

Electric Vehicles on Roll-On and Roll-Off Passenger Ferries

CAPABILITY AND PREPAREDNESS



Introduction

Purpose and Scope

This guidance provides practical insight into how battery electric vehicle (BEV) fires may differ from conventional internal combustion engine (ICE) vehicle fires on RoPax ferries, particularly regarding battery thermal runaway and vapour cloud explosions (VCE). It is intended to support both operational and command-level decision-making by identifying EV-specific hazards, behaviours, and uncertainties, and by integrating these considerations into existing shipboard fire-response frameworks.

EV fire risk is different, but not inherently higher. However, unfamiliarity with EV fire behaviour can significantly increase the consequences of an incident if these characteristics are not properly understood and anticipated.

This document does not replace SOLAS requirements, Flag State instructions, Class rules, or Company Safety Management System (SMS) procedures. Instead, it clarifies where EV-specific behaviour may require adjustments to assumptions, thresholds, and timelines, while operating fully within established regulatory and organisational processes.

Section 1

Understanding the risks

Risk Characteristics

EV incidents on RoPax ferries are **low-frequency, high-consequence events**. While incidents remain rare, limited operational experience and evolving evidence mean that risk understanding will continue to develop as EV carriage increases. A low probability of occurrence does not equate to low impact.

Decision-making should therefore focus on **consequence management, escalation potential, and time-dependent behaviour**, rather than likelihood alone.

Thermal Runaway and Fire Behaviour

Thermal runaway is the defining characteristic of lithium-ion EV battery failure. It can escalate rapidly from localised heating to large-scale gas release, sometimes before any visible fire is present.

Battery venting may be energetic and directional, producing jet flames or pressure-release events that differ from conventional vehicle fires. Once thermal runaway begins, it is difficult to arrest and can involve extremely high energy release rates. Temperatures within the battery pack may exceed 1,000 °C, even in the absence of sustained external flame.

During this process, large volumes of flammable gases may be released. In enclosed or semi-enclosed Ro-Ro spaces, these gases can accumulate and migrate, potentially forming an ignition-ready vapour cloud and creating the conditions for a Vapour Cloud Explosion (VCE) if ignition occurs.

Early indicators of battery failure do not imply that it is safe to approach. Initial response should prioritise assessment, isolation, and preparedness for escalation over immediate close-range intervention.

Causes of EV Battery Failure

EV battery failure may result from a range of factors, including:

- Manufacturing defects or material failure
- Battery-management-system faults
- Mechanical damage (including damage from prior road accidents)
- Overcharging or over-discharging
- High ambient temperatures
- Internal or external short circuits
- Ageing and end-of-life degradation

In many cases, the initiating cause may not be immediately apparent.

Fire Growth and Energy Release

Fire growth from EV batteries can be rapid and difficult to control once established, with high and sustained heat-release rates.

State of Charge (SoC) significantly influences severity. A higher SoC increases the peak heat-release rate and the overall energy available. Lower SoC reduces ignition likelihood but may still present **significant gas-production and explosion hazards** and should not be assumed to represent a low-risk condition.

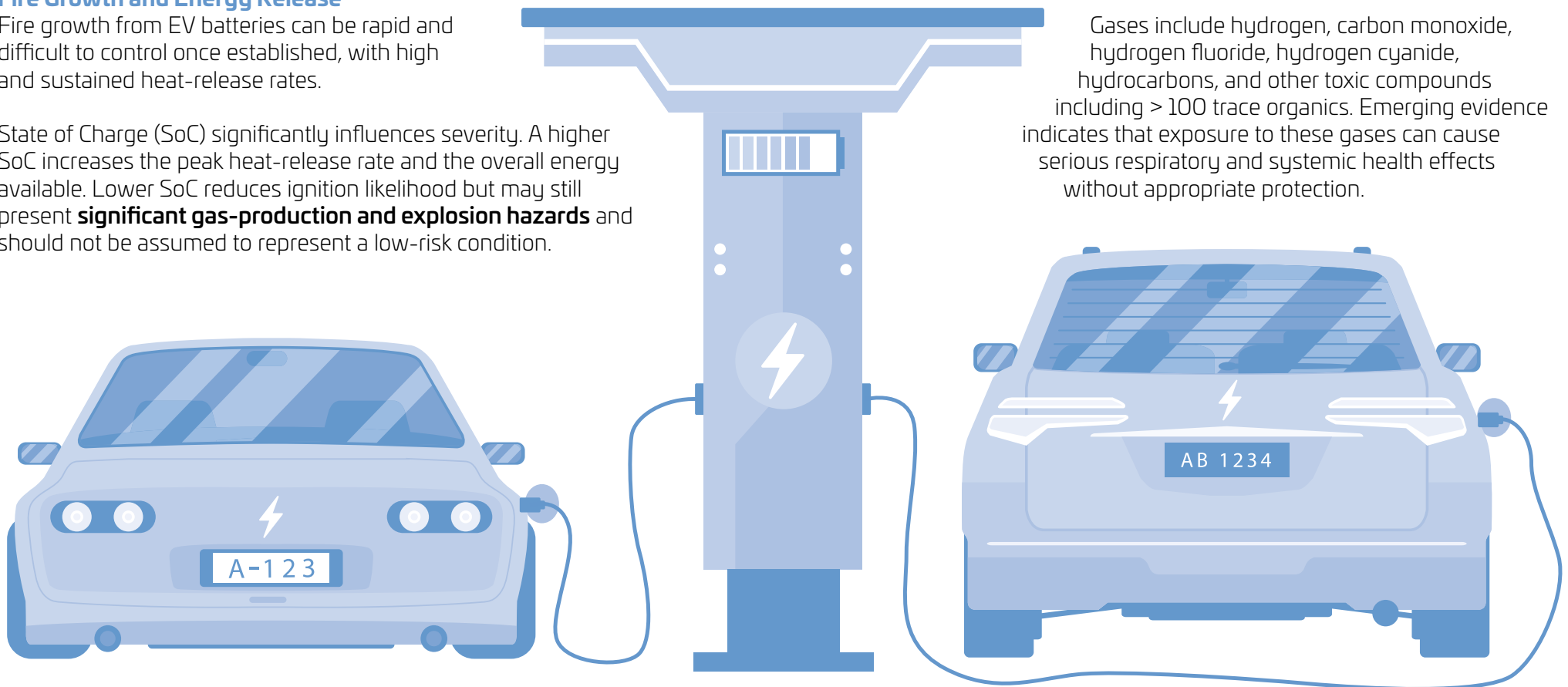
Gas Production and Vapour Hazards

Thermal runaway releases a mixture of flammable, toxic, and irritant gases. These include lighter-than-air gases (including significant quantities of hydrogen) and heavier vapours that spread unpredictably, accumulate at deck level, or migrate into adjacent spaces.

Early signs may include white vapour, often mistaken for steam or smoke. This vapour is flammable and toxic and can present an explosion risk even in the absence of visible flame.

Hazardous atmospheres can develop away from the vehicle and prior to ignition. The absence of flame or smoke does not indicate a safe environment.

Gases include hydrogen, carbon monoxide, hydrogen fluoride, hydrogen cyanide, hydrocarbons, and other toxic compounds including > 100 trace organics. Emerging evidence indicates that exposure to these gases can cause serious respiratory and systemic health effects without appropriate protection.



Ventilation Considerations

Ventilation strategies effective for ICE-vehicle fires may not behave as expected during EV incidents. Significant gas production can occur before ignition, and mixed-buoyancy gases may disperse in unpredictable ways within ro-ro spaces.

Ventilation should therefore be treated as a **tactical decision**, based on risk assessment rather than automatic application. Decisions should consider gas dispersion, flammability limits, ignition potential, and explosion risk, which may differ depending on whether the vessel is in port or at sea.

Scale of Risk – Number of EVs

Risk is driven more by **individual battery behaviour** than total energy onboard. A single EV can produce a very high heat-release rate and escalate rapidly.

However, the number of EVs carried and their approximate state of charge remain important indicators of **potential severity, duration, and resource demand**, and should inform command-level planning and response thresholds.

Persistence and Re-Ignition

EV battery packs may retain significant internal energy even after apparent suppression. Individual cells can fail hours or days later, resulting in re-ignition.

EV fire incidents should therefore be treated as **ongoing energy events**, requiring:

- Extended monitoring
- Conservative re-entry decisions
- Continued stand-off distances

Premature declaration of resolution may expose personnel to renewed fire or gas hazards.

Passenger and Public Interface

EV fires may escalate quickly and produce large volumes of toxic gases that can spread beyond the vehicle deck, potentially affecting escape routes and accommodation spaces.

While escape routes are designed to support safe evacuation, the presence of vapours and the duration of incidents may influence conditions in practice.

Passenger communication should be calm, clear, and controlled, avoiding any suggestion that an incident is fully resolved while monitoring, cooling, or exclusion measures remain in place.

Training and Preparedness by all stakeholders

Operational experience with EV fires remains limited. As described above, EV incidents may involve early-stage vapour hazards and gas production that existing PPE and procedures may not fully address.

Operators should review training, drills, procedures, and the suitability of breathing apparatus to ensure crews are prepared for EV-specific risks, including prolonged incidents and delayed escalation. The training should focus on the differences between BEV and ICE fires so that the crew's early recognition and assessment are reliable.

LOW PROBABILITY



HIGH IMPACT

Section 2

Risk Controls and Prevention

Administrative Controls for EV Carriage

Advance Declaration

The number and type of EVs and hybrid vehicles should be declared prior to loading, with vehicle locations recorded on the loading plan where practicable.

Booking Declaration

Passengers should confirm that vehicles are in good condition and have not been recently damaged, involved in accidents, or subject to known battery faults.

Check-In Verification

Visual checks should be conducted to identify warning indicators, external battery damage, or other signs that may indicate elevated risk prior to embarkation.

Damaged or Faulty EVs

The carriage of damaged or faulty EVs should be subject to specific procedures, including risk assessment and defined control measures. Some operators may choose to refuse carriage in line with company policy.

Section 3

Planning scenarios

- Fire at sea
 - **Freedom to manoeuvre:** concentrate on fire suppression and managing passenger response, obtaining support of other commercial vessels to assist.
 - **No access to external firefighting support:** speed of emergency response reduced with distance
 - **Disembarking passengers:** use of ferry LSA lifeboats and liferafts, supported by external shipping in the vicinity.
 - **Vehicle decks closed:** an optimistic scenario, as this keeps passengers separated from possible toxic fumes.
 - **Weather:** distance from the land will affect opportunities to shelter in a lee



| EV Ro-Pax- Fire at Sea | | | |
|--------------------------------------|---|---|-------------------------|
| Situation | Key Risks | Possible Actions | Comments / Ideas |
| Fire at sea – ship free to manoeuvre | Fire spreads; smoke exposure; passenger panic | <ul style="list-style-type: none"> • Send Mayday • Contain fire • Navigate closer to shipping lanes with caution • Keep passengers informed | |
| No external firefighting support | Delayed response; limited crew | <ul style="list-style-type: none"> • Focus on containment • Ready LSA for evacuation • Early RCC contact | |
| Passenger evacuation required | Panic; injuries; exposure | <ul style="list-style-type: none"> • Launch LSA • Coordinate with nearby ships • Assign crew for passenger control | |
| Vehicle decks closed | Toxic fumes; limited access | <ul style="list-style-type: none"> • Keep sealed • Monitor structure • Use remote systems if available | |
| Heavy weather / far from land | Difficult evacuation; long survival | <ul style="list-style-type: none"> • Seek lee shelter • Adjust course • Brief SAR assets about on-scene weather | |

EV/Ro Pax Fire – Underway in or near harbour

| Situation | Key Risks | Possible Actions | Comments / Ideas |
|--|--|--|------------------|
| Proximity of navigational hazards while containing the fire and passengers | Loss of situational awareness and loss of control | Allocate resource to maintain safe navigation and containing the fire passenger management | |
| Reduced freedom of manoeuvre | Collision / grounding | Divert all traffic away from the Ro-Pax to reduce the risk-exclusion zone | |
| Venting of toxic gases to atmosphere | Health implications for the passengers, crew and the local population | Coordinate with port authorities, environmental agencies /SOSREP/ police and fire for mass evacuation order and port closure | |
| Pre-designated emergency berth or anchorage | Positioned away from resources and maybe exposed to weather if at anchor | It becomes a single point of focus for emergency response | |
| Impact on other port activities | Port closure and operational and commercial loss for port stakeholders | | |

EV Ro-Pax Fire in port alongside loading/unloading

| Situation | Key Risks | Possible Actions | Comments / Ideas |
|---|---|---|---|
| Bow/Stern ramp opened | Uncontrolled release of toxic fumes over port and nearby town | Consult with emergency services before closing the ramp as they may require access to the vessel through it | |
| Presence of passengers on the car decks | Muster and control of passengers and risk to life and health. | Use mass evacuation equipment and LSA | |
| Evacuation of large numbers of passengers | Uncontrolled crowd management. Difficult evacuation due to non-aligned escape routes | | |
| Impact on operations on adjacent berths | Fire and gas spread to nearby vessels and facilities | Communicate quickly and get vessels to depart their berth or abandon their ship | |
| Access for the emergency services | LSA equipment may be out of action depending on the proximity of the fire | Consider all available means of access to affected compartment or vehicle deck, incl internal and external routes. Assess the risk of each option. Including smoke, heat, structural layout, and potential for rapid fire development | Do not rely solely on fixed systems such as CO ₂ or foam, as their effectiveness in vehicle spaces may be limited. Prioritise safe access, containment, and sustained cooling. |

Section 4

Implementing the Plan

4.1 Detection & Initial Assessment

Early detection saves time- time is the Master's greatest ally.

- Use continuous monitoring with CCTV, infrared cameras, thermal imaging, and gas detection (including HF sensors).
- If abnormal heat or smoke is detected:
 1. Alert the bridge immediately. Crew to evacuate the area immediately and monitor the area.
 2. Confirm source and extent- *is it isolated or spreading?*
 3. Inform the Harbour Master and initiate initial situation reporting (SITREP 1).

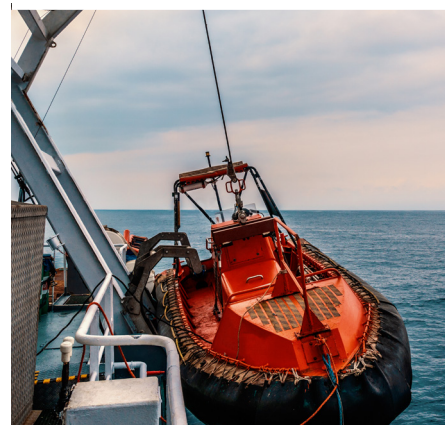
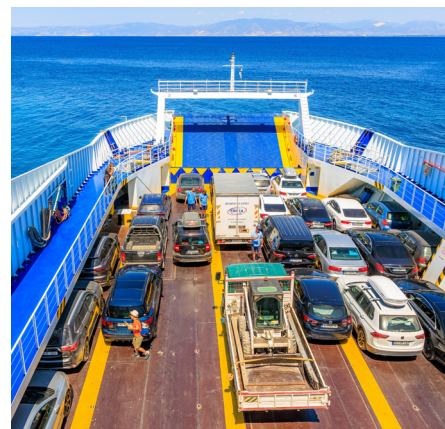
Thermal runaway can develop unpredictably and very quickly. Once confirmed, assume escalation until proven otherwise.

4.2 Activation Thresholds & Initial Actions

The Master activates the shipboard response as per SMS and the emergency plan.

- **Activation trigger:** confirmed or suspected EV fire, or rapid heat rise.
- **First actions:**
 1. Sound the alarm and muster crew.
 2. Consider shutting the ventilation if in port and opening it if at sea to the affected deck (if safe).
 3. Isolate power and stop vehicle movements.
 4. Begin boundary cooling using fixed systems or monitors.

Priority: Life before ship – but evacuation timing must weigh heat/smoke/explosion threat versus lifeboat exposure.



4.3 Situational Awareness & Decision Making

Maintain a shared mental model among all responders through:

- **Observation:** deck condition, smoke behaviour, thermal readings.
- **Orientation:** compare against fire plans and emergency zones.
- **Decision:** choose Go / No-Go / Abort.
- **Action:** implement and communicate decisions immediately.
All updates logged with time and rationale.

4.4 Command, Control, and Coordination

A unified response depends on shared information:

- **Ship's crew:** immediately operate the fixed firefighting system, boundary cooling, and evacuation control.
- **Port/Harbour authority:** incident command, safe anchorage, pollution control.
- **Fire & Rescue:** firefighting support, hazmat control, contaminated water management.
- **OEMs/Salvage:** technical advice on battery behaviour and safe recovery.
- **Regulators:** oversight and coordination with SOSREP, Port State Control.
- **Unified Command:** Regular SITREPs between Master, Harbour Master, SOSREP and emergency services.

4.5 Tactical Onboard Response

1. Evacuate non-essential personnel and passengers from affected decks.
2. Cool continuously; rotate crews; maintain SCBA use and facemask filters.
3. Monitor deck and boundary temperatures.
4. Keep communication short, clear, and multilingual to reduce panic.

If containment fails: Prepare to abandon to pre-identified safe anchorage or commence passenger evacuation.

4.6 Passenger Management

- Keep instructions short, simple, and multilingual.
- Muster upwind of smoke; avoid choke points.
- Prepare for both "go" (disembarkation) and "no-go" (shelter in place) scenarios.
- Ensure passengers receive pre-travel safety briefings about EV fire response.



4.7 Port & Harbour Coordination

Before arrival:

- Confirm safe anchorage and tugs on standby.
- Establish exclusion zones based on wind, current, and plume modelling.
- Coordinate with environmental and health agencies for water/air contamination.

Ports should have:

- Pre-designated stand-off positions.
- Clear triage and evacuee reception arrangements.
- Pollution control and firefighting support ready.

4.8 Information Management

Accurate cargo information underpins decision-making:

- EV flag, battery kWh, SoC, SoH, vehicle condition, and location on deck.
- Segregate EVs where possible; avoid mixed stowage blocks.
- No charging at sea unless risk-assessed and approved.

4.9 Equipment & Monitoring Requirements

Ensure availability and readiness of:

- Thermal, CCTV and gas monitoring ().
- Fixed water deluge and portable cooling equipment.
- Containment tanks for contaminated runoff.
- Drones for external observation (if authorised).

4.10 Training, Drills & Learning

Preparedness must be exercised, not assumed.

- Annual tabletop drills (ship–port–rescue–regulators).
- Annual live exercise including EV fire scenario.
- After-action reviews circulated across agencies.
- Crew knowledge of the environment on the car deck at the start of a fire, (e.g. *Hearing popping (blast caps or pouch cells/hissings or screaming (high volumes of gas being released)).* Anything that looks like smoke or steam. If it can be smelled, the crew and passengers are at risk.

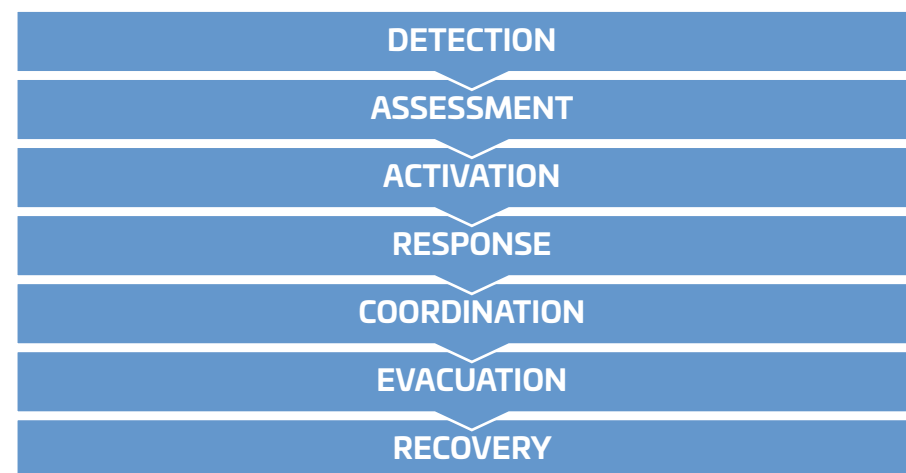
4.11 Oversight & Assurance

Port State Control and Flag Administration should verify:

- EV manifest procedures and SoC policies- knowing where EV's are is essential.
- Monitoring, ventilation, and containment systems.
- Drill records and crew competency.
- Availability and suitability of PPE/FFA.

4.12 Post-Incident & Recovery

- Manage contaminated water, debris, and air quality impacts.
- Conduct structured debriefs and lessons learned review.
- Update risk assessments and training accordingly.



Key Takeaways:

1. Early detection buys time; time saves lives.
2. EV fires behave differently — fast, hot, and persistent.
3. Continuous cooling, monitoring, and communication are essential.
4. The unified command ensures coherence among the ship, the port, and the rescue agencies.
5. Drills, clear messaging, and passenger preparation turn plans into capability.

Appendix 1

Case Study: Learning from the Felicity Ace

The loss of the car carrier *Felicity Ace* in 2022 highlighted the complexity of EV-related fires at sea. While investigations did not attribute the casualty solely to battery ignition, the presence of electric vehicles raised important questions regarding:

- Gas generation in enclosed cargo decks
- Fire detection response times
- Ventilation effectiveness
- Firefighting tactics where lithium-ion batteries are involved

The incident reinforced a critical point

Modern vehicle cargoes can introduce different fire dynamics, including sustained heat release and the potential for significant flammable-gas production. Analyses of EV and mixed-cargo fires show that vapour clouds may accumulate in enclosed ro-ro spaces, creating a combined toxic-gas and explosion hazard.

Key Maritime Safety Considerations

- Treat EV battery failure as a **flammable gas release scenario**, not just a conventional car fire.
- Assume **a flammable atmosphere may form before visible flame** is present.
- Consider **hydrogen dispersion** in ventilation design (as hydrogen rises rapidly).
- Recognise that **other battery-off-gases may be heavier than air** and may **accumulate at deck level or flow laterally** into adjacent vehicle bays.
- Understand that conventional gas detection may not identify all battery gases.
- Use respiratory protection for re-entry.

Vapour Cloud Formation During EV Battery Thermal Runaway Overview

When a lithium-ion EV battery enters thermal runaway, it can release a large volume of **flammable and toxic gases within seconds**.

This is not simply smoke from a vehicle fire. It is a rapid gas-generation event capable of forming a significant vapour cloud, particularly hazardous in enclosed or semi-enclosed spaces such as ro-ro decks. Industry reports note that these vapours may accumulate and pose explosion risks if not properly ventilated.

Gas Volumes – Practical Planning Figure

For risk assessment purposes, a commonly used engineering range is: **≈ 300–6000 litres of gas per kWh** of battery capacity.

In simple terms:

50–100 kWh EV battery → approximately 15–60 m³ of gas

Full pack involvement may produce more, particularly at a high state of charge.

In a confined vehicle deck, this volume is sufficient to create a **flammable atmosphere before ignition**.

What the Vapour Cloud Contains

The vapour cloud typically includes:

- **Hydrogen** (very light and buoyant)
- **Carbon monoxide** (slightly lighter than air but can accumulate in pockets)
- **Methane and ethylene** (lighter and heavier fractions)
- **Carbon dioxide** (heavier than air)
- **Trace hydrogen fluoride** (dense and ground-seeking)
- **Aerosolised electrolyte droplets** (heavier than air and able to settle or remain suspended)

Important clarification:

While hydrogen rises rapidly, **many other vapours and aerosols generated during thermal runaway are heavier than air** and can therefore:

- **Pool at deck level,**
- **Flow along the vehicle deck,** and
- **Accumulate in low points or behind obstructions,** increasing the risk of delayed ignition and confined-space explosion.

Vapour Cloud Behaviour

The gas cloud:

- Forms rapidly
- Is initially hot and buoyant
- Begins stratifying:
 - **Hydrogen rises,**
 - **Heavier vapours and aerosols can remain low and spread laterally**
- Can accumulate under deckheads
- May travel before ignition
- Can ignite immediately, or after a delay

Delayed ignition in a confined space introduces a significant explosion risk.

This hazard has been highlighted in industry analysis of EV fires on Ro-Ros, where trapped hydrogen-rich mixtures may reach explosive limits.

“

Industry reports note that these vapours may accumulate and pose explosion risks if not properly ventilated

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*Appendix 2***Strategic Actions for EV / ICE Incidents on Ro-Ro Passenger Ferries****1. Master’s Command and Decision-Making Authority**

- The Master retains overriding authority for the safety of the vessel, passengers, and crew.
- Strategic decisions regarding containment, muster, evacuation, diversion, or port entry should be guided by immediate risk to life, vessel integrity, and navigational safety.
- Early, factual reporting to relevant authorities should provide sufficient information to enable risk assessment and coordinated response planning.

2. Organisational Responsibilities**Ferry Crew**

- Implement vessel emergency procedures for EV or ICE thermal or fire incidents.
- Apply appropriate firefighting, boundary cooling, monitoring, and mitigation measures.
- Use suitable PPE and breathing apparatus as required.
- Maintain clear internal communications and provide timely situation reports to the Master.
- Support passenger safety measures as directed, including relocation, muster, or controlled evacuation.

Port Authority

- Coordinate with the Master to support safe arrival, berthing, anchorage, or contingency arrangements.
- Where necessary, designate berths or anchorages that minimise wider community risk.
- Facilitate access for emergency responders and establish appropriate safety or exclusion zones.

Local Authority

- Support reception and welfare arrangements for passengers and evacuees.
- Coordinate temporary accommodation and information services.
- Manage public communications to support community awareness and reassurance.

Emergency Services (Fire, Medical, Hazardous Materials)

- Assume tactical control on scene in line with local incident command structures.
- Assess and manage risks from smoke, toxic emissions, and hazardous materials.
- Plan for potential burns, inhalation injuries, and trauma, including surge capacity where required.
- Support casualty triage, treatment, and onward evacuation.



Acknowledgements

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