evfiresafe.com

EV FireSafe

Enhancing safety for emergency responders at electric vehicle fires

SES Road Crash Rescue Workshop
25th March 2022

Supported by:

Australian Government
Department of Defence

In partnership with:

DEAKIN UNIVERSITY

Welcome to EV FireSafe

EV FireSafe is a research & testing project that's developed the world's first database of global EV lithium ion traction battery fires.

We provide data-driven learnings to emergency agencies, particularly military & government fire & rescue at evfiresafe.com

And we're an all-female team funded by the Department of Defence with assistance from Deakin University.

Defence funding

Milestone 1

EV battery fire research

Delivered:
First (only) global database
evfiresafe.com

Milestone 2

Battery cell & EV charging fire testing

2022:
Testing AC/DC charging with Fire Rescue NSW

Milestone 3

Product prototype development

2023:
Safety product design & dev with universities

What does the EV fire research tell us?

EV traction battery fires are very rare.

Approx a third happen while connected to energised charging.

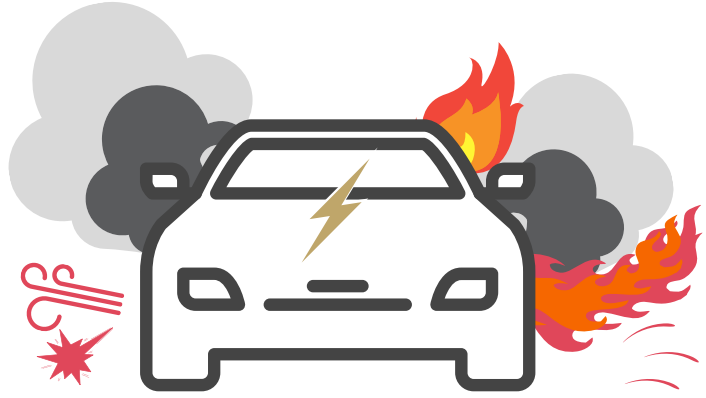
EV battery fires present new & different challenges & threats for emergency responders.

Global EV fires

We have verified*:

150 EV traction battery fires globally, 2010-today

+ 24 currently being cross checked

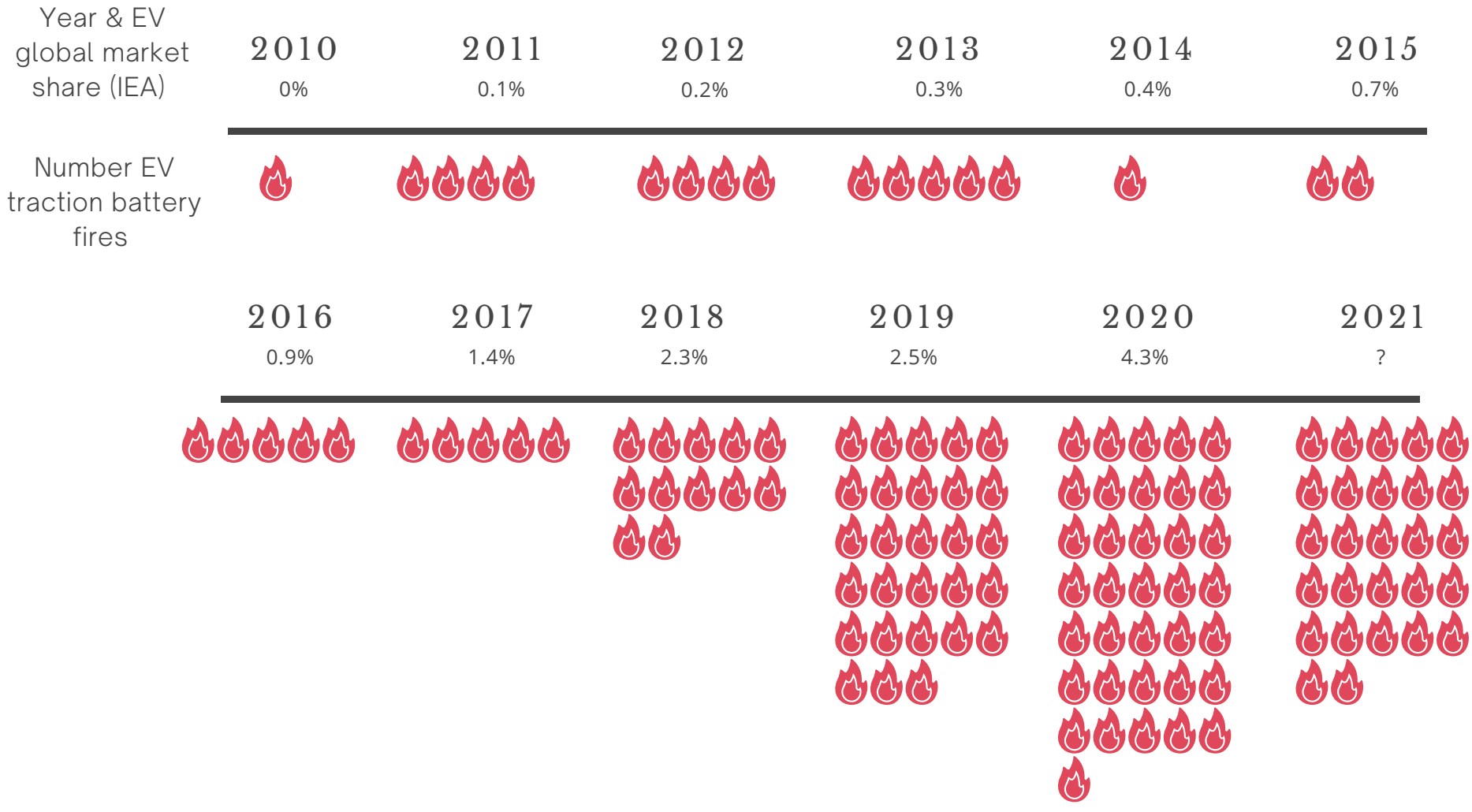


"There were 10 million electric cars on the world's roads at the end of 2020, following a decade of rapid growth."

International Energy Agency, Global EV Outlook 2021

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

By year & market share



EV battery ignition

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

EV battery ignition

Vapour cloud explosion

An EV explosion looks like this

Vapour cloud explosion

Vapour cloud explosion

The data-driven challenges we've identified...

1. EV identification

Challenge

What is it?
How many are there?
What are EV identifying features?
What if they're not helpful?

EVFS

Creating a series of short 'walk around' & ERG review videos with EVs from manufacturers

What is an EV?

BEV - Battery electric vehicle
PHEV - Plug in hybrid electric vehicle

ALL plug in to charge up
ALL have lithium ion traction battery

These are the most common electric vehicles in Australia (2021)

Nissan Leaf
BEV

MG ZS EV
BEV

Tesla Model 3
BEV

Hyundai Ioniq
BEV

Hyundai Kona
BEV

Mitsubishi
Outlander PHEV

How many are there?

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

At June 2021

Forecast 2030

~70%

compound annual growth rate of EVs since 2010

EVs across all sectors

All these vehicles are electric & currently in operation in Australia

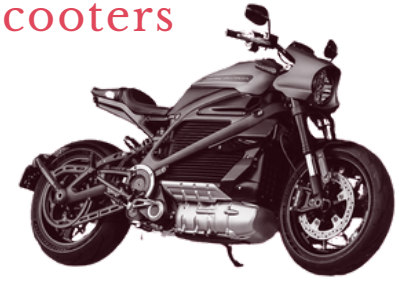
Heavy commercial

Last mile delivery

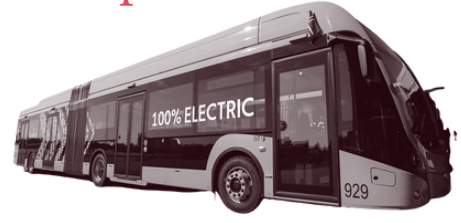
Light commercial

Tradies & mining

Bikes & scooters



Public transport



How do we ID an EV?

The blue triangle 'EV' sticker is mandatory in many states & becoming standard nationally

ID is not always helpful

By the time emergency responders arrive on scene, it may not be possible to see identifying features

2. EV fire ID

Challenge

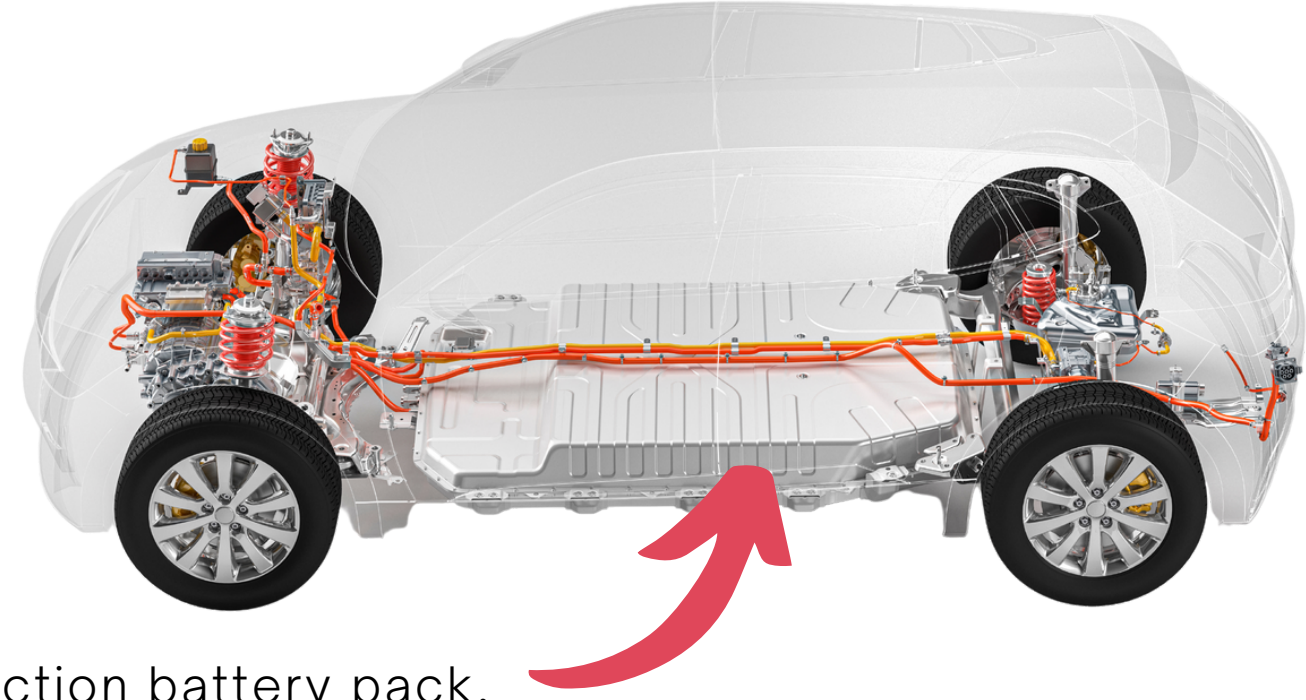
Where is HV battery?
What is thermal runaway?
What are signs of thermal runaway?

EVFS

Creating case study examples - blog & videos

EV HV battery

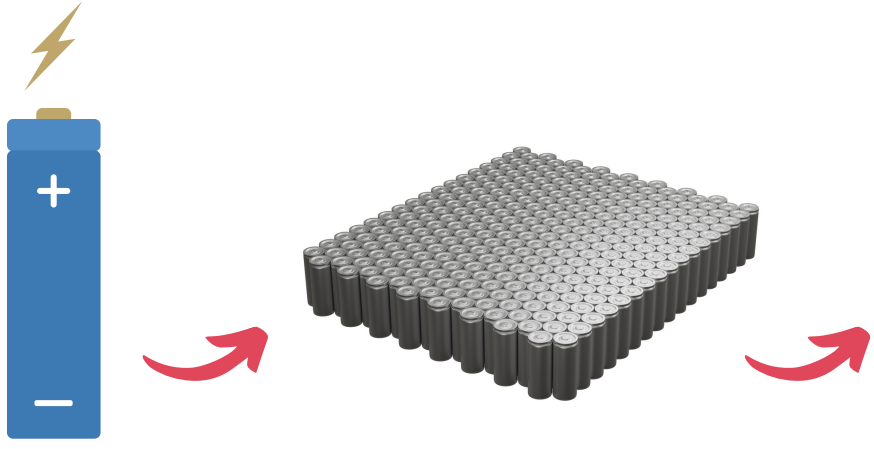
The traction battery supplies power for vehicle momentum & is usually located beneath the vehicle, along the floor pan



Traction battery pack,
between 400-800V DC

EV HV battery

A 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 a battery casing

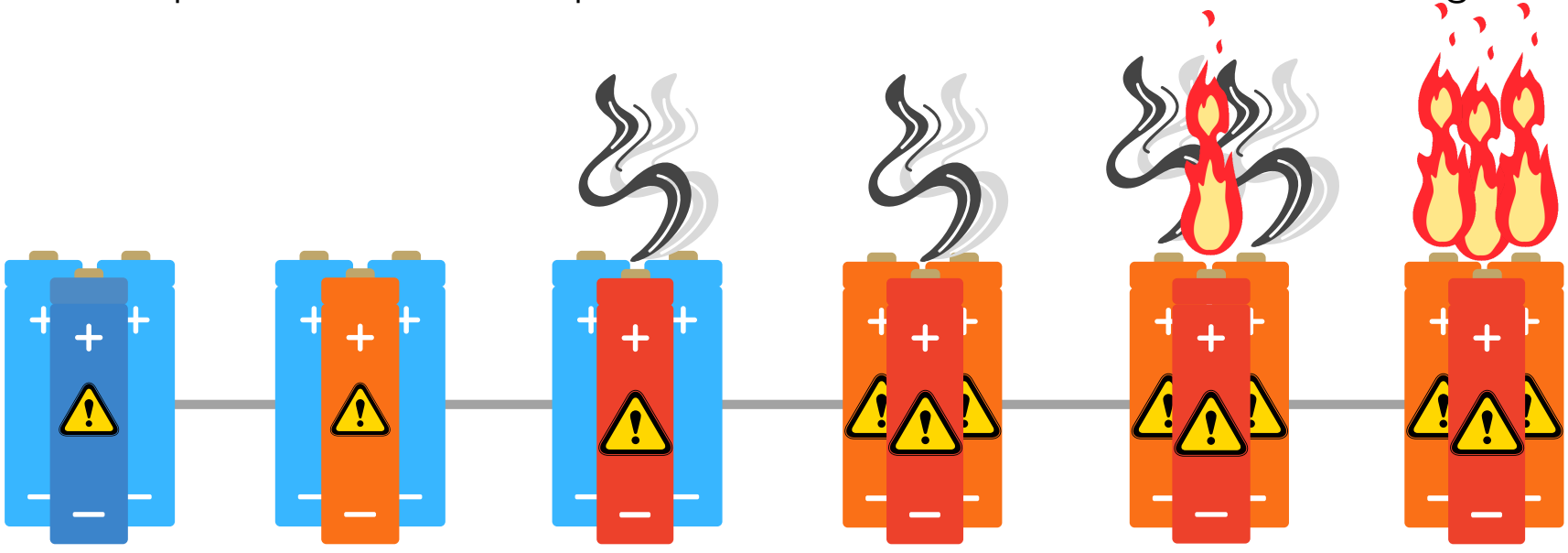
Causes of battery cell abuse

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

*Data current November 2021
^Percentage of incidents EVFS studied

What is thermal runaway?

Thermal runaway occurs when a battery cell suffers abuse, for example from a traffic collision. This causes a short circuit, which heats up the cell & dissipates that heat into other surrounding cells.



A battery cell suffers abuse (ie. traffic collision)

The cell short circuits & heats up

Pressure (in the form of gases) escape via cell safety valve

Other nearby cells heat up

Ignition or vapour cloud explosion occurs

Other cells follow

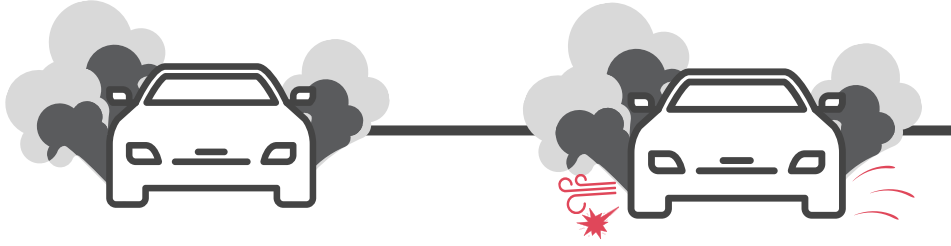
It's an unstable chemical process that is difficult to bring under control.

Thermal runaway

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

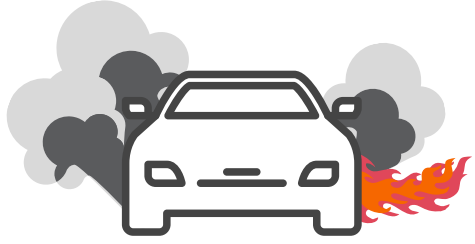
Dark vapour cloud,
light vapour cloud
(it's NOT smoke)

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



At this point, one of two things will occur

Ignition
Jet like, directional flames up to 2700 degrees



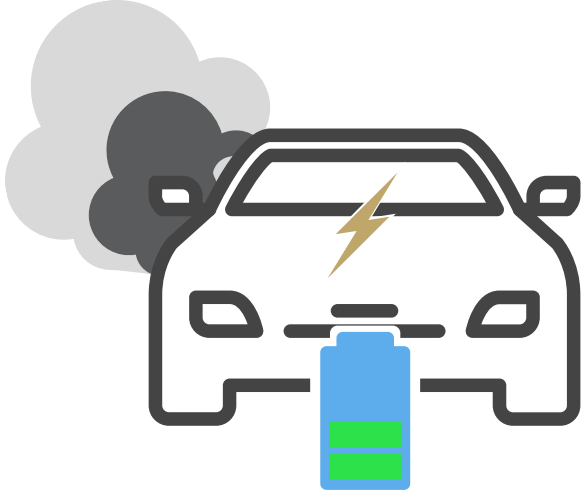
~90%

Vapour cloud explosion
Violent deflagration

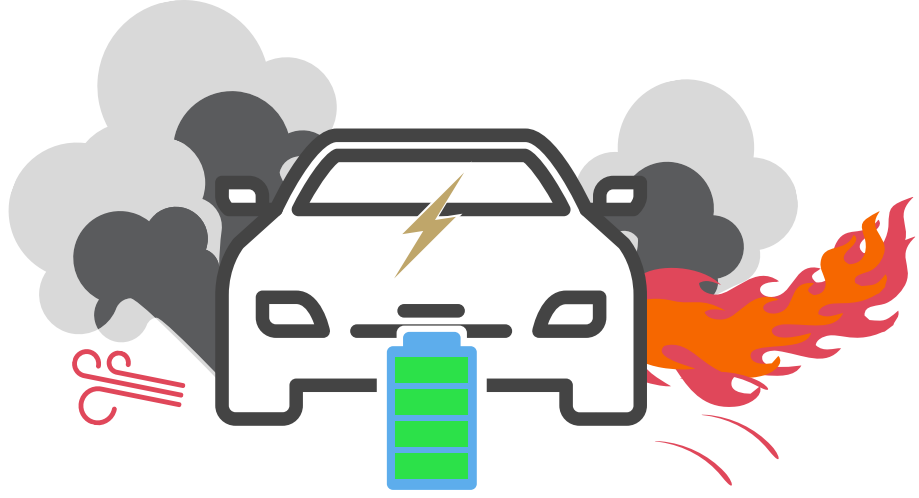
~10%

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%

3. Vapour cloud explosion

Challenge

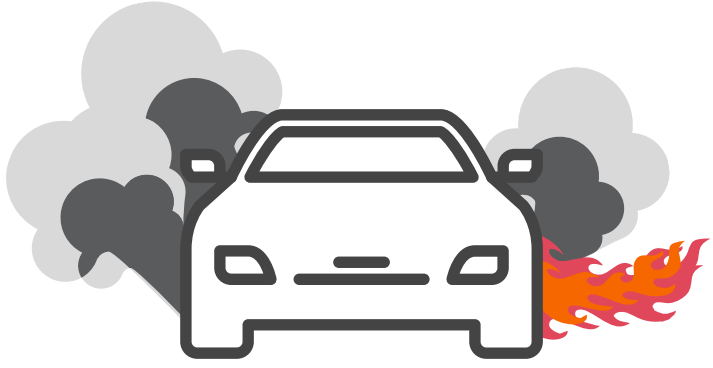
Research & testing on cause, warning & scenario

EVFS

Data analysis & sharing
First hand accounts of previous VCE, creating case study examples

Ignition vs explosion

Ignition
Jet like, directional flames



89.23%

Vapour cloud explosion
Violent deflagration

10.77%

Vapour cloud explosions

6	Home garage
3	Underground carpark (residential)
1	Collision
3	Charging - energised
1	Charging - stopped within 15 mins

64.3%

Underground / enclosed space

35.7%

Open air

Enclosed + charging + VCE

Enclosed & charging

13 incidents globally that described the EV being connected to charging

Enclosed, charging & VCE

4 incidents globally that described EV connected to charging with explosion

4. EV fire at charging

Challenge

33% of EV LiB fires occur at charging

EVFS

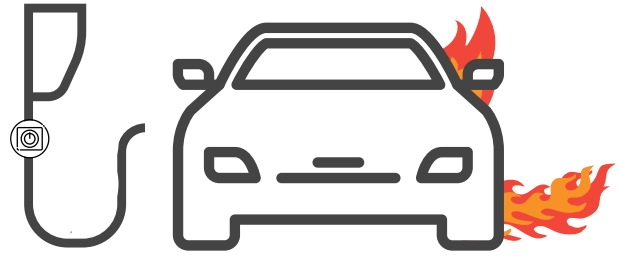
Data analysis & sharing
Testing of current theories
Online course for charging site owners/managers

EV fire & charging

Of 130 incidents, we found:

26.15% were connected to energised charging (34 incidents)

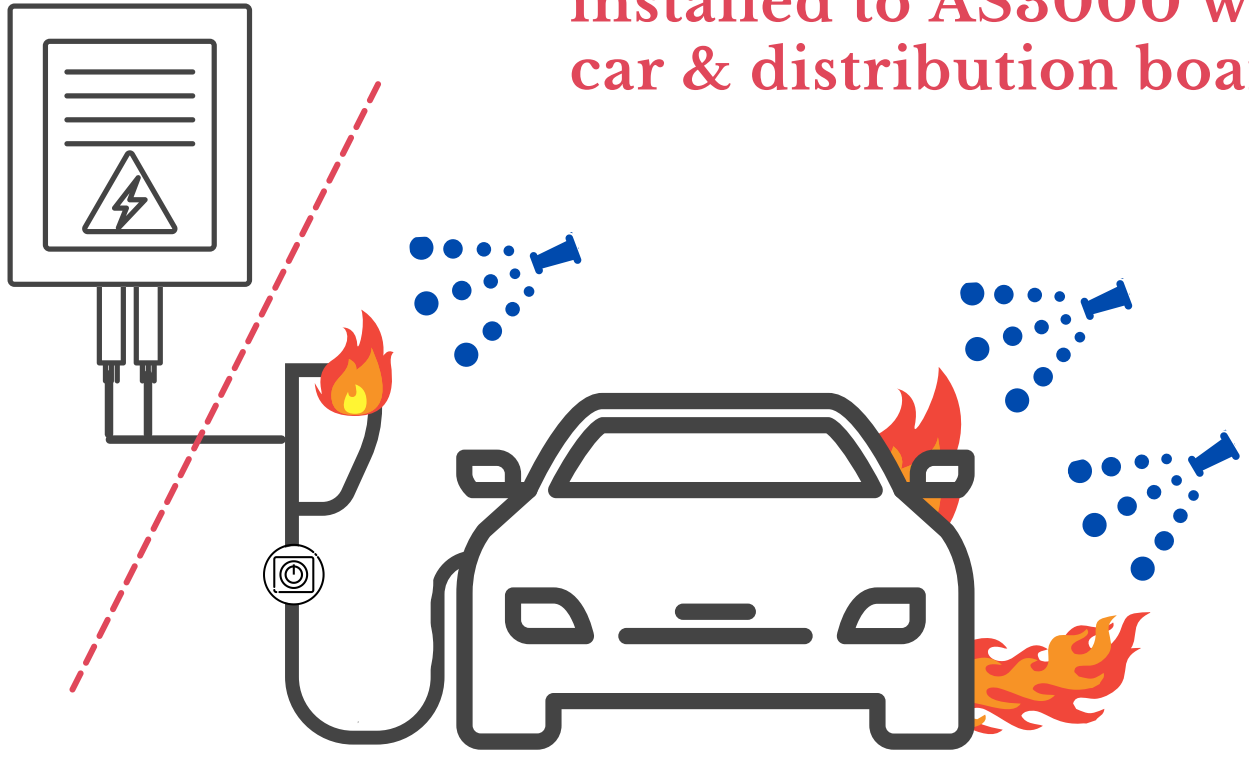
4.62% had been disconnected from energised charging within 60 minutes (6 incidents)



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

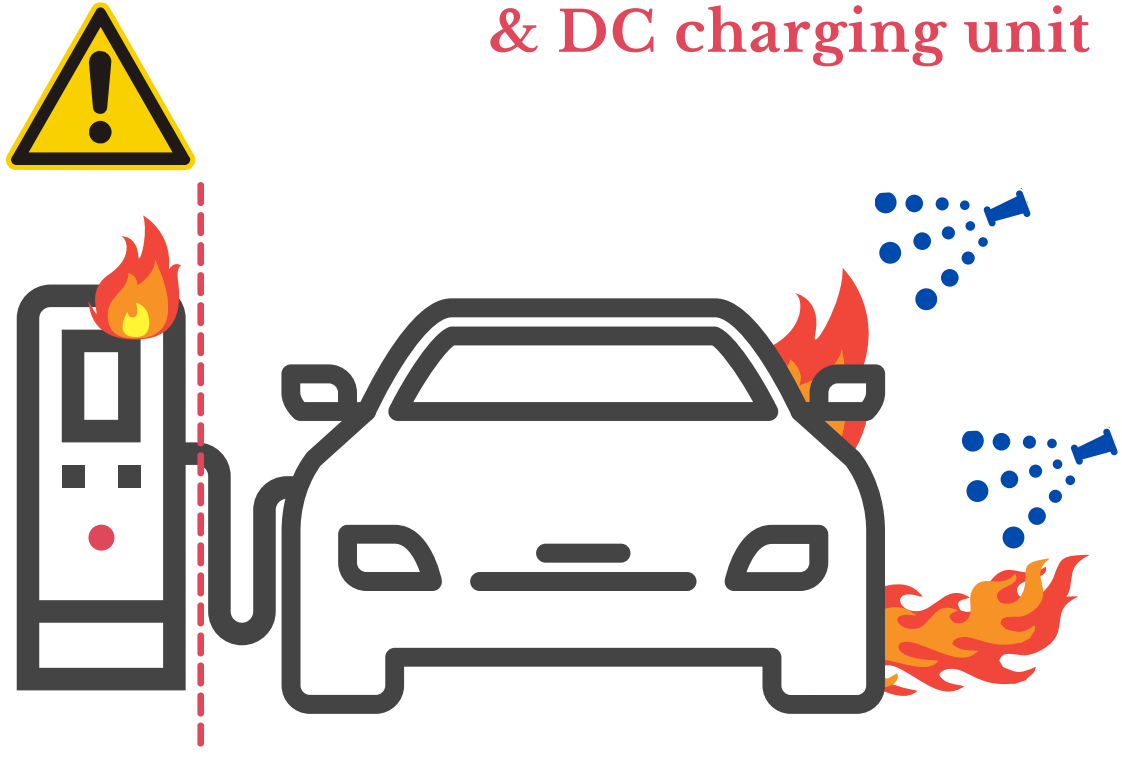
If connected to AC EV charging (7/22kW)

In theory, electrically compliant units installed to AS3000 will cut between car & distribution board



If connected to DC EV charging (50/350kW)

In theory, electrically compliant units installed to AS3000 will cut between car & DC charging unit



5. EV extrication

Challenge

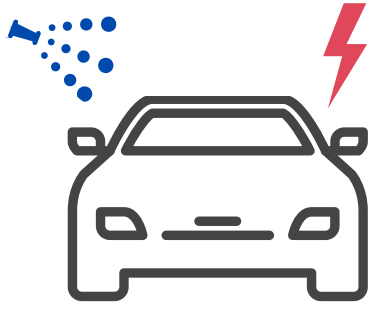
Little to no knowledge
Varies across models

EVFS

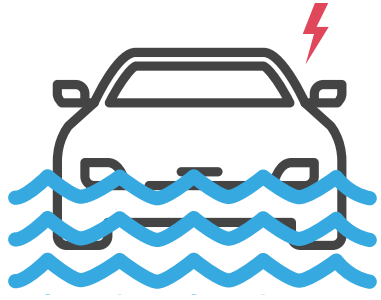
Video of Nissan Leaf cutting

Electrocution

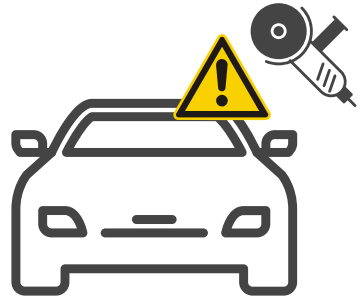
We found NO reports or evidence of electrocution of emergency responders from:



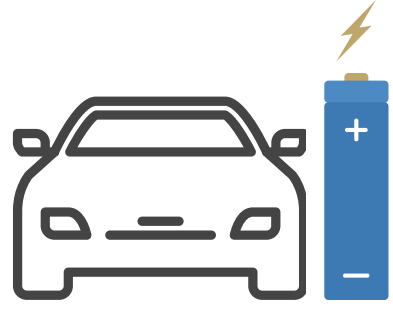
Direct stream of water onto damaged HV cables, components or battery



Submersion



Extrication of driver / passengers



Stranded energy - remaining SoC in traction battery

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

Construction - Model 3

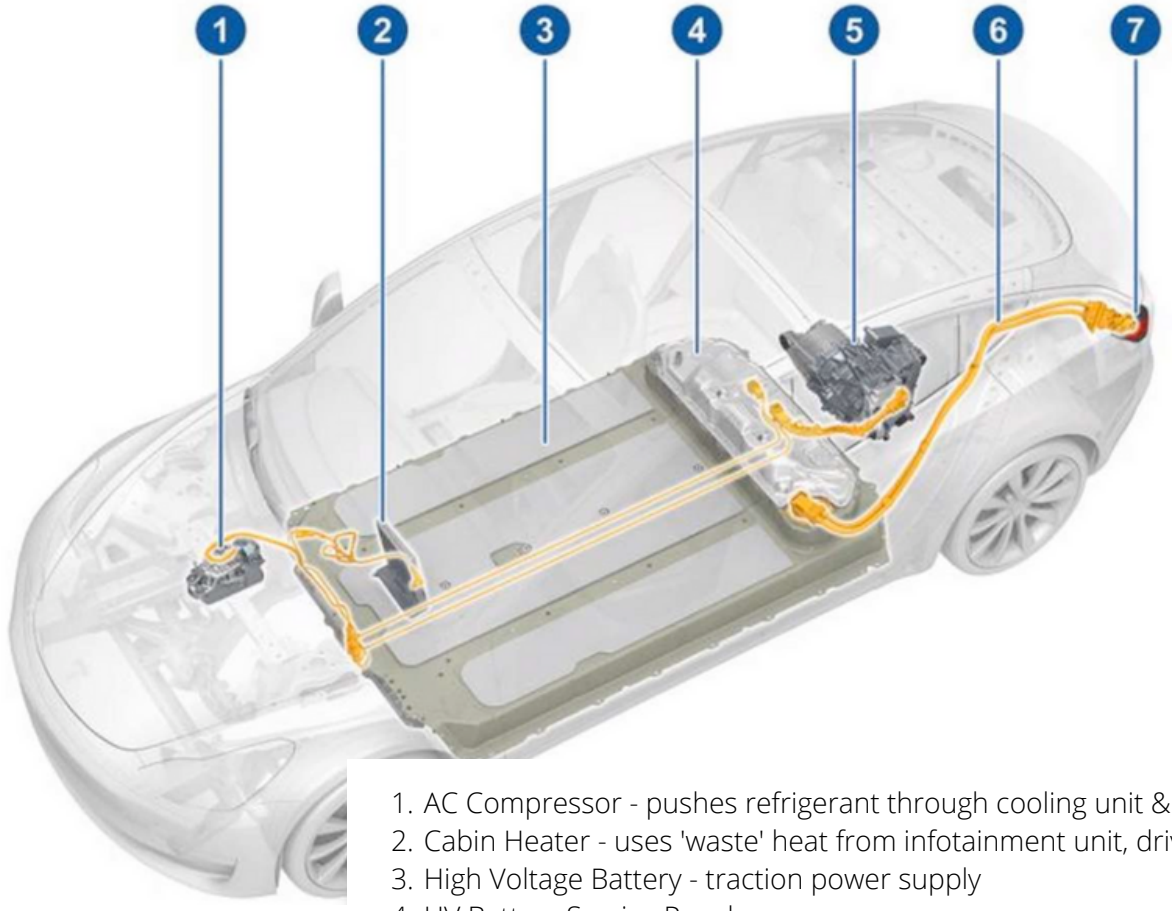
Body Structure Materials Diagrams

Use the color codes below in conjunction with the diagrams in Figures 1–7 to determine the component material.

Figure 1 (Front quarter exploded view)

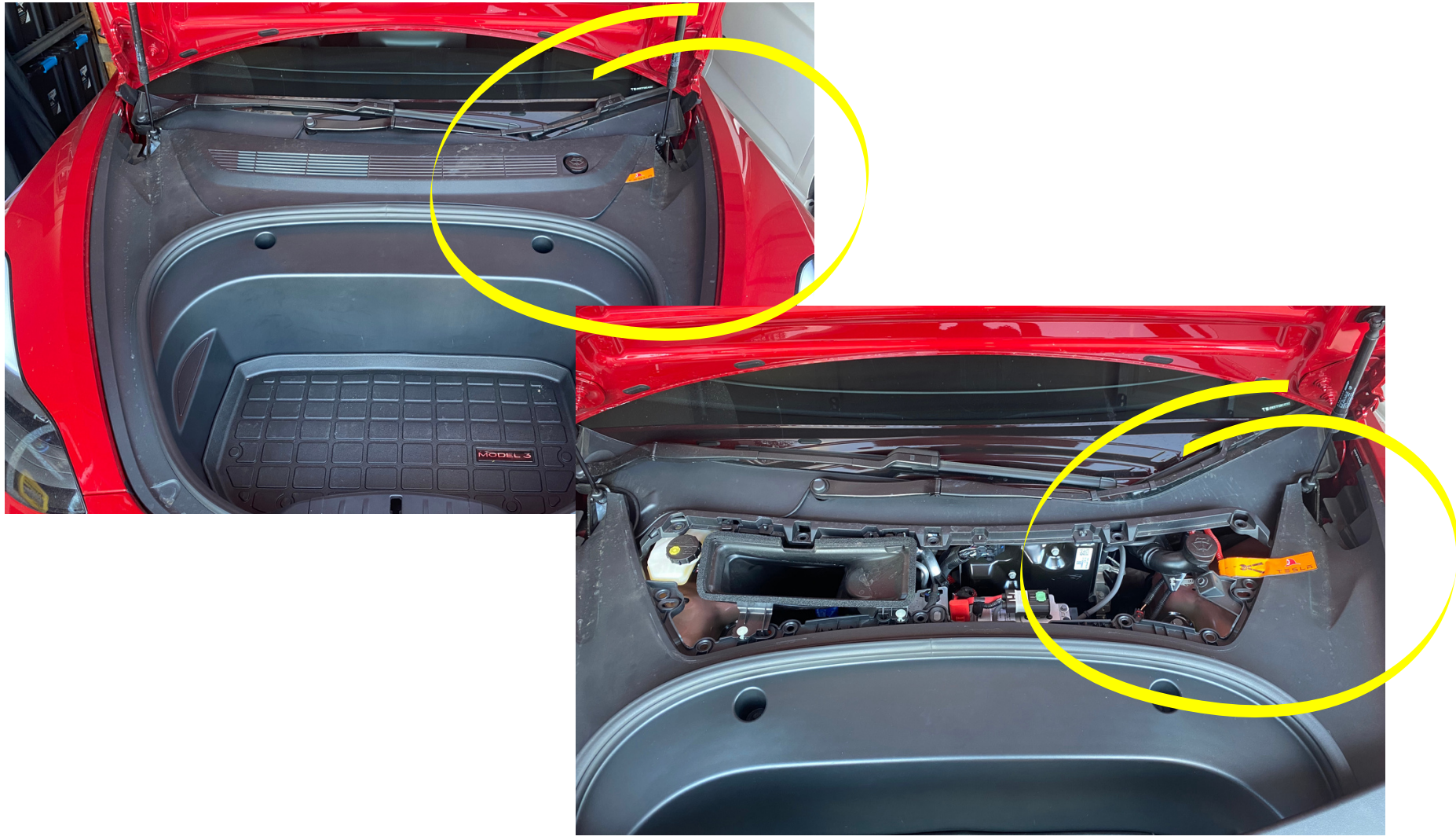
Aluminum	Mild Steel	High-Strength Steel	Ultra High-Strength Steel

HV layout - Model 3



1. AC Compressor - pushes refrigerant through cooling unit & cools air for AC
2. Cabin Heater - uses 'waste' heat from infotainment unit, drive unit & battery to heat cabin
3. High Voltage Battery - traction power supply
4. HV Battery Service Panel -
5. Rear Motor - some models have dual motors, front & rear
6. HV Cabling - supplies power to HV components
7. Charge Port - socket for external power supply

HV isolation



Extrication videos

For Tesla EVs only...got nada for other manufacturers...

Emergency Response to the Tesla Model 3

82,206 views • Jan 19, 2019

Tesla Model X First Responder Training - Advanced Extrication

150,100 views • May 25, 2016

572 DISLIKE SHARE CLIP SAVE DESCRIPTION

Tesla EV Safety Training

195,202 views • Mar 2, 2013

LIKE DISLIKE SHARE CLIP SAVE DESCRIPTION

ERGs & Rescue Cards

Depending on manufacturer, can be well written

6. EV fire suppression

Challenge

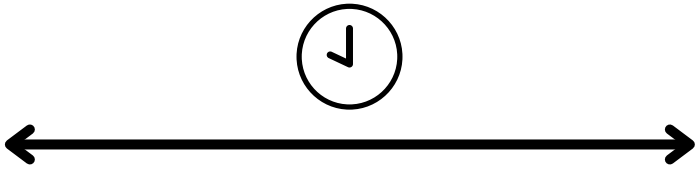
Prolonged response

EVFS

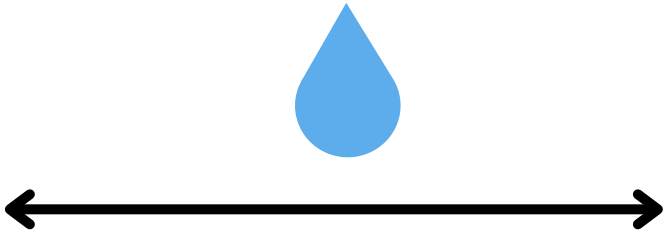
Product testing
Emergency response guide
review videos

Suppression requires more time & resources

Best case *Worst case*



10min **3-5 hours (>50 hours to clear highway)**



1,000L **110,000L**

Suppression products

Limited use / needs further testing

Submerge entire vehicle

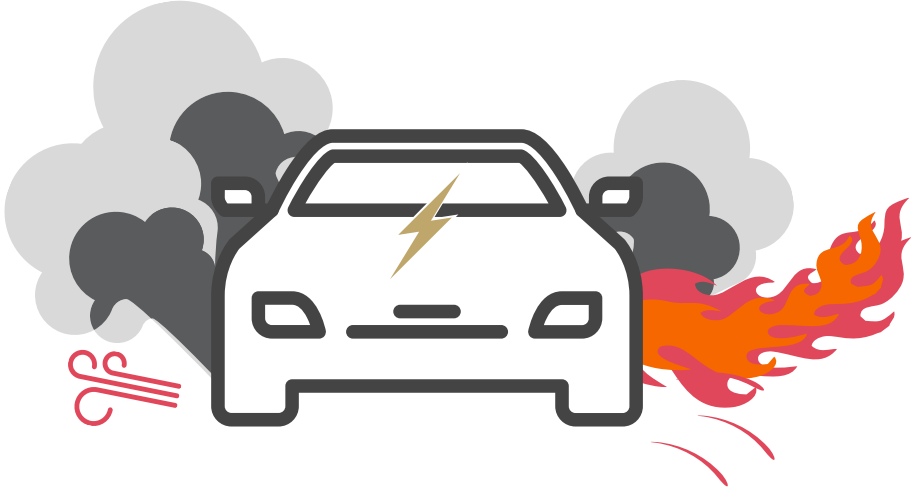
Fire blanket

Water lance

Emergency plug

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

7. EV fire reignition

Challenge

Unknowns
No early warning detection

EVFS

Further research needed
Product development
Online courses for tow, storage, wreckers

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

EV fire reignition is a risk to secondary responders

In 6 cases Damage caused to tow truck

In 4 cases Injuries to drivers

evfiresafe.com

Thank you for having me!

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