A Holistic Performance-Based Fire Safety Framework for Electric Bus Depots in Australia

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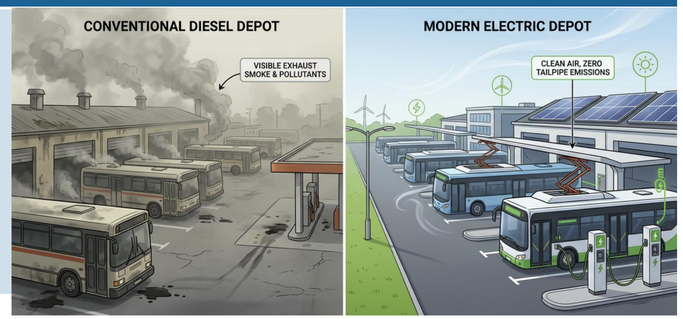
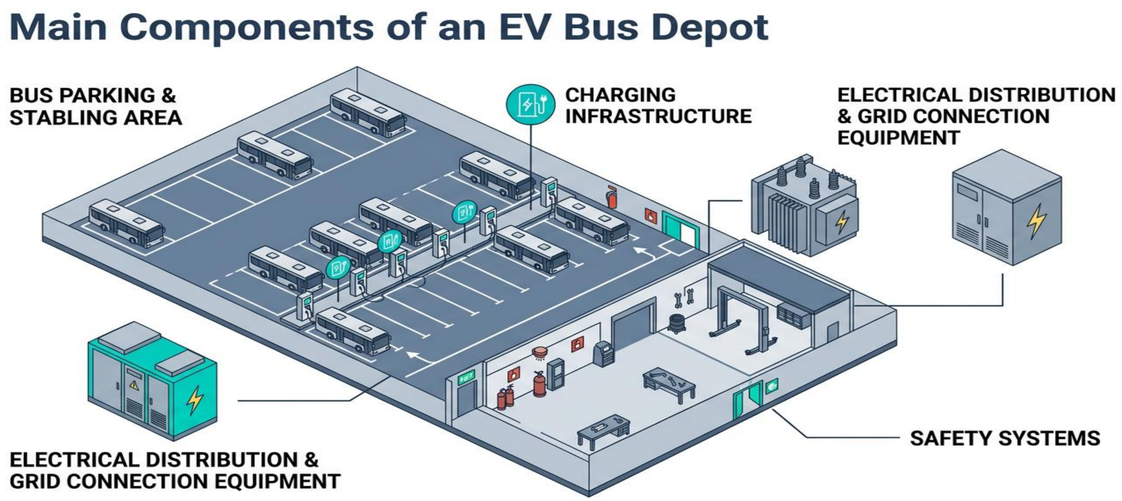
Part 1 - Background

EV Bus Depot Drivers in Australia

- Zero emission goals by 2050
- Improved air quality and sustainability
- Reduce dependency on Diesel buses and infrastructure



Key EV Bus Depots Components



Types of EV Bus Depots

Aspect	Open-Air EV Bus Depot	Enclosed EV Bus Depot
Environment	Outdoor parking areas	Fully enclosed building
Ventilation	Natural ventilation	Automatic smoke exhaust and Hazardous gas dissipation
Smoke behaviour	Rapid dispersion	Smoke accumulation
Heat behaviour	Heat dissipates to atmosphere	Heat trapped within enclosure
Hazardous gas accumulation	Low likelihood	Higher likelihood (CO, HF)
Fire spread drivers	Separation distance & radiation	Radiation, smoke & gas confinement
Fire suppression strategy	Layout and spacing dominant	Reliance on passive compartmentation and active measures

EV Bus Depot Fire Design Objectives

Objective	Focus Area
Life Safety	Occupant evacuation and firefighter protection
Code Compliance	Meeting relevant standards and codes
Other Regulatory Objectives	SFAIRP (So Far As Is Reasonably Practicable)
Asset Protection	Safeguarding vehicles, infrastructure, and buildings
Business Continuity	Maintaining depot functionality and bus availability
Insurance	Risk mitigation and coverage protection

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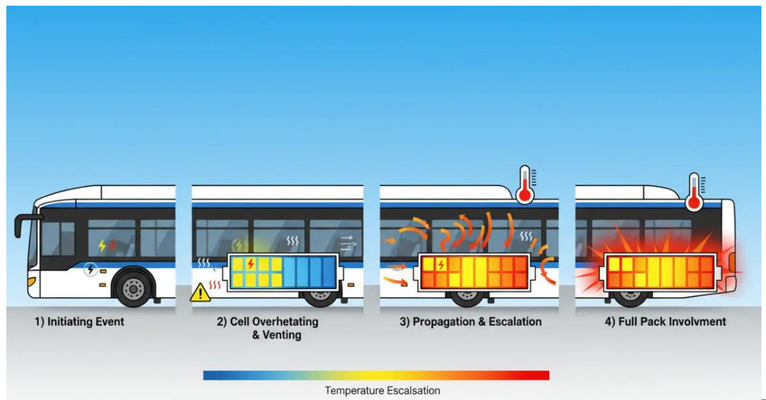
Part 2 - Special Fire Hazards in EV Bus Depots

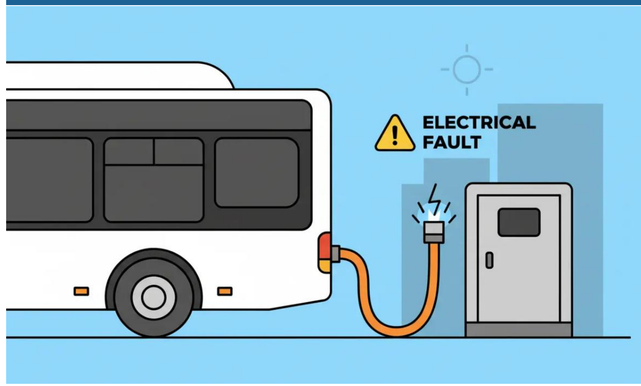
Thermal Runaway



Electric Bus Thermal Runaway: System-Level Heat Event

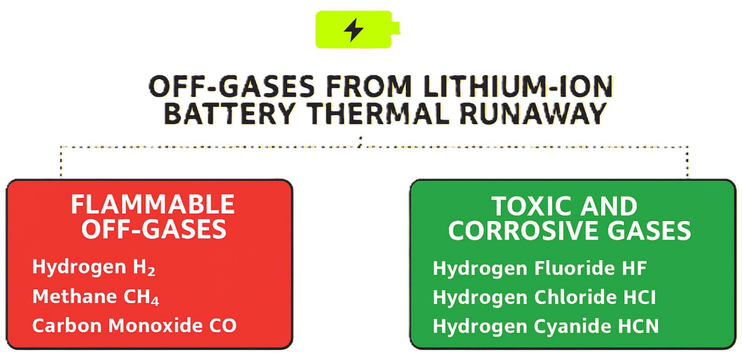
- **Chain reaction**: Overheated cell ignites others, spreading rapidly in the battery
- **Intense output**: Reaches 600–1000 °C, releasing flammable and toxic gases
- **Challenging to stop**: Reaction is self-sustaining and resists cooling or suppression

Charging and Electrical Infrastructure



- **Equipment faults**: Electrical failures in the charging units that spread to buses
- **Load surges**: Simultaneous bus charging raises fault risk and strains protection systems
- **Collision Risk**: Accidental collisions causing electrical fault or battery damage leading to thermal runaway

Flammable and Explosive Gases



Fire Brigade Strategy

- **Direct water application** on LIBs (Lithium-ion batteries) is discouraged by Fire Brigades
- **Risk of reignition** due to residual heat from thermal runaway
- Fire Brigades now use a **defensive approach** based on exposure protection rather than offensive approach to mitigate fire spread
- Above ground and internal hydrant coverage based on **Australian Standards**
- **Performance-based** fire water demand and containment

Impact on Fire Brigade Intervention

- **High-voltage hazard**: Live electrical systems risk electrocuting firefighters
- **Unpredictable re-ignition**: Battery fires can restart hours or days later, requiring extended monitoring and quarantine
- **Toxic gas exposure**: Off-gas contains HF, HCL, HCN
- **Water ineffectiveness**: Conventional suppression may not control thermal runaway
- **Contaminated runoff**: Fire water mixed with battery chemicals may runoff and harm the environment
- **Defensive strategy**: Cool surrounding infrastructure to prevent spread instead of direct water application on batteries

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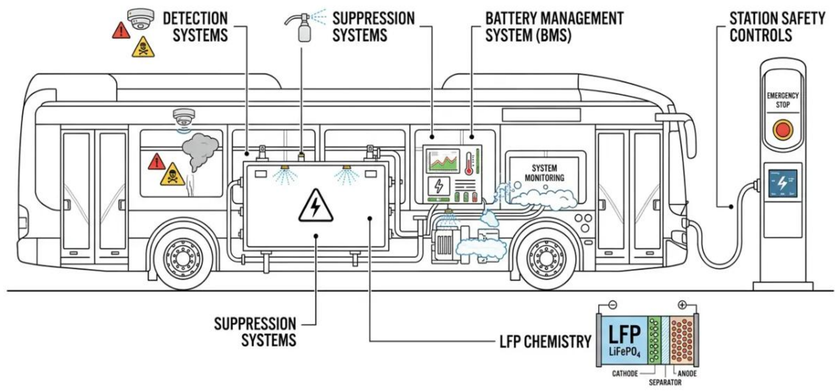
Part 3 - Performance-Based Fire Strategy Considerations for EV Bus Depots

On-Board Fire Suppression Measures



Applicable Codes and Standards

1. **BCA E1D17 and E2D21**: Special hazards under Fire Code
2. **ABCB and AFAC guidance**
3. **UL 9540A**: Test method for Battery Energy Storage Systems (BESS) fire behavior assessment
4. **IFC Section 320**: International Fire Code LiB provisions
5. **ISO AS 31000**: Systematic risk identification, assessment, and mitigation
6. **Fire and Rescue New South Wales:** Fire safety in bus depots [5]
7. **HIPAP2 -** Evidence-based hazard analysis and quantitative risk assessment

Depot Protection Measures and Strategy

1. Primary Protection Measures

a) Sprinklers: Fixed suppression for enclosed depots and maintenance workshops considering **Full Scale Testing** (SUVEREN4Depots) . to prevent fire spread and limit thermal exposure under severe, late-detected fires, rather than on extinguishing LiB thermal runaway

b) Targeted Structural Fire Protection

2. Secondary Protection Measures

a) Water Curtains or Water Mist Walls

3. Ancillary Protection Measures

a) Detection: Smoke detection

b) Off-Gas Detection: HF, HCL, HN, CO, H2, CH4

c) Thermal Imaging: In cases where smoke detection can lead to spurious alarms

d) Ventilation for smoke management and explosive gas control

e) Emergency Response Plans

f) Hazardous Water Runoff Management

4. Emerging technologies including solid-state batteries, active cooling solutions, and AI-driven battery management

Risk-Based Fire Performance Strategy

- EV bus depots require a **risk-based approach** to address the LiB hazard to SFAIRP followed by integration into a **Holistic performance-based fire strategy**