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Battery-Electric Container Handling Equipment Battery Fire Risk and Safety

A transitioning fire risk profile

ZEPA Zero Emission Port Alliance

About this document

This document aims to help key stakeholder in the container handling equipment industry **understand and manage the evolving fire risk profile** associated with transitioning to battery-electric container handling equipment (BE-CHE). It provides visibility into **how BE-CHE fire risk profiles differ from diesel-based systems**, transitioning the fire risk profile for terminal operators to be lower frequency and (potentially) higher impact when they occur. The document concludes with specific recommendations for terminal operators, OEMs and first responders to **strengthen battery fire safety** through **proactive risk assessment**, **revised emergency response plans and targeted training**.

About ZEPA

The Zero Emissions Port Alliance (**ZEPA**) was formed expressly to **accelerate port decarbonisation**. Decarbonised ports are our vision. Container terminals are our focus because the electrification of container-handling equipment is a particularly powerful lever for decarbonising ports as it has interdependencies with other segments. ZEPA aims to **accelerate take-up of battery-electric container handling equipment** among terminal operators by making BE-CHE **affordable and accessible by 2030**.

The Secretariat is hosted by **Systemiq** and is responsible for managing ZEPA's day-to-day operations and coordinating member activities, including research and analysis, deliverable creation, project management, and industry engagement.

Executive Summary

BE-CHE battery fire risk and safety

1

The introduction of battery electric container handling equipment (BE–CHE) transitions the fire risk profile

- The global container terminal industry is shifting from diesel to BE-CHE, **transitioning the fire risk profile for terminal operators to be lower frequency and (potentially) higher impact when they occur.**
- **Battery fires result from thermal runaway, are hard to extinguish and can last hours. Several precautions can be taken on the equipment level to prevent battery fires.**

2

Studies consistently show that Battery Electric Vehicle (BEV) fires are less frequent and no more dangerous than Internal Combustion Engine (ICE) fires

Traditional fuels come with known risks that we have learned to manage over time. Lithium-ion batteries introduce different hazards, and the industry is still developing the knowledge and protocols to handle them safely. Key facts from research into battery electric vs diesel vehicles include:

- BEVs are **~8-20 times less likely**[1] to catch fire than ICE.
- BEV fires are **similar in temperature**, but often **last for longer durations**.
- Battery fires are **not more likely to occur during charging** compared to other phases of operation.
- **Battery quality in BE-CHE varies**, affecting fire risk.
- Not all EV fires are directly attributed to the battery – **with only 25% of BEV fires involving the battery**.[2]

Note: **[1]** Based on RISE Sweden (Electric Trucks – Fire Safety Aspects" - 2023): 8-20 times less likely. Please note that this is a proxy and not relevant specifically to BE-CHE.
[2] Based on 2024 data from the Netherlands.

3

Terminal operators, in collaboration with port authorities and OEMs, can take specific actions to address battery risks, focusing on a local and people focused approach

- **Terminal operators can take specific actions - in collaboration with port authorities and OEMs - to address risks, focused on dedicated protocols – rather than adapting diesel fire protocols:**

  1. **Perform risk assessment for BE-CHE to understand mitigation measures needed;** assessing how likely fire incidents are and what their impact could be, including a focus on battery failure modes, thermal runaway, mitigation across design and operation, and options for responsibly and safely disposing of damaged battery packs.
  2. **Revise global Emergency Response Plan, tailoring it to changed fire risks;** based on risk assessment, drafting response recommendations for different scenarios.
  3. **Organise local training and learning opportunities with operating staff, emergency response team, OEMs, fire departments and (where applicable) unions** on the updated risk situation at the port, aligning on updated inspection and safety protocols.

- **Most EV fire safety insights to date are based on road going commercial and passenger EVs, as BE-CHE data remains limited.** It is important to consider specific port-specific factors — including (1) (Marine) operational environment with above average exposure to salty air and humidity increasing risk of corrosion, (2) low experience and data availability, and (3) high maintenance discipline. Terminal operators should work together with OEMs and other sectors that already have tested and proven protocols in place.

- **Overall, expertise (internal or external) is key** to strengthen the risk mitigation process, avoid a false sense of security (in regards to EV fire risk and EV fire products) and reduce risk to lives, equipment and operations.

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2 What the data tells us – Comparing BEV and ICE fires

3 Key actions for terminal operators to take

What happens in a battery fire?

Battery fires result from thermal runaway, which is an electrochemical process that can result in fire, toxic gas release, and in some cases explosion risk.

Thermal runaway cause and propagation through an electric vehicle high voltage battery pack

Initiation event

External to cell

- Electrical abuse (short circuit overcharging)
- Mechanical abuse (collision, impact)
- Thermal abuse (external fire)

Internal to cell

- Faults
- Self-heating ignition
- Dendritic growth

Heat generation

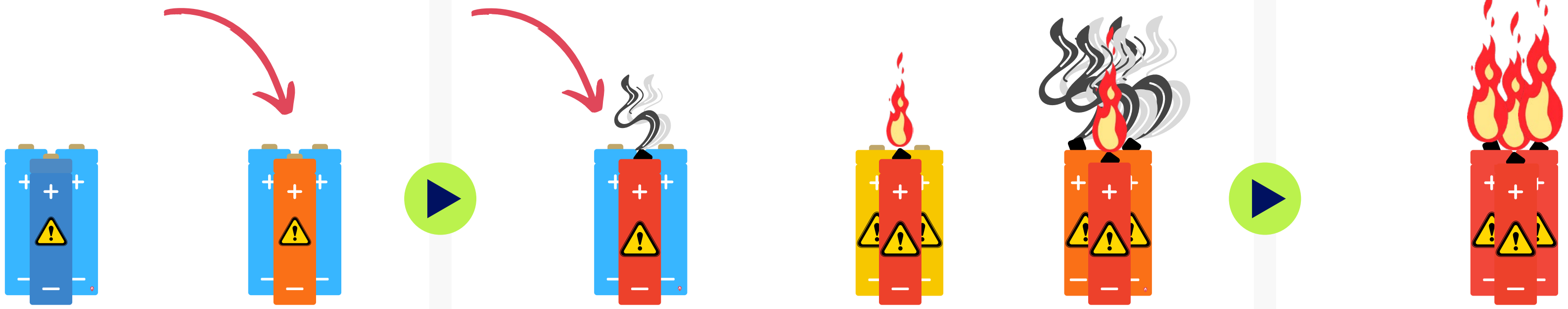
Approx 50-60 °c

Approx +170 °c

Temperature rise

Highly toxic and flammable gases (30-50% hydrogens)

Increased reaction



A battery cell suffers abuse

The cell short circuits & heats up

Pressure builds. Electrolyte boils, vapourises, bursting the safety valve

Vapour ignites, starts to form a jet-like flame

Heat propagates to nearby cells

Other cells follow, feeding flame and increasing the reaction rate

Hazards per phase:

Temperature rise	**Off gassing**
Temperature rise	**Vapour cloud explosion**
Increased reaction	**Ignition**

Source: From knowledge materials available at www.evfiresafe.com

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Battery fires result from thermal runaway, are hard to extinguish and can last hours

Why fire happens

- **Thermal runaway is an electrochemical process that can result in fire, toxic gas release, and in some cases explosion risk.** It occurs when heat generated within a battery exceeds the rate at which it can be dissipated, potentially escalating into uncontrollable reactions.
- **Common causes of thermal runaway include** mechanical damage (e.g., from collision or impact), internal or external short circuits, overcharging, overheating during charging, water ingress (especially salt water), exposure to nearby fires, and manufacturing defects.
- **Early warning signs include** loud popping sounds, whistling or hissing noises, and visible gas or vapour clouds.

What happens and what to do

- Battery fires can produce jet-like flames, **toxic and flammable vapour** clouds, **violent fire behaviour** and (in enclosed space) explosion risk.
- Fires can last **several hours** and are **difficult to extinguish** (e.g., as it is challenging for water to penetrate and reach the reacting material).
- As is also the case with ICE fires, overall risks include **facility damage**, **toxic exposure and flying projectiles.** Specific for BEV fires, **secondary ignitions** are a larger risk—sometimes days or even weeks later.
- There are many strategies to deal with Li-ion fire with varying risk profiles. Key actions include allowing it to **burn out**, using **large water volumes, isolating the area**, **controlling water runoff**, and following emergency **transport and storage protocol, as guided by local emergency services.**
- Following a battery fire, there is a risk of reignition for days, weeks or even months after the initial incident. **Due to the risks, continuous temperature monitoring is essential post-incident**. Due to the risks of thermal runaway, continuous temperature monitoring should only be conducted by trained personnel or requested of local fire services by the vehicle owner or operator.

How to prevent

- **Examples of safety measures which can be implemented in the design** include thermal control mechanisms, fire-resistant cell materials and advances in Battery Management Systems (BMS).
- **Attention to safety of Li-Ion battery systems and charging infrastructure[1] varies significantly within the BE-CHE industry**. Unlike the passenger vehicle industry, which operates under well-established global standards, this sector's regulations are still developing. Standards typically do not apply to BE-CHE or other types of equipment unless noted by the manufacturer. As a result, there can be variation in equipment quality and associated fire risk.

More information on next slide

Note: **[1]** Just like the vehicle, it is a risk to have a poor-quality chargers without proper disconnects.
Sources: RISE (2024), Fires in electric vehicles; MSB; Energy Saving Trust (2025), Are electric vehicles a fire risk?

Deep-dive: Several precautions can be taken on the equipment level

Note: as electrified container handling equipment is still emerging, there is no central safety standard (yet)[2]. Manufacturers currently subscribe to different safety practices, considering environmental and operational nuances. The precautions listed below can be used as starting points.

Equipment development	**Testing procedures**	Conducted during development, covering mechanical abuse, thermal and electrical stress, and internal short-circuit scenarios, to help identify and prevent possible battery failures.
	Design of battery placement	Battery placement design ensures protection against physical damage, vibration, thermal exposure, decrease (fire) risk overall. Battery fire suppression systems may be a useful consideration[1].
Equipment operations	**Machine control system**	Machine control system receives alerts from the Battery Management System (BMS), notifies the driver (e.g., visual or audio alarm), and initiates automatic protective responses such as power reduction or operational shutdown when critical thresholds are reached.
	Thermal management system	Thermal management systems maintain batteries within optimal temperature ranges for performance and longevity; however, they do not by themselves prevent propagation of thermal runaway during a fire.
	Battery management/ monitoring system (BMS)	BMS monitors battery state, health, voltage, temperature, and consistency. It reports critical conditions—such as over-temperature—to the machine control system and can trigger warnings or corrective actions.
Charger fire safety		Charger and charging safety rely on high-quality, certified components and proper installation (to relevant wiring standard) and integration with the BMS. Charging should be in accordance with supplier/manufacturer instructions and processes, including maintenance schedule. Incorrect or low-quality chargers can significantly increase fire risk.

Source: Expert input from ZEPA members and external parties. Notes: [1] While battery fire suppression systems may be useful, their efficacy is currently unknown. They are not a panacea for battery cells and packs, which should meet relevant quality and manufacturing standards first. [2] Trying to prescribe one standard here is likely to make procurement of equipment difficult, as manufacturers all subscribe to differing safety approaches. As a minimum, all batteries should however meet UNECE 38.3.

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What the data tells us: Studies consistently show that BEV fires are less frequent and no more dangerous than ICE fires

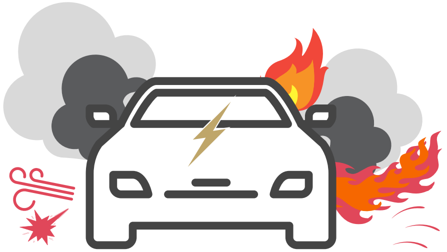
Battery Electric Vehicles (BEV) catch fire 8-20 times less often than ICEVs[1]	▪ **Yet, the low rate of current incident data of BEV's should not be seen as a fully representative indication of safety in BE-CHE**, as there are very few electrified port vehicles in operation currently. ▪ Globally, EV FireSafe[6] has been able to identify and **verify at least two incidents involving electric trucks** in the port environment, with **at least two additional incidents where electric vehicles and/or lithium-ion batteries have significantly impacted port operations**.
BEV fires are similar in temperature, but often last for longer durations	▪ The flames of BEV are at **similar temperature** to those from an ICE.[2] ▪ BEV fires are not necessarily more intense, but they do often **burn considerably longer than ICE[3]**, making them more complex to manage operationally and leading to a larger potential interruption to operations (e.g., they require **more water[4]**, and pose **specific risks** like jet flames). ▪ Research demonstrates that when batteries are involved, EV fires are at least as toxic as, and in some cases more toxic than, fires in comparable ICE vehicles.
Battery fires are not more likely to occur during charging	▪ The causes of battery fires remain diverse. For BEVs, approximately **22%** are linked to **collisions or impacts**, **15%** to **charging incidents** (though charging is often coincidental rather than causal), **7%** to **known recall issues**, **4%** to **submersion** in salt water, and **4%** to **exposure to external fires**. Notably, around **50%** of cases have **unknown or unconfirmed causes.** Greater data sharing is essential to improve understanding and risk mitigation.
Battery quality in BE-CHE varies, affecting fire risk	▪ Most EV safety standards relating to battery safety are concerned with road-registered, specifically passenger electric vehicles. **These standards typically do not apply to BE-CHE** unless noted by the manufacturer. ▪ **Focus for Terminal Operators should be on due diligence during procurement process** to ensure OEM battery safety is suitable for operator risk appetite. It is critical is to ensure an Emergency Response Guide of the equipment is written to ISO 17840[6].
Most BEV fires do not involve the battery – only ~25% do[5]	▪ Not all electric vehicle fires originate from the battery; some are caused by other onboard systems or external factors. For terminal operators, this highlights the importance of implementing comprehensive fire risk management across all vehicle systems and operations. ***More information on next slide***

Note: [1] Based on RISE Sweden (Electric Trucks – Fire Safety Aspects" - 2023): 8-20 times less likely. Please note that this is a proxy and not relevant specifically to BE-CHE. **[2]** Based on scientific research Cui et al. **[3]** Specific duration will depend on a range of factors, including overall kWh capacity, State of Charge, chemistry and module/pack design. **[4]** Vast quantities of water may be consumed at an incident, but ineffectively used due to design characteristics and inappropriate strategies and tactics. **[5]** Based on 2024 data from the Netherlands (see next slide). **[6]** High-quality batteries are produced under rigorous manufacturing controls—with certified cells from reputable manufacturers that meet recognized safety standards and undergo strict quality assurance. **[6]** EV Fire Safe is one of the few parties that maintains a global database of electric vehicle battery fires.

Source: European Alternative Fuels Observatory (EAFO), EV Engineering Online; energy saving trust (2025), Are electric vehicles a fire risk? ; Cui, Y., Liu, J., Cong, B., Han, X., & Yin, S. (2022). Characterization and assessment of fire evolution process of electric vehicles placed in parallel. Process Safety and Environmental Protection, 166, 524-534; RISE (2023), Electric Trucks – Fire Safety Aspects

Deep-dive: ~25-50% of EV fires registered in the last 4 years are attributed to the battery, the rest had no battery involvement

Comparison of EVs on fire vs EV battery fires, Data from Institute of Public Safety (NIPV) in the Netherlands



	2021	2022	2023	2024
EV ON FIRE No battery involvement	33	65	90	160
EV BATTERY FIRE Battery in thermal runaway	36	45	31	57
Share of EV fires where battery was in thermal runaway:	52.1%	40.9%	25.6%	26.2%

Source: NIPV, graphic via EV FireSafe

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Key actions: Three steps can be taken to start addressing battery fire risks

1

Perform risk assessment for BE-CHE to understand mitigation measures needed

Assessing how likely fire incidents are and what their impact could be, including a focus on battery failure modes, thermal runaway, mitigation across design and operation, and options for responsibly and safely disposing of damaged battery packs.

2

Revise global emergency response plan, tailoring it to changed fire risks

Draft **response recommendations for different scenarios,** including:

1. cabin fire and/or battery fire
2. flooding/submergence in water, particularly salt water and
3. any EV that has suffered significant collision damage that may have impacted the battery pack[1].

3

Local training and learning with key stakeholders

Engage with operating staff, emergency response team, OEMs, fire departments and (where applicable) unions through practical training, to build trust and ensure coordinated emergency response readiness. Ensure data is collected when incidents occur, to educate other terminals.

Note: [1] Additionally, develop a system to 'triage' damaged EVs and whether or how they can be accepted into a port.
Source: Expert Interviews

Managing battery fire risks requires different stakeholders to take specific actions at each of the three presented steps

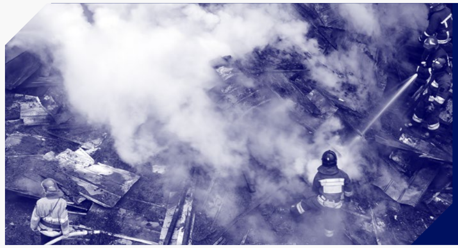
	1 Perform Risk Assessment for BE-CHE to understand mitigation measures needed	2 Revise global Emergency Response Plan, tailoring it to changed fire risks	3 Local training and learning with key local stakeholders
(Terminal) leadership and strategy teams	Liaise with HSE lead/team to assess where highest exposure exists and evaluate risk trade-offs against operational priorities with procurement team.	Encourage proactive risk management. Ensure fire and incident protocols are regularly updated based on evolving industry best practices; collect data to benchmark against other more mature or experienced industries.	Ensure learnings from workshops become an input for global guidelines and provide guidance for other terminals - strengthening reporting culture for near misses and minor collisions. Emphasize need to re-evaluate existing measures based on reporting.
Local Health, Safety, and Environment (HSE) team	Map where highest exposure exists, liaise with procurement team on quality standards for batteries. Establish a list of relevant questions for OEMs regarding testing standards and emergency response guides. Review on-sites safety capability, and potential need for external support.	Ensure fire and incident protocols are regularly updated based on evolving industry best practices; lead regular cross-stakeholder plan reviews and include EV-specific fire risk and emergency response in drills.	Set up battery-fire safety workshop with operating staff, emergency response team and fire operators. Expand knowledge and ensure team stays informed as best practices evolve within the container handling industry.
Local maintenance team	Ensure awareness and thorough understanding of common causes of battery-fires, and how to minimize risk.	Integrate EV-related risks into maintenance Standard Operating Procedure (SOPs), and understand the location and use of battery disconnect switches (for electrocution risk).[1]	Include equipment thermal monitoring in preventive maintenance plans. Practice drills for hazard identification and battery isolation, using e-stop or similar. Drills should be conducted with safety team, fire brigade and OEM.
Local operators	Be trained on how to identify early warning signs of fire (e.g. popping sounds, hissing, vapor) and evacuation procedures. Training materials must be visual and language-adapted, focused on what signs to notice and how to act. Perform regular inspection of battery / equipment and telemetry monitoring for equipment malfunction.		
Local Fire Department	Keep updated records of equipment type and models on site. Be informed of equipment type and request an Emergency Response Guide (ISO 17840) from the supplier and/or manufacturer.	Ensure response plans are co-developed and tested with relevant fire agencies and other stakeholders such as Port Authorities.	Participate in joint site walkthroughs and understand EV-specific hazards (e.g., reignition risks, battery disconnect method to reduce electrocution risk, expected duration of fire incident).

Overall, it is recommended actions are taken in close partnership with (internal/ external) experts and/or training organisations to inform inputs.

Note: [1] ZEPA Voluntary Standards TT8 and SC8 of the voluntary standards explicitly mentions this "Ensure each vehicle has a safety switch concept that can manually turn off all power electronics in case of emergency, and is clearly indicated in an open-source technical drawing".

Source: Expert Interviews

EV fire safety insights mainly stem from commercial vehicles; it important to consider the impact of port-specific factors on battery fire insights



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	Port specific context that may influence battery fire risk	**Impact on safety**	**Preventative measures**
(Marine) Operational environment	Above average exposure to salty air and humidity. Increased risk of flooding	Corrosion, insulation loss, short circuits, fire	Sealed enclosures; Regular maintenance when battery is being swapped frequently; Anti-corrosion coatings; Regular cleaning/washing to reduce impact of salty air and corrosion
Experience and data availability	Limited operational data specific to BE-CHE; BEV data often used as a proxy	Knowledge gaps due to limited real-world experience can affect risk identification and response	Promote data and experience sharing across the sector to improve collective understanding and reduce misinformation
Level of maintenance discipline	High maintenance discipline in a typically high-utilization context, may result in lower risk level. Yet, lower discipline may lead to lower inspection rigor or infrequent checks	Fault propagation leads to higher risk of fire and equipment down time	Comprehensive training programs; inspections of battery pack, cabling, connectors and seals, with maintenance checklist checking for physical deformities, leaks, corrosion, heat build-up and swelling

Sources: Expert input; European Alternative Fuels Observatory, EV Fire Safe ; Field Ex

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