Association**
CPSA	**Consumer Product Safety Act**	**NRTL**	**Nationally Recognized Testing Laboratory**
CTIF	**Intl Assoc. of Fire & Rescue Services**	**OODA**	**Observe–Orient–Decide–Act**
EKG	**Electrocardiography**	**PAH**	**Polycyclic Aromatic Hydrocarbon**
EMS	**Emergency Medical System**	**PHMSA**	**Pipeline and Hazardous Material Safety Administration**
EPA	**Environmental Protection Agency USA**	**PPE**	**Personal Protective Equipment**
EPRI	**Electric Power Research Institute**	**SCBA**	**Self-Contained Breathing Apparatus**
EV	**Electric Vehicle**	**SoC**	**State of Charge**
FAA	**Federal Aviation Administration**	**TSA**	**Transportation Security Administration**
FDNY	**Fire Department of New York**	**UL**	**Underwriters Laboratories**
FRS	**Fire and Rescue Service (UK)**	**UL 2271**	**Batteries for Light EVs (LEV)**
FSRI	**Fire Safety Research Institute**	**UL 2849**	**e-Bike Electrical Systems**
H.R.	**U.S. House bill**	**VCE**	**Voltage Collector-Emitter**
VOC	**Volatile Organic Compounds**		

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