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EV FireSafe

Enhancing safety for emergency responders at electric vehicle fires

EV Extrication
High level considerations

Developed in collaboration with the Victorian State Emergency Service

Supported by:

Australian Government
Department of Defence

With assistance from:

DEAKIN UNIVERSITY

EV extrication

As electric vehicles become commonplace, the emergency response community worldwide will see collisions & thermal events (battery fires) more frequently.

From a patient extrication perspective, what do we know & what do we need to learn about rescuing someone from an electric vehicle, compared with a traditional internal combustion engine vehicle?

What's an electric vehicle?

BEV Battery electric vehicle
100% electric

PHEV Plug in hybrid electric vehicle
Electric & petrol driveline

Tesla Model 3 BEV

Nissan Leaf BEV

MG ZS EV
(BEV & PHEV)

Hyundai Kona
(BEV & PHEV)

Hyundai Ioniq
(BEV & PHEV)

Mitsubisihi
Outlander PHEV

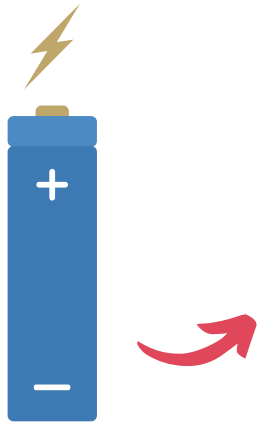
Hyundai Ioniq 5
BEV

Polestar 2 BEV

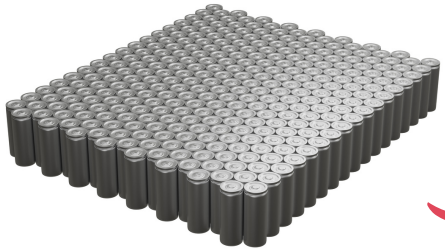
All have a high voltage traction battery (over 60V) that charges up using a cable plugged into power supply.

EV battery pack construction

An EV battery pack is constructed with individual lithium ion battery cells:



Lithium ion battery cell



Multiple cells make a battery module

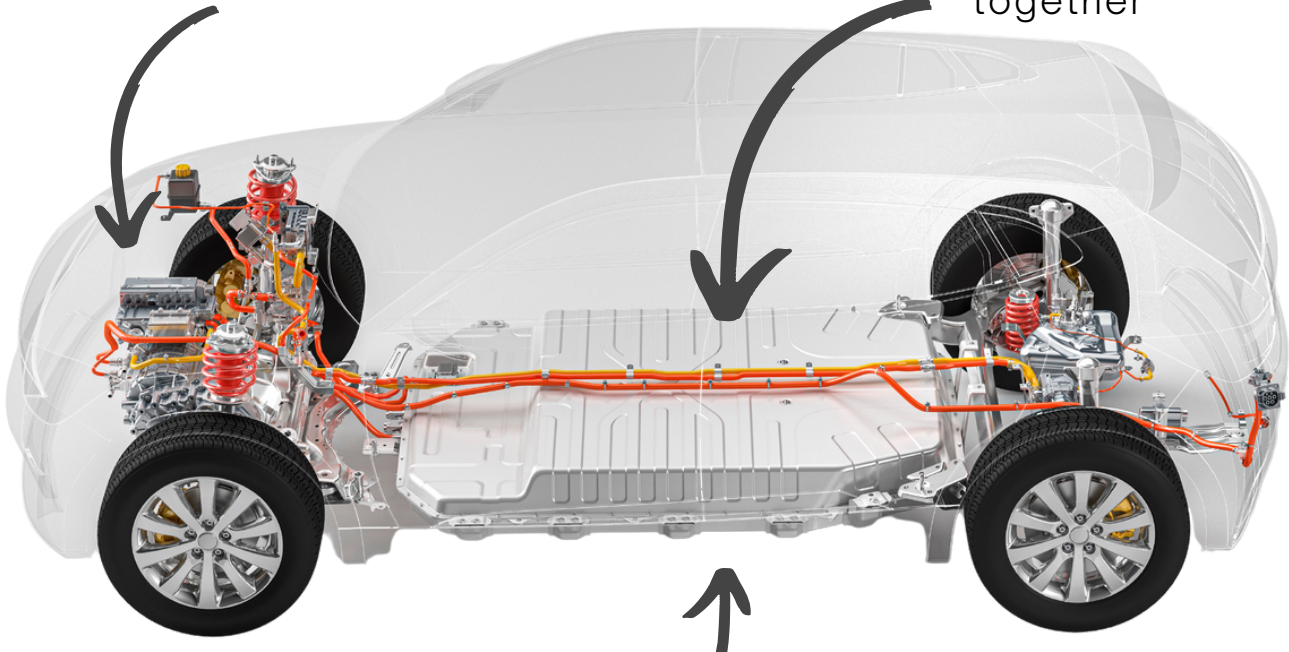
Multiple modules make a battery pack, which is enclosed in protective battery casings

Battery pack location

In passenger EVs, the traction battery supplies power for vehicle momentum & is located beneath the vehicle, between chassis rails

HV components, such as the motor & DC:DC converter, are located around the vehicle

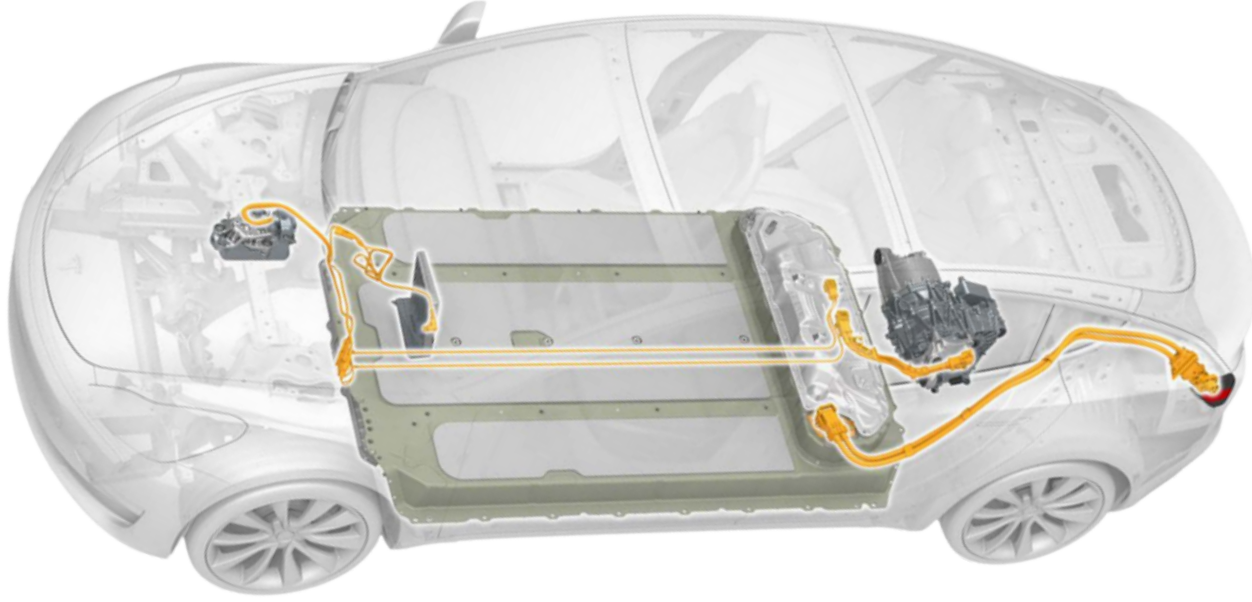
Orange cables connect HV components & battery together



EV traction battery pack

What is stranded energy?

Even at 0% state of charge, an EV battery cell holds 2.4V. Stranded energy describes power within a battery cell that cannot be de-energised.



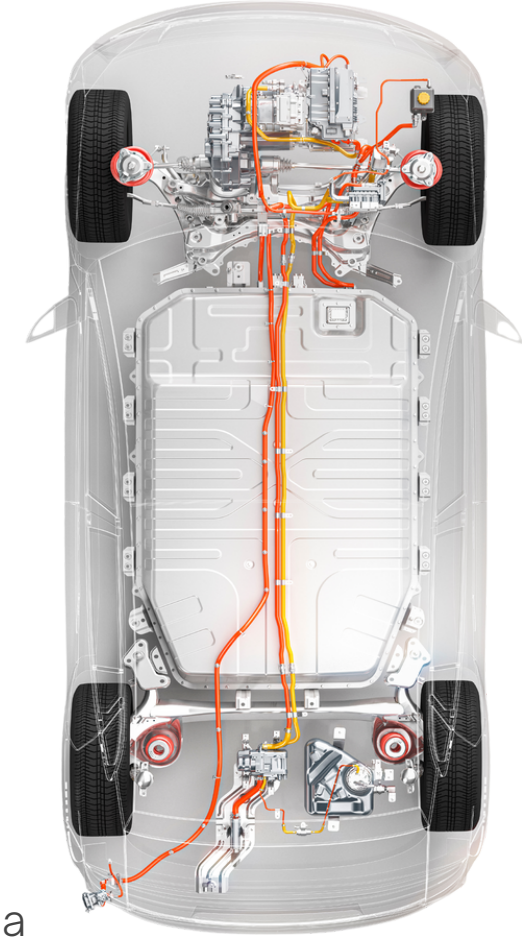
Even after responders isolate high voltage (HV) systems, the risk of fire & electrocution from stranded energy remains

Stranded energy still exists in the HV battery, isolation just stops it moving around the HV systems (battery to components, via cables)

Electrocution - low risk

Low voltage - 12V

- Doors
- Windows
- Lights



High voltage - marked in orange (>60V)

- HV battery
- Electric motor
- Inverter
- BMS / VCU
- Charge port
- DC:DC converter
- Cables

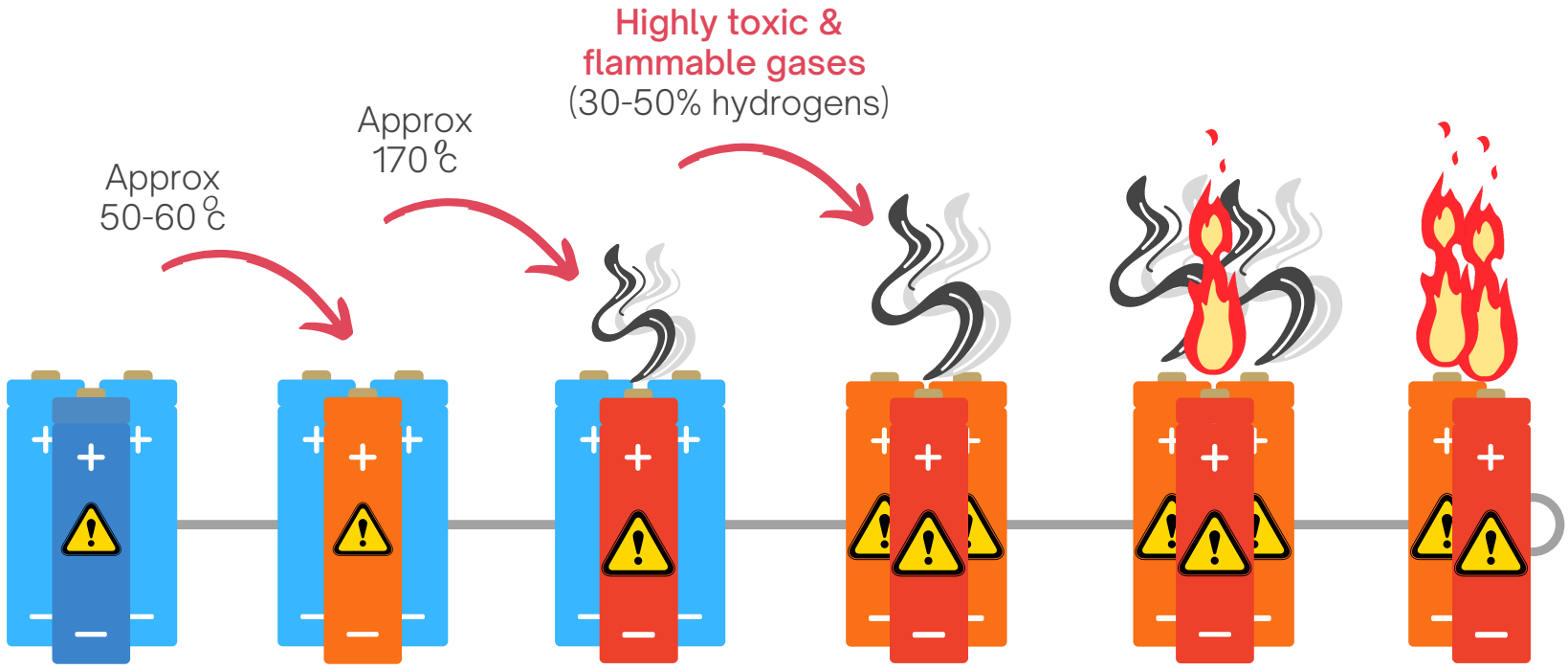
Charging unit

- AC grid power - same as a mains connection

Responders cannot detect HV & there is no way to de-energise

Thermal runaway

If battery cells are abused they may go into thermal runaway, leading to fire &, in very rare cases, a vapour cloud explosion.

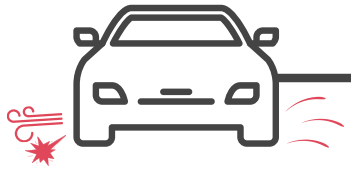


Thermal runaway can occur very quickly.

Thermal runaway - fire / explosion

Rescuers should be constantly assessing for the signs of thermal runaway & should evacuate immediately if they see or hear any of these signs.

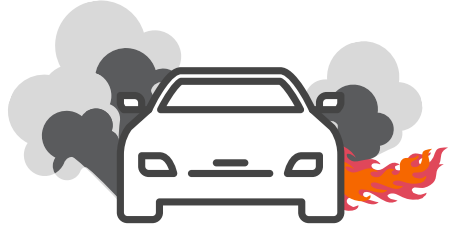
Popping - gunshots
Hiss/whistle - gas venting
'Cherry bubblegum' smell
Projectiles - cell debris



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

At this point, one of two things will occur

Ignition
Jet like, directional flames



~90%

Vapour cloud explosion
Violent deflagration

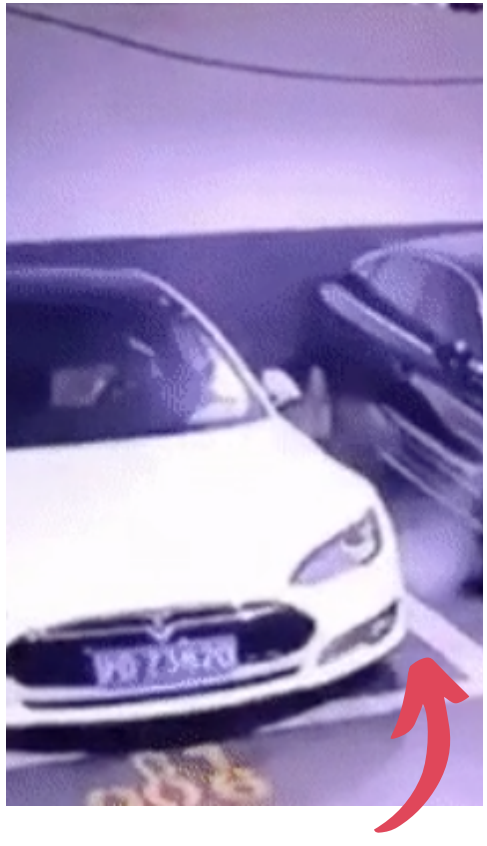
~10%

Both pose a serious risk to rescuer safety

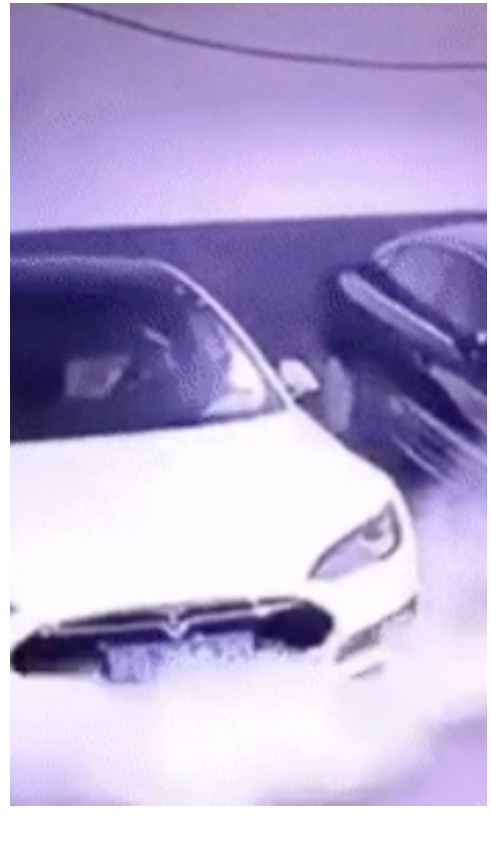
Case study

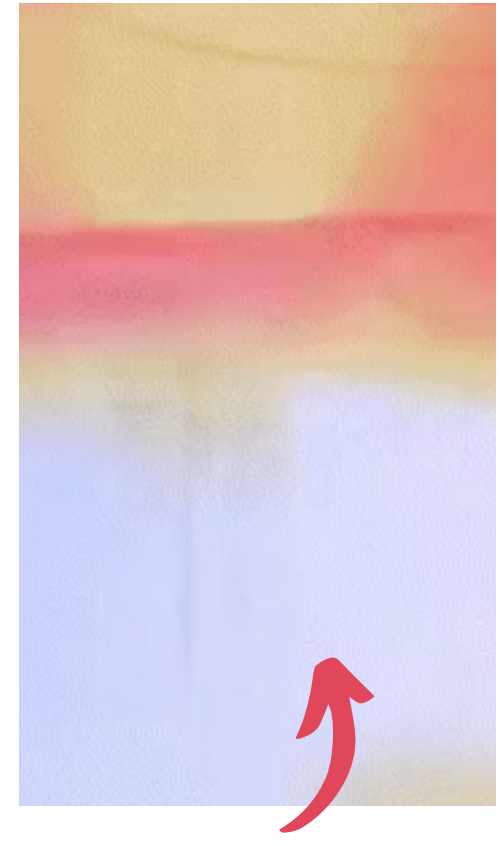
Tesla Model S parked in underground residential apartment building carpark. Battery had been damaged 30 minutes earlier after driving into an open manhole cover.

Elapsed time: 10 seconds

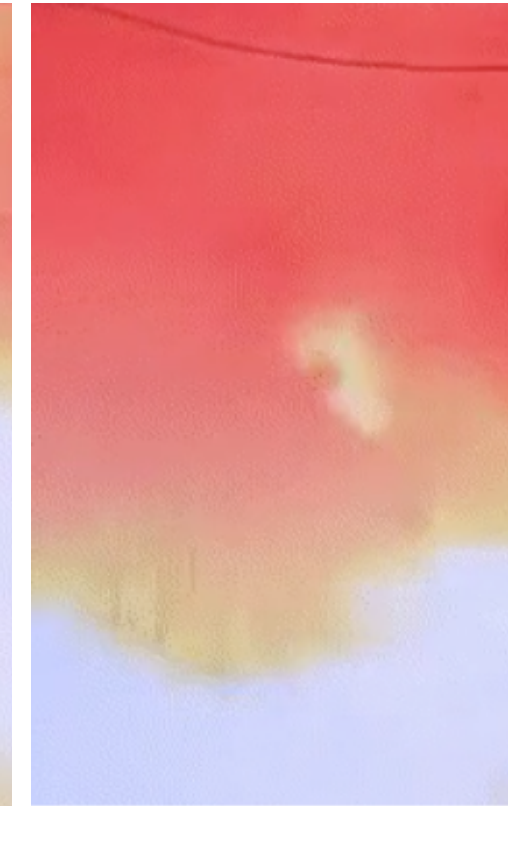


Vapour showing





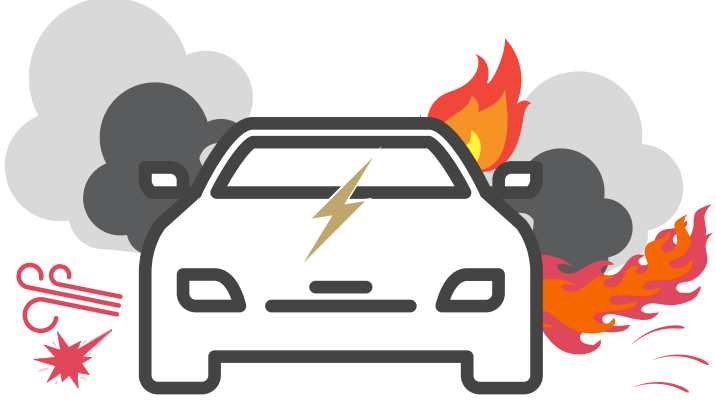
Vapour cloud explosion



Thermal runaway - DRA

Incident controllers managing EVs should consider a **dynamic risk assessment** throughout the entire incident duration:

- Requesting firefighters even for minor incidents
- Lay & charge hose lines for immediate battery cooling &/or suppression
- Ensure BA Operators are standing by
- Monitoring with TIC of HV battery pack (underside of EV) for increasing heat
- **Constantly monitoring for signs of thermal runaway until vehicle handover**



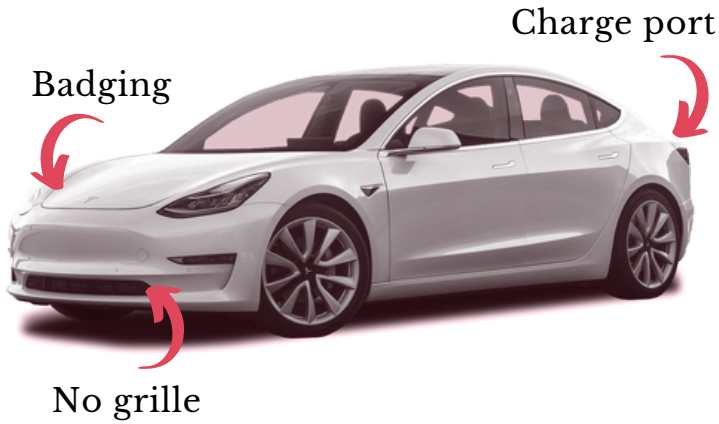
TR DRA

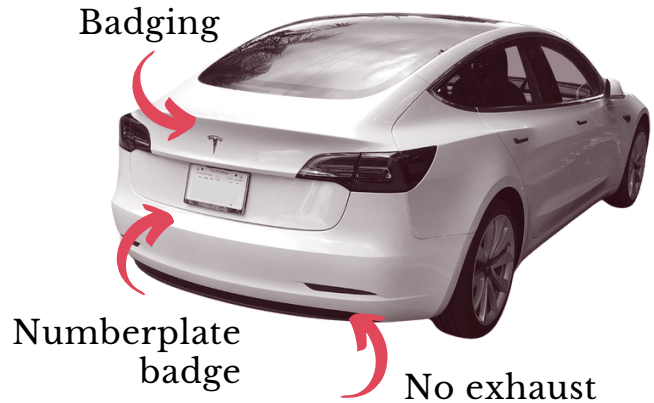
We've used this image throughout this pack to remind responders of the need to CONSTANTLY monitor for signs of thermal runaway

EV identification

Assume you're dealing with an electric vehicle until proven otherwise:

- Look for:
  - Blue EV badge on numberplates
  - External badging saying 'electric', 'low emissions', 'PHEV', 'EV'
  - Ask driver &/or passengers
- Use ‘EV’ tape to immediately identify to all responders attending
- Find relevant ERG, via CRS, ANCAP Safety App or online

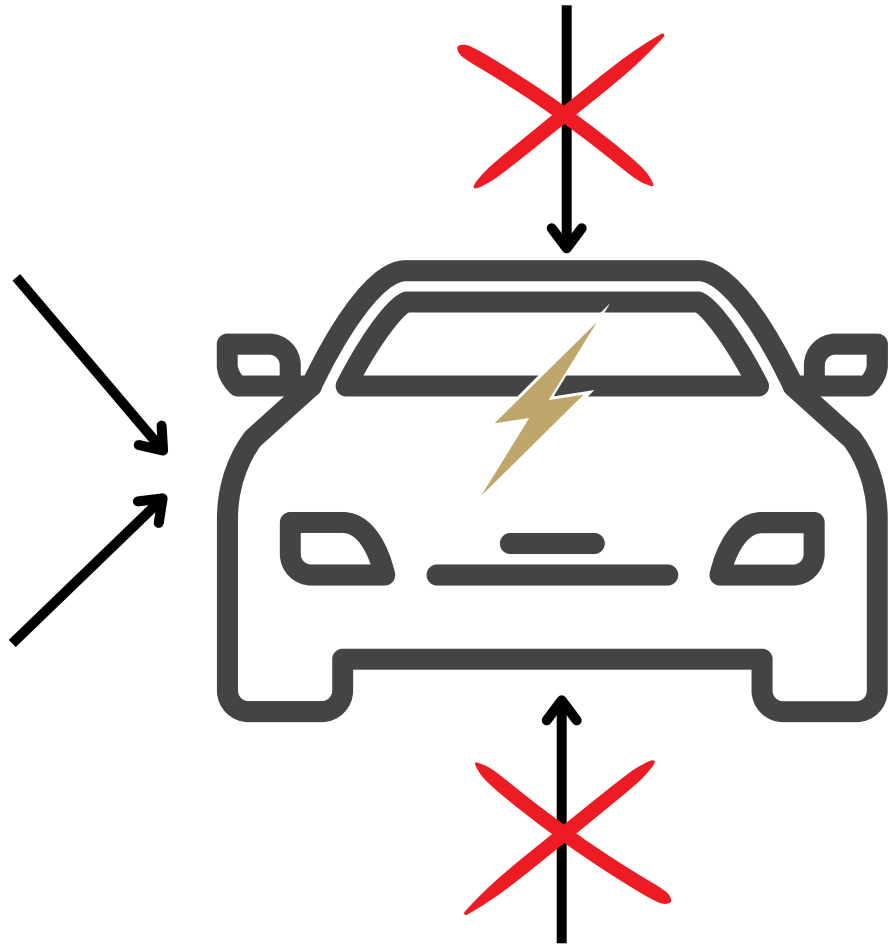




Approach

As responders approach an electric vehicle, remember:

- There may be no engine noise
- EV may move silently & rapidly
- Consider approaching from a 30% angle (similiar to a BLEVE approach) to avoid responder injury from suddenly moving vehicle



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Exposures

Rescuers should look for:

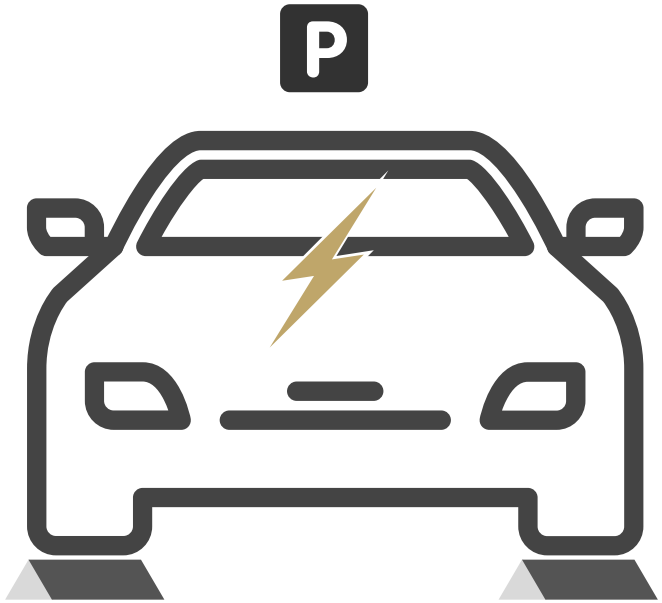
- ORANGE HV cables – EVs run at 400V & above
- Battery cells exposed or scattered – these present an electrocution risk
- Dark patches on battery pack (underside) that may indicate rapid heat build up
- Obvious damage to the battery pack
- Fluids on ground

Immobilise

Electric vehicles can move silently & with instant speed. Rescuers should:

- Ensure you have correct ERG for the EV make & model
- Chock wheels - truck-sized chocks may be needed to adequately hold EV in place
- If possible:
  - Engage with driver
  - Put EV into park
  - Push On/Off button
  - Remove proximity keys

Note: Tesla EVs primarily use drivers smartphone as a key, but may also use a 'card' key' or a finger ring. They do not have an On/Off button.



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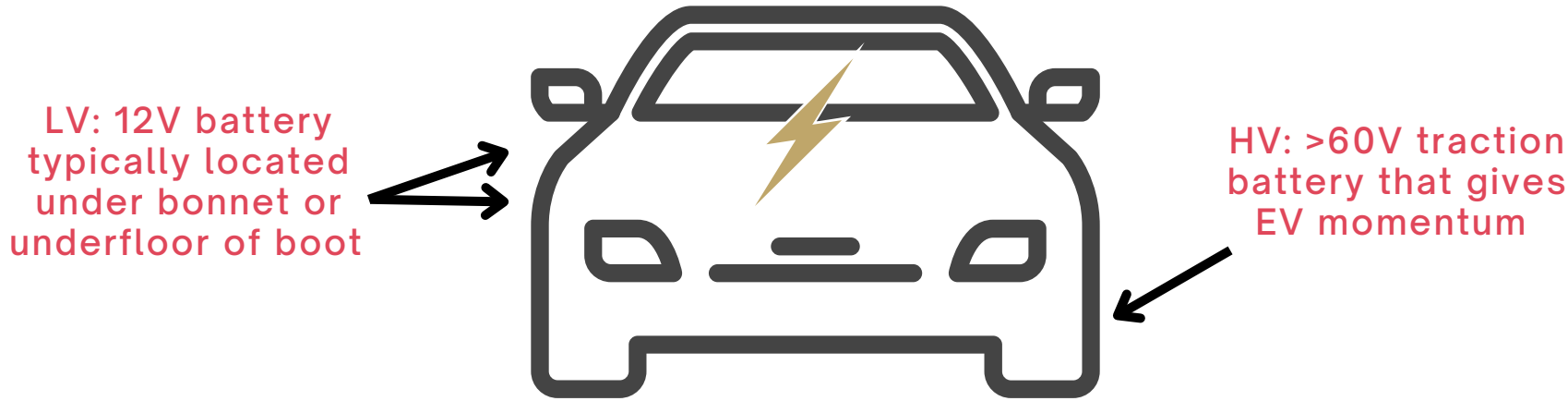
Isolate high voltage systems

To make the EV safer to work around, rescuers should isolate low voltage (LV) & high voltage (HV) systems.

- LV 12V battery:
  - Ensure doors / windows / bonnet / boot are open if required – these cannot opened once 12V disconnected
  - Review ERG to locate & disconnect 12V battery to disable SRS
- HV traction battery:
  - Review ERG for isolation method for HV system specific to EV
    - Responder cut loop - use 18 inch insulated bolt cutters
    - Responder pull fuse - refer to your agency for PPC requirements



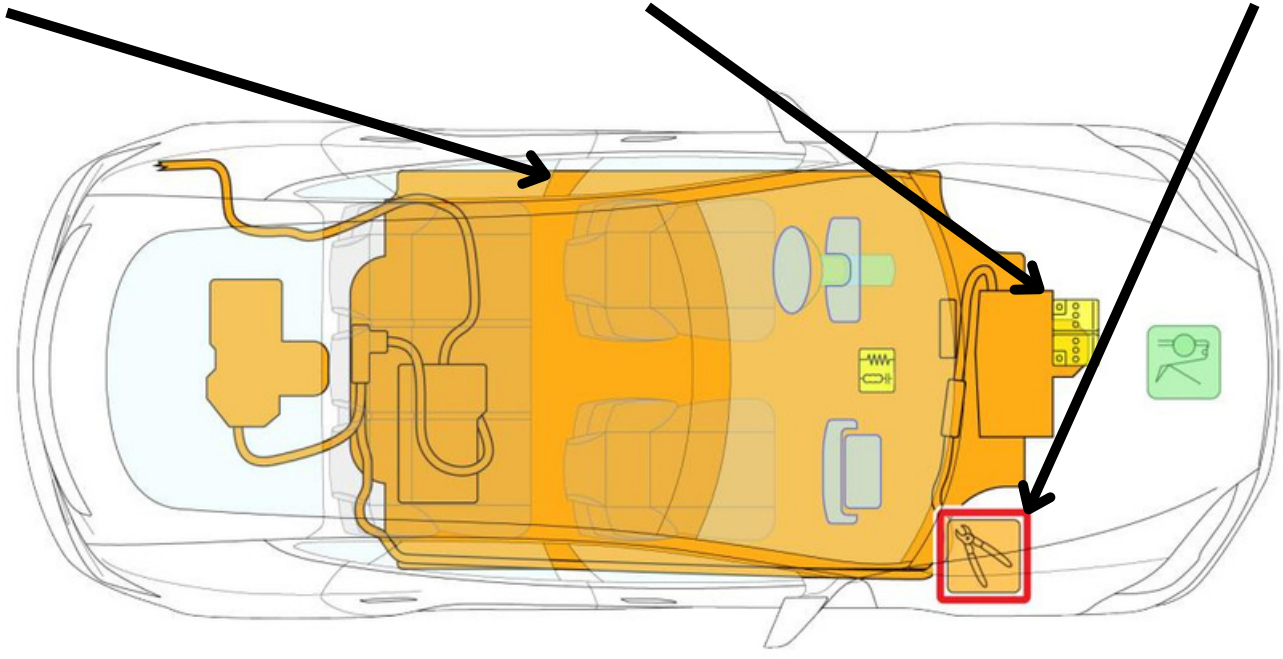
Isolate high voltage (HV) systems

Note:

HV systems should automatically isolate upon impact involving safety systems (airbags, seatbelt pretensioners)

When LV (12V) system is disconnected, contactors to the HV system should remain in the 'open' position, thereby isolating HV

Where available, also conduct manual isolation of HV systems for additional safety while extrication is taking place



Risk of electrocution remains!

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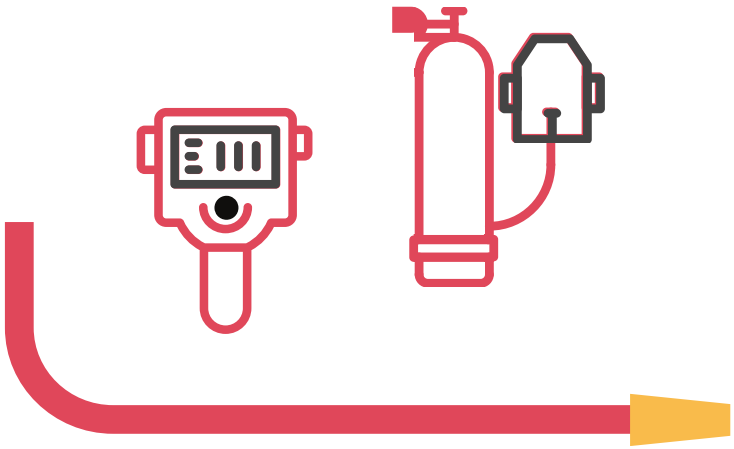
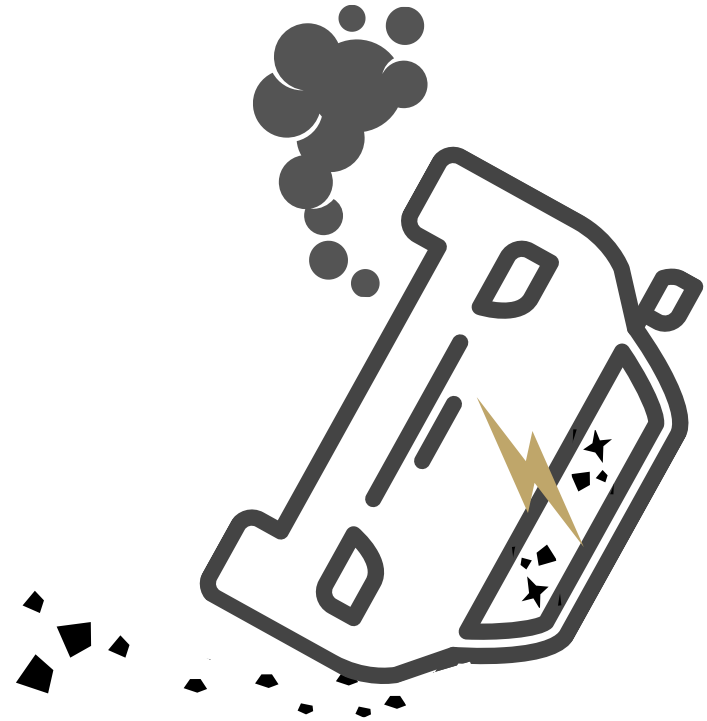
Rescue responder protection

To enhance rescue responder protection:

- Monitor HV battery pack (underside of EV) with TIC to detect rising heat
- Lay & charge hose lines for battery cooling &/or suppression
- Ensure BA Operators are standing by





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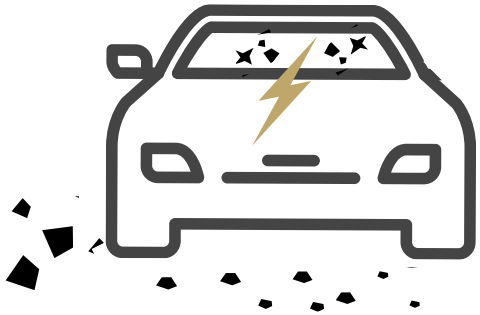
Stabilisation

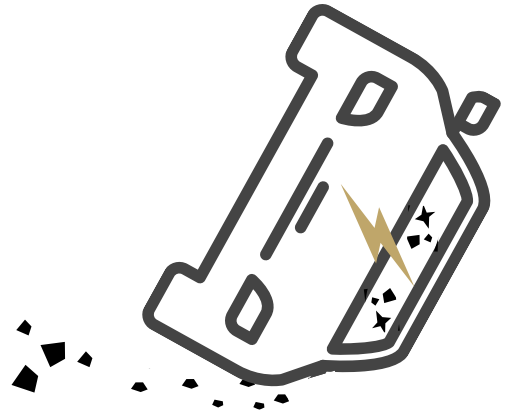
An EV HV battery is heavy & EVs may be more likely to stay on wheels:

- EV average kerb weight 1800kgs
- HV battery average weight 550kgs



EV on wheels:

- Consider where block & wedge stabilisation will go
- Add EV tape to battery pack for visible reminder (if possible)



EV on side:

- Use side stabilisation with multiple wedges
- Underside stabilise forward of front tyres & rear of rear tyres
- Consider construction – soft materials like aluminium & kevlar may rip if used as an anchor (eg. Tesla bonnet is light aluminium)
- Add EV tape to battery pack for visible reminder

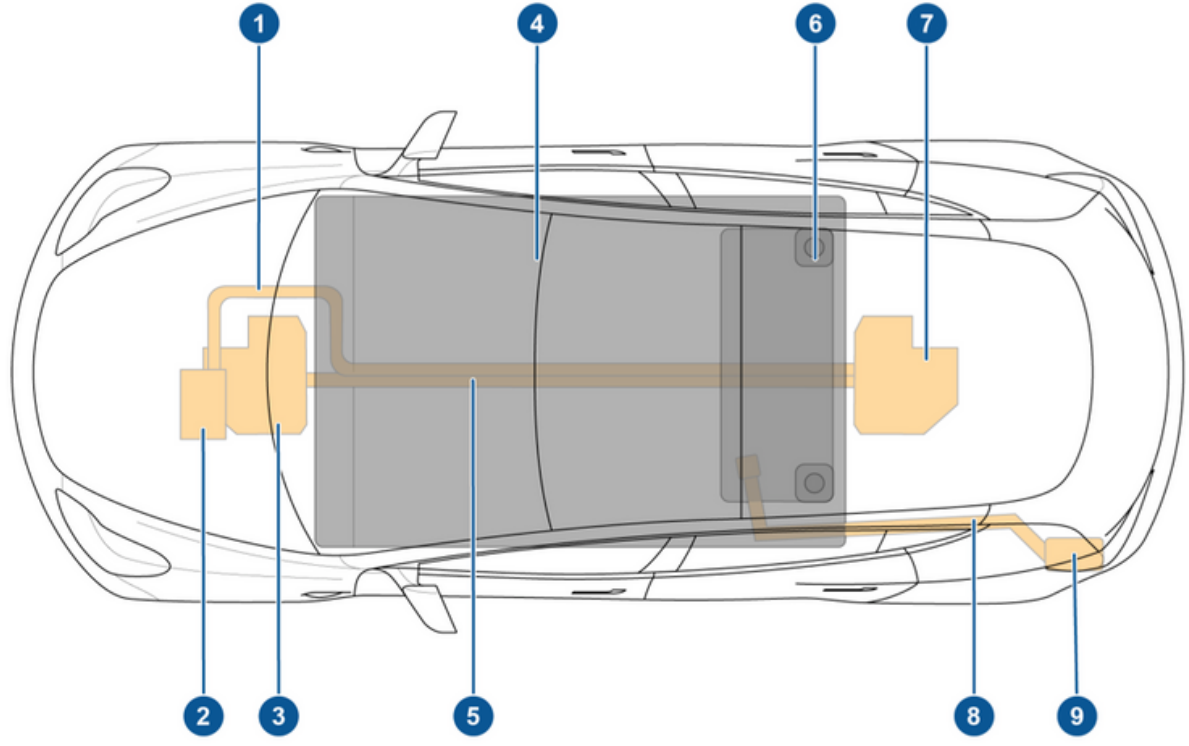
EV on roof:

- Similar to all ICE vehicles
- Consider access to HV cut loop or pull fuse for HV disconnection
- Add EV tape to battery pack for visible reminder (if possible)

Stabilisation (con't)

- Relocation considerations (if on wheels)
  - Roll EV away from structures to enable access to patient
- Check ERGs & look for hoisting points on EVs which provides 4 point stabilisation
- 5th point stabilisation – depends incident type

Note: Do not touch, push off or penetrate the HV battery pack area (shown in grey), which sits along the floor pan between chassis rails on all passenger EVs. Stick outside of battery zone – front & rear of tyres



1. High Voltage Cabling
2. Heat Pump
3. Front Motor (Dual Motor vehicles only)
4. High Voltage Battery
5. High Voltage Cabling
6. High Voltage Battery Service Panel
7. Rear Motor
8. High Voltage Charge Port Cables
9. Charge Port

TR DRA

Glass management

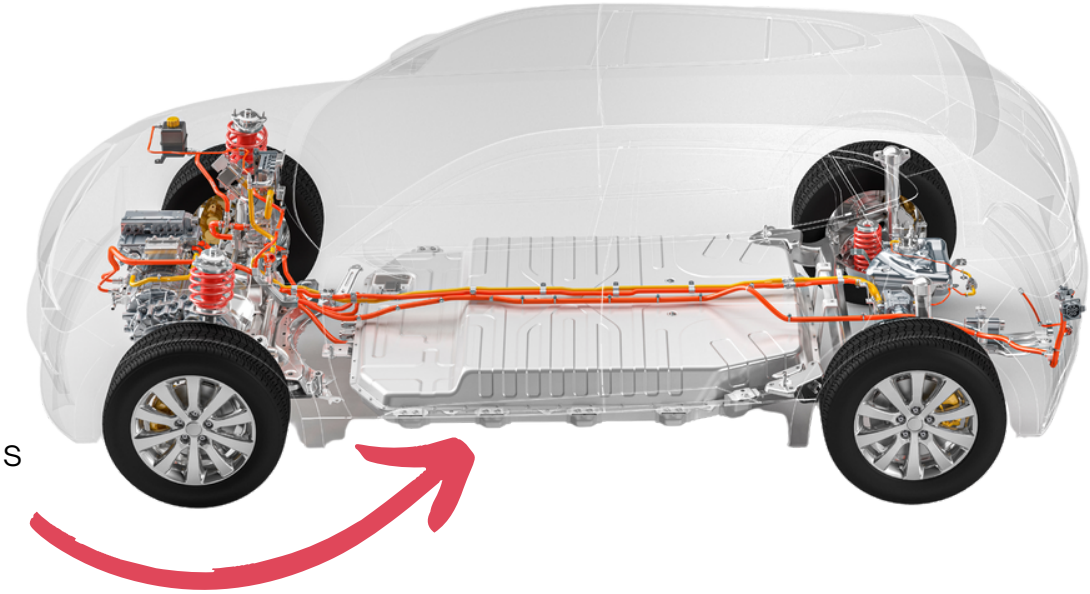
Glass may form part of the structural integrity of EV

- Tempered breaks into small pieces / laminated breaks as slab glass
- Check ERG for glass type (side laminated glass) that may need to be removed/managed to reach HV disconnects etc
  - Use beluga tool for laminated glass
  - Use windscreen splinter guard
- Cutting laminated glass leads to glass dust and needs to be managed accordingly
- Casualty protection (soft/hard) & sharps protection

Gaining access & extrication

Rescuers should consider:

- Further review of the ERG for vehicle schematics
- That traditional entry &/or cutting points may vary in an EV
- Expose / Investigate before commencing tool operations
- Ramming off vehicle floor may cause battery abuse leading to thermal runaway.
  - Consider placement of ram supports
  - If using cross rams, consider penetration of ram into car & HV cable locations
- Refer to ERG for location of AC/DC converter, which may be located in EV footwell
- EV airbags, seats & vehicle controls are managed similarly to other vehicles
- Existing techniques
  - Check the basics
    - Open doors or ask occupant to open locked doors
    - Use manual override latch (Check ERG)

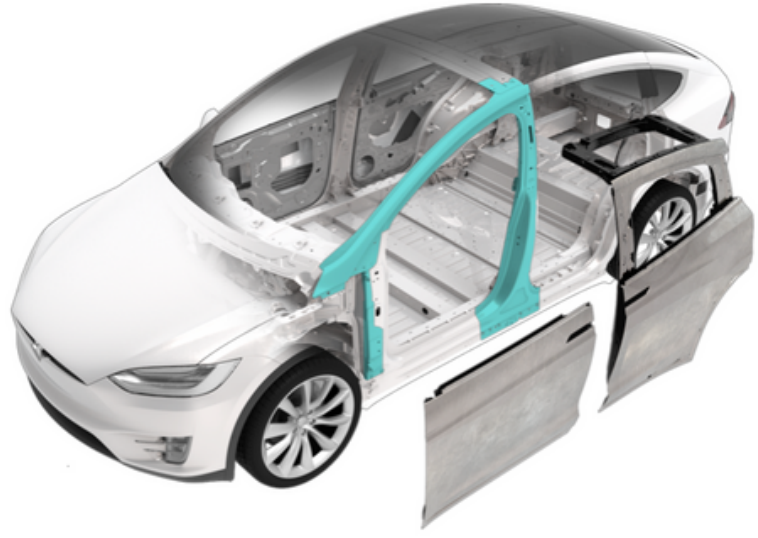


Passenger EV HV battery is located between chassis rails, along floor pan

Gaining access & extrication (con't)

Extrication via doors using rattle / spread / cut method:

- From front:
  - manipulate front guard to expose hinges & check for HV cables
- From rear:
  - consider working tool along door edge to access Nader bolt to minimise skinning doors, checking vehicle construction & for HV cables
- Consider potential for gull wing doors – **only** in Tesla Model X
- Consider power assisted doors, such as tailgate



Gaining access & extrication (con't)

Side extrication:

- Remove both doors then B pillar, referring to ERG for location of HV cables

Rear extrication

- If possible, wind windows down to minimise cutting side laminated glass windows.
- DRA Glass roof - Remove / leave?

Ramming:

- B to A - Dash roll
  - Consider relief cut location with vehicle HV systems?
- Internal - Floor, Dash / Doors
  - Refer to ERG for locations of HV systems.

Dash Lift:

- Refer to ERG & consider:
  - EV cables
  - Vehicle construction
  - Pushing off HV systems (expose first) & pushing off floor pan (risk of damaging battery cells)

Model 3 / Y rocker / door sill

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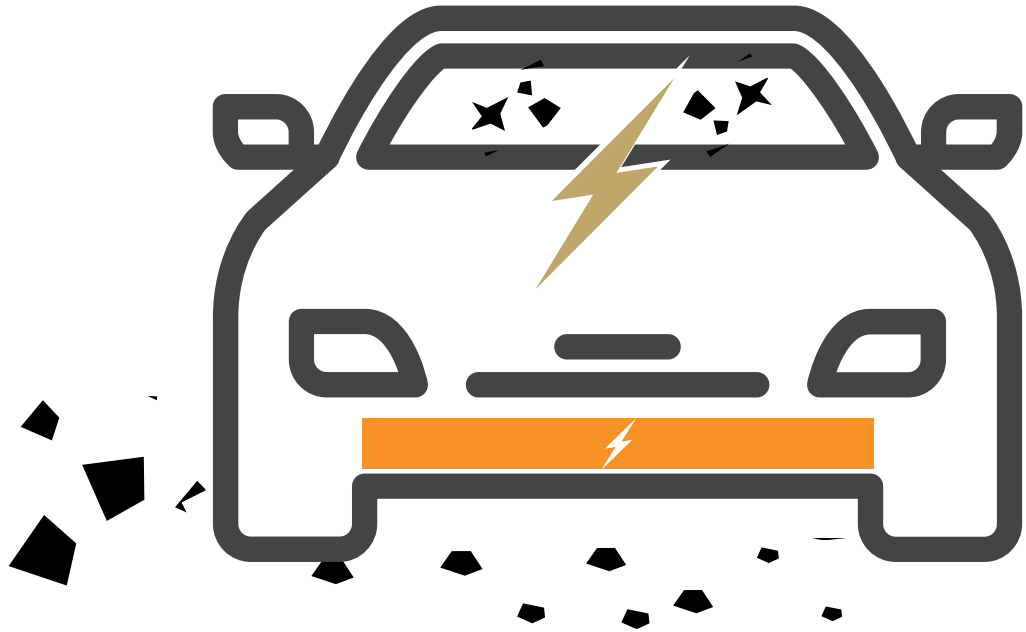
Patient packaged

Once extrication is complete, package patient for delivery to medical team



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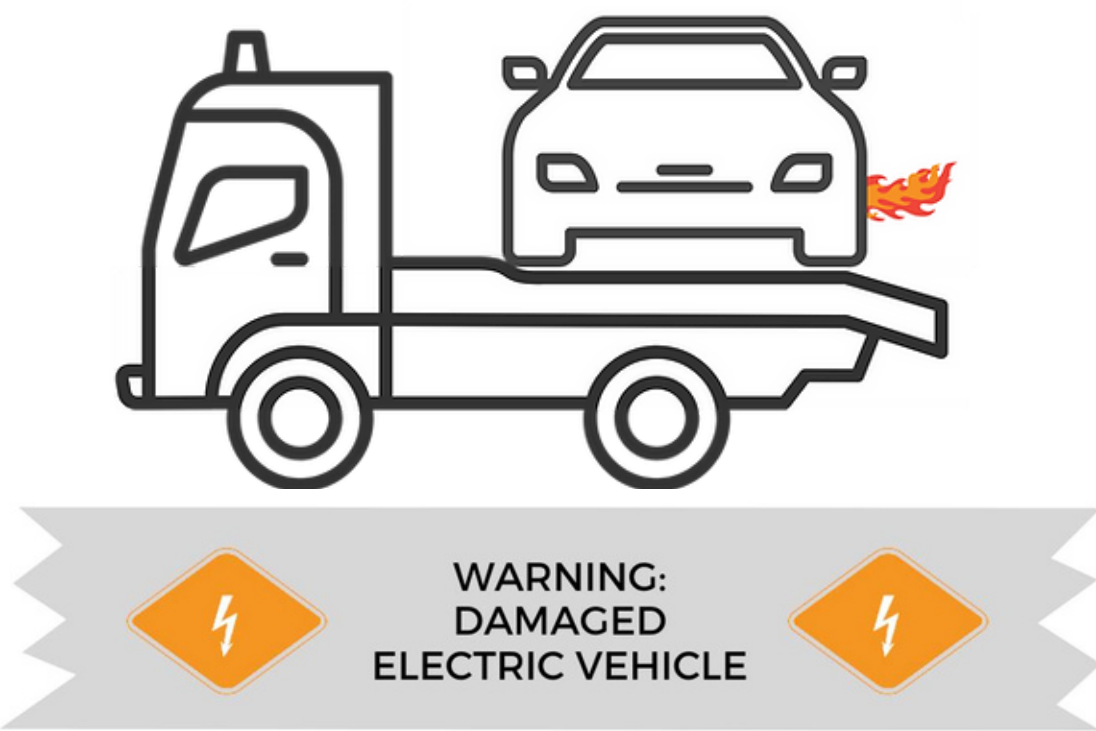
Conclude rescue & handover

Consider potential contamination of PPC / PPE & follow agency clean up procedures

- Incident controller should make towing / recovery aware vehicle is electric
  - Provide make, model & ERG for towing instructions if required
- Use ‘EV’ tape for immediate identification
- Brief investigators on modifications made, such as cut seat belts, HV isolation cut loop etc

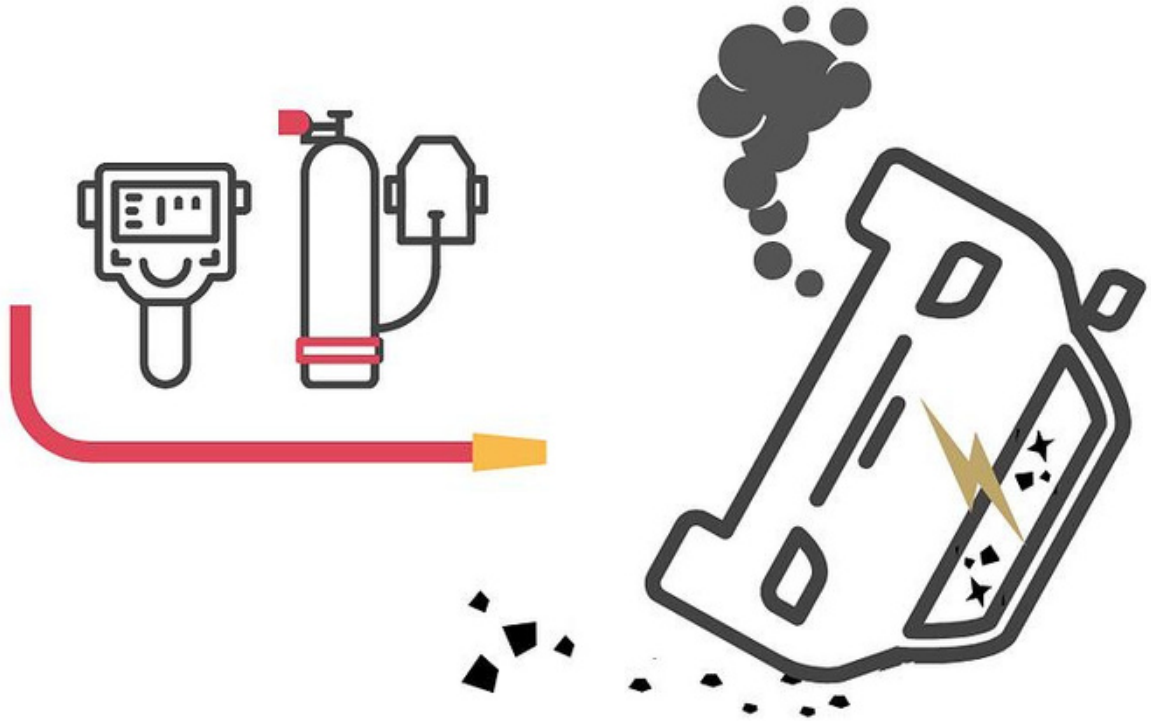


Example only, refer to your agency for guidance

Body recovery

Rescuers should keep all previous considerations in mind:

- Fire agencies should remain on scene to provide charged line for immediate suppression & cooling
- BA operators should be on standby
- Responders should brief controlling agency for investigation on inherent EV risks
- Fire to remain on scene until EV has been handed over to towing/recovery



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Post incident

- EV tape for immediate identification
- Ensure towing / vehicle recovery personnel are aware vehicle is electric
  - Storage / tow yards should consider keeping damaged EVs separated from other vehicles due to risk of secondary ignition

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