evfiresafe.com

EV FireSafe

Enhancing safety for emergency responders at electric vehicle fires

Emma Sutcliffe
Project Director

Supported by:

Australian Government
Department of Defence

In partnership with:

DEAKIN UNIVERSITY

We're researching

EV lithium ion battery fires

What do they mean for emergency responders?

+

connection to energised charging

What additional risks do emergency responders face?

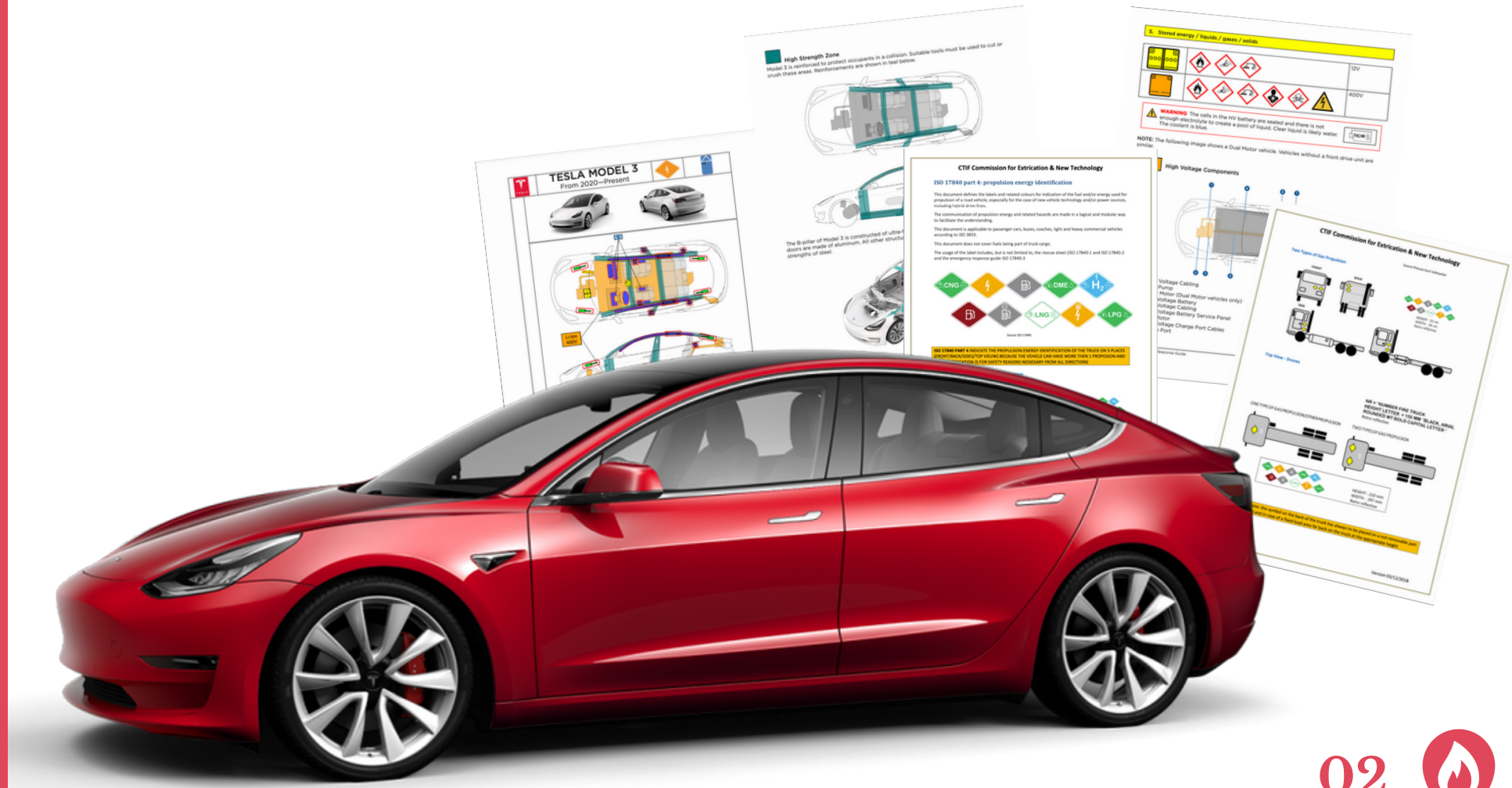
It all started with a bushfire

nine.com.au | 9NEWS

“The day’s not over. It’s still hot.”

Betty the Tesla Model 3

Experiencing EVs is one of the best ways to reduce firefighter FUD

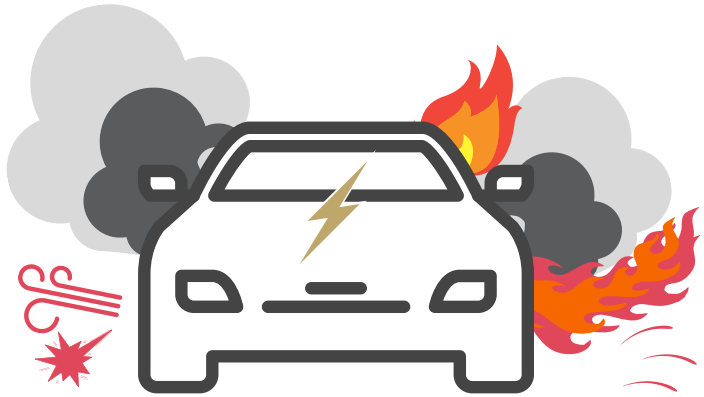


EV LiB fires are very rare

In passenger plug-in EVs, we have verified*:

187 EV traction battery fires globally, 2010-today

+ 24 currently being cross checked

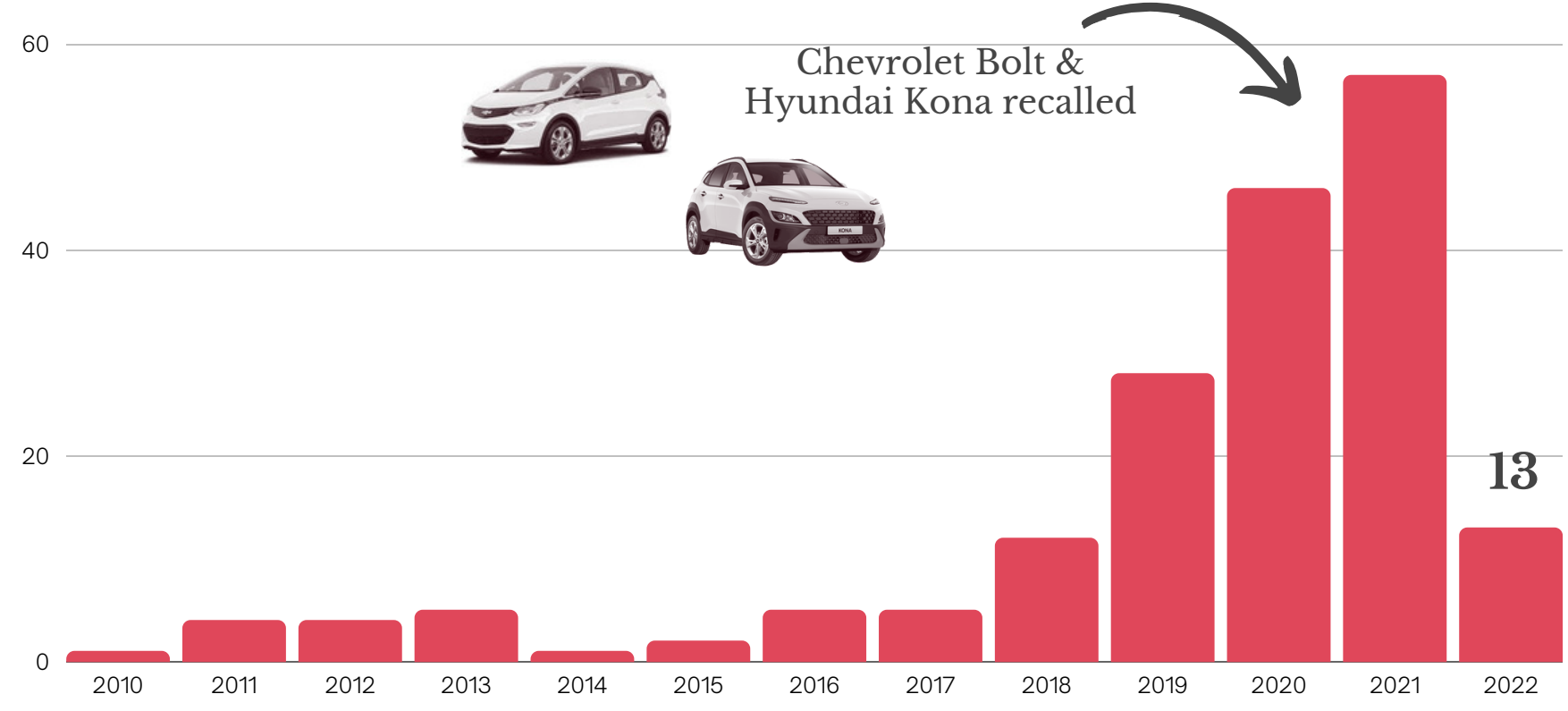


'In the world of clean energy, few areas are as dynamic as the electric car market. We estimate there are now **around 16 million electric cars** on the road worldwide...'

International Energy Agency, January 2022

*Not exhaustive. From more than one online source, interviews, first hand accounts, videos, images, academic & fire agency reports & online training

EV fires by year



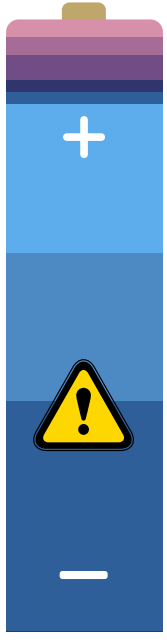
EV fires by manufacturer

Most number of EVs on the road
Most number of 'collision at speed'

60
40
20
0

Tesla
Chevrolet
Hyundai
BMW
Renault
Unknown
Nissan
Porsche
Jaguar LR
Mitsubishi
VW
BYD
Fisker
Mini
Audi
Peugeot
Lucid
NIO
Xpeng
Chery

Causes of battery cell abuse



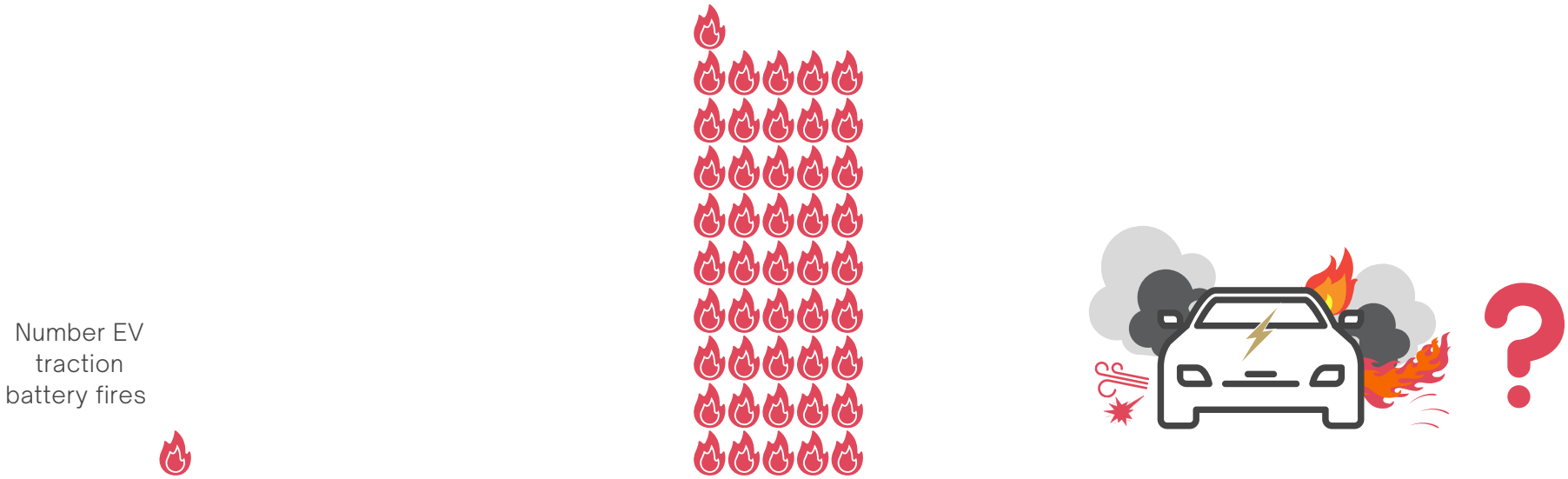
Overheating	1.57%
Submersion	1.57%
External fire	2.31%
Arson / malicious	2.31%
Workshop / repair	3.08%
Collision / debris	18.90%
OEM battery fault	18.90%
Unknown	29.13%

*Data current November 2021
^Percentage of incidents EVFS studied

EV & fire projections

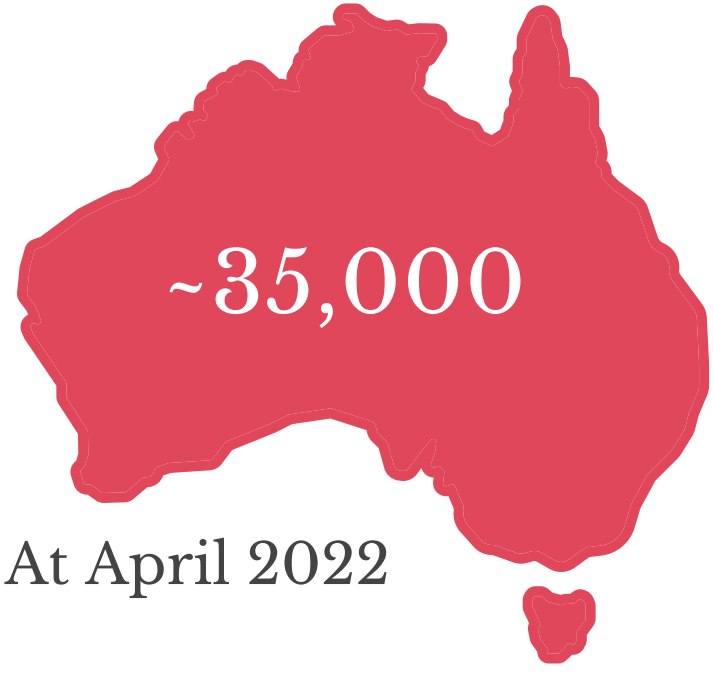
'The average age of electric vehicles in the US is 3.9 years of age and has been hovering between 3.8 and 4.1 years since 2016...'

IHS Markit, January 2021

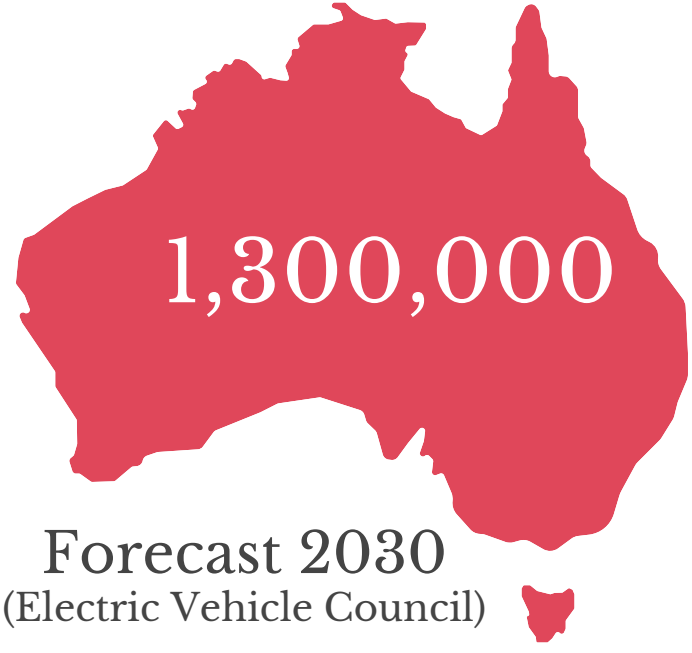


EVs in Australia

EV ownership* is concentrated in capital & major cities, but there are now EVs in every Australian region



At April 2022



Forecast 2030
(Electric Vehicle Council)

~70%

compound annual growth rate of EVs since 2010

*Doesn't include hydrogen fuel cell vehicles!

EVs in Victoria

'The **state of Victoria is Australia's largest and most important electric vehicle market**, with the most electric vehicle purchases in Australia between 2011 and 2021.'

Electric Vehicle Council, State of EVs Report 2021

At April 2022

Forecast 2030 for passenger EVs

Total number of all vehicles registered in Victoria, end 2021: 5.1 million

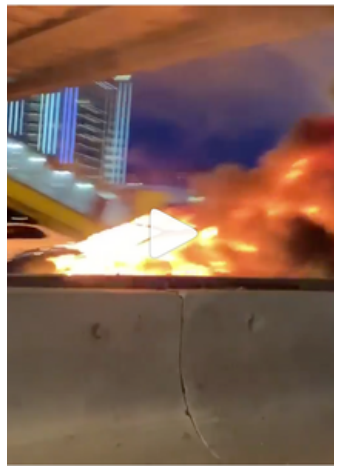
Age of ICE is over

Brands with EVs currently available in Australia

Brands with new EVs coming in 2022/3

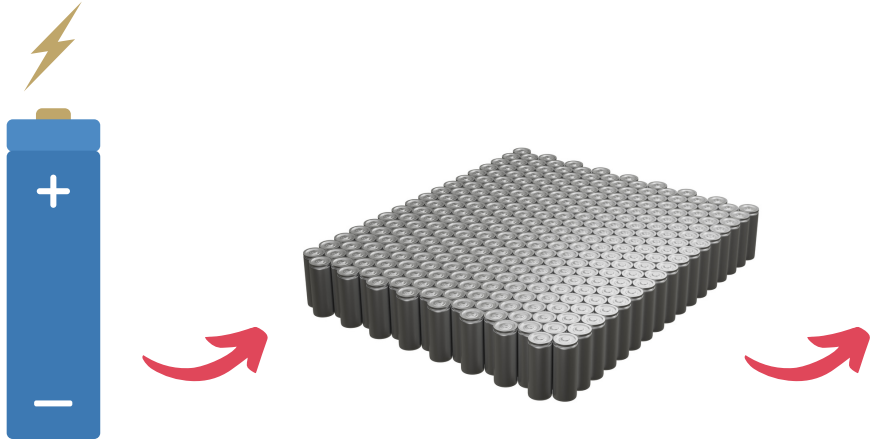
Brands not electrifying (yet)

New risks & challenges



Battery pack construction

An EV traction battery pack is typically constructed like this:



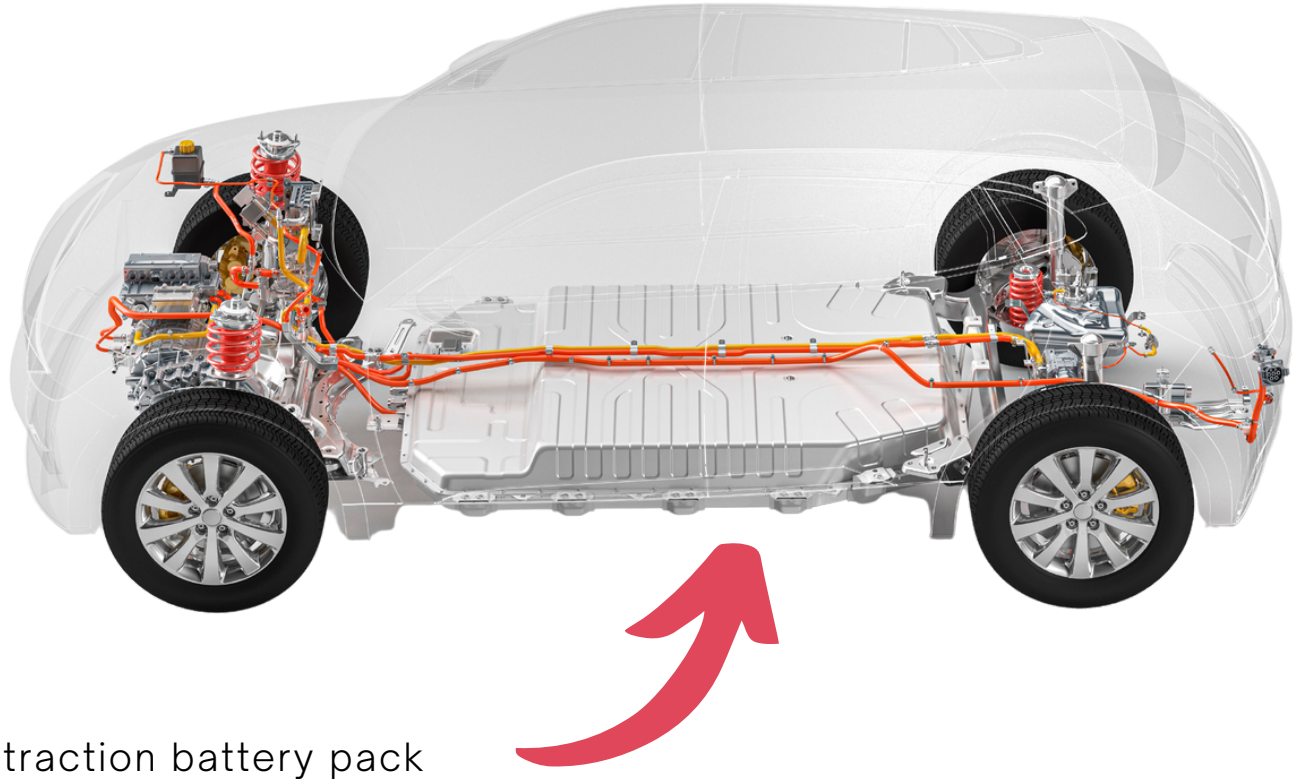
Lithium ion battery cell

Multiple cells make a battery module

Multiple modules make a battery pack, which is enclosed in protective battery casings

Battery pack construction

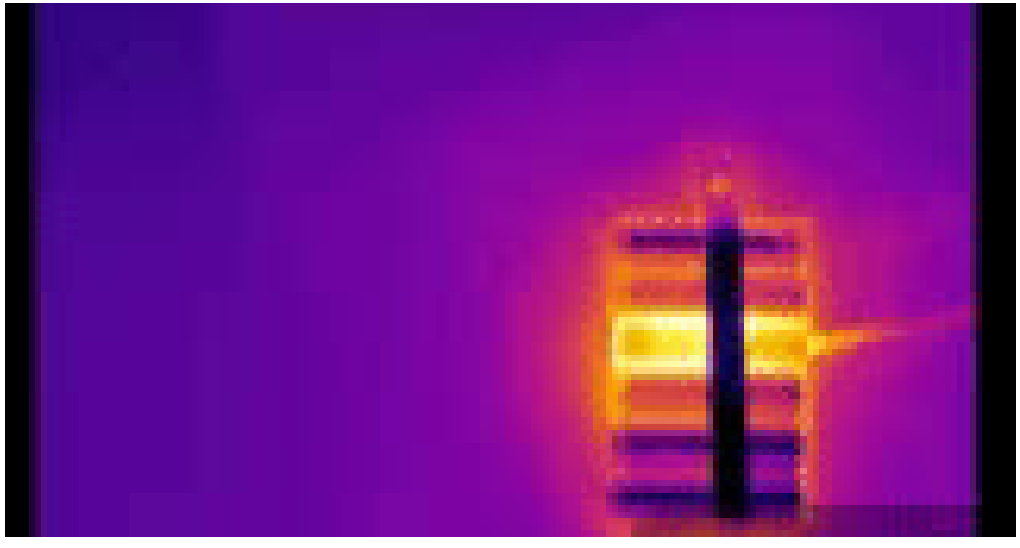
The traction battery supplies power for vehicle momentum & is usually located beneath the vehicle, along the floor pan



EV traction battery pack

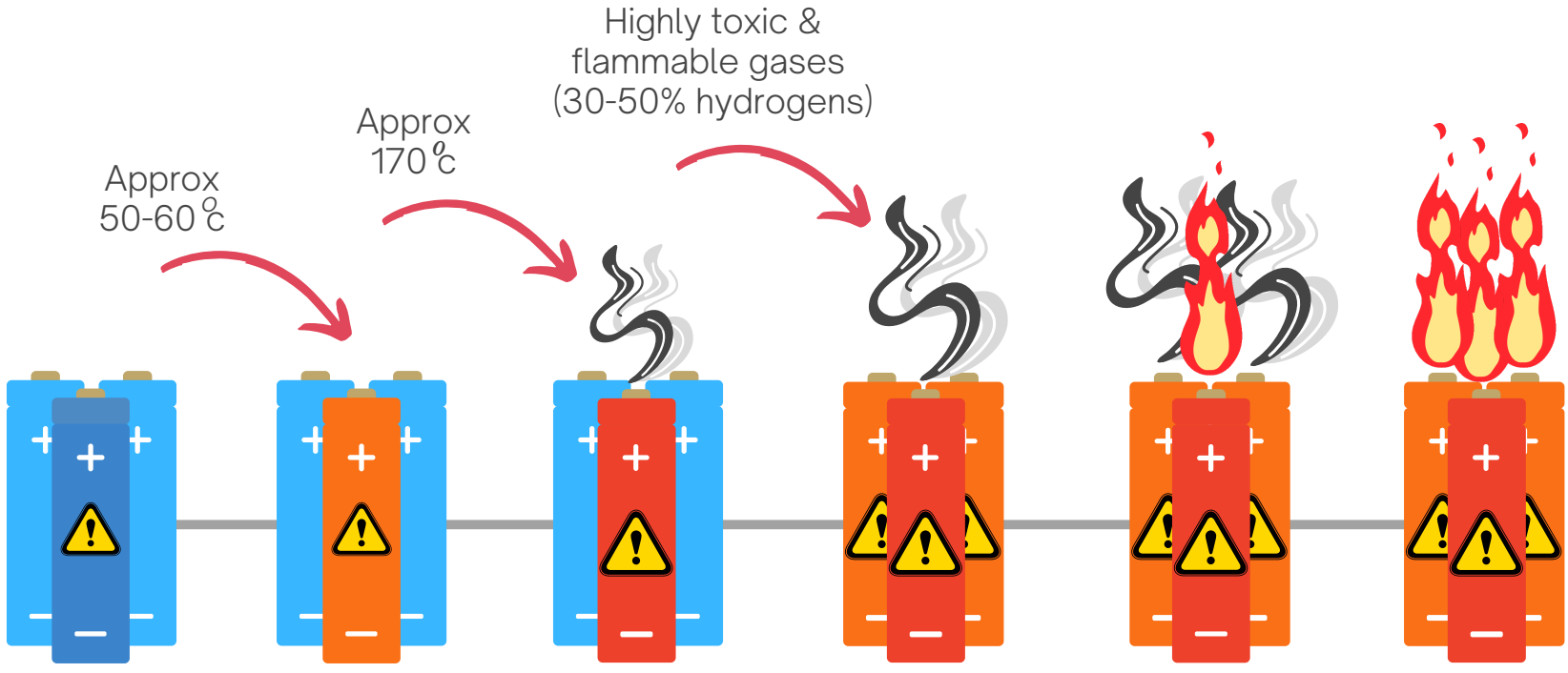
Thermal runaway

An unstable chemical process that is difficult to bring under control



Thermal runaway

Thermal runaway occurs when a battery cell suffers abuse, short circuits, heats up & bursts.

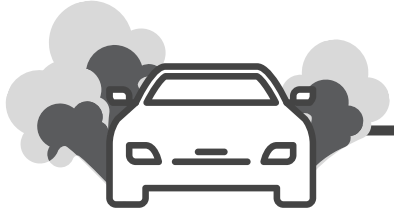


From outside the EV

From an emergency responder perspective, thermal runaway looks & sounds like this

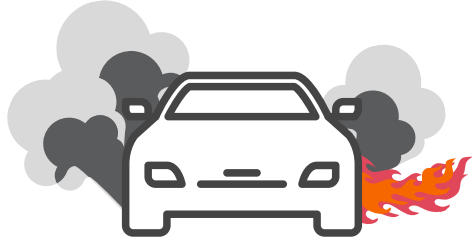
Dark vapour cloud,
light vapour cloud
(it's NOT smoke)

Popping - blast caps
Hiss/whistle - gas venting
Projectiles - cell debris



At this point, one of two things will occur

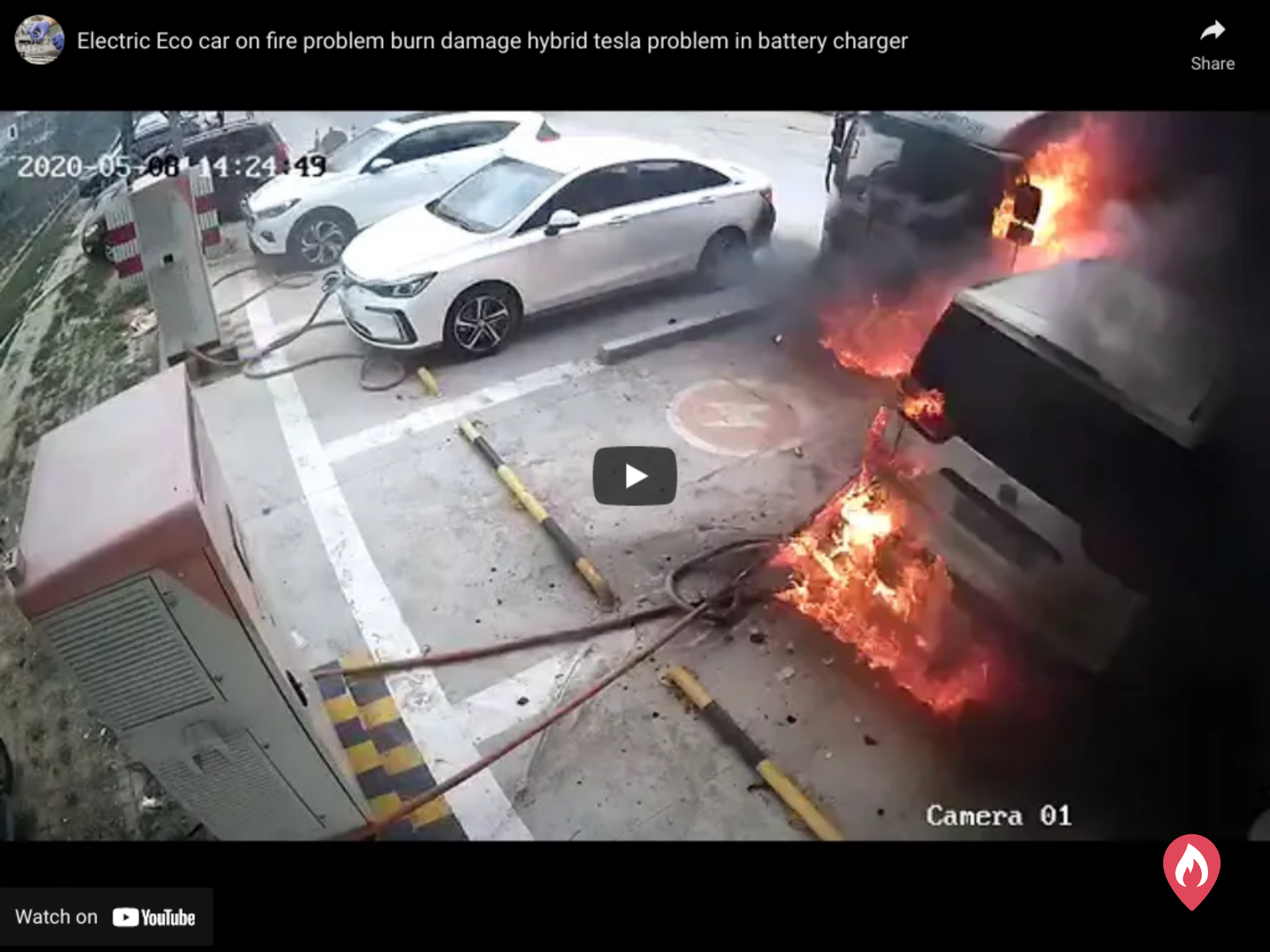
Ignition
Jet like, directional flames



~90%

Vapour cloud explosion
Violent deflagration

~10%


Electric Eco car on fire problem burn damage hybrid tesla problem in battery charger
Share
2020-05-08 14:24:49
Camera 01
Watch on YouTube

Vapour - it's not smoke

Gases: 30-50% hydrogen, 7-30% carbon monoxide & 2-15% methane

Vapour cloud explosion

Total of **18 VCE incidents** globally since 2010:

64.3%

Underground / enclosed space

35.7%

Open air

4 incidents verified of:

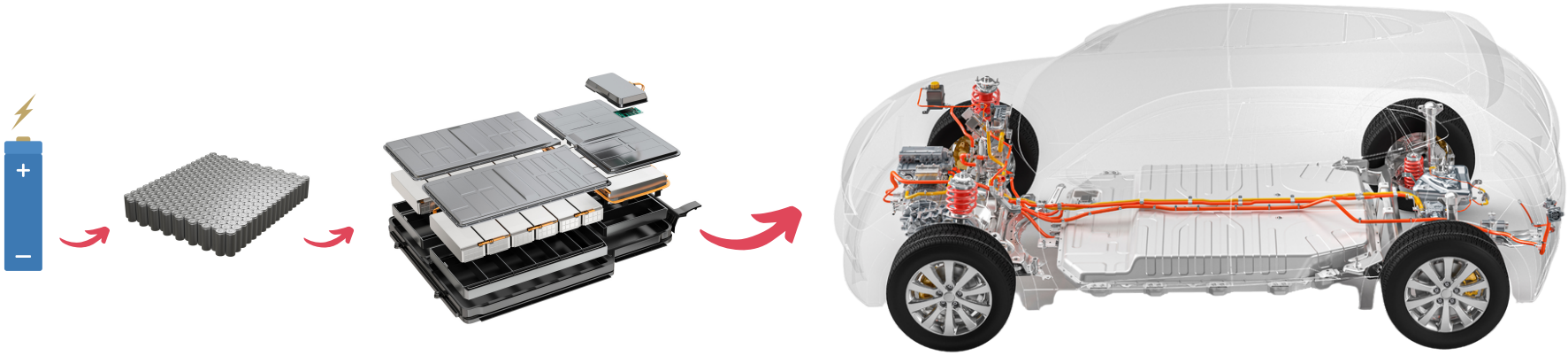
- vapour cloud explosion
- in an enclosed space
- while connected to energised charging

Vapour cloud explosion

Vapour cloud explosion

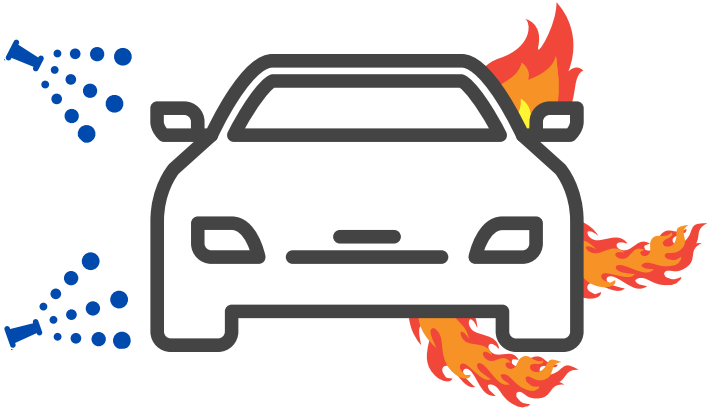
EV fire suppression

It doesn't actually take much water to suppress a battery pack fire...the problem is getting it directly onto the cells to cool them down

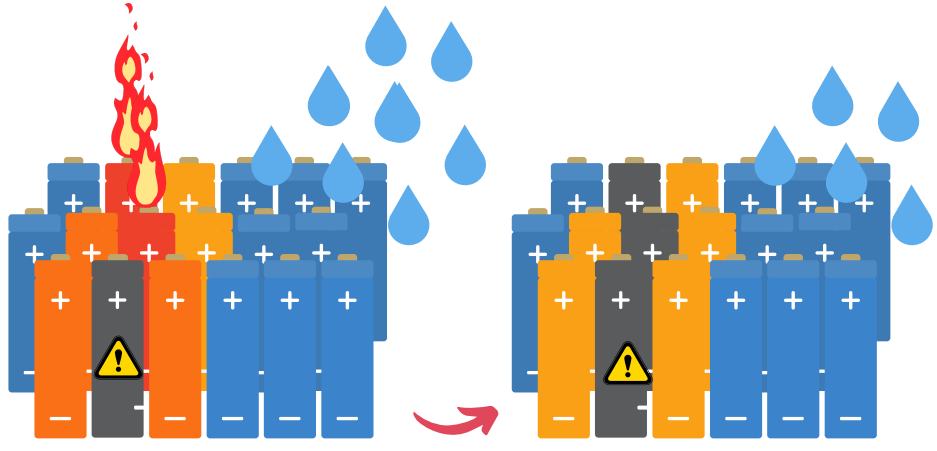


EV fire suppression

A stream of water onto the underside of the EV will dissipate heat
= slow & stop thermal runaway



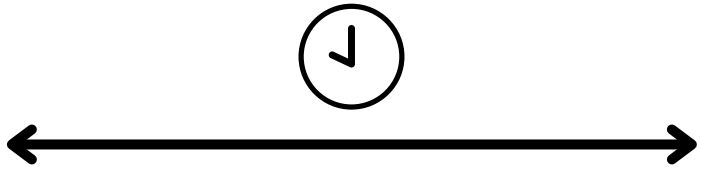
Cooling battery cells within a pack may take several hours



Suppression challenges

Suppression = time, resources

Best case *Worst case*



10min

3-5 hours (>50 hours to clear highway)

1,000L

110,000L

Case study

November 2020, Audi e-Tron, charging at time of thermal runaway

'Initial attempts to use dry power unsuccessful. Hose reel underneath the EV, go-jacks to move vehicle away from adjacent property.

Audi tech requested to isolate HV system.

Minimum 30 hours initial, then intermittent cooling & temperature monitor using TIC on an hourly basis.

Used 10 pumps with 4 officers over the 30 hour period.

Both Audi & recovery company refused to move the EV for 48 hours due to reignition risk.'

Greater Manchester Fire & Rescue Service

Emerging products

Fire blanket

Water lance

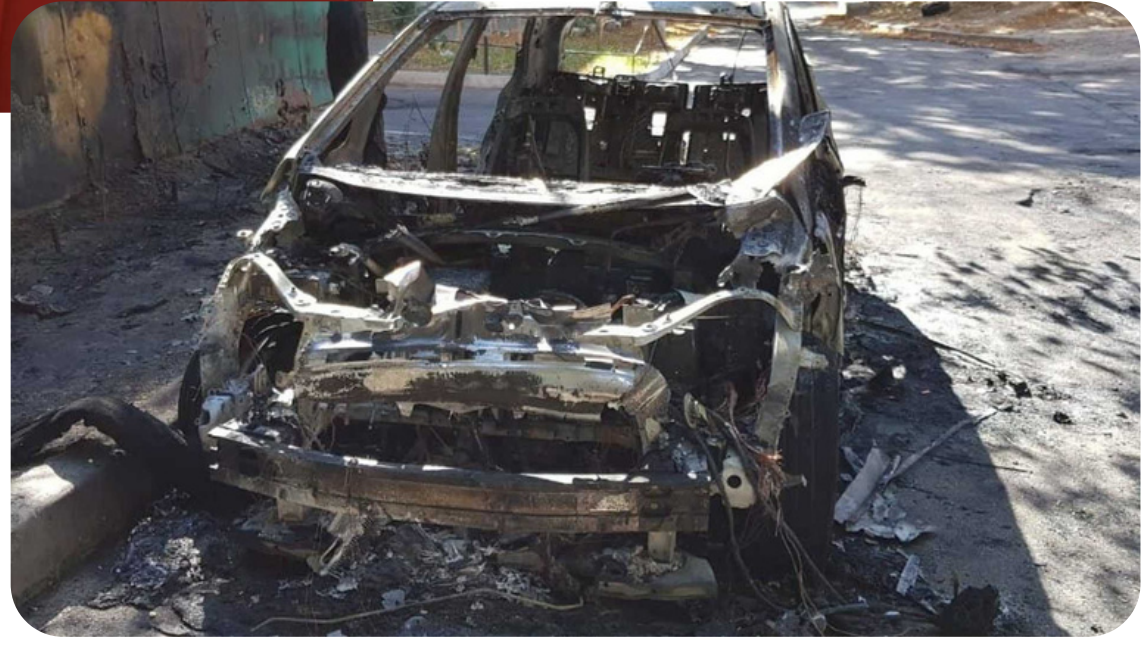
Cold Cut

Emergency Plug

International best practice

Submerge entire EV.
Not recommended by Tesla

Can it burn out?

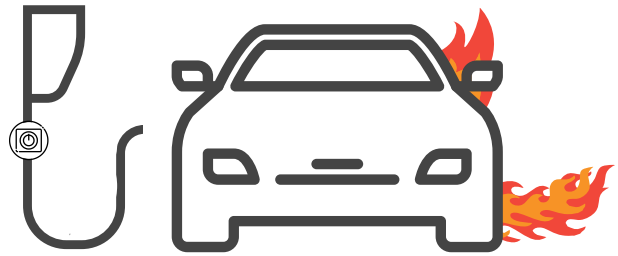


EV fires at charging

Of all incidents, we found:

26.15% were connected to energised charging (34 incidents)

4.62% had been disconnected from energised charging within 60 minutes (6 incidents)

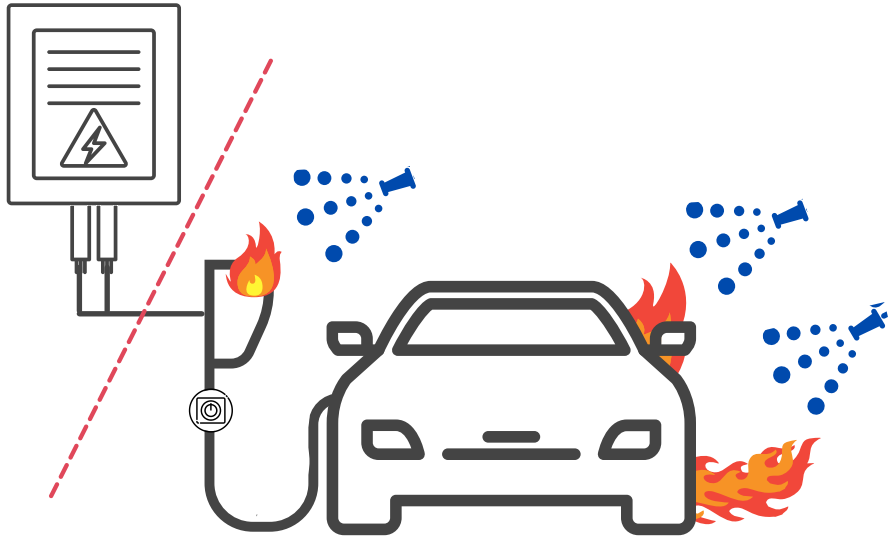


Charging wasn't necessarily the cause of fire, but consideration needs to be given to truck & water access at charging hubs

If connected to charging

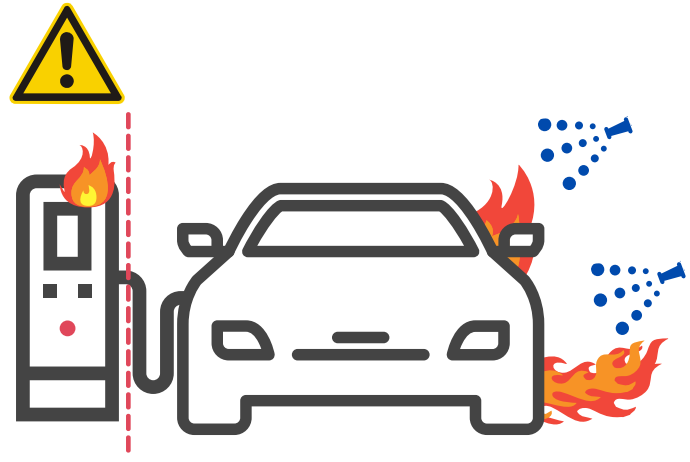
AC EV charging (7/22kW)

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

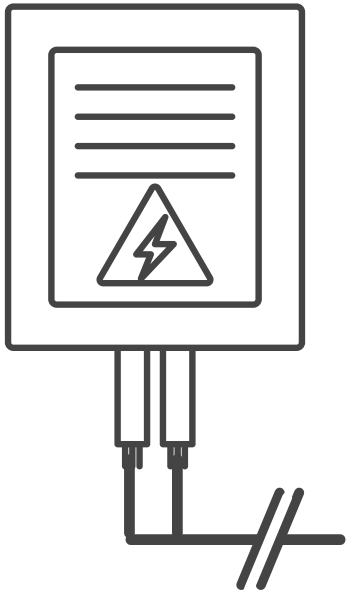


DC EV charging (25/350kW)

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



Best practice

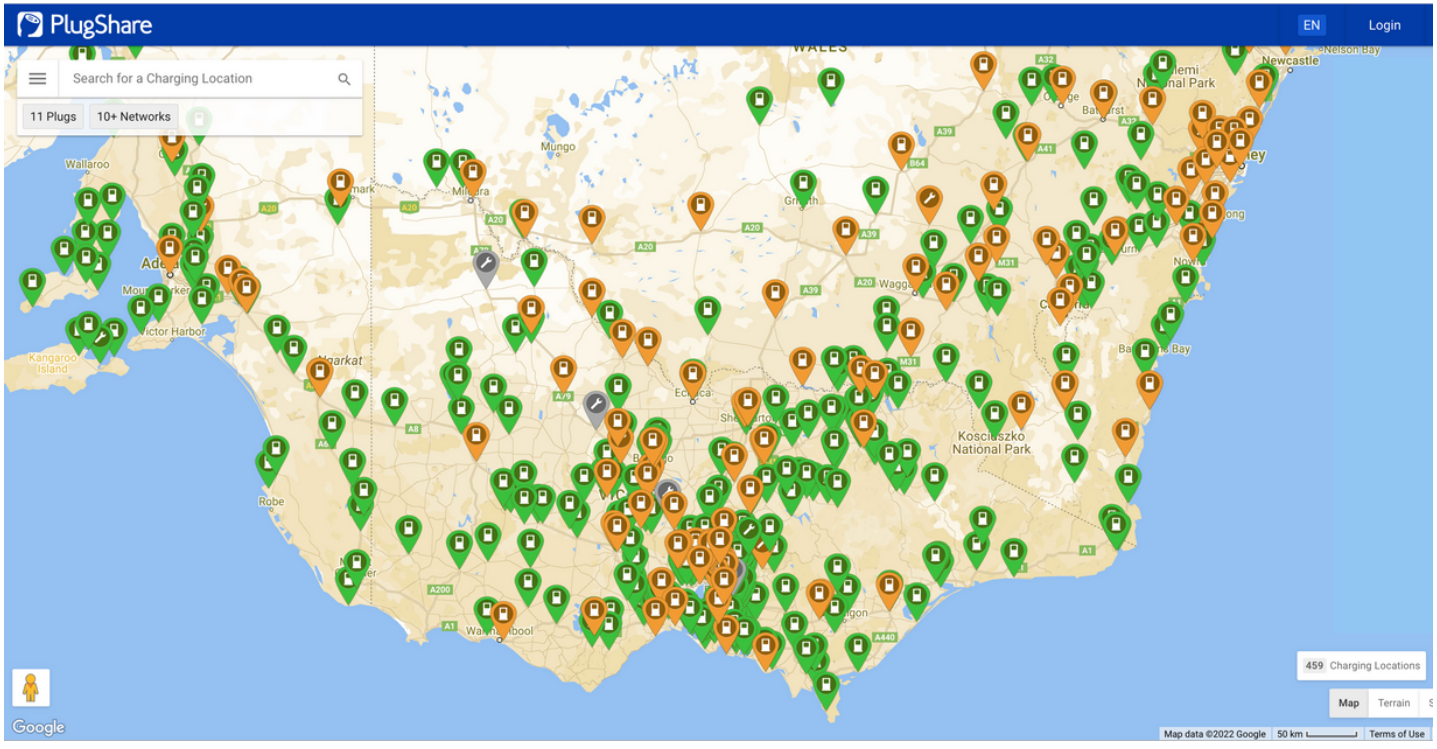


Treat as an energised electrical fire & follow SOPs

Don't touch anything until distribution board is located & cut

Charging in Victoria

Public charging locations; Council carparks, shopping centres, dealerships, schools. Not known how many are underground or in enclosed spaces. Charging plugs can be found in lightposts, roadside curbs, roadside substations & in ticketing machines.



'Victoria is also Australia's most significant electric vehicle market because it had the most electric vehicle chargers in the country..'

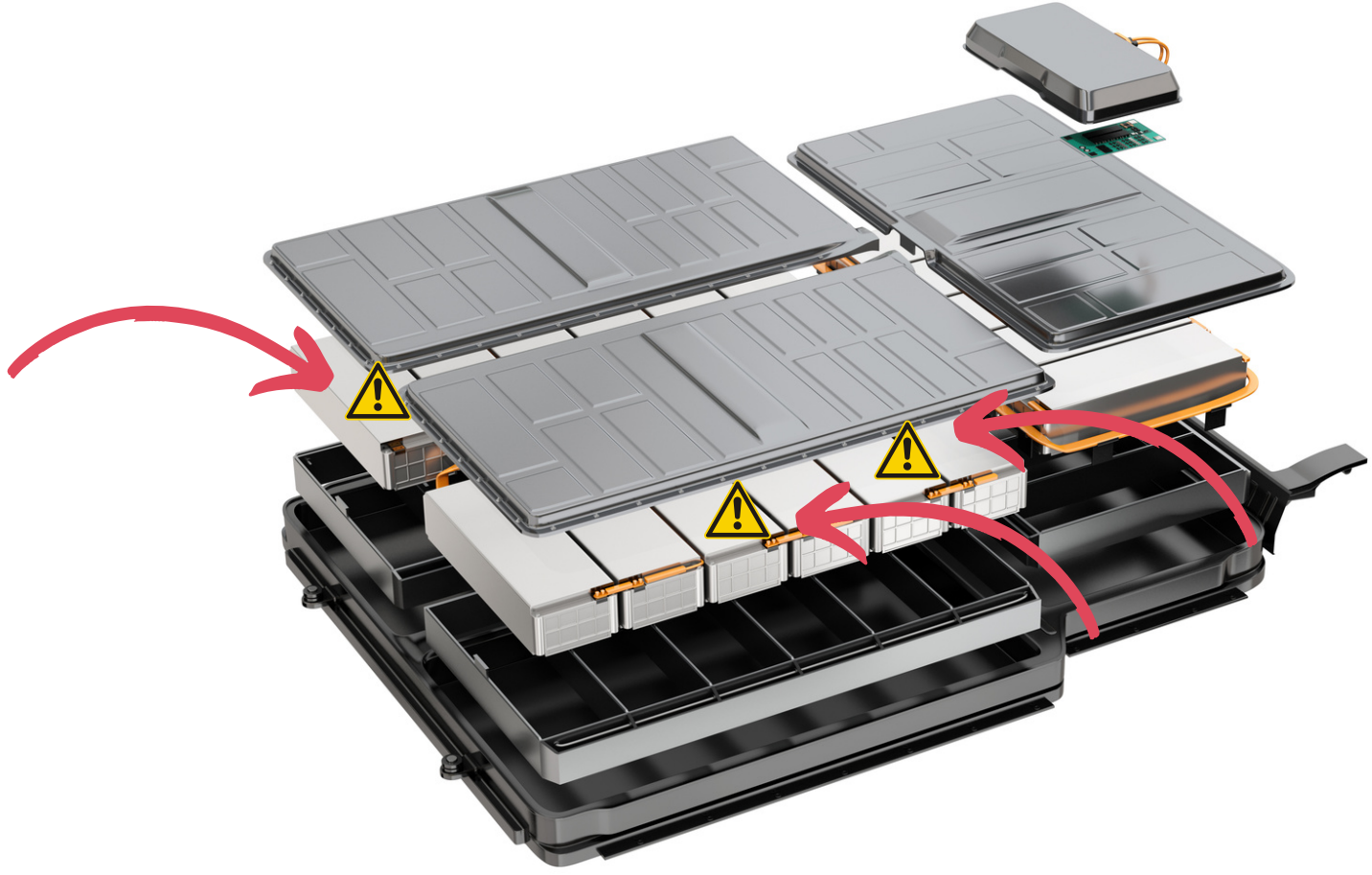
Electric Vehicle Council, State of EVs Report 2021

Reignition is a risk

In 6 cases Damage caused to tow truck
In 4 cases Injuries to drivers, one hospitalised

Reignition = multiple cells abused

Reignition - or secondary ignition - occurs when multiple battery cells are abused, but short circuit & go into thermal runaway at different times. Cells may also be affected by fire & short circuit later.



Reignition occurred in ~10% of incidents

Upon impact

48 hours later

Ignition

Reignition (on scene)

Reignition on tow truck

Reignition in storage yard

Upon impact

68 days later

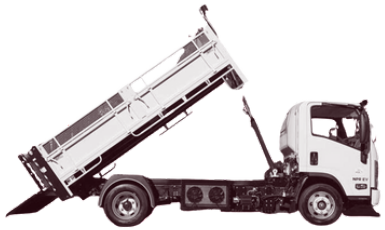
Ignition

Reignition in storage yard

Challenges & opportunities

Electric vehicles aren't coming; they're already here & they're across every transport sector.

Heavy commercial



Last mile delivery

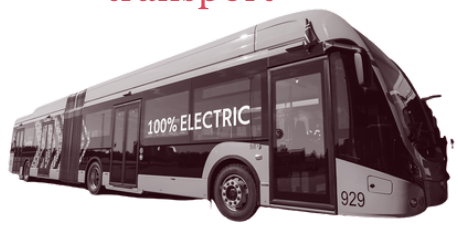
Light commercial

e-Scooter

Tradies & mining

Motorbikes

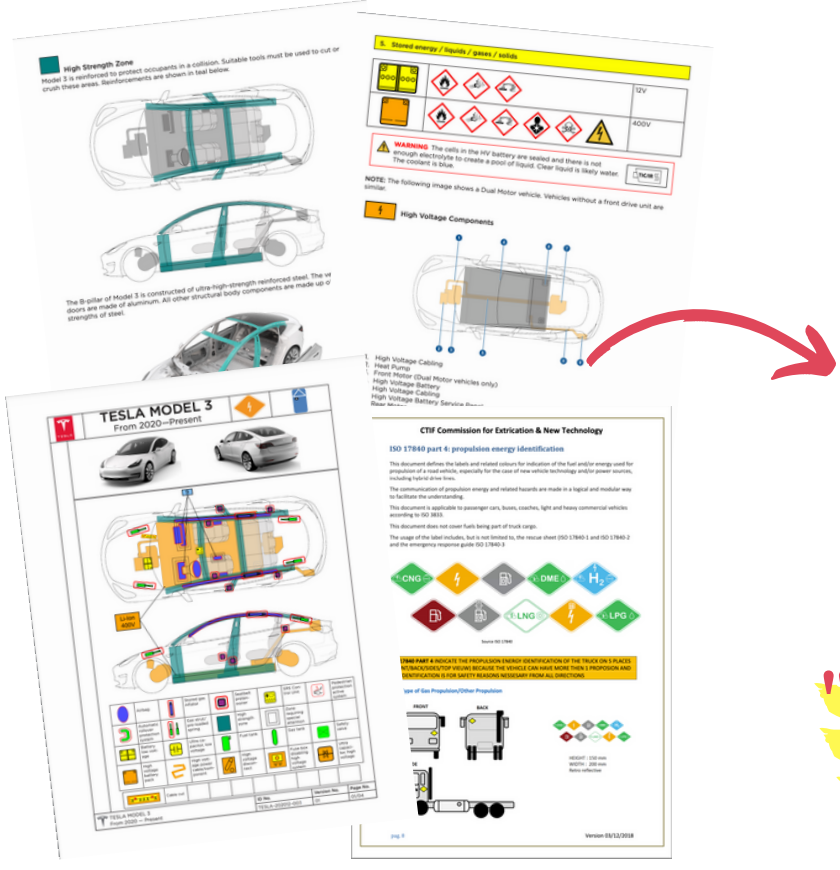
Public transport



e-Bike

We're behind the EV tech

Emergency response is being left behind, but manufacturers are using ISO 17840.



- Continuously sprayed with a large amount of continuous water.

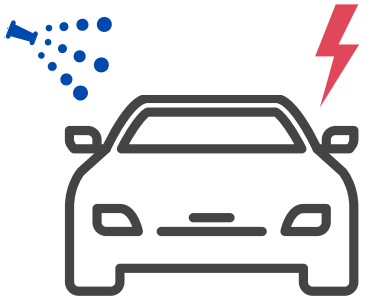
"Call 000, they'll know what to do..."

There's a lot to learn & test...

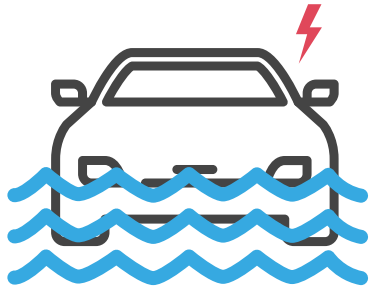
There are a range of other issues we haven't discussed today:

- EV identification & immobilisation
- HV system isolation
- Electrocution
- Stranded energy
- Extrication
- Vapour cloud venting underground
- Water run off
- Flame intensity & temperature
- Fire spread through buildings
- Induction & bi-directional charging

Eg: most surprising finding from our research - electrocution risk is lower than anticipated



Direct stream of water onto damaged HV cables, components or battery



Submersion

Extrication of driver / passengers

Stranded energy - remaining SoC in traction battery

...& knowledge to share...

Data-driven learnings at evfiresafe.com

Our online knowledge hub has been referenced by:

- AFAC
- Country Fire Authority
- Fire Rescue NSW
- SA Metropolitan Fire
- NT Fire & Emergency
- Vic State Emergency Service (SES)
- EPA (Vic & NSW)
- Tesla
- National Fire Chiefs Council (UK)
- Comité Technique International de prevention et d'extinction de Feu (Global)
- Institute of Fire Engineers
- International Firefighter Magazine
- CNBC
- Arup Engineers

and more

...& collaboration

Global expert collaboration

Peer reviewed & connected with Prof Christensen, CTIF, SAE, CFA, FRNSW, VACC, EPA, AfMA, Vic DoT, EV manufacturers, charging, towing & conversions

Data analysis & knowledge sharing

Data-driven analysis of ignition vs vapour cloud explosion, thermal runaway, reignition
Case studies of previous incidents

Data-driven F2F & online education

Video, animation & graphic based online EV fire & safety training courses
Partnerships with JET Charge, VACC, Vic DoT

International media & speaking

CNBC, International Firefighter, The Driven
Presenting to Australian Fleet Management, Fire Protection Association Australia & Tall Buildings Fire Protection (UK) conferences

Socials & video content

Video intro to EV & battery tech
EV ID walkarounds with review of emergency response guides for emergency familiarisation

Paul Christensen
LITHIUM ION SAFETY

RI.
SE

IFV Instituut Fysieke Veiligheid

NFCC
National Fire Chiefs Council

IFE The Institution of Fire Engineers

CTIF

Next steps

Defence funding (Milestone 2)

Battery cell & EV charging fire testing

2022-'24
Testing AC/DC charging with Fire Rescue NSW SARET Program

Work with policy makers

Charging site owners
Charging suppliers
Secondary responders
Vehicle transport & storage
Fleet managers
Mechanics/repair
Battery recycling

Build firefighter awareness

Brigade visits
Regular webinars
Look at road crash rescue

CFA
BELLBRAE
EMERGENCY
000
BDQ 823

BMR 700

CFA
Barwon Security

TORQUAY

evfiresafe.com

Many thanks for your kind attention.

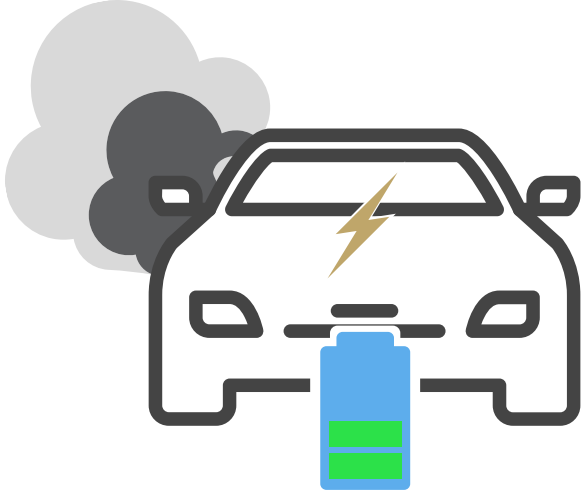
Emma Sutcliffe
Project Director
emma@evfiresafe.com
0409 040 499

Scan with your smart phone camera to jump to the EVFS website

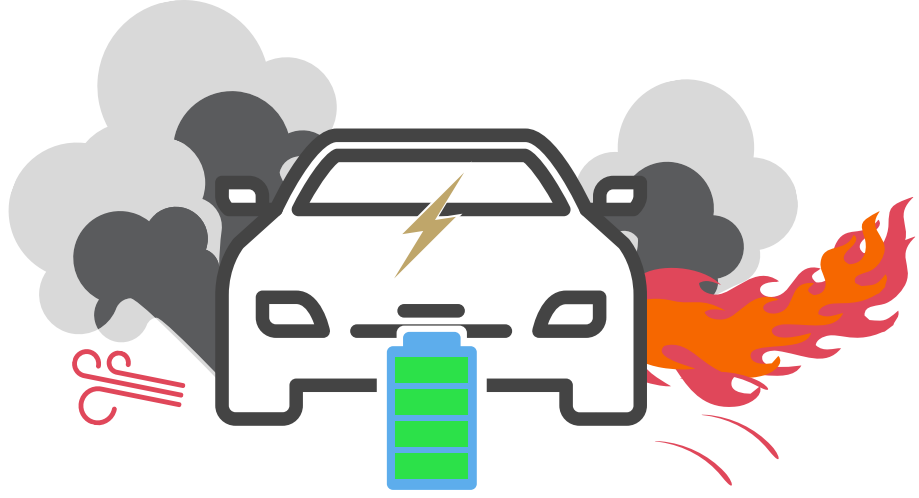
Additional slides

State of charge vs likelihood of ignition

Early testing indicates lower battery SoC won't support thermal runaway



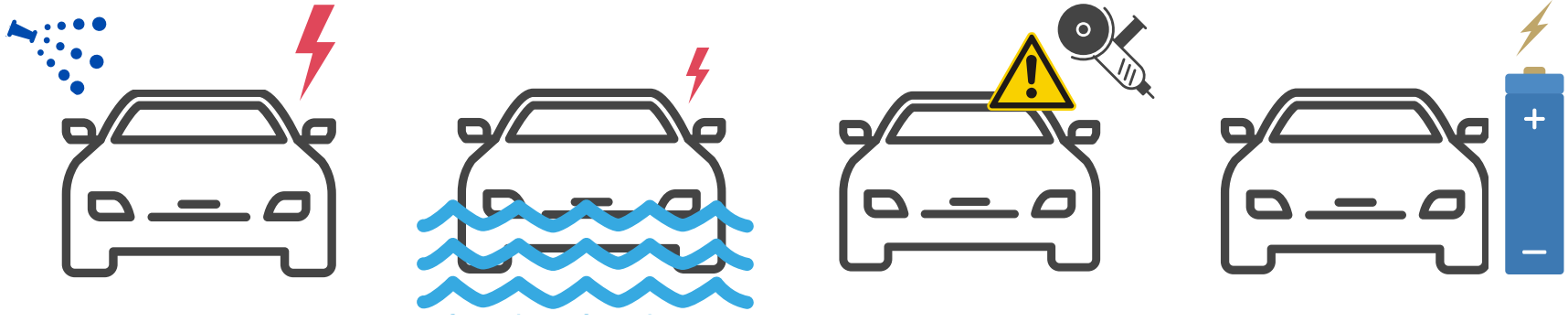
Battery SoC
under 50%



Battery SoC
over 50%

Electrocution

We found NO reports or evidence of electrocution of emergency responders from:



Direct stream of water onto damaged HV cables, components or battery

Submersion

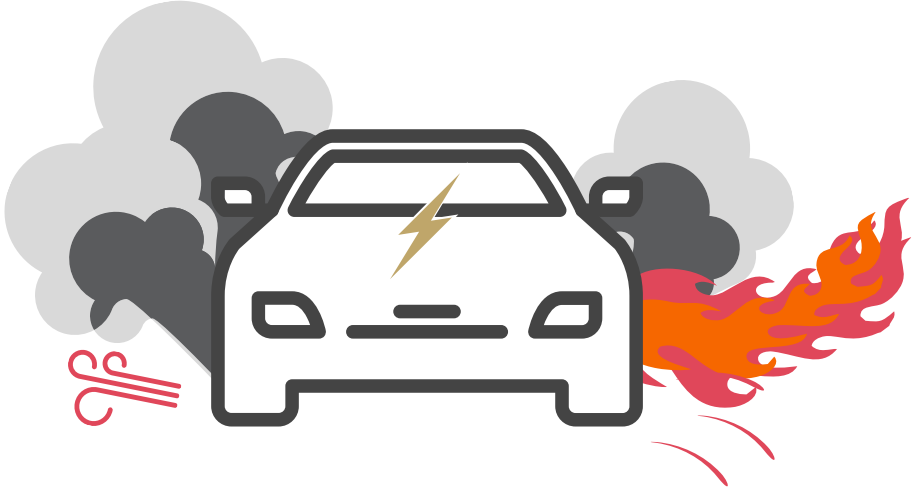
Extrication of driver / passengers

Stranded energy - remaining SoC in traction battery

Risk of electrocution is low (but is still a risk!)

Heat release rate & flame temperature

Electric



Up to 2700
degrees celsius

Internal combustion

Up to 1000
degrees celsius

Early testing indicates similar heat release rate (rate at which fire releases energy) between vehicle types

Spread of fire in structures

"Electric vehicles: Observations during the fire indicate that electric vehicles did not contribute to the fire development beyond what is expected from conventional vehicles."

'Investigation of massive fire in a multi-storey car park in Norway'
The fire at Stavanger airport Sola, 7 January 2020, Fire spread and contribution from electrical vehicles