Electric Vehicle & Charging Safety for Emergency Response

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Prepared for:
The Australian Building Code Board

Prepared by:
EV FireSafe
With peer review by Professor Paul Christensen

Executive summary:

Electric vehicles aren't coming to Australia, they're already here.

Anything that moves people or goods around the country is being electrified, with the support of AC & DC charging hubs being rolled out with significant private sector, state & federal government funding.

While Australian drivers have an increasingly greater choice of low-emission vehicles & places to drive them, the management of electric vehicles involved in an incident is a new challenge for the Australian emergency response community.

We're at the start of the EV emergency response journey with more questions than answers. Primary among them is that of EVs & charging in buildings & whether they pose an increased risk to life & property safety.

Global research & testing programs are emerging, but unable to keep pace with a sector accelerating towards decarbonisation. Real world incident learnings are often siloed within attending fire & rescue departments. International collaboration is only just developing.

But, to keep emergency responders safer around EVs & charging, we can't wait for research & testing maturity. We must start now.

EV FireSafe, a private company funded by the Department of Defence to research electric vehicle battery fires & emergency response, was engaged by the Australian Building Code Board to provide a foundational set of EV & charging safety considerations.

Based on our research, discussions with Australian & international emergency agencies & peer review by an international battery fire expert, Professor Paul Christensen, this report sets out the first step in an ongoing journey to making driving & charging EVs safe & easy.

Level 1 considerations provide close to cost-neutral, implementable actions that can be retrofitted to existing sites & designed into new builds. These have the dual aim of enabling a faster emergency response & attracting the support of the EV & building sectors, for whom clear guidance is overdue.

Developing these as a *nationally* consistent pathway for managing safety while supporting EV uptake across a range of building classes, has been the toughest challenge of this work.

Level 1 considerations are supported by our data indicating passenger EV lithium-ion battery fires are very rare, with 292 verified incidents globally since 2010 in an operational stock of 16 million. Of these, 70 EV battery fires occurred in an enclosed space, with 21 connected to charging at the time. In all cases, we have not been able to find evidence of serious structural impact, however one is currently under investigation, & there have been no recorded emergency responder deaths due to a passenger EV battery fire.

We also looked to developed countries with mature EV markets for guidance, conducting a literature review & interviews. At the time of writing, none have published regulatory guidance on EVs &/or charging in buildings.

Most importantly, we consulted every Australian state & territory fire agency to better understand their knowledge gaps, wider concerns & to present the Level 1 considerations for their review & feedback. This work is key & is highlighted in this report for the ABCB's newly established EV Readiness Roundtable where they will be ongoingly reviewed & discussed as tangible, data-led learnings are tested & published.

Finally, while a focus on passenger EV battery fires is vital to responder safety, we believe there are a range of low cost, high benefit activities that are being overlooked & should be given priority by the relevant government agencies.

As an example, our database indicates only 2 passenger EV battery fires have occurred domestically (arson & external fire), however Australian responders are regularly dealing with EVs involved in collisions. No Australian road rescue agency has been able to explore cutting techniques on an EV, & there is no EV training currently available regarding identification, immobilisation & isolation of high voltage systems.

These supporting activities complement testing programs & will dramatically reduce the fear, uncertainly & doubt commonly displayed throughout our research & consultation processes.

Emma Sutcliffe, Project Director, EV FireSafe

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1. Introduction

1.1 Background:

As the world moves away from carbon-based fuel and energy systems, there is a rapid transition to electrification and the development and use of alternate fuels, such as hydrogen.

The charging of electric vehicles (EVs) is one of the earliest emerging, and fastest growing, issues that needs consideration. At the end of 2022, there will be approximately 50,000 EVs registered in Australia; by 2030 this number is expected to exceed 2 million.

Buildings being planned and designed today can reasonably be expected to accommodate near 100% occupancy of EVs by the time they are complete.

To help the Australian community make this transition, it is essential that our building regulatory systems examine appropriate means to support EV readiness – making it easy and safe for EV parking and charging in our future buildings.

The Australian Building Code Board (ABCB) aims to act as a connection point for emerging knowledge, research being undertaken on different elements by different bodies and to bring it together for the benefit of the national approach to building regulation.

To support this national approach, the ABCB approached EV FireSafe, a private research & education company funded by the Department of Defence to research EV lithium-ion battery (EV LiB) fires & emergency response, particularly where charging is involved.

EV FireSafe & Project Director, Emma Sutcliffe, who is also an operational firefighter with Victoria's Country Fire Authority, was engaged to provide subject matter expertise & technical insight into the risks in responding to EV LiB fires in buildings & incorporation of initial EV charging infrastructure in new buildings.

This work will inform the ABCBs understanding of how the National Construction Code (NCC) may need to change to support the transition to EVs. It consists of:

- The drafting of three levels of considerations
- Conversations with key stakeholders
- Participation in EV Readiness Roundtable discussions
- Literature review & expert peer review by Professor Paul Christensen, Newcastle University, UK

This is not a risk assessment, rather a snapshot of the Australian electric vehicle & charging infrastructure market, linked with a look at the knowledge gaps & concerns of emergency agencies as they work to better understand this rapidly emerging, constantly evolving sector & the new challenges it presents for emergency responder safety.

To collate all supporting documents & incident details in one place for ease of use, we have established a hidden website page at https://www.evfiresafe.com/abcb

1.2 Aim:

This initial snapshot by EV FireSafe provides foundational considerations upon which the ABCB can develop strategic & effective guidance for building regulatory systems. It should be noted that this work has been delivered as:

- Research into real-world EV LiB fire incidents matures, &
- Emerging large & small scale testing programs begin to supply evidence-led answers to the multiple questions relating to emergency responder safety at incidents involving EVs & charging. These testing programs include:
    - Fire Rescue NSWs Safety of Alternative & Renewable Energy Technology (SARET) [1]
    - Fire Protection Research Foundation at NFPA (USA)
    - LASH (RI.SE, Sweden)
    - Extinguishing agent & nail penetration tests by Newcastle University (UK)
    - Small scale testing by various other organisations

1.3 Methodology:

With a tight timeframe, we approached this work in two stages:

Data, literature & thought leadership review:

- A review of EV FireSafe's established global database of passenger EV LiB fires from 2010 to present (September 2022) – please see methodology of that database below
- A call out to a global network of fire & technical experts via Professor Paul Christensen for similar guidance being produced or published
- Desktop study & literature review of global thought-leading organisations
- Attendance &/or speaking at Fire Protection Association Australia Conference (May 2022), Australasian Fleet Managers Conference (May 2022), Smart Energy Conference (May 2022), AFAC Conference (August 2022) & the Institute of Fire Engineers Lithium Battery Professional Development Day (August 2022)

Cross sector consultation:

- Initial engagement with the Alternative Energy Doctrine Group & AFACs Built Environment Committee
- Formal meetings with the peak body, state & territory fire agencies:
    - AFAC
    - Fire Rescue Victoria
    - Country Fire Authority
    - Tasmania Fire Service
    - South Australian Metropolitan Fire Service & the South Australian Country Fire Service
    - Department of Fire & Emergency Services, WA
    - Northern Territory Fire & Rescue Service
    - Queensland Fire & Emergency Service
    - Fire Rescue New South Wales
    - ACT Fire & Rescue
- Meetings & discussions with EV charging networks, supplier & peak body:
    - Electric Vehicle Council
    - JET Charge
    - Evie Networks
    - NRMA
    - EVSE
- Discussions &/or meetings with international fire agencies & research organisations:
    - City of London
    - National Fire Chiefs Council, UK
    - Fire Research Protection Foundation (NFPA, US)
    - RI.SE (Sweden)
    - IPV (Netherlands)
    - National Transportation Safety Board (US)

1.3.1 EV FireSafe database

EV FireSafe's established database of all passenger EV LiB fire incidents was commenced in February 2019 & received seed funding in August 2021 from the Australian Department of Defence, under the Defence Science & Technology Group.

The database captures battery electric vehicle (BEV) & plug-in hybrid electric vehicle (PHEV) fires that involve the high voltage battery. These are referred to throughout this document as EV LiB fires. It does not capture mild hybrid (non-plug in vehicles containing a lithium-ion battery) or EV fires where the high voltage battery was not involved in fire; emergency response for non-EV LiB fires is the same as for ICEV fires.

It is collated into:

- Verified EV LiB fires – confirmed with at least two independent sources
- Non-verified EV LiB fires – we are confident the incident occurred, but haven't been able to find a second independent source
- Investigating EV LiB fires – online rumour, tip off, clickbait

Incidents are gathered from media & social media reports, videos, images, first-hand accounts, fire agency reports, research reports, online wikis, online training & private sources. We cross reference our data with IPV (Netherlands) who are the only organisation tracking national EV LiB incidents, as well as the University of Texas database, media articles containing lists of previous incidents, wiki pages & other online sources.

While our database research is painstaking, we acknowledge that it cannot be exhaustive due to several factors, primarily the global nature of the data & difficulty identifying whether the EV battery was involved in fire; incidents not involving the high voltage traction battery are not captured in the database. We research & hold contacts on all continents, however there is a language barrier.

Additionally, not all countries track LiB fire data & those that do have only just started. This is further compounded by the nascency of emergency agency understanding of LiBs; twice the EV FireSafe team has contacted a fire department regarding an incident, only to realise they were unaware it involved a LiB.

The dataset is also currently limited due to the small number of incidents; however EV FireSafe has recently been awarded a second round of funding by the Department of Defence, which will enable an additional 18 months of research, participation in testing programs & allow us to open source all database incidents in a searchable format that will be hosted on at evfiresafe.com

1.4 Inclusions & exclusions

This document discusses passenger electric vehicles & supporting charging infrastructure, with a focus on emergency responder safety in relation to EVs & charging in buildings.

We have included all passenger EV LiB incidents that occurred:

- In an enclosed space; anything not open air, including carports, side walls – any surrounding structure that fire can spread to
- In enclosed spaces in private homes or publicly accessible carparks, including commercial & residential strata
- While connected to Mode 2, 3 & 4 charging, however Level 1 considerations apply only to Mode 3 & 4 charging units

We have excluded & do not take into consideration:

- E-bike, scooters, skateboards & EUCs in structures or associated charging
- Electric bus (e-bus) depots & charging
- Other large or commercial electric vehicles, including trucks, agricultural machinery, mining, or depots & charging

1.5 Assumptions

There are a range of new & familiar risks & challenges associated with the emergency management of EVs that our project has identified in collaboration with a global network of battery & fire experts. Rather than repeat ourselves, we have assumed understanding of the following concepts & identified risks in relation to EV LiB incidents. Hyperlinks to explainer pages at evfiresafe.com are provided.

- Definition of a battery electric vehicle & plug-in hybrid electric vehicle
- How an EV HV traction battery is constructed
- Basics of how EV charging works
- RCM Tick for electrical compliance & AS 3000 App P for EV charging installation
- Overall risks of EV LiB fires vs ICEV fires, including risk of electrocution
- How thermal runaway in an EV battery pack occurs
- Early signs of thermal runaway for emergency responders
- EV LiB suppression challenges & methods
- Low risk of vapour cloud explosion
- Secondary ignition risk

We also highlight the 'FAQ' page for supporting evidence to our own findings that passenger EV LiB fires & vapour cloud explosions are very rare.

1.6 Disclaimer

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1.7 Glossary

ABCB	Australian Building Code Board
EVC	Electric Vehicle Council
EV	Electric vehicle (including BEV & PHEV only)
LiB	Lithium-ion battery (HV traction battery)
ICEV	Internal combustion engine vehicle
AFV	Alternative Fuel Vehicle
Charging modes	*Charging modes listed here are in line with the Electric Vehicle Council's [2] guidelines.
Mode 2	Portable electric vehicle supply equipment (EVSE) carried by driver
Mode 3	Dedicated wall or pole mounted AC EV charging unit up to 22kW (32 amp, three phase)
Mode 4	Dedicated wall or floor mounted DC EV charging unit from 25kW to 350kW (40-500kW, three phase)
LCO*	Lithium Cobalt Oxide
LMO*	Lithium Manganese Oxide
NMC*	Lithium Nickel Manganese Cobalt Oxide
LFP*	Lithium Iron Phosphate
NCA*	Lithium Nickel Cobalt Aluminium Oxide
LTO*	Lithium Titanate

*All chemistry descriptions from Battery University [3]

2. What's currently known?

EVs present a mix of familiar & new risks & challenges to emergency responders & agencies globally are grappling with developing standard operating procedures for managing incidents involving EVs & charging.

"We've had 100 years to learn how to manage petrol & diesel car fires, but we're just starting to understand electric vehicles." ~ Professor Paul Christensen

2.1 EV LiB fires are very rare

Currently, passenger EV LiB fires are very rare; we provide further details at 3. EV FireSafe's research.

However, the average age of EVs in the United States of America is around 4 years [4], compared to 12 years for ICEV, & whether the risk of LiB fires will increase as the current cohort ages is unknown.

2.2 The Nissan Leaf is the oldest EV on the road globally

However, we can get a glimpse of the future by looking at the oldest EV on Australian roads, the Nissan Leaf, which was first sold in Australia a decade ago & globally for 12 years. There are approximately 2000 on the road nationally & 600,000 globally [5].

Our database indicates only 8 Nissan Leaf LiB fires globally since 2010; 1 arson, 1 submersion, 1 suspected electrical fault & 5 of unknown cause.

2.3 More mature EV markets are a future indicator for Australia

Another useful predictive exercise is to examine the number of EV LiB fires in developed countries with far greater EV market share than Australia.

In terms of market penetration, Europe, USA & China are leading the race to decarbonised transport. In terms of number of EVs on the road, estimates by Bloomberg show Australia is roughly 5 years behind Europe & the USA, while lagging around 10 years behind China [6].

The United States has an estimated 2.32 million EVs in operation [7] & our research has been able to verify 97 EV LiB fires (to 15th September 2022).

One in every 11 passenger vehicles sold last year in Europe was electric (BEV) [8], with 95 verified incidents.

China sits at approximately 3.2 million EVs [9], with 47 verified EV LiB incidents, however it should be noted that accurate reports are challenging due to several factors. Recent media reports give incident numbers in the hundreds, but ongoing efforts to verify numbers with listed sources have so far proved fruitless.

While Norway, China, the United State of America & Great Britain are common comparisons, EV FireSafe is in regular contact with The Nederlands Instituut Publieke Veiligheid (NIPV or Netherlands Institute of Public Safety), who have begun to track national EV LiB fire data from 2021.

Throughout 2021 the following numbers applied to The Netherlands EVs & charging [10]:

In 2021, the number of:	**Netherlands (May 2022)** [10]	**Australia (March 2022)** [11]
Regular (AC) charging points	97,537	1580
Fast (DC) charging points	3,172	291
BEV + PHEV	433,353	~35,000
EV LiB fires (BEV & PHEV)	36	0

EV LiB fires connected to charging	17	0
Incidents in enclosed space	0	0
Incidents caused by charging	1	0
All vehicles (ICEV, BEV & PHEV) registered nationally	8.7m [12]	20.1m [13]
All vehicle fires (ICEV, BEV & PHEV) nationally	4753 [14]	Unknown nationally, NSW = 2,942 in 2021/2022 [15]

As a rough 'crystal ball' look, based on these numbers from NIPV, & assuming 100% EV penetration of 20.1m EVs in Australia, we could expect to see 1,733.53 passenger EV LiB fires across Australia each year. We were unable to find national car fire statistics for Australia, however as per table above, Fire & Rescue NSW attended 2,942 in 2021/2022.

An interesting learning from NIPV's research is that thermal runaway primarily occurred following emergency services arrival on scene. From their NIPV Incidents with Alternative Fuel Vehicles in the Netherlands Annual Report 2021, thermal runaway occurred:

- 10 x prior to the arrival of fire services
- 21 x while fire services were present
- 3 x unknown

Therefore, from an emergency response perspective, additional awareness, training & testing of cooling a battery pack, & the development of mitigation tools, would be highly desirable.

2.4 More EV testing & research is required to understand emergency response to EVs & charging in structures

Australian responders understand petrol & diesel vehicle (ICEV) fires & have well-rehearsed & established standard operating procedures to manage such incidents. EVs, on the other hand, pose a mix of similar & new risks & challenges to emergency responders.

To provide a starting point, we have developed operational comparisons from an emergency response perspective, which we outline on our website at '[Risks EV traction battery fire]'.

A further comparison in relation to incident management relevant to EVs & charging in structures is provided below; this has been created in collaboration with Professor Paul Christensen. It is followed by a list of the highest priority questions posed by both Australian & international emergency response agencies.

	ICEV	**EV LiB**
Cause of fire	Electrical, fuel tank	Thermal runaway
Exposure to toxic gas	Burnt plastics, fuel, metal	Mix of hydrogens, plastics, metal
Explosion	Running fuel fire, vapour cloud explosion (fumes)	Vapour cloud explosion
Temperature	Approx. 800-1000 ˚c	Potential for up to 1000-1200 ˚c [16]
Duration	Typically 1-2 hours	No average known, upwards of 3-5 hours typical
Secondary ignition	Only if not fully extinguished	Occurs in approx. 10% of incidents
Electrocution	Very low	Very low
Fire spread	Believed to be similar – testing to confirm	
Heat release rate	Believed to be similar – testing to confirm	
Fuel load	Believed to be similar – testing to confirm	

Initial testing & research from global organisations indicate similar heat release rate, fuel load & fire spread in ICEV versus EV; this work is emerging & requires corroboration with programs such as those listed in 1.2 Aim.

However, the fire dynamics also need to be considered; for example, overall heat release rate may be similar, but is delivered differently & potentially for longer & in one direction with an EV, when compared to ICEV.

2.5 Highest priority questions & concerns

2.5.1 What are the effects of off-gassing, including volume & opacity?

Often described as smoke, the off-gassing produced from an EV LiB in thermal runaway is typically a thicker, more turbulent cloud of toxic & flammable gases, than seen in a combustible smoke cloud.

According to research conducted by Professor Paul Christensen, during combustion, similar gases are produced when comparing ICEV with EV, however the main different is the production of hydrogens, specifically hydrogen fluoride with EV LiB in thermal runaway.

Additionally, Professor Christensen estimates between 600 & 3000 litres of vapour can be released per 1 kWh of battery capacity from an EV LiB in thermal runaway. This may be dependent on the battery state of charge, chemistry & form type, but requires further research & testing. For context, the most common EV on Australian roads has a minimum 54kWh battery pack.

Clouds of lighter than air combined with heavier than air of vapour have been captured on video, both in a real-world incident of an e-scooter in thermal runaway & during testing conducted by Professor Christensen. It is not yet well understood why they occur.

In the absence of a similar passenger EV images, the images below refer to an e-scooter thermal runaway event in 2018 showing rapid build-up of vapour cloud [17].

If this vapour cloud doesn't ignite, there may be an increased risk of vapour cloud explosion due to small droplets of electrolyte solvents [18]; or if there is no ignition or deflagration, an increased risk of harmful levels of chemicals & heavy metals, with a potentially higher volume of gas. This risk may vary depending on battery chemistry; NMC, NCA & LMP all contain heavy metals harmful to human health.

Additionally, there are some concerns & questions about the efficacy of a thermal imaging camera, a tool commonly used by firefighters at all incidents, through LiB vapour cloud. A recent home battery energy storage system incident in Canberra, ACT, indicated the heat signature of the unit could not be identified until the vapour cloud had dissipated. This is under discussion & investigation globally.

2.5.2 Vapour cloud explosion is a risk

Vapour cloud explosion (VCE), the build-up of toxic & flammable gases that deflagrate rather than ignite, pose a risk to responders, particularly in enclosed spaces.

We have been able to identify 15 EV LiB incidents that involved VCE, with 6 connected to charging; 3 were Mode 3 charging at home, 2 x Mode 3 in a public space & 1 x Mode 4 in a public space. These included two EVs that were later recalled due to a battery fault during manufacture. One incident, in which gases built up inside the cabin of the EV resulted in doors being blown through a carport roof & across the carpark.

While extremely rare, better understanding how to mitigate this risk is vital to responder safety.

Images below show a Tesla Model S in an underground carpark in vapour cloud explosion in 2019 [19]. This incident occurred following impact on the battery pack by an open manhole cover.

2.5.3 Difference in flame type

It's important to note the major difference between ICEV & EV fire behaviour is in the off-gassing & ignition initial phase of an EV LiB fire.

As gases escape under pressure from the EV LiB battery pack, they are ignited by an external source or potentially from friction against the battery casing. This appears as a 'jet like' flame from underneath the EV.

That directional jet flame is of particular concern at road rescue incidents where responders may be working to extricate patients when thermal runaway occurs.

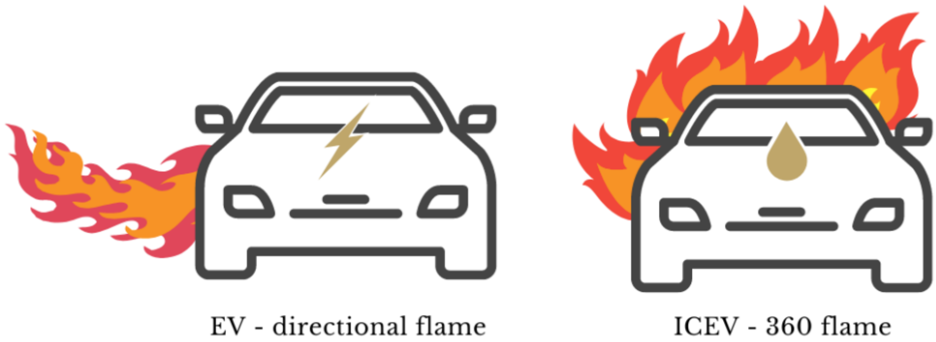
It's important to note that it is common in EV incidents for off-gassing to occur without ignition or vapour cloud explosion. It has been commonly thought that this is due to a lower battery state of charge (SoC); some testing has indicated <50% SoC typically doesn't lead to ignition, however RI.SE recently found NMC chemistry LiB may still flame at a low SoC.

It is worth noting that one manufacturer is addressing this risk by designed battery packs that vent ignitable gases to the rear of the EV, enabling safer working spaces to the sides & front (where road rescuers would more typically be standing). It is unclear if other manufacturers are considering similar.

2.5.4 Heat release is directional

While the heat release rate of an EV may be similar to ICEV, it is more directional & focused in what's commonly referred to as a 'directional jet like' flame. Calculations by Professor Paul Christensen increased intensity in the amount of heat from the 'blowtorch' effect of a thermal runaway.

This is caused by gases venting under pressure from battery cells & escaping from the battery pack through a vent or breach. As they are released & ignite, we see 'flares' of directional flame; often steady with a passenger EV, but pulsing with a smaller light EV, such as an e-bike or e-scooter.



The length of both the directional flame & its duration are currently unknown but will be largely determined by battery state of charge & other unknown or emerging factors.

Whether this directional flame has a similar or greater impact on fire spread, concrete spalling & associated structural integrity is unknown.

2.5.5 Fire water run-off & air quality

The rarity of EV LiB fires means the testing of water run-off & air quality is either not considered or done late in the incident when considerable water has diluted contaminants & gases have dissipated.

There are only two real-world incidents with official investigations into both issues, Stavanger Airport & the Victorian Big Battery fire, that we discuss in more detail at Relevant past incidents.

However, testing of lithium ion batteries in thermal runaway within a tunnel environment, conducted by the Swiss Federal Department of the Environment, Transport, Energy and Communications in 2019 [20] found ‘Firefighting and cooling water resulting from an electric vehicle fire is highly contaminated’ with high concentrations of lithium, cobalt, nickel & manganese that were unsafe to be disposed of into sewerage without prior treatment.

Additionally, the ‘Risk minimisation of electric vehicle fires in underground traffic infrastructures’ report recommended further testing of the effectiveness of water misting systems for EV LiB fires, as well as further research into the risks of EVs, particularly heavy goods EVs in underground infrastructure.

3. EV FireSafe's research findings

The focus of EV FireSafe's initial research was to identify how many EV LiB fires occur at charging & the additional layer of risk this presents to emergency responders.

Currently, EV LiB fires are very rare, with only 292 verified incidents globally, from 2010 to the time of writing, in a global stock of 16.5 million EVs [21]. We additionally have another 74 incidents under investigation.

We are not yet able to provide advice on, or comparisons regarding, the year of EV manufacture, or LiB chemistry & form type. As our second funding round commences, this detailed work will be undertaken.

3.1 Database breakdown of EV LiB fires

The 'Location' column refers to EV LiB fires that we have verified occurred at:

- Home: a private residence, in a garage or driveway
- Communal private, multi-occupancy residential such as apartment buildings
- Public: shared public space, such as shopping centres

3.1.1 EV LiB fires overall

Number of EV LiB fires (global, 2010-September 2022)	Location	Total number of incidents	Percentage of total incidents
Total overall		292	N/A
Total in enclosed space		70	23.97%
Total connected to charging		55	18.82%
Total possibly connected to charging (being investigated)		5	1.71%
Total disconnected from charging within 10 minutes of fire		4	1.36%
Total disconnected from charging within 60 minutes of fire		2	0.68%

3.1.2 EV LiB fires while connected to EV AC or DC charging

Number of EV LiB fires while connected to charging	Location	Total number of incidents	Percentage of total incidents
Mode 2 (portable 10/15amp EVSE)	Home	3	1.02%
Mode 2	Communal residential	1	0.34%
Mode 2	Public	2	0.68%
Total Mode 2		**6**	
Mode 3 (dedicated AC 7 / 22 kW)	Home	4	1.36%
Mode 3	Communal residential	1	0.34%
Mode 3	Public	12	4.10%
Total Mode 3		**17**	
Mode 4 (DC >25kW)	Home	0	0

Mode 4	Communal residential	0	0
Mode 4	Public	12	4.10%
Total Mode 4		**12**	
Unknown Mode	Home	6	2.05%
Unknown Mode	Communal residential	3	1.02%
Unknown Mode	Public	4	1.36%
Unknown Mode	Unknown	7	2.39%

3.1.3 EV LiB fires in enclosed spaces

EV LiB fires in enclosed spaces	Location	Total number of incidents	Percentage of total incidents
Total enclosed space		70	23.97%
Mitigating factors / known causes (Note: there are 35 with unknown cause)			
No. of recalled models due to known battery fault during manufacture		17	5.82%
No. due to prior collision		6	2.05%
No. due to arson		2	0.68%
No. due to EV impacted by external fire		2	0.68%
No. due to manufacturer defect		2	0.68%
No. due to overheating / electrical fault		1	0.34%
No. in workshop under repair / servicing		5	1.71%

3.1.4 EV LiB fires in enclosed spaces & connected to EV AC or DC charging

EV LiB fires in enclosed spaces + connected to charging	Location	Total number of incidents	Percentage of total incidents
Total enclosed space + connected to charging	N/A	21	7.19%
Enclosed space + Mode 2	Home	0	0
Enclosed space + Mode 2	Communal residential	0	0
Enclosed space + Mode 2	Public	2	0.68%
Enclosed space + Mode 3	Home	3	1.02 %
Enclosed space + Mode 3	Communal residential	1	0.34%
Enclosed space + Mode 3	Public	3	1.02 %
Enclosed space + Mode 4	Home	0	0

Enclosed space + Mode 4	Communal residential	0	0
Enclosed space + Mode 4	Public	1	0.34%
Enclosed space + unknown Mode	Home	3	1.02 %
Enclosed space + unknown Mode	Communal residential	3	1.02 %
Enclosed space + unknown Mode	Public	2	0.68%
Enclosed space + unknown Mode	Unknown	3	1.02 %

3.1.5 EV LiB fires in enclosed spaces, connected to EV AC or DC charging & with vapour cloud explosion

EV LiB fires - enclosed spaces, charging & vapour cloud explosion	Location	Total number of incidents	Percentage of total incidents
Enclosed space + charging (all modes) + VCE		4	1.36%
Enclosed space + unknown Mode + VCE	Home	1	0.34%
Enclosed space + Mode 3 + VCE	Home	2	0.68%
Enclosed space + Mode 4 + VCE	Public	1	0.34%

3.2 Fatalities & injuries from EV LiB fires & incidents involving EV charging

Our research indicates:

- No emergency responder fatalities from EV LiB fires
- One emergency responder injury (heat exposure) at an EV LiB fire
- No emergency responder fatalities or injuries due to electrocution from EV AC or DC charging
- 2 x fatalities (driver & passenger) due to EV LiB fire following high speed collision [22]
- 41 x injuries in driver & passengers due to collision – all believed to be due to impact, not fire
- 45 x fatalities in driver & passengers in collisions - all believed to be due to impact, not fire
- 3 x minor burns & 1 x inhalation (requiring hospitalisation) to tow truck drivers during & following secondary ignition incidents

3.3 AC & DC charging – behaviour on fault detection

Our initial research aimed to understand how AC & DC EV charging units would behave when connected to an EV LiB in thermal runaway.

EVs require an external electrical supply to power high voltage DC systems of 60V & above. To power the high voltage battery, AC grid power is supplied to both AC & DC EV charging units:

- AC units provide that to an EV where it is converted by the onboard inverter to DC power
- DC units convert power inside the charging unit

Understanding how charging units detect a fault & where they should cut power from, assists emergency responders to:

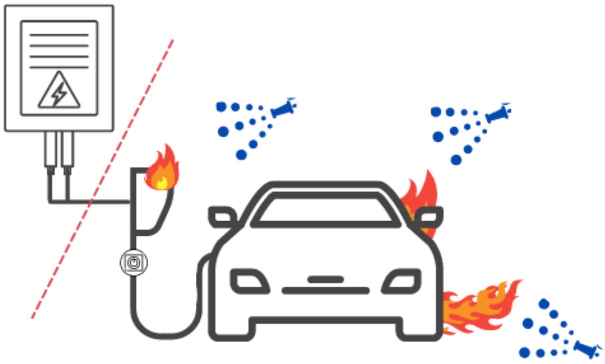
- Reduce the risk of electrocution from unexpected contact with a charging unit during or post incident
- Reduce risk of electrocution from an uninterrupted stream of water on charging units powered by AC grid power

The risk of electrocution is very low, with no recorded injuries or fatalities at EV incidents involving charging. While standard operating procedures (SOPs) are still being developed by fire & emergency agencies, both here in Australia & internationally, EV charging can be managed similarly to any large electrical device, where best practice is to cut power upstream, typically from the distribution board.

Discussions with manufacturers & installers of EV charging, in addition to global case studies, provided these possible scenarios for AC & DC charging. It's important to note that these theories assume that charging units have the RCM Tick & are installed to ASNZ 3000 Appendix P.

AC EV charging (7/22kW)

In theory, electrically compliant units installed to AS3000 will cut between car & distribution board
Average unit cost: $800-$1500



DC EV charging (25/350kW)

In theory, electrically compliant units installed to AS3000 will cut between unit & car
Average cost: $50,000 - $750,000

4. Available or emerging guidance & information

For ease, we have listed all documents in the bibliography & on a hidden page of our website at https://www.evfiresafe.com/abcb

4.1 Australia

4.1.1 QFES Position Statement

Queensland Fire & Emergency Service are the first Australian agency to publish guidance, titled 'Electric vehicle charging stations & electric vehicle carparks [23]', which outlines 'safety concerns for QFES with regards to Firefighter intervention'.

QFES ask building certifiers to deem EV charging stations in buildings a 'Special Hazard' under the NCC Part E1.10, with considerations that include updated block plans, emergency shutdown & impact protection.

With regards to EVs in carparks, the position statement asks building certifiers to 'provide suitable levels of protection for occupants & Fire Brigade intervention', including higher cost items like early detection & warning, smoke management, hydrants, sprinklers & fire-resistant bounding construction.

During our consultation with QFES they expressed their position statement aimed to promote building designer thought around the safe installation & positioning of EV charging, & to consider items such as smoke management, firefighter access, extinguishing & removal.

QFES do not have a trigger for determining what size or power supply an installed charging hub could be before it's considered a Special Hazard – ie. a single AC charging unit vs 10 AC units – preferring to take each Building Development Application on a case-by-case basis.

4.1.2 AFAC - position statement being developed

AFAC, the peak body for fire & emergency services in Australia & New Zealand, are working on a position statement regarding EVs & charging in buildings, however this was in progress at the time of writing.

Most state fire & emergency agency stakeholders consulted expressed they will follow AFAC guidance as it becomes available.

4.2 Internationally

4.2.1 City of London, Guidance on the Installation of Fast, Rapid & Super Vehicle Charging Units

Led by City of London's Fire Safety Advisor, this well thought out guidance [24] that advises adherence to & enforcement of existing regulation & establishing new regulation following further research & testing.

This guidance applies to fast charging hubs – anything over 50kW DC - & as a brief snapshot, these include, but are not limited to:

- Structural standards:
  - 2 hour fire rating of bounding materials, surfaces impermeable to battery & battery fire contaminants & a separation of 1200mm to front / 900 – 1200mm to sides of charging spaces
- Ventilation standards:
  - Mechanical ventilation preferred with a nominal 14 air changes per hour
- Electrical standards:
  - Dedicated supply so fault or fire does not interrupt other electric services, manually operated isolation at primary entrances &/or staffed areas. EVs & charging to only allow a 80% state of charge limit on LiB
- Sprinkler & fire detection systems:
  - Automatic ceiling mounted sprinklers, designed & tested internally by CoL, installed to discharge between EVs with the aim of offering protection against fire spread until firefighters arrive

While the CoL guidance forms a highly desired 'wish list' for dealing with EV LiB fires, it should be noted that:

- It applies solely to City of London Corporation carparks in enclosed structures – there are only 22 in their borough; CoL are also undertaking refurbishment of at least 10 sites

- They are high-cost design options where efficacy & necessity is yet to be proven by large scale research or testing programs; eg: a sprinkler head with one bulb & six open valves, designed to spray water to the sides of an EV added approximately AU$10,200 of cost per parking bay.

4.2.2 Office of Zero Emission Vehicles guidance (UK)

The UK Government's Office of Zero Emission Vehicles engaged Ove Arup & Partners Ltd in early 2022 to develop an Electric Vehicle Parking in Enclosed Space document. Via the National Fire Chiefs Council (NFCC), EV FireSafe contributed data & subject matter expertise, along with Professor Paul Christensen, during Ove Arup's consultation round in March 2022. The NFCCs response is available to view at https://www.evfiresafe.com/abcb

At the time of writing, that document has not been published, but we believe it is in the final stages of drafting & should be referred to by the EV Readiness Roundtable when available.

4.2.3 Nederlands Instituut Publieke Veiligheid (NIPV) & Brandweer Nederland (Netherlands Fire Service)

The NIPV & Brandweer Nederland have released several reports regarding EVs & charging.

4.2.3.1 Incidents involving alternative fuel vehicles, 2021, Fact Sheet

Of 243 total incidents involving alternative fuel vehicles (including hydrogen, CNG etc), 36 involved an EV LiB on fire.

In the 'Lessons from incidents with AFV' [25], the NIPV state 'If there is a fire with an electric vehicle, the battery pack of the vehicle is not always involved in the fire. The battery of an electric vehicle involving in a fire therefore not always has to be submerged into water as a precaution.'

4.2.3.2 Incidents involving alternative fuel vehicles, 2021, Annual Report

To quantify the number of EV incidents, the NIPV collated 2021 data from fire departments to explore the characteristics of EVs in collisions & LiB fires in the 2021 Annual Report [26].

A total of 62 alternative fuel vehicle (AFV) fires involved 77 vehicles; in one incident, multiple EV delivery vans were affected. They state that 'Most fires took place in built-up areas, but none of them was in a multi-storey car park.'

Additionally, the NIPV go on to say, 'Fighting fires inside multi-storey car parks remains a tricky business and fires involving electric vehicles take a different course than fires involving fossil-fuelled vehicles. And what's more, only 4% of the Dutch vehicle fleet is electric. Any scenarios that do not or only rarely occur now could become more common in the future as the vehicle fleet grows.'

4.2.3.3 Brandweer Nederlands Fire brigade action near charging infrastructure

Released in December 2020, this guidance document [27] outlines EV charging infrastructure & suggested fire brigade response guidance when attending such incidents. EV FireSafe has translated this document to English.

The document states it is 'possible' to physically cut Mode 2 & 3 charging cables using '1000V gloves & full PPE (breathing air)', however cutting Mode 4 (DC) cables is 'not possible'.

4.2.4 Austrian Road Safety Board (KFV), Fire prevention & firefighting for e- cars

Released in July 2021, KFV used a third-party market research company to survey members of the public & determine their level of knowledge & concerns about EVs. Largely identified as '…very lurid & less scientifically based…' media coverage, 41% of Austrian's interviewed thought EVs were unsafe.

The report [28] states 'E-cars don't burn more often, they just call more attention' & 'According to experts, e-car fires do not require any special changes to the rescue chain & system'.

Additionally, when asking the question of whether EVs pose a greater danger in enclosed spaces, KPV found 'Renowned experts and research institutions as well as important stakeholders are therefore not in favour of blocking underground car parks for e-cars. Safety in underground garages depends on the general quality of fire protection and not on the drive system of the cars parked there.

‘Although the extinguishing work is more complex in the case of an e-car fire than in the case of a fire involving a car with an internal combustion engine, it can be stated in principle: A burning car in an underground car park is always associated with a certain danger, regardless of the drive.’

KPVs recommendations called upon EV manufacturers to develop a standard method of isolating the high voltage battery in an EV & for greater awareness of emergency personnel.

4.2.5 General Association of Insurers (Germany), E-cars in underground car parks: no increased risk of fire

Investigating EV LiB fires from an insurance perspective, the German General Association of Insurers researched EV vs ICEV fires [29].

GDVs Head of Loss Prevention, Alexander Kusel, stated ‘There is no evidence from our statistics that electric vehicles catch fire more often than cars with combustion engines’. Mr Kusel goes on to say ‘Because of their combustible fuel, cars with internal combustion engines even have a higher fire load than electric vehicles. Blocking underground car parks for electric vehicles would be a step backwards in the expansion of electric mobility in Germany.”

The article then outlines that ‘Fighting vehicle fires in closed garages is difficult because of the high temperatures and the smoke gases released,’ but that this applies to both EV & ICEV.

Importantly, the GDV claim ‘Sprinkler systems and smoke extraction systems have proven their worth for effective fire protection in closed garages’ but do not give supporting case studies.

Finally, GDV state ‘Defective vehicles should never be parked in underground garages.’

4.2.6 Swedish Civil Contingencies Agency (MSB), Electric vehicles and rescue

Released in April 2020 to explore the risk of electrocution when dealing with road traffic incidents involving EVs, the MSB report [30] states ‘There is nothing to suggest that an electric vehicle has worse fire safety than a conventional fuel-powered vehicle. However, a fire in a lithium-ion battery poses greater challenges when extinguishing than a fire in a conventional vehicle.’

4.2.7 German Fire Brigades Association, Underground carparks & fire fighting

In an article dated February 2021 [31], Peter Bachmeier, senior fire director and Chairman of the Technical Committee for Preventive Fire and Hazard Protection of the German Fire Brigades Association, states ‘Fighting a vehicle fire in a garage is always associated with considerable risks and dangers for the emergency services. The operational tactics of the fire brigades are designed and prepared for this.’

‘The development of new drive technologies is closely monitored by the fire brigades. The fire events known to date do not indicate that the risk has increased significantly in comparison to the dangers that already exist.’

‘Furthermore, the fire brigades also observe particularly difficult fire incidents, which also affected the load-bearing structure of garages and in which a large number of vehicles caught fire. However, these developments do not justify the blocking of garages for electric vehicles.’

5. Relevant past incidents

There are only two global incidents – Stavanger Airport carpark collapse & the Victorian Big Battery fire – that have published investigation results relevant to this work.

While limited, they do provide some initial answers to the questions of fire spread in buildings, water run off contamination & air quality during & post incident. As with all in this emerging sector, more research & testing is needed, particularly at real-world incidents.

Another incident, the Felicity Ace cargo ship fire & capsize, is mentioned here because it involved multiple EVs, but as it has now sunk there is no opportunity to investigate the role EVs may or may not have played.

5.1 Stavanger Airport

Stavanger Airport in Sola, Norway, was shut down on 7th January 2020 after a ICEV sparked a fire on the ground floor of the adjoining multi-level carpark [32]. The carpark eventually collapsed, with the loss of several hundred vehicles.

As Norway has a high uptake of EVs, the RI.SE Research Institute of Sweden was engaged to investigate the incident & published the 'Evaluation of fire in Stavanger Airport Carpark 7 January 2020'. This investigation took into consideration the question of Norway's high uptake of EVs & whether they played a role in fire development & water run off contamination.

Images: RI.SE / Nordic Unmanned.

The report states 'Observations during the fire indicate that electric vehicles did not contribute to the fire development beyond what is expected from conventional vehicles'. Additionally, 'Water analyses of selected metals relevant for batteries in electric vehicles did not show any lithium, and only low concentrations of cobalt…indicates batteries in electric vehicles did not contribute to pollution of nearby water resources."

However, further research & testing was also recommended by RI.SE as a learning opportunity for management of future incidents.

5.2 Victorian Big Battery fire

On Friday 30th July 2021, a single Tesla Megapack at the Victorian Big Battery site went into thermal runaway & spread to a neighbouring pack [33].

This incident was managed by the Country Fire Authority & Fire Rescue Victoria. EV FireSafe's Project Director, Emma Sutcliffe, attended in her capacity as an operational volunteer firefighter with the CFA. Fire agencies were alerted to the incident at around10am on Friday 30th July 2021, & the scene was deemed under control at 3.05pm on Monday 2nd August 2021.

A post incident report by Fisher Engineering Inc outlines the cause & management of this incident, the details of which are not relevant to this document, but the 'Victorian Big Battery Fire: July 20, 2021, Report of Technical Findings' is available.

Images: The Guardian / Channel 7 News

The investigation found air monitoring 2 hours after the fire commenced by the Victorian Environmental Protection Authority found there '…was "good" air quality…demonstrating that no long-lasting air quality concerns arose from the fire event…'

Additionally, water samples indicated '…the likelihood of the fire having a material impact on firefighting water was minimal…'

5.3 Moss Landing

The PG&E Elkhorn Battery Energy Storage System consists of 256 Tesla Megapack lithium-ion battery units at Moss Landing in California, USA. A single pack went into thermal runaway on 20th September 2022 at 2am & a 'shelter in place' notification sent to surrounding communities due to risk of smoke, which was lifted at 7pm the same day [34].

Air sampling conducted by the US EPA & a private health consultant was conducted in multiple places around the site & affected pack to monitor for 'potential…air borne toxic exposure' including hydrogen fluoride. The County of Monterey released a statement on 30th September 2022 stating results indicated 'no threat to human health or the surrounding environment' [35].

5.4 Felicity Ace

The Felicity Ace cargo ship, a 2005 built car carrier operated by MOL Ship Management, was enroute from Germany to the US with around 4000 vehicles on board, of which approximately 281 were EVs [36]. All vehicles were built by the Volkswagen Group. On 16th February 2022 the Felicity Ace crew reported a fire, later evacuating. The fire burned for several days before the ship capsized & sank on 1st March 2022.

Cargo ship fires are not unusual, however it's the first one where EVs were noted in mainstream media, following a claim by ship's Captain Joao Mendes Cabecas to news outlet Reuters that the EV batteries were 'keeping the fire alive'.

As the Felicity Ace is not able to be investigated, it remains unclear whether the EVs onboard contributed to fire spread, intensity or duration. However, it's worth noting that MOL's policy with EVs is to carry them at sub 50% state of charge to reduce the risk of thermal runaway & flame, but it is not known whether this requirement was enforced on the Felicity Ace.

6. Stakeholder consultation – considerations & concerns

6.1 Consultation with state fire agencies & AFAC

At least one discussion with each stakeholder listed in *1.3 Methodology* was conducted, as well as individual phone calls, virtual meetings & presentations. An introduction to the Australian EV & charging landscape & ABCB's EV Readiness Roundtable was provided, with a presentation of Level 1 considerations for discussion.

While all stakeholders understood the scope of this initial piece of work, consultations naturally turned to the larger issue of suitability of buildings to withstand modern ICE vehicle fires, as well as EV LiB fires. All stakeholders understood that EV LiB fires are currently very rare & that their wider concerns sat outside the current scope but would start to be addressed through future research & testing.

All expressed their concern at the current, global, lack of knowledge with regards to EVs & charging in structures; all agencies are linked to Fire & Rescue New South Wales's Safety of Alternative & Renewable Energy Technologies (FRNSW SARET) testing program.

Stakeholder questions & comments that follow are an aggregation of information to assist future EV Readiness Roundtable discussions as an ongoing national forum for knowledge sharing & preparedness. They have been de-identified.

6.2 Level 1 considerations – stakeholder review & response

When presented with the Level 1 considerations developed by EV FireSafe, all agencies expressed broad agreement, with the understanding they provide a foundation that:

- Will provide both retrofit & new build EV charging installations an almost cost-neutral solution to enhancing responder safety
- Can be used as a platform from which to build additional guidance as further research & large-scale testing is conducted, analysed & published
- Are a starting point – not an end point – for the EV Readiness Roundtable

Initial feedback comments included:

- *"Level 1 considerations are sensible & necessary"*
- *"At first glance, it looks like a good initial set of guidance"*
- *"We don't want to overcomplicate EV charging installation requirements"*
- *"Concerned that if these Level 1 considerations are released by ABCB without bigger picture answers, that will be an issue"*

6.3 Wider stakeholder concerns & questions

While FRNSW SARET & other international large-scale testing programs develop, both EV FireSafe & emergency agency stakeholders wished to prioritise the following concerns.

6.3.1 Building suitability for modern ICEV & EV

- Current NCC carpark fire system guidelines relate to vehicle testing that occurred with older vehicles; more modern ICEV & EV have a higher heat release & fire load
- Are current fire protection systems suitable for EVs?
    - Limited current testing & research
    - Is there an increased risk of fire spread?
- Is there a Risk Assessment existing or being developed for EVs in structures?
- Will a Building Permit be required to install charging?

6.3.2 Compliance of charging units & suitability of installers

- Are all EV charging units installed in Australia electrically compliant & how can this be enforced?
- How are installers being trained & what qualification is necessary?
- How are units being maintained & how?

6.3.3 Firefighter access/egress

- Access to master isolation if too close to charging site
- To enclosed spaces, particularly with significant vapour cloud / off gassing
- Some concerns about effectiveness of thermal imaging cameras in EV LiB vapour cloud, as it may 'mask' heat signature

6.3.4 Ventilation

- If the size of a vapour cloud off gassing from an EV is significant, how do we manage smoke & vapour cloud explosion risk in structures?
    - Are current mechanical ventilation systems suitable?
    - If so, how many air changes per hour & what type of system is best?
    - Should <40 space carparks install ventilation in order to allow EVs & charging?

6.3.5 Sprinklers

- Sprinklers may limit directional flame fire spread until responders arrive, but this is still unknown
- If sprinklers do assist in limiting fire spread, what type, configuration, spray pattern is optimal?
- Should <40 space carparks install sprinklers in order to allow EVs & charging?

6.3.6 Early detection

- Smoke alarms – do not detect thermal runaway gases
- Effective, proven gas detection for thermal runaway currently not suitable for open spaces
- When a suitable product comes to market, where should it be located (ie. under vehicle, on wall etc)

6.3.7 Fire fighting water

- Is fire water run off contaminated?
- Given high volume typically required for EV LiB cooling, concerns about limitations of supply
- Given the higher volume, could it affect structural integrity or impregnate slab?
- Where will water run off to in an enclosed space?

6.3.8 Temperature / heat release

- It's believed the directional flame seen with EV LiB fires can reach 2700°c, but testing required
- Duration of high temperature flame is unknown & dependent on EV LiB state of charge
- How will increased temperature affect structure?

6.3.9 Incident duration

- Incidents typically are a longer duration, commonly of 3-5+ hours, with ICEV 1-2 hours
- Concerns from agencies:
    - Do smaller agencies have the resources to manage an EV incident in a structure?
    - How will agencies manage BA swap out?
    - Ventilation / pressure fans for an extended period
    - Evacuation of occupants

6.3.10 Air quality

- What is the risk to surrounding environment & people from toxic & flammables gases?

6.3.11 Secondary ignition / removal

- 'Skull' dragging an EV post incident may contribute to secondary ignition through engagement of regenerative braking systems, but more research/testing is needed
- Ceiling height is a possible issue for removal access/egress
- Cornering in tight spaces also
- EVs multi-levels underground pose highest risk of secondary ignition

6.3.12 Harmonic distortion

- How do multiple EV charging units affect harmonics of a building & how can that risk be mitigated?
- JET Charge & Electric Vehicle Council have provided risk profile & mitigation solutions

6.3.13 Hacking EV charging units

- A set of charging units on the Isle of Wight, UK, were hacked to show a porn site URL [37] on the payment screen in April 2022, which led to concerns units can be hacked to overcharge an EV to cause thermal runaway, or to try & overload a building's power supply to shut down sensitive sites
- We have confirmed with two EV sector leaders that, while the addition of URLs to a screen is clearly possible, forcing a charging unit to overcharge or draw excess power is not possible

6.4 New ways of thinking

Two very interesting concepts arose during fire & emergency stakeholder discussions, that we believe should be considered in EV Readiness Roundtable discussions.

6.4.1 Expand the concept of 'EV Ready'

EV Ready describes the design of EV charging hubs in buildings by installing the 'backbone' wiring infrastructure to each parking space, ready for a charging unit to be added when the parking space owners purchase an EV.

While research & large-scale testing is conducted, can the concept of 'EV Ready' be extended to encompass any considerations building designers can include that enable easier potential retrofitting of early detection, ventilation & sprinkler systems?

6.4.2 Invest in low cost, high value responder knowledge

EV LiB incidents are currently very rare & modern EV HV systems & battery chemistry improvements may have the effect of reducing incident rates, even as the global stock of EVs increases.

If responders are 'comfortable' with the current incident rate, rather than imposing significant additional cost on building owners installing charging, a range of supplementary activities can be funded to collaborate with EV manufacturers & operators, as well as support training, global knowledge sharing & tools to assist in the management of EV LiB fires, collision, submersion, in addition to secondary responders in roadside assist, accident recovery & storage.

As our research has progressed, some of the knowledge gaps have become evident. Therefore, we provide a list of suggested activities at '5.5 Supplementary low cost, high impact responder safety activities'.

6.5 Consultation with EV sector

The Electric Vehicle Council (EVC), Australia's peak body for the EV & charging sector, outlined their position on emergency considerations at EV charging in a submission to the ABCB [38] regarding EV ready buildings for the 2022 National Construction Code.

The EVC recommended the National Construction Code move from an initially suggested 25% EV readiness in new builds, to a full 100%, which was successful, stating they intend to '…work with stakeholders in the fire safety & construction sectors to address these (fire) concerns." Additionally, they are 'open to the idea' of extra fire protection once provided with '…the data to define what these requirements might be."

7. Considerations

7.1 Basis of considerations

Based on our research, stakeholder consultation & international best practice, we put forward three Levels of considerations. These relate to Mode 3 & 4 public charging sites.

It's important to remember that we are attempting to develop Levels that are implementable *nationally*, for passenger EVs & charging sites across a vast range of spaces & circumstances, from open sided multi-level carparks to basements of large apartment blocks.

Additionally, given there are over 291 fast charging sites [39] (DC sites only) already in the ground, with an additional 700 to be installed following over $441 million of state & federal funding, we have designed Level 1 considerations to be relatively easy to both retrofit & install in new builds on a national scale.

Level 1	Level 2	Level 3
Close to cost neutral *Low visual impact* *Enables greater responder & public awareness* *Implementable on retrofit & new builds* *Cross sector in-principle support* *Common sense approach*	*Intermediate cost impact* *Intermediate visual impact* *Enables greater responder & public awareness* *Implementable for new builds only* *Encompasses some desired concepts (pending testing)* *Requires evidence of risk to drive regulation*	*High cost impact* *Intermediate visual impact* *Enables greater responder & public awareness* *Implementable for new builds only* *Encompasses some desired concepts (pending testing)* *Requires evidence of risk to drive regulation*

7.2 Levels of considerations…where do we start?

As a starting point in the journey to 100% EV ready Australian buildings, & before further research & testing outcomes can be delivered to provide the much needed data-driven answers to the wider stakeholder concerns & questions discussed during consultation, we propose Level 1 considerations be discussed for adoption & implementation by the ABCB.

We believe this set of considerations forms a foundation upon which the ABCBs EV Readiness Roundtable can build further guidance as research & testing programs mature.

7.3 Level 1

This level puts forward considerations that are close to cost neutral, have low visual impact, are easily implementable & are likely to attract multi-sector in-principle support. Please see below for a fuller explanation of each consideration.

We strongly recommend that Level 1 considerations are reviewed by the ABCB & EV Readiness Roundtable in conjunction with wider government consideration of the list of 'Supporting low cost, high benefit activities' that will significantly enhance national emergency responder awareness through familiarisation & training.

Safer charging	Safer environment	Safer people
Master isolation at distribution board	Collision protection	Placarding at charging hub
Regular maintenance	Break glass fire alarm	Directional signage
Smart charging	*Proximity to flammable risks*	Emergency services information pack
RCM Tick compliance		Block plans (FIP & booster)
Installed to AS 3000 App P		Placarding at site entrance
Isolation to each unit		Pre-incident plan

Level 1 contains considerations that enhance responder safety at incidents involving EVs & charging, but which are industry led, regulated by other state & federal bodies, or require further research & testing, that are outlined below.

Sector led (happening anyway)

Smart charging

Oversight by other state or federal authorities

RCM Tick Compliance

Installed to AS 3000 App P

Isolation to each unit

Primarily to light electric vehicle (LEV) charging, gas mains, other flammable risks on case by case basis

Proximity to flammable risks

7.3.1 Level 1 justifications, recommendations & closer look explainers

	Justification	Recommendation
Master isolation	The ability to immediately shut down all AC & DC charging may mitigate electrocution risk to responders from accidental contact with a live charging unit or from an unbroken stream of fire water.	All charging sites with more than one dedicated Mode 3 or 4 charger installs master isolation at a position near the charging site & at one other point, such as FIP or primary entrance to building. Directional signage should point responders to the master isolation, ESIP & block plans should also be updated to reflect location/s.
Regular maintenance	An increasing number of charging sites contain stranded &/or unmanaged by site AC units, due to charging suppliers going out of business or exiting the sector. Regular maintenance may reduce fire risk at charging hubs.	All charging sites with more than one dedicated Mode 3 or 4 charger: • Enters a maintenance agreement with the installer or a qualified person to ensure annual operational testing with an appropriate diagnostic tool that simulates an EV on charge. • Conducts a weekly visual check to be carried out by the site manager or owner
Collision protection	Real world incidents indicate wheel chocks & bollards around charging sites can protect EVs from battery damage, potentially leading to thermal runaway – this may also become an insurance industry directive	All charging sites install wheel chocks & bollards (dynabolt / concreted in), or otherwise protected from front, side or rear impact from vehicles or other objects
Break glass fire alarm	Local or monitored break glass fire alarms may assist in evacuation of site &/or calling emergency services to site faster.	Where applicable to building fire protection systems, break glass fire alarms should be installed at charging hubs with more than one dedicated Mode 3 or 4 charger
Placarding at site	Raising EV driver & public awareness about the signs of thermal runaway may assist in the earlier identification & alert to emergency services – similar concept to mandatory CPR signs for back yard swimming pools	All charging sites with more than one dedicated Mode 3 or 4 charger to install placard at site, that must be visible from all points of the charging hub, not obstructed & maintained in an easily readable condition
Directional signage	Discreet signage pointing public & emergency services to the charging site distribution board or fire protection systems such as emergency exit or fire attack hydrant assist in egress &/or response	Directional signage in the form of wall stickers should be installed at charging sites with 5 or more Mode 3 or 4 chargers for: • Distribution board or closest master isolation • Fire attack hydrant • Emergency exit
Emergency services information pack (ESIP)	For relevant sites, ESIPs may assist with incident management (see FRNSW ESIP information)	ESIPs should be updated for existing sites & implemented for new builds to clearly show the location of charging hubs & master isolation
Block plans (tactical fire plans)	For relevant sites, Block Plans may assist with incident management (see FRV Tactical Fire Plans)	Block Plans should be updated for existing sites & implemented for new builds to clearly show the location of charging hubs & master isolation
Placarding at site entrance	Emergency response & incident management may be hampered by large or complex sites with multiple entrances to carpark or spaces where EV charging is located	Such sites with 5 or more Mode 3 or 4 chargers to install ground level or other appropriate level placarding to indicate which entrance is most closely located to EV charging hub

Pre-incident Plans (PIP)	Emergency response may be hampered if responders are unfamiliar with EV charging sites in their brigade, station or unit area	With onus on EV charging installer & charging site owner or manager with 5 or more Mode 3 or 4 chargers, the state fire authority &/or local brigade, station or unit should be given a courtesy notification that EV charging has been or is being installed & responders invited to attend a familiarisation visit in order to update or create a PIP (if deemed necessary)

	Closer look	Recommendation
Smart charging	'Smart charging' or AC units with Open Charge Point Protocol (OCPP) enable remote monitoring, payment & access to connect or disconnect power supply to a connected EV, often with a 24/7 EV driver hotline – this gives emergency responders a potential method of shutdown from unit to EV	The EV sector is largely moving to 'smart' charging in order to more easily manage charging units remotely. The benefit to emergency responders should be made clear to the Electric Vehicle Council & major suppliers for awareness. Encourage operators to monitor for faults & provide early intervention when detected.
RCM Tick compliance	Electrical compliance in Australia is governed by the RCM Tick, & it should be obtained for every electrical appliance sold in Australia to prove compliance; EV FireSafe have developed theories about responder safety based on Mode 3 & 4 chargers having RCM Tick	Responsible authority (EESS & NSW Fair Trading) should be consulted to highlight important of compliance for EV charging in relation to responder safety
ASNZ 3000 App P wiring	All Mode 3 & 4 chargers should be installed by a qualified person using ASNZ 3000 Appendix P; EV FireSafe have developed theories about responder safety based on chargers being installed to this standard	Australian Standards should be consulted to highlight the important of wiring for EV charging installation in relation to responder safety; this input should be considered as Appendix P is reviewed in 2023.
Proximity to flammable risks	Nearby flammables may increase risk of fire spread should an EV LiB go into thermal runaway or increase risk of impact on EV should an external fire start	Flammable risks include, but are not limited to: • Charging & storage for light electric vehicles (LEVs); electric-bikes, scooters, skateboards & unicycles • Gas or water mains • Recycling or other bins containing cardboard or other flammables

7.4 Level 2

This level puts forward considerations that have an intermediate cost impact, are implementable for new builds only & require evidence of risk to drive a regulatory response.

Safer charging

Limit charging to 80% in high risk & sensitive buildings

Safer environment

Charging hub positioning
Proximity to fire protection
Automatic fire alarm connected to master isolation

Safer people

Larger placarding signs with QR code (establish national 'EV safety' website)
Emergency exit egress lines on ground

7.4.1 Level 2 justifications & recommendations

Important: These Level 2 justifications & recommendations are all pending data-driven outcomes of relevant research & testing.

	Justification	Recommendation
Limit to 80% SoC in high risk & sensitive buildings [40]	Passenger EV LiBs operate most effectively in the 20-80% state of charge range; LiB degradation & heat loss is greater when charging at 80-100%. High risk or sensitive buildings may include hospitals, airports, childcare or aged care.	Limit EV charging to a SoC at or below 80%. It should be noted that this will be impractical for many EV drivers & will not meet expectations of EV ownership. Not all EVs & charging units can limit SoC in this way; most DC chargers can, however this may have to be enabled by the EV driver via app (consumer led action). Requires evidence of risk for regulatory response.
Charging hub positioning	Charging sites close to natural ventilation, such as open sided carparks or near undercrofts, may dissipate vapour cloud faster.	Position charging bays closer to natural ventilation. It should be noted that this may not be possible for all charging bays with 100% EV Ready buildings.
Proximity to fire protection	Fire hydrants & boosters located in close proximity to charging hubs may assist emergency management	Position charging hubs in near fire protection systems. It should be noted that this may not be possible in 100% EV Ready buildings.
Automatic fire alarm connected to master isolation	The automatic isolation of all energised EV charging upon activation of AFA may assist emergency management & responder safety	Connect master isolation to AFA
Larger placarding signs with QR code	Higher visual impact signage may assist in greater public awareness. The establishment of a national 'EV safety' online hub may be considered for those wishing to learn more	Increase size of charging hub placard signage. Consider establishing a national EV safety online hub.
Emergency exit egress lines on ground	Clearly visible, textured egress lines may assist the public in exiting a building where an EV LiB is in thermal runaway	Incorporate egress lines at all charging hubs

7.5 Level 3

This level puts forward considerations that have a high cost impact, are implementable for new builds only & require evidence of risk to drive a regulatory response. Fire protection discussed here means sprinkler, ventilation & early detection systems.

Safer charging » **Safer environment** » **Safer people**

Safer charging

Limit charging to 50% in high risk & sensitive buildings

Separation between charging bays of ~900mm each side

Thermal 'rate of rise' monitoring all charging bays

Safer environment

Fire protection to <40 space carparks

Upgraded fire protection in all carparks

Concrete barriers / non-combustible materials 'compartments' bounding charging bays

Safer people

National EV fire public awareness program

7.5.1 Level 3 justifications & recommendations

Important: These Level 3 justifications & recommendations are all pending data-driven outcomes of relevant research & testing.

	Justification	Recommendation
Limit to 50% SoC in high risk & sensitive buildings	Passenger EV LiBs at 50% SoC may off-gas if in thermal runaway, but typically don't ignite or explode. High risk or sensitive buildings may include hospitals, airports, childcare or aged care.	Limit EV charging to a SoC at or below 50%. It should be noted recent testing may indicate a sub-50% SoC for NMC EV LiB cells may still ignite. This will be impractical for many EV drivers & will not meet expectations of EV ownership. Not all EVs & charging units can limit SoC in this way; most DC chargers can, however this may have to be enabled by the EV driver via app (consumer led action)
Separation between charging bays of ~900mm each side	Separation between bays may limit the spread of the 'jet-like' directional flames witnessed in EV LiB fires.	Design separations between charging bays in new builds. It should be noted that this will create a significant cost increase in new builds. The figure of ~900mm is consistent with desired concepts, NCC fire separations & not based in tested fact.
Thermal 'rate of rise' monitoring at all charging bays	Above ambient or a rapid increase of temperature may indicate an EV LiB is going into thermal runaway.	Design to enable thermal monitoring for all charging bays. It should be noted that no such product exists currently, & once developed will likely cause a significant cost increase in new builds.
Fire protection for <40 space carparks	Carparks with less than 40 spaces currently do not have to provide fire protection systems – ventilation, sprinklers etc	All <40 space carparks in new builds must incorporate fire protection systems.

Upgraded fire protection in >40 carparks	Larger capacity fire protection systems may assist in emergency management of EV LiB incidents	All >40 space carparks to update fire protection systems, pending recommendations from testing & research
Concrete barriers / non-combustible materials 'compartments' bounding charging bays	Bounding barriers between charging bays may limit fire spread to one or more vehicles	Design the compartmentalisation of EV charging sites to a number of EVs – eg. Bounding barriers every 3 EVs – with non-combustible materials
National EV fire public awareness program	Raising awareness of the risks of EVs as uptake increases may assist in earlier identification of EV LiB fire & more rapid emergency response	Establish a public-facing awareness package that incorporates passenger EVs, light electric vehicles, electric buses & electric trucks

8. Supporting low cost, high value activities

Our research knowledge combined with Australian & international emergency agency discussions have identified common knowledge gaps that we feel can be rapidly addressed to enhance responder safety around EVs, in collisions, road rescue, submersion, fire & battery fire events.

Modest government funding for these activities would complement emerging testing programs & dramatically enhance agency understanding & awareness of rapidly emerging electrified transport, reducing the fear, uncertainly & doubt commonly displayed through these discussions.

These suggested activities are sorted in order of cost & priority, with a high impact benefit to all agencies & responders. Some of these activities have been commenced by EV FireSafe on an un-funded basis using volunteer interns in partnership with Deakin University &/or in collaboration with fire & emergency agencies.

8.1 Highly recommended activities for wider government support

The responsibility for these activities does not sit with the ABCB, however they may champion their importance to the relevant bodies or departments.

8.1.1 National rollout of blue 'EV' badging in all states

Activity:

A blue 'EV' badge on numberplates of vehicles carrying a lithium-ion battery has already proven invaluable for vehicle identification when attending a road traffic accident.

This is currently only mandatory in Victoria, NSW, South Australia & Queensland, so it is recommended that all states & territory road authorities implement it as an urgent priority.

8.1.2 Collaborative exploration & development of EV LiB fire management tools

Activity:

Early detection of the signs of thermal runaway & effective cooling methods while managing an EV involved in a road traffic incident is vital to responder safety & often overlooked.

- Provide a national approach to product trial & purchasing
- Encourage the development of new products & tools to assist with EV collision & LiB fire management, particularly:
    - For the early detection of thermal runaway & cooling techniques
    - For smaller state agencies who may struggle to resource extended duration EV LiB fires

Invest in:

- Monthly online meetings with manufacturers / suppliers to discuss products with working group (made up of state agencies)
- Testing of products deemed of interest

8.1.3 National EV & charging online learning sessions

Activity:

In collaboration with the EV sector, coordinate a series of monthly webinars throughout 2023 for fire & emergency agencies to better understand:

- EV LiB 101 basics
- EV road rescue considerations
- EV HV systems
- EV charging basics
- Bi-directional charging & emerging technology

Invest in:

- Professional management, promotion & delivery of webinars

8.1.4 EV Emergency Response Guide National Database

Activity:

Create a database of passenger, light & commercial electric vehicle Emergency Response Guides (ERGs) & Rescue Cards (RCs) to identify HV isolation similarities & provide details to ANCAP for cross-checking against the ANCAP Rescue app:

- Identify manufacturers not creating ERGs to ISO 17840 & work with them to standardise across EV sectors

- Reduce the need for agencies to find funding for private ERG platforms, which can be cost prohibitive
- Include SDS & spec sheets for all EV charging unit models available in Australia

Invest in:
- Database resource

8.1.5 EV Registration National Heat Maps

Activity:
Purchase 5 years of searchable EV registration data for the purpose of:
- Creating locational heat maps for agencies, brigades, stations, branches & units to understand EV numbers in their area
- Provide state agencies EV locational hotspot data:
    - Should an EV be recalled for fire risk
    - During natural disasters, such as flood & bushfire

Invest in:
- Registration data
- Data analysis & creation of national spreadsheet & heat maps for agencies to roll into online platforms

8.1.6 EV Road Rescue Demonstrations

Activity:
- Discuss & refine a national set of EV road rescue considerations
    - An initial set, titled EV Extrication Considerations, has been developed by EV FireSafe in collaboration with the Victorian State Emergency Service & individual experts
- Organised supply of written off EVs to each state for multi-agency road rescue demonstration, awareness & videoing for online training

Invest in:
- Written off EVs x 8 (minimum)
- Shipping & storage
- Disposal & clean up

8.1.7 EV Training Prop

Activity:
Source new EV to create delaminated & fully functioning EV training prop showing HV systems, components, cables & battery casing
Invest in:
- Purchase of new EV
- Safe delamination & protection of HV systems

8.1.8 Responder awareness videos in collaboration with EV OEMs

Activity:
- Video walkarounds of most popular EVs for awareness & HV isolation familiarisation

Invest in:
- Professional video production

8.1.9 Pre-incident plan EV charging hub template for responders

Activity:
Create a template checklist for brigades, stations or units visiting EV charging sites to assist with the creation or update of pre-incident plans.
Invest in:
- Professional template creation

8.2 Other supplementary considerations

8.2.1 Raise public awareness of damaged EVs in enclosed space risks

A total of 6 EV LiB fire incidents in enclosed spaces were caused by the EV LiB being impacted in a recent collision. Of these:
- Chevrolet Volt suffered a crack in battery casing due to side impact testing by the National Highway Traffic Safety Administration (US; fire occurred three weeks later in storage yard
- Tesla Model X driver lost control & crashed into a residential garage, causing a LiB fire

- Tesla Model S hit an open manhole cover & around 30 minutes later experienced a vapour cloud explosion
- BYD Han crash tested by Chinese media caught fire 48 hours after initial test collision
- A Tesla, one unknown EV & two other ICEVs were involved in a collision in an underground carpark, with the two EV LiBs on fire
- An unknown Tesla that had been involved in a collision was left at a Tesla service centre where the LiB caught fire later that night

A further 53 incidents (not in enclosed spaces) are linked to collision or road debris; eg. One incident describes a tow ball falling off a truck & hitting the underside of an EV, leading to battery fire.

It makes sense therefore that awareness activities alerting EV drivers to the increased risks of entering an enclosed space if they've been involved in a collision or submersion should be encouraged.
While it would be unreasonable to require every public carpark to carry such signage, the inclusion of this information in 'What to do in a crash' information cards or webpages released by various state police authorities (example [41]) should be updated & consideration given to inclusion in drivers licensing tests.

8.2.2 Thermal sensors at carpark entrance &/or parking bays

Entrance:
The use of thermal monitoring at the entrance to larger or sensitive carparking sites could also be considered; a thermal sensor pad upon entry checks the battery temperature & bars entry if deemed to be high. This however has its deficiencies; no such product currently exists, it could potentially be expensive to install & it may be the case that not all EVs in future have the battery pack underneath the vehicle.

Parking bays:
Individual thermal sensors located in the floor of or above parking bays that thermally monitor EVs & provide early warning of above ambient or rapidly rising temperatures. This however has its deficiencies; no such product currently exists, it could potentially be expensive to install & it may be the case that not all EVs in future have the battery pack underneath the vehicle.

8.2.3 Annual EV & charging safety check

In addition to the regular maintenance of public EV charging infrastructure outlined in Level 1, some consideration should be given to:

- Mode 2 (portable EVSE cables) having a regular test & tag electrical check
- Mode 3 home charging undergoing regular visual inspections
- Consideration of an annual EV safety check as part of regular servicing, bearing mind that EVs do not require as many logbook servicing actions as ICEV

8.2 4 Standardisation of EV HV isolation methods

Isolating high voltage systems in an EV makes it safer for emergency responders to touch & cut into when handling an EV in a collision or road rescue. Essentially, HV isolation de-energises the components & cables, capturing all power in the traction battery located under the vehicle.

There are several ways EVs are or can be isolated:

- HV systems in passenger EVs will isolate upon impact when safety systems (airbags, seatbelt pretensioners) are engaged
- Disconnecting the negative terminal on the 12V (low voltage) battery will open contactors to the HV battery, therefore isolating power
- Manual isolation methods:
    - Cut loop – a LV wiring harness that, when cut or unclipped, has the same effect as disconnecting the 12V battery
    - Pull fuse – a LV fuse that, when cut or unclipped, has the same effect as disconnecting the 12V battery
- Manual Service Disconnect Plug – this is a direct connection to HV systems & should only be used by trained & qualified personnel, not emergency responders. However, it is usually listed in the emergency response guides as a method for emergency use.

These HV isolation methods vary depending on make, model & year of manufacture, & can be unnecessarily confusing for emergency responders.

The standardisation of isolations to a single method for EVs entering the Australian market is recommended. A primarily & secondary cut loop that can be unclipped & placed in the pocket of an Incident Controller would be the preferred method as it can be easily replaced in the EV if required, removing the need for towing & repair of the wiring harness (usually ~$1000.00)

8.2.5 Collisions involving EV charging (non-fire)

During collaboration with global insurance company Allianz, EV collisions with charging infrastructure has been identified as a new exposure & is worth highlighting.

While we have not analysed these incidents in detail, Allianz consider charging hubs a new site of exposure. Additionally, there is a mix of direct impact – the EV hits the charging unit - & 'push' impact – the EV is pushed into the unit by another vehicle. Collision risk & incidents should be raised with both the EV & emergency response sectors, to highlight the importance of impact protection & explore best practice methods.

1. *Tesla Model 3 pushed into DC charging unit by Volvo, Germany, May 2022*
2. *AC charging unit ripped out of ground by ICEV, Daylesford, Victoria (supplied by CFA)*
3. *Tesla Model S ran over concrete bollard at charging hub, Australia (supplied by Allianz)*
4. *Range Rover collided with Tesla Supercharger hub, London, August 2022*

8.2.6 Higher risk charging installations:

While EV LiB fires are very rare, there are some sites that may pose, or are already recognised to pose, a far higher risk & challenge from an emergency response perspective.

Car stacker systems:
One example is automated car stacker systems; the complex management of a recent ICEV engine fire on such a system in Melbourne was used to highlight fire agency concerns about the containment & suppression of EV LiB fires two or multi-level car stackers.

A submersion tank or isolation bay with additional sprinkler heads above & below the EV, that are integrated into base level of carparking space may be one – very expensive – solution. Upon activation of fire alarms, the pallet could be directed to submerge or isolate the EV.

Mechanic hoists:
Another example is EV charging units installed on the side of service centre mechanic hoists. This may encourage the mechanic to charge an EV while they are underneath the vehicle, with battery pack at head height. We believe this poses too great a risk before national SOPs are developed by such facilities to thoroughly assess an EV for potential battery damage through visual, thermal & diagnostic checks.

8.2.7 Post incident removal, secondary responders, storage & wrecking

Awareness of EV LiB fire risks in the secondary response sector remains low & should be addressed with some urgency; our database indicates four tow truck drivers have been injured while managing removal of an EV.

Collaboration of the secondary response sector with emergency & government agencies to develop removal tools & procedures, such as metal-sided 'tubs' that can be filled with water, should be considered, as should protocols for the safe storage & wrecking of EV LiBs.

This action has a direct benefit to emergency agencies; we're aware that international transport agencies have experienced significant delays in EV removal companies providing services, tying up emergency resources to 'babysit' the vehicle in the meantime.

8.2.8 Display EVs at venues

Activity:
The popularity of electric vehicles means they're increasingly on display in shopping centres, conferences or similar. Fully charged, or >50% state of charged EVs are often located near large numbers of bystanders, cafes, playgrounds etc, posing a small but potentially significant off-gassing & fire risk.

National guidance for the display of EVs at such events or venues should be developed as a matter of urgency, that incorporates information for site managers to ensure & enforce the guidance is being appropriately followed.

8.2.9 Battery electric bus & light electric vehicle charging

Battery electric buses (BEB) & light electric vehicles (LEV) sit outside the scope of this piece of work but are considered by EV FireSafe to pose a higher risk to emergency responders than passenger EVs.

LEV - activity:
City street e-bikes & e-scooters being taken up by local government authorities (LGAs), however the bulk charging of these EVs &/or their removable battery packs, poses a far greater fire risk than passenger EV charging hubs. ACT Fire & Rescue have already experienced a warehouse fire due to these 'juicing' sites [42].

National guidance for the transport, storage & charging of bulk units of e-bikes & e-scooters should be developed as a matter of urgency. Additionally, agreements between LGAs & e-mobility operators should be updated to reflect fire safety requirements.

BEB - activity:
BEB LiBs packs are typically located the bus roof, causing significant fire spread to other vehicles & buildings. While not the focus of our work, we have identified 21 BEB LiB fires since 2011, in a global stock of less than 400,000 BEBs. Additionally, ERGs do not always follow ISO 17840 & training is not available to emergency responders. National training & guidance for BEB emergency response should be developed urgently.

9. Conclusion

The historically low uptake of electric vehicles in Australia presents our emergency agencies, the ABCB & the EV sector a unique opportunity to prioritise safety before EVs become ubiquitous.

This report sets out a path to introduce safer EVs & charging sites in buildings &, if implemented, Australia would be the first country to prioritise safety around EVs & charging.

Throughout our research there have been numerous conversations about requiring every building to retrofit or install sprinkler, ventilation & fire alarm systems.

Of course, in an ideal world, every carpark would have full sprinkler, ventilation & early detection systems in place for the rollout of EVs. However, the currently available data & information does not justify a significant cost impost on the building & EV charging sectors.

Should research & testing indicate upgraded fire protection systems are required - & exactly *how* they should be installed - we believe the best first step are sensible, almost cost-neutral considerations that support a safe transition to electrified transport & are likely to be accepted & implemented by stakeholders Australia-wide.

Therefore, we put forward the Level 1 considerations for review by the ABCB.

The ABCB's EV Readiness Roundtable will be the connection point for emerging knowledge, research being undertaken on different elements by different bodies, bringing it all together for the benefit of the national approach to building regulation.

As such, backing for research & testing programs should be given high priority as these, particularly the Fire & Rescue NSW SARET program, which will provide some of the answers needed to reduce emergency agency uncertainty in the fast-moving EV technology & transport sector.

While outside the scope of this work, we want to caution against the focus on passenger EV LiB fires overshadowing other issues related to electrified transport.

Significant knowledge building, awareness & training is needed for Australian emergency responders to effectively manage collisions, submersion & other non-fire incidents involving passenger EVs. EV FireSafe will continue to urgently progress the items listed in 8. Supporting low cost, high value activities in collaboration with Australian & international emergency agencies & seek the ABCB's assistance in connecting with the relevant government departments to provide backing.

I believe that developing innovative EV incident training & tools will build a confident national emergency response community.

While there are clear challenges for the emergency community in the rapidly emerging EV sector, we are delighted the safety conversation has commenced via the ABCB & the EV Readiness Roundtable.

EV FireSafe appreciates the opportunity to participate & provide data-driven evidence to guide this important national discussion. We wish to thank the many contributing fire & emergency agencies & individuals, as well as AFAC, & their Alternative & Renewable Energy Technologies Working Group, & the Built Environment & Planning Technical Group. Our appreciation extends to EV charging sector companies, particularly the technical knowledge provided by JET Charge & NHP, with discussions led by the Electric Vehicle Council.

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I welcome questions regarding the information contained within to emma@evfiresafe.com

Emma Sutcliffe, 30 September 2022

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11. Further reading

Review of battery fires in electric vehicles,
https://www.researchgate.net/publication/338542510_A_Review_of_Battery_Fires_in_Electric_Vehicles

Modern Vehicle Hazards in Parking Structures & Vehicle Carriers

https://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/Building-and-life-safety/RFModernVehicleHazards-in-ParkingGarages.pdf

Battery Safety Science Webinar Series

https://ul.org/research/electrochemical-safety/battery-safety-science-webinar-series#initiative-updates