EV Fire Considerations

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Introduction

Introduction

What is an EV?

The Basics

1. Battery-Electric Vehicle (BEV) – a vehicle powered entirely by electricity via an electric motor and associated batteries. Currently the only EV to be considered a **zero-emissions vehicle** (ZEV) due to its potential to run entirely off renewably generated electricity.
2. Plug-in Hybrid Electric Vehicle (PHEV) – powered by both an ICE and an electric motor. The batteries require charging from an external source.
3. Hybrid Electric Vehicle (HEV) – similar to a PHEV, however the system works to charge the batteries when possible; hence, the batteries do not require charging from an external source.
4. Fuel cell Electric Vehicle (FCEV) – has a fuel cell in which hydrogen and oxygen are combined to produce electricity, which in turn powers an electric motor.

Current Supporting Infrastructure Classes

Stage 1 – EV-Capable

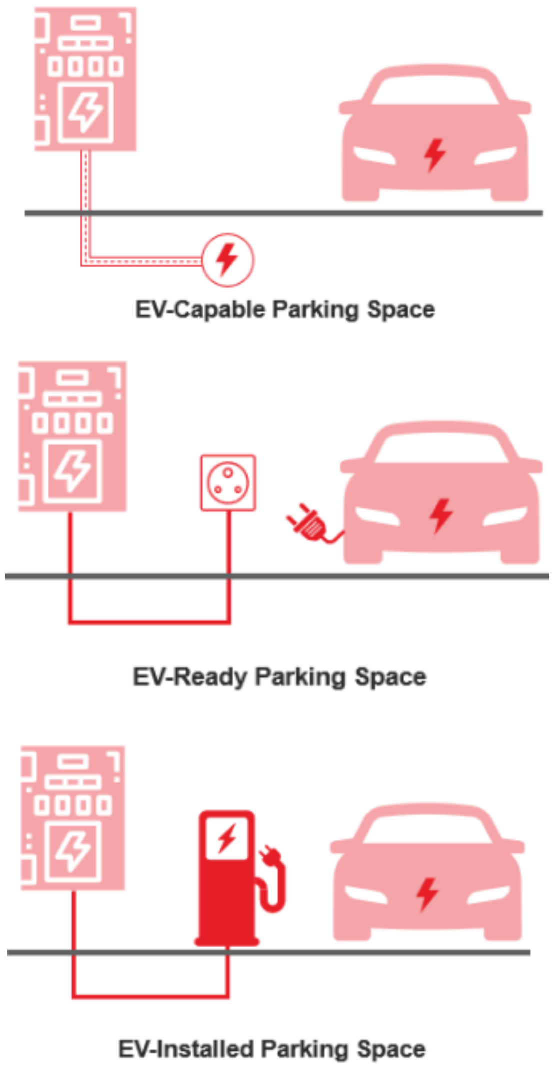
- Electrical capacity is present for future supply of EV charging points; for example, a separate circuit and spatial allowance for the infrastructure required to offer charging points is present in the building.
- There is no requirement for the infrastructure to be installed at this stage of EV-readiness.

Stage 2 – EV-Ready

- Above mentioned electrical capacity allowances are installed on the premises.
- Requires user to plug the car in with appropriate charging plug.

Stage 3 – EV-Installed

- All required infrastructure is installed.
- Minimum of Level 2 charging provided; user does not need to bring his/her own plug.



Stages of EV-Readiness

Introduction

Background

There is a global gap in carpark EV charging fire safety requirements.

The introduction of EV charging facilities in a carpark can pose an additional fire hazard, EV battery failure is more common during charge cycles, and the presence of significant stored energy in an EV battery system presents different challenges compared to traditional Internal Combustion Engine (ICE) vehicle.

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Australian Standards

National Construction Code

The 2022 National Construction Code (NCC) publication is yet to be formally released and thus there is no current mandate for EV charging infrastructure in buildings.

These minimum provisions have been set following consideration of international building codes and with respect to Australia's projected EV-uptake.

At-home charging

Class 2 - Apartment
Class 4 - Residential Dwelling
Class 9c - Aged Care

- EV-Capable
- 100% of permanent residential bays Level 1
- 25% of visitor bays * Minimum of 1 bay Level 2

Class 3 - Hotel

- EV-Ready
- 100% of temporary resident bays Level 2
- 20% of employee bays Level 2

At-work charging

Class 5 - Office

- EV-Ready
- 20% of employee bays Level 2
- 100% of operational bays Level 1

Class 7b - Warehouse
Class 8 - Factory

- EV-Ready
- 20% of employee bays Level 2
- 100% of operational bays Level 2
- 100% of heavy vehicle bays (GVM >4.5 tonnes) Level 2

At-destination charging

Class 6 - Shops + Retail

- EV-Ready
- 20% of visitor bays Level 2
- 20% of employee bays Level 2
- EV-Installed * Case by case basis Level 2 or 3

Class 9a - Hospital
Class 9b - Public Buildings

- EV-Ready
- 20% of visitor bays Level 2
- 20% of employee bays Level 2
- EV-Installed * Case by case basis Level 2 or 3

On-route charging

Public Charging Hub

Investigate the formation of a new Building Class for 'Charging Hub'

- EV-Installed * Case by case basis Level 2 or 3

Fire Safety

Australian Code Compliance

The current NCC 2019 Amendment 1 is silent on fire safety requirements related to the hazards associated with Energy Storage Systems (ESSs) in a building. In the NCC 2022 public comment draft (Stage 2)28, ABCB has noted that no changes are planned for existing fire safety provisions for carparks due to the lack of data.

ESSs constitute the primary fire hazard in buildings, and these can be in several configurations:

- The batteries within EVs; and
- Fixed ESSs that might be part of, or separate to, an EV charging station often associated with a PV array system.

Recommendations for Fire Safety with EV Charging Infrastructure

It is recommended having a fire engineer involved in the project to conduct a fire safety risk assessment. Early engagement with the local fire brigade is also recommended, with a focus on EVs and associated charging infrastructures (e.g., Lithium-Ion ESSs).

Engagement with the local fire brigade is essential to understand the special hazard classification for EVs and associated EV charging infrastructures and their operational requirements relating to firefighting (NCC E1.10) and smoke management (NCC E2.3).

ABCB

Summary of changes

NCC 2022 public comment draft (stage 2)

Energy efficiency and condensation management

NCC Reference	Changes and commentary
	buildings. Class 2 buildings will also be required to install charge control devices to ensure EVs will only be charged when there is available electrical capacity in the building. Without this requirement, Class 2 buildings would be required to size their electricity supply to support 100% of car parking spaces being used to charge EV at times of peak demand. This would at least double the required electrical supply capacity for the building. **Consultation question** Are existing fire safety provisions sufficient for carparks where EVs are parked? EVs present a different type of hazard should they be involved in a fire within the building. ABCB Investigation has found that based on the available evidence (see report: Hazard Assessment of the impact of Electric Vehicles, available on request), the risk profile of a car park filled with 100% EV is equivalent to a carpark filled with 100% of conventional vehicles. On this basis no changes to existing fire safety provisions are proposed for carparks at this time. The ABCB will continue to monitor this issue as further information arises.
Specification 36 (formerly J1.2 material properties)	Specification 36 (previously Specification J1.2) provides thermal resistance values (R-Values) for commonly construction materials. It allows NCC users to calculate the thermal resistance of the building fabric when developing a DTS Solution for Part J4. An update is needed to Specification 36 because the airspace R-Values to align with AS/NZ 4859.2 (2018). The existing values in Specification 36 are based on an airgap average temperature of 10°C and temperature difference of 15°C between internal and external conditions. This does not reflect typical Australian conditions. AS/NZ 4859.2 (2018) uses a maximum temperature difference of 10°C. Updating the values by using the current AS/NZS 4859.2 (2018) method will remove the inconsistency between

Australian Building Codes Board 20

Consultation question

Are existing fire safety provisions sufficient for carparks where EVs are parked?

EVs present a different type of hazard should they be involved in a fire within the building. ABCB Investigation has found that based on the available evidence (see report: Hazard Assessment of the impact of Electric Vehicles, available on request), the risk profile of a car park filled with 100% EV is equivalent to a carpark filled with 100% of conventional vehicles. On this basis no changes to existing fire safety provisions are proposed for carparks at this time. The ABCB will continue to monitor this issue as further information arises.

Infrastructure ABCB – Summary of Changes – NCC 2022 Public Comment Draft (Stage 2) for Energy Efficiency and Condensation Management[28]

[28] *Summary of changes Energy efficiency and condensation management NCC 2022 public comment draft (Stage 2), ABCB, 2021*

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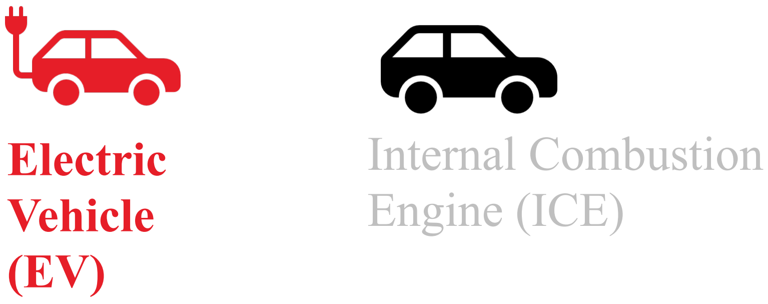
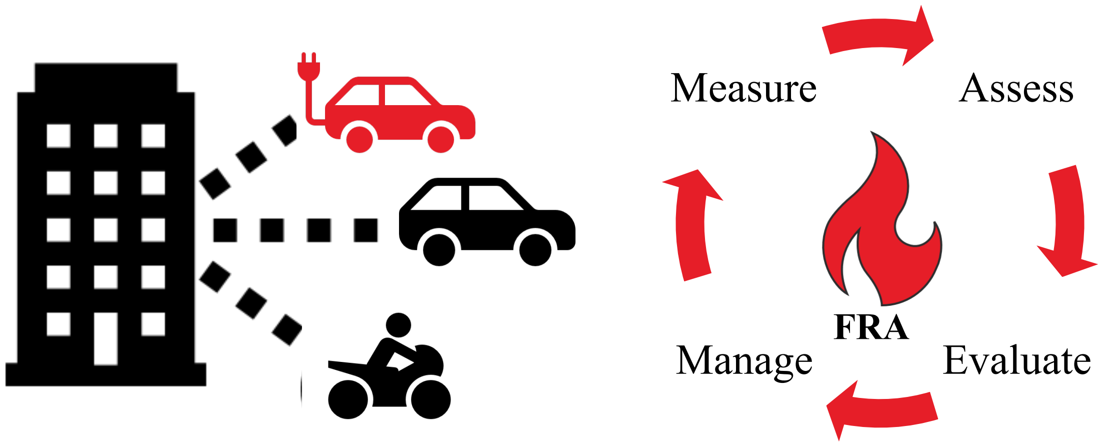
Introduction

What are the potential fire & life safety risks resulting from additional EV charging facilities in an existing carpark?

What are the impacts from an EV fire while charging in carpark?





Fire Safety

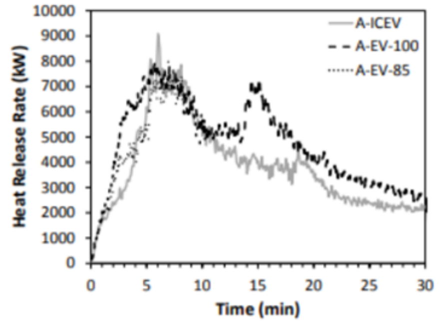
Emerging Fire Safety Issue of EV Charging Infrastructure

The introduction of EV charging infrastructure in a carpark can pose an additional fire hazard as EV battery systems present different fire challenges than traditional Internal Combustion Engine (ICE) vehicles.

The aspects we must consider include:

1. Possible increased likelihood of a fire occurring whilst an EV is charging
2. Different Fire Size or fire spread behaviour between an EV vs an ICE vehicle
3. Specific Fire-fighting strategies for EV

	EV	Analogous Diesel vehicle
Fire development	Similar for all vehicles - no explosion or projection related to the battery was observed during EV fire tests.	
Mass loss	Approx. 20% of the initial mass.	Approx. 20% of the initial mass.
HRR	4.2 – 4.7 MW	4.8 – 6.1 MW
Effective heat of combustion	30-31 MJ/kg	36-36.5 MJ/kg



EV HRR curve showing secondary peak [13]

Large scale fire test result on EVs vs Internal Combustion Engine (ICE)[1]

Type of EVs	Time of FE Suppression	Volume of Water
Li-ion Battery A (4.4 kWh battery pack)	16 to 59 mins (2 x ~8 L/s hydrant flow)	1041 to 4013 Litres
Li-ion Battery B (16 kWh battery pack)	36 to 59 mins (2 x ~8 L/s hydrant flow)	4410 to 10,000 Litres

Fire-fighting strategy and requirements for EVs fire[2]

[1] *Comparison of the fire consequences of an electric vehicle and an internal combustion engine vehicle*, *Lecocq et. Al*
[2] *Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results*, *Long et. Al*

Likelihood of Fire Associated with EVs

Emerging Technology – Potential teething issues

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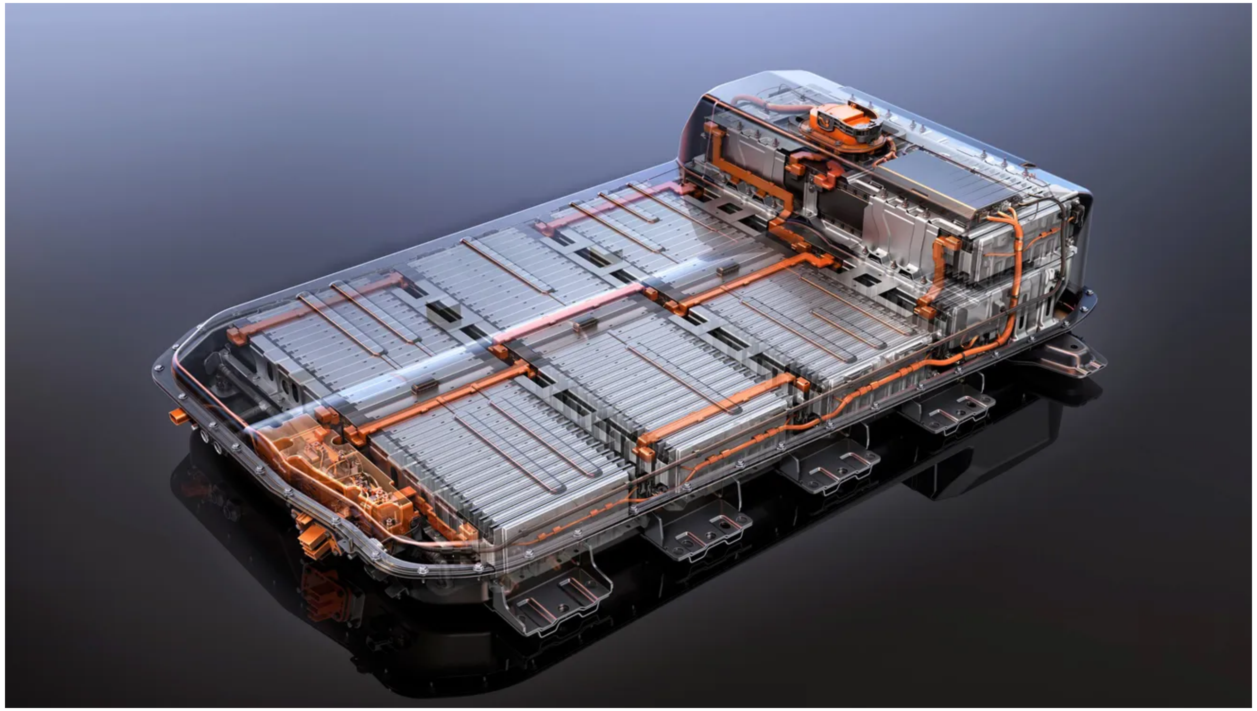
2019 to 2021

There are recent global headline news related for the EVs manufactures to recall the EVs due to potential EV battery risk.

- November 2021 : Major multinational –EVs (2017-2022) and EUVs (2022) [5]
- November 2020 : 2019–2020 Electric and Electric vehicles (R0185) [6].

Both EVs were recalled based on defect in battery modules.



Battery.

Global Statistics for EV related Fires

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2011 to 2021

Plug-in electric vehicle fire incident data are referenced in Wikipedia [1] and other webpages [2] have collected and summarised EV related fire information.

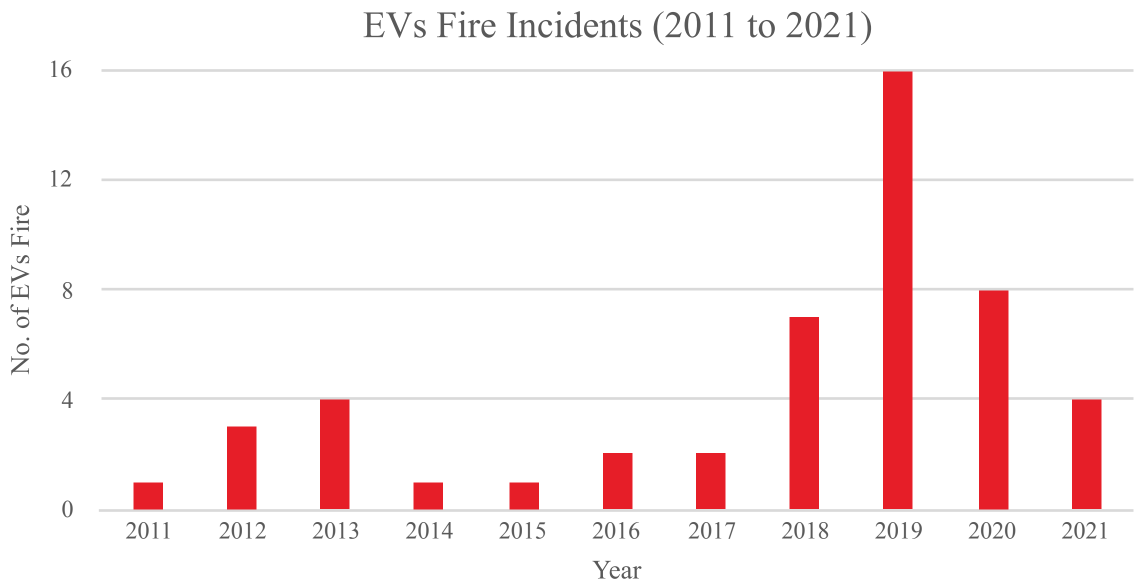
According to LaBovick's Law Group's database of electric vehicle fire incidents [2],

- a total of 49 EV fires were recorded during the period of 2011 to 2021.
- 14 fires (29%) were recorded with the fire incident as EV fire while being charged
- 16 fires (33%) started while the vehicle is parked.

Findings

While there is a general lack of data there appears to be a potential fire risk for the ignition of an EV fire while being charged. There is also increasing unpredictable EV fire incidents such as spontaneous ignition of EV while parked.

Type of EV Fire Incidents (2011 to 2021)	Records
Fire in the parked vehicle	16 (33%)
Fire while being charged	14 (29%)
Post-crash fire	13 (27%)
Fire while being driven	6 (12%)
Total EV Fire 2013 to 2021	49



Reference:

1. Wlikipedia, "Plug-in electric vehicle fire incidents," Wlikipedia, 2021. [Online]. Available: https://en.wikipedia.org/wiki/Plug-in_electric_vehicle_fire_incidents#Electric_vehicle_incidents. [Accessed 16 Nov 2021].

2. LABOVICK LAW GROUP, "ELECTRIC VEHICLE FIRE INCIDENTS AND STATISTICS," 29 June 2021. [Online]. Available: https://www.labovick.com/blog/electric-vehicle-fire-incidents-and-stats/.

Differences between EV Fires and ICE fires

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Difference between EV vs ICE vehicle - Output

1. Large Scale Fire Tests - INERIS, France

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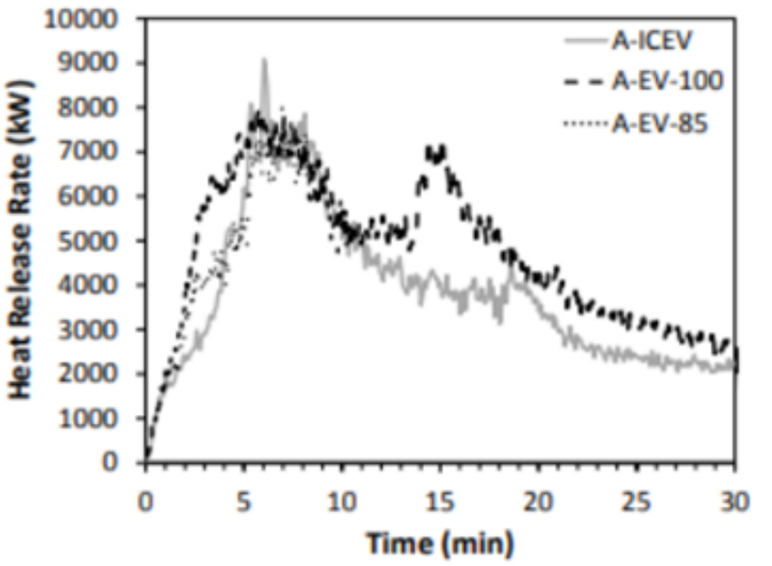

EV HRR curve showing secondary peak [13]

Reference:
13 A. Lecocq, M. Bertana, B. Truchot and G. Marlair, Comparison of the fire consequences of an electric vehicle and an internal combustion engine vehicle, Collection of open conferences in research transport (2012). Vol. 2012, 141 URL https://www.scipedia.com/public/Lecocq_et_al_2012a

Difference between EV vs ICE vehicle - Output

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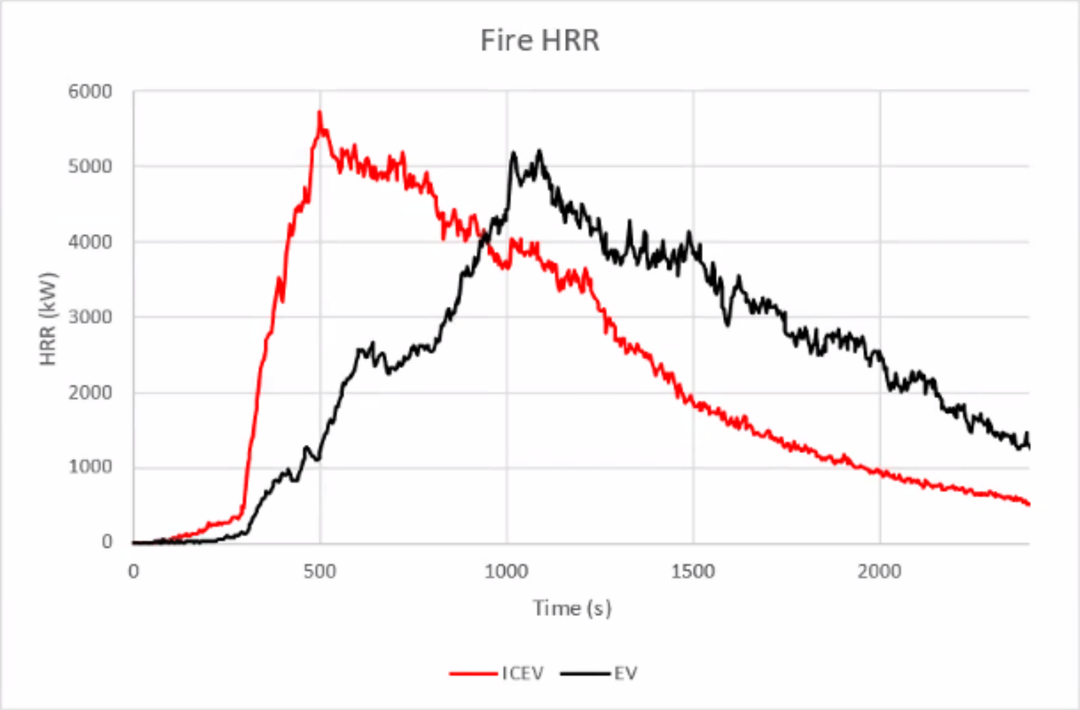
2. Large Scale Fire Tests – RI.SE, Sweden



Difference between EV vs ICE vehicle – Fire Spread

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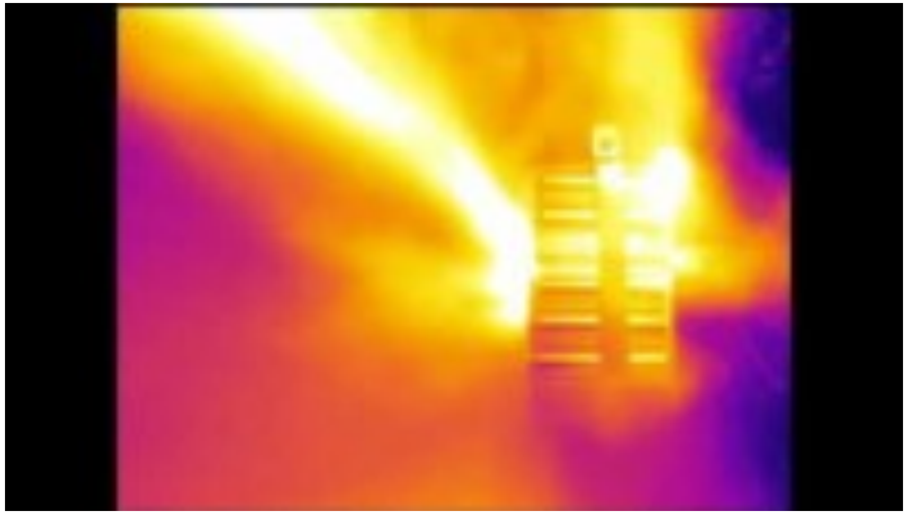
The spread of fire between EVs and other cars has not been studied in detail.

However, the fire spread from a burning EV will depend on the ignition of the battery compartment, resulting in the other vehicle going into a thermal runaway of LIB [1]

Investigation of massive fire in a multi-storey car park in Norway (a fire broke out in an Opel Zafira (ICE)) [2] noted that the fire brigade's observations during the fire indicate that electric vehicles did not contribute to the fire development beyond what is expected from conventional vehicles.

However, it is noted that the decision of manufacturers to use side venting of battery gases creates the potential issue of side flame discharge from batteries under vehicles.



Reference:
Thermal imaging Li-ion cells in Thermal Runaway by George Brilmyer. [Online]. Available: https://www.youtube.com/watch?v=hwXccpeN6Qc&t=39s.

Reference:
1. Sun, P., Bisschop, R., Niu, H. and Huang, X., 2020. A Review of Battery Fires in Electric Vehicles. *Fire Technology*, 56(4), pp.1361-1410.
2. Storesund, K., Sesseng, C., Fjellgaard Mikalsen, R., Holmvaag, O.A. and Steen-Hansen, A., 2020. Evaluation of fire in Stavanger airport car park 7 January 2020.

Fire Spread between EV vs ICE vehicle – Fire Fighting

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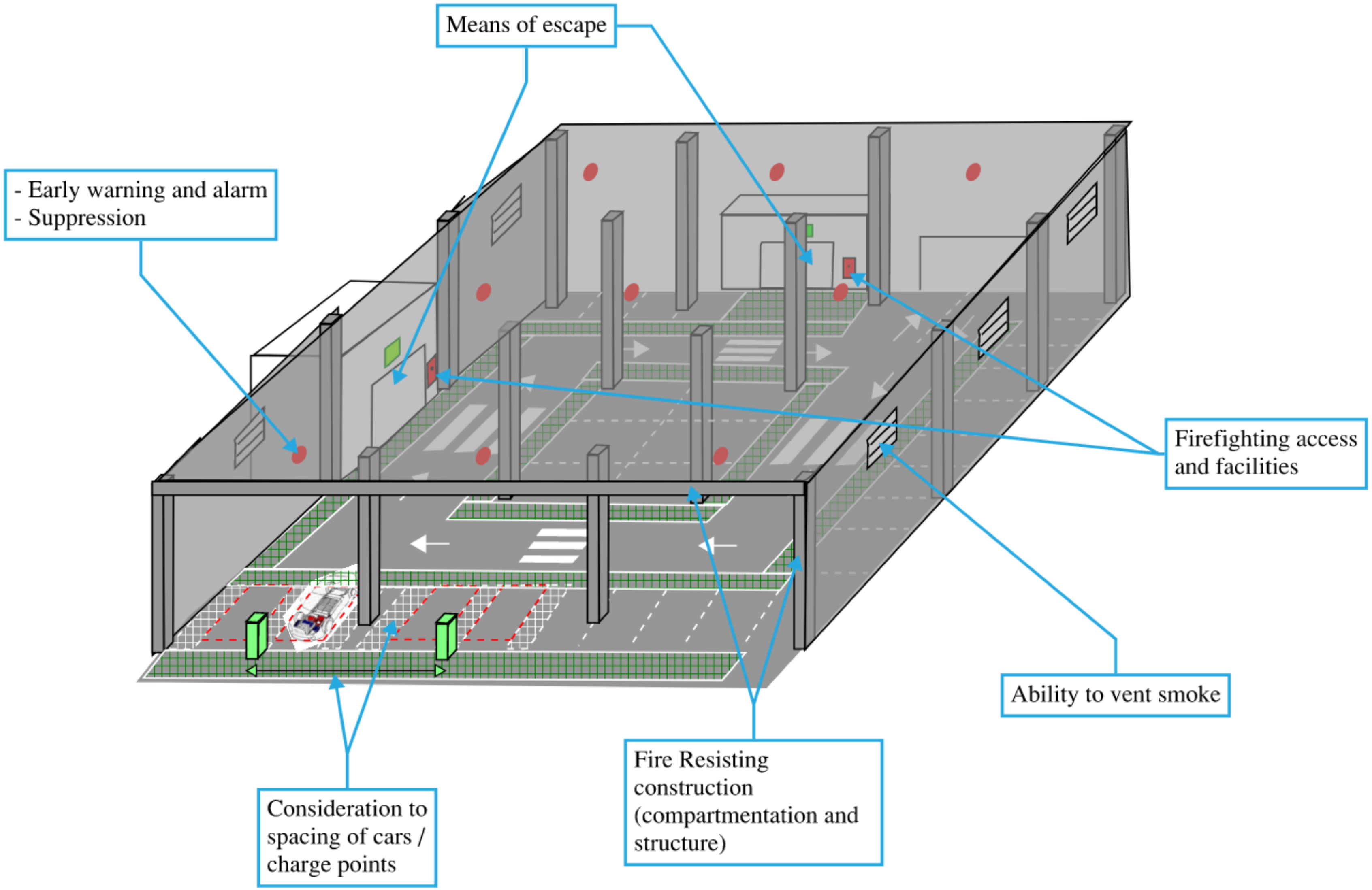
- The fire-fighting approach to an EV fire is different to the fire-fighting approach of a conventional ICEV fire
- Particularly if the battery becomes involved in the fire
- The main differences are:
  - Larger quantities of water are required to extinguish an EV fire.
  - Different tools required to reach the EV battery
  - Risk of electrocution is a concern that must be mitigated
  - Reignition of EV batteries can occur
  - Firefighting water run-off

Risk Mitigation

Risk Factors



Mitigating risk – Case study 1

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Fire safety feature	Adopted design approach
EVCP	Preference for EVCP with tethered or retractable cables so that cables are maintained as part of EVCP, to reduce risk of faulty cables being used.
Spacing of EVCP and signage	All EVCP are located with between 900 – 1200 mm clear width, to enable access to the chargepoint and allow greater distance between EVs. This meant three car parking spaces were converted to two spaces with EVCP. The access areas are hatched, with a clear sign in the centre to identify this as a charging parking space.
Automatic detection and alarm	Full system throughout
Automatic suppression	Existing town mains fed sprinkler system has sprinkler heads with an activation temperature of 68 °C. This was supplemented by localised drenching system over EV chargepoints, activated by 57 °C rated bulb above the vehicle parking space, with spacings of heads around the EVCP of no more than 2m. Design density of system follows FM Hazard Category 2, with a density of 8 mm/min over 230 m^2 (300 m^2 for dry systems), as well as BS EN 12845 and LPC rules. Two options developed, a deluge system for up to 20 heads activating at once, and a multi-jet system where 6 activate at once, activated by a frangible bulb located above the carpark space associated with the EVCP. The bespoke arrangement was verified through full scale testing in February 2022.
Smoke ventilation system	Mechanical smoke ventilation system upgraded beyond code requirements, with ACH informed by constraints of existing carpark configuration. System activated with delay after sprinkler activation to limit risk of forced ventilation delaying sprinkler activation.
Electrical supply to EVCP	Dedicated electrical supply to EVCP.
Isolation switches	Facility to manually isolate the EVCP from fire service entrance area, as well as automatic isolation of EVCP upon activation of the fire detection system. Reset of the electrical supply only permitted manually (no auto-reset).
Fire resisting barriers between EVCP	Discounted as not possible to achieve accessible arrangement, nor cost effective.
Structural fire resistance	Where practical, upgrades were made to the existing structure.
Fire mains	Dry falling mains provided where feasible to enable firefighting water application.
Post fire	Provisions in place with third party hauling company for EVs to be removed from the carpark. Surfaces of carpark to be impermeable to support post fire environmental clean-up of contaminated firefighting water. Drainage should incorporate receptors such as those used for oil spills and the design should avoid having contaminated water entering natural water supplies such as rivers or bore holes.

Mitigating risk – Case study 2

- Multi-storey Car Park (MSCP) to support a masterplan development for commercial activities in a large development site in England.

- Client wishes to adapt the site for future increases in EV usage, the MSCP is designed for fast charging provision to 20% of the parking spaces upon completion and futureproofed for that to increase to 100% over the life of the building.

Mitigating risk – Case study 2

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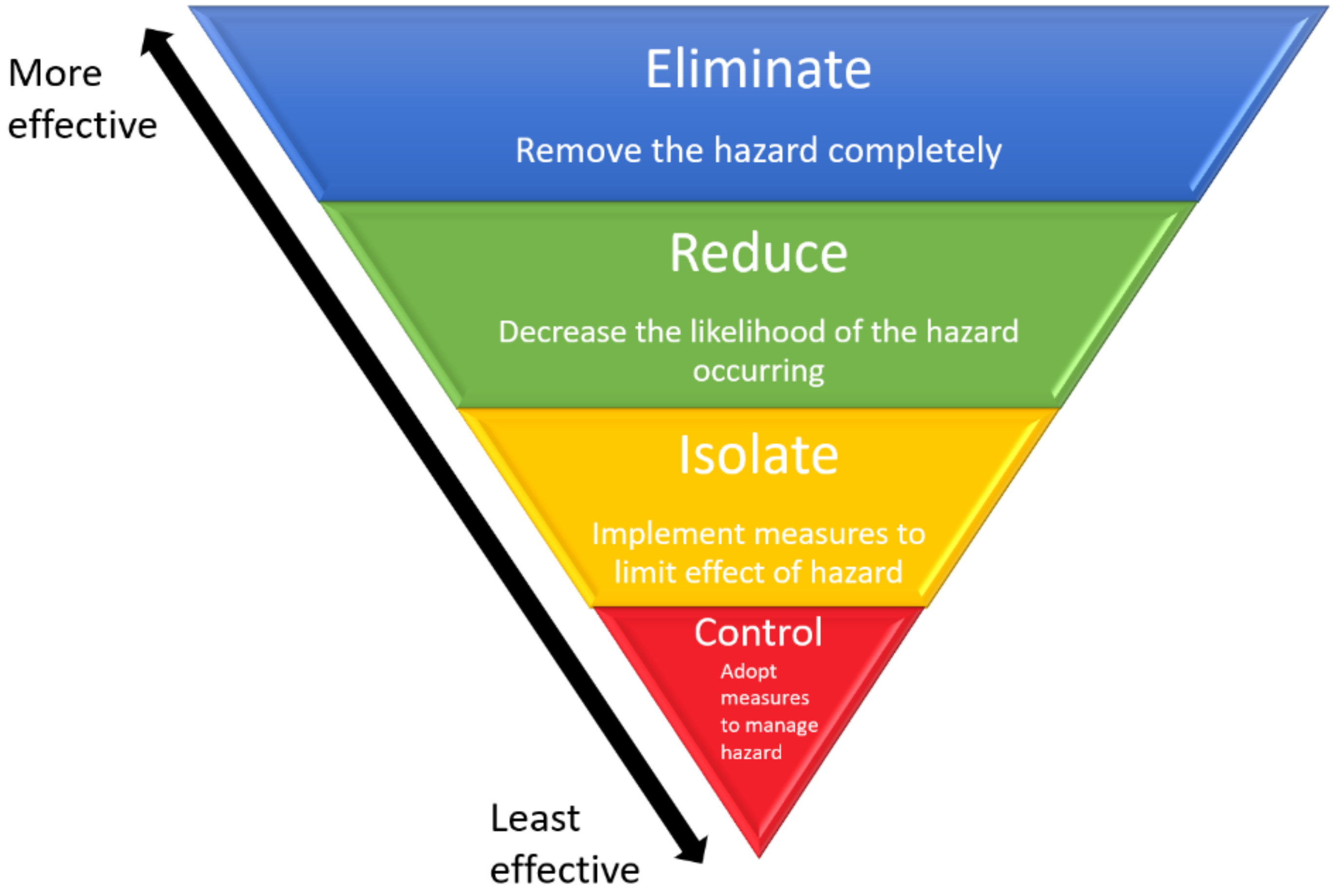
Fire safety feature	Adopted design approach
EVCP	EVCPs should have collision protection
Signage	Instructions and information on using charging facilities correctly should be easily accessible to all users of the car park
Automatic detection and alarm	Fire detection system to be installed throughout. Separate, analogue, addressable heat detectors are to be provided above each chargepoint to allow isolation of the chargepoint power supply.
Automatic suppression	A sprinkler system designed in accordance with BS EN 12845 [86] and the FPA's LPC automatic sprinkler installation rules should be provided. The system should be designed so that in the event of sprinkler activation, power supply to all EVCPs is isolated.
Smoke ventilation system	MSCPs should remain open-sided, to allow for adequate ventilation
Isolation switches	A manual isolation switch should be provided at each floor, to isolate the power supply to EVCPs on that floor.
Fire resistance of stairs	The existing stair cores should be upgraded to become 120-minute fire-resistant fire-fighting shafts. This was to allow space for firefighting operations to be staged and to allow hose coverage requirements to be met.
Structural fire resistance	On the basis of sprinkler provision, the current structural fire resistance of the MSCPs (30 minutes in terms of load-bearing capacity) would not need to be upgraded.
Fire mains	Each stair core should be provided with a dry riser to allow deployment of water to all areas of the car park.
Fire water supply	The current guidance to provided 25 L/s of water for firefighting purposes should be met. Given the provision of sprinklers and research showing similar fire sizes between EVs and ICEVs, additional water was not considered necessary.
Fire service information	A fire brigade information box containing the as-built charging system, location of chargepoint units and isolation switches should be provided.
Management Procedure	An appropriate management procedure should be developed for all staff who would be expected to respond to a fire in the MSCP.
Fire extinguishers	Portable fire extinguishers (in accordance with BS 5306-8 and BS 5306-3).
Installation of EVCPs	Charging equipment must be installed in accordance with: • BS EN 61851-1:2019, Electric vehicle conductive charging system. General requirements (incorporating corrigendum February 2020). • BS 7671:2018+A1:2020, Requirements for Electrical Installations – IET Wiring Regulations 18th Edition. • IET Code of Practice for Electric Vehicle Charging Equipment Installation. • Electricity Safety, Quality and Continuity Regulations 2012.
Water run-off	There should be provision for run-off of firefighting water.

Case Study – Hierarchy of Controls



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Design Elements to Consider

Mitigation measure	Classification of Control
Water based fire suppression (e.g. sprinklers)	Reduce
Increase distance between parked cars	Isolate
Provide thermal monitoring cameras within the car park	Isolate
Provide certified and approved electric vehicle charge points	Reduce
Install EV Charging Points (EVCP) by competent persons	Reduce
Provide a manual isolation switch to cut supply of EVCP	Control
Provide automatic isolation of power supply linked to the fire detection system	Isolate
Provide controlled speed limits / layout that reduces the likelihood of collisions.	Reduce
Secure storage of vehicles	Isolate
Provide crash protection to EVCPs	Reduce
Routine inspections by a responsible organisation	Reduce
Position the EVCP so that the charging cable length is minimised	Reduce
Provide security systems to deter deliberate damage	Isolate
Install EVCPs with the capability to monitor faults within the charge point.	Reduce
Design the EVCPs for Ease of returning the cable to its rest position	Reduce
Eliminate faulty EVCPs from service	Eliminate
Provide sufficient firefighting water supply	Reduce
Place EVCPs on top level of the car park (where open)	Isolate
Provide access for removals of EVs that have been on fire	Isolate
Provide increased spacing between cars	Reduce

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Design Elements to Consider

Mitigation measure	Classification of Control
Provide additional information on premises block plans (information for fire service)	Control
Provide an enhanced smoke management system	Control
Provide appropriate structural fire resistance	Control
Locate EVCP near to fire service access points (balanced against egress)	Isolate
Locate EVCP away from escape routes (balanced against fire service access)	Isolate
Provide automatic detection and alarm	Isolate
Maintain general means of egress signage, lighting & routes	Control
Maintain existing fire resisting construction (penetrations through fire resisting construction)	Reduce
Provide manual firefighting measures	Control
Façade design	Isolate
Provide appropriate water run-off control and containment	Control

Conclusions

- There is limited data available for EV fires currently. This is changing.

- EV fires have differences to ICE fires:

  - Suppressing a fire involving the battery requires different firefighting techniques and equipment;
  - Smoke produced when involving the battery can be more toxic;
  - Fires involving the battery can re-ignite;
  - Duration of EV fires can be longer than ICE vehicle fires.

There are also similarities:

  - Peak heat release rate is similar to an ICE vehicle based on current battery sizes.
  - The time for a fire to reach its peak heat release rate is comparable;
  - The temperature and visibility of smoke emitted are comparable;

The carpark owner/operator should carry out a fire risk assessment to determine whether the introduction of EVs or EVCPs into their car park creates new or additional hazards and the appropriate mitigation measures.

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