Submission No 30

ELECTRIC AND HYBRID VEHICLE BATTERIES

Organisation: Encap Fire & Safety Pty Ltd

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Encap
Fire and Safety

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Mr Greg Warren MP
Chair
Joint Standing Committee on Road Safety
NSW Parliament House
6 Macquarie Street
SYDNEY NSW 2000

RE: NSW JOINT STANDING COMMITTEE ON ROAD SAFETY - ELECTRIC AND HYBRID VEHICLES INQUIRY

1. We are a recently established company whose purpose is to research and develop fire suppression and safety products addressing the risks associated with Li-ion batteries (including those contained in EVs, LEVs and hybrid vehicles ("HVs")), for the purpose of sale to the general public. We expect to release a number of products to the market in the coming year.

2. The pervasive use of lithium-ion batteries in EVs and HVs calls for a paradigm shift in risk assessment and fire response. The doctrine of putting "wet stuff" on "hot stuff" has serious limitations. Rather than having a single method to control risk, prevent or suppress fire, responding agencies and the public are now in a position where they require a number of tools to manage risks and prevent or suppress fires depending on the particular circumstances they find themselves in. For instance, an RFS response to an EV fire in a remote area of Western New South Wales would present different issues to a FRNSW response to an EV fire in a multi-level basement fire in the Sydney CBD.

Risk and Management of Fires and Other Issues

3. As a starting point, it would be prudent to standardise descriptors relating to lithium-ion (Li-ion) battery fires so that they might be better understood. In an ordinary fire, people refer to the generation of "smoke". That is an inapt description for the product of a Li-ion battery fire. The products of a lithium-ion battery fire that might be described

as "smoke" are in fact toxic, explosive gases that pose a risk to human health and emergency services personnel.

4. The gases produced include highly toxic gases (i.e. hydrogen fluoride, hydrogen cyanide); explosive gases (i.e. hydrogen, volatile organic compounds) and asphyxiants (i.e. carbon monoxide, carbon dioxide). Plumes produced also contain aerosolised heavy metals (i.e. cobalt, nickel and manganese) and plastic components that pose a risk to human health.

5. Hazards posed by EVs, HVs and Li-ion batteries generally are complex. There are physical hazards associated with the unexpected movement of vehicles or collapse of thermally damaged structures such as ceilings and walls; chemical and gas exposures; blast, burn and shrapnel injuries associated with fire, deflagration or explosion of vapour clouds, or the detonation of batteries themselves. There are also risks of chronic exposure to the chemicals produced by a venting or fire incident.

6. During the 2023 International Tall Building Fire Safety Conference, there were two presentations that provided an excellent overview of the risks posed to first responders, and the general public by Li-ion batteries contained in EVs and LEVs. Each of those presentations are available online. The first was presented by Prof. Paul Christensen and can be found here: https://www.youtube.com/watch?v=AIXTP-TgPEw. The second was presented by Dr Francesco Restuccia and can be found here: https://www.youtube.com/watch?v=rJsoWD0J7bQ. We respectfully commend those presentations to the Committee.

Barriers to Understanding Risks

7. There are many confounding factors when assessing the safety of Li-ion batteries in EVs and HVs. For instance, there is no standardisation of nomenclature when referring to batteries. The use of the general term "battery" does not make it sufficiently whether a person is referring to an individual battery cell, or a battery pack which contains many cells. By way of example, a statement of probability (i.e. 1 in 10,000 batteries will fail) is apt to cause confusion as to whether a person is suggesting that 1 in 10,000 individual battery cells will fail (noting that battery packs can contain many thousands of individual cells), or whether a person is speaking of 1 in 10,000 battery packs actually installed in vehicles.

8. Academics, experts and other commentators often provide opinions via the prism of their own expertise. That is not a bad thing. However, specialist opinions can have inherent limitations in the sense that a chemist sees a chemical problem, an engineer sees an engineering problem, and a doctor sees a health problem. One barrier to easily understanding the area is that there is a tsunami of information from disparate sources with differing approaches, without a centralised method of combining and distilling the best evidence into public safety messages, standards, codes of practice, risk assessment and control techniques and best practice fire prevention and suppression protocols.

9. A further challenge is that failures and fires occur in the real world and not in a laboratory environment. There is no way to anticipate every imaginable circumstance that might arise in a fire, road crash rescue, venting incident, spill incident, or other failure. That is where data collection, sharing and analysis has a role to play.

10. A practical difficulty we have observed is that experts, government agencies and industry commentators generally identify risks associated with EVs, HVs and other Li-ion batteries; suggest that people should, or are required by law to, take steps to control those risks; but, offer little by way of solutions to actually manage the risk. That is understandable given the technology is in its nascent stage. However, it provides little guidance as to what practical steps employers, occupiers, employees, and the public should take to protect themselves from risks posed by EVs, HVs and Li-ion batteries generally.

<u>Multi-disciplinary and Multi-agency Research and Information Sharing</u>

11. Before addressing the risks in a meaningful way, the Parliament will need to surmount the vagaries posed by Rumsfeldian known-knowns, known-unknowns and unknown-unknowns. That can only be done if the government and its agencies possess the right information.

12. It is respectfully submitted that it would be appropriate to establish a central office or body, which can be tasked as the central repository for data and information collected by all NSW government agencies about EV and HV related incidents. Such a body would be an appropriate co-ordinating point for research, data interpretation, interstate and international information sharing partnerships, and co-ordination of academics, experts and other industry stakeholders for the purpose of research, information analysis and advice. It would be appropriate for such a body to either be created as a

new, separate and independent government agency, or for such a body to be created within an appropriate existing agency framework.

13. The important point is that the body should be independent; multidisciplinary; rigorous in its research, data collection and analysis; and, proactive in identifying extant and emerging risks. It is appropriate that such a function be performed by government given the public interest in the matter, and the likely requirement to co-ordinate with government agencies to draw upon their respective data, knowledge and experience. In order to properly manage risks, a multi-agency approach is required. The risks presented, and methods of controlling them, touch upon such responsibilities as public health, environment, education and training, emergency response, product liability and surveillance, transport infrastructure, workplace health and safety, carriage and management of dangerous goods, and the like. The establishment of a central point within government would permit equal access to information, advice and service delivery across New South Wales.

Current Limitations in Data and Statistical Analysis

14. The presence of confounding factors and a lack of standardisation negatively affects data collection and statistical analysis in the area.

15. Firstly, EVs and LEVs are a relatively new technology. Market penetration has increased drastically over the last few years and can be expected to increase exponentially in the future. The issue that poses for data collection and analysis is that, as a function of time, there has been limited opportunity for longitudinal studies and datasets are relatively small. To the extent that longitudinal studies have been attempted, results are potentially affected by the age of EVs and HVs. Whilst it may be accepted that on the current understanding of the data available, EVs appear to be involved in less fire incidents than ICEVs per kilometre travelled, there may be a degree of artificiality in the sense that one is comparing EVs less than a few years old to ICEVs of more advanced age. It is also noteworthy that on the current understanding of the data available, it appears that Plug-in Hybrid Electric Vehicles and Range Extended Electric Vehicles are more likely to be involved in a fire incident than standard EVs.[1]

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[1] UK Office for Zero Emission Vehicles, *T0194 - Covered car parks: fire safety guidance for electric vehicles*, [2.6] (https://www.gov.uk/government/publications/covered-car-parks-fire-safety-guidance-for-electric-vehicles)

16. Secondly, it is difficult to compare data and analyses in circumstances where publishing bodies do not disclose their methodologies for inclusion, assessment and verification; or, where methodologies differ between such bodies. For instance, some bodies publish data and statistics based on all fires involving an EV – including arson, situations where a house fire causes an EV to burn, and the like. At the other end of the spectrum, some bodies publish data and statistics only where an EV fire is caused specifically by fire or thermal runaway that starts within a battery.

17. In the former case, the data does not permit a complete understanding of the actual risks and effects of a pure battery cell or battery pack fire. The data does not allow one to identify battery fire trends in particular brands, or trends relating to environmental or other factors that might contribute to spontaneous combustion. In the latter case, the data does not permit a complete understanding of the actual risks and effects of fires that cause EV battery packs and cells to burn. As a matter of practicality, if a battery pack is on fire, the question as to whether the fire was started by something internal or external to the battery pack is of little moment to the people who are affected by it.

18. Thirdly, there is no standardisation of data collection processes. That affects the product of collection in three ways. Where there is no standardisation of the data collection process: a question arises as to whether the data is in fact being adequately reported and collected; there is less confidence in the analytical process, as one may not be comparing data of a similar nature; and, there is a chance that important data is not being appropriately categorised, which in turn undermines any inferences or conclusions that might be drawn.

19. Fourthly, whilst statistics are important, they can often obscure the human cost involved in fires and other incidents. If an emergency services worker, automotive worker, or a member of the public is killed or catastrophically injured as a result of an EV fire, it would be cold comfort to their family that the death or injury was a statistical improbability.

20. Fifthly, a comparison of the likelihood of fires in EVs and ICEVs does not take into account the different resources required to deal with the fires. It is impossible to state with precision the resources required to put out an EV fire, nor the time required to quench the fire. In the case of hybrid vehicles, there is evidence to suggest between 1,000 and 4,000 litres of water is required with a quenching time of between 15 minutes and 56 minutes. In the case of EVs, there is evidence to suggest between 4,400 litres

and 10,000 litres of water is required, with a quenching time of between 36 minutes and 60 minutes. That is to be compared with an ICEV fire, which takes about 5 minutes to quench with far less water.[2] Time and water required is affected by EV type, state of charge, fire attack methods and a multitude of other factors. There are a number of incident reports and research papers that suggest in past incidents, up to 60,000 litres of water has been used and some EVs have taken up to 5 hours to extinguish. Those reports have not been the subject of peer review or independent verification, which may affect their quality or accuracy.

21. The fact of the matter is that EV fires take significantly more water, and significantly more time, to extinguish than ICEV fires. There is data to suggest that flames generated by EV fires spread faster than flames produced by hybrid vehicle and ICEV fires[3] and EV fires develop faster than ICEV fires.[4]

22. Sixthly, statistical analyses are generally based upon fire risk during charging or normal operation. There is very limited data and research available as to fire risk during abnormal operation – such as road crashes, collisions, submersion or flooding, and the like.

23. Seventhly, it is not to the point to suggest that EVs are statistically less likely to be involved in a fire incident than ICEVs. The fact is that EVs and LEVs are involved in fire incidents and those incidents pose a risk to human health, safety and property. Those risks need to be controlled, and they need to be controlled differently to the risks posed by ICEVs.

24. It has been submitted above that a central repository for data collection and analysis should be established. In addition, there are a number of practical things that can be done at an agency level to assist in the data collection process. It would be prudent to identify what agencies are in fact collecting relevant data, and what agencies could collect relevant data. Once that is established, action could be taken to standardise terms, classifications and categories of incidents with a high degree of specificity.

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[2] R Bisschop, et al, *Fire Safety of Lithium-Ion Batteries in Road Vehicles*, RISE Fire & Transport Fire Research Report 2019:50, [6.2.2] (https://www.diva-portal.org/smash/get/diva2:1317419/FULLTEXT02).

[3] Y Cui, *Characterization and assessment of fire evolution process of electric vehicles placed in parallel* (2022) 166 Process Safety and Environmental Protection 524 (https://www.sciencedirect.com/science/article/pii/S0957582022007455).

[4] S Kang, et al, *Full-scale fire testing of battery electric vehicles* (2023) 332 Applied Energy 120497 (https://www.sciencedirect.com/science/article/pii/S0306261922017548).

25. By way of example, in the 3rd edition (Revision 1) of the Australian Safety and Compensation Council *Types of Occurrence Classification System*, the detailed classifications of the "breakdown agency" and "agency of injury/disease" that might apply to injuries sustained as a result of an EV or LEV battery fire include code 5229 (acids, including battery acid, spirits of salt); code 1689 (vehicle batteries); code 5199 (other nominated chemicals); code 5219 (other and not specified industrial gases, fumes); classifications under code 24 (road transport); code 5289 (other and not specified nominated organic chemicals); code 5359 (other and not specified organic solvents); code 5399 (other and not specified chemical products); code 6319 (fire, flame and smoke).

26. It is submitted that it would be appropriate for data collecting agencies to review and consider whether their collection systems are fit for the purpose of collecting data relating to EV, HV and other Li-ion battery incidents. Such a review would necessarily involve consideration of whether there should be an umbrella classification relating to Li-ion battery incidents, and whether current classification models are suited to sub-categorisation or differentiation between incidents involving EVs, HVs and other categories of Li-ion battery powered products. It would be appropriate to train staff on data collection requirements, and provide a mechanism by which incidents suspected of being caused by EVs, LEVs and Li-ion batteries can be captured along with incidents that are confirmed to have been caused by EVs, LEVs and Li-ion batteries.

27. There are further steps that can be taken by government agencies to promote the development of a knowledge base relating to EV, HV and Li-ion battery fire risks and management, including:

27.1 NSW Health and SafeWork NSW to consider whether current statistical models are sufficient to capture appropriate data relating to injuries caused by Li-ion batteries within EVs and LEVs to form the basis for an epidemiological and/or relative risk study.

27.2 NSW Health and SafeWork NSW to consider whether, and when, an epidemiological and/or relative risk study may be appropriate to consider the type, rates and effects of injuries (including burn, dermal and inhalation injuries) caused by Li-ion batteries within EVs and LEVs.

27.3 NSW Health to consider follow-up studies with patients who have presented after exposure to EV, HV and Li-ion battery fires.

27.4 NSW EPA and SafeWork NSW to consider whether an air quality monitoring study, or atmospheric/smoke plume modelling, would suitably capture data relating to exposure risks generated by EV and HV battery fires generally; and, specifically for the purpose of understanding the effects of ventilation and discharge of gases from confined spaces such as underground car parks in the event of EV or HV fire.

Risk to workers in the automotive industry and emergency services personnel

Hydrogen Fluoride

28. One matter that sets LEV and EV fires apart from ICEV fires is the generation of hydrogen fluoride (HF) gas. The electrolyte contained in the battery (generally lithium hexafluorphosphate and organic solvents) and other battery components can undergo decomposition and "ejection". The ejection phase involves the venting of hot gases from the battery pack. The venting gases may or may not be ignited at that point. In the initial part of the phase, phosphorous pentafluoride and phosphoryl fluoride are produced. Both of those substances react with water (whether in or around the battery pack, moisture in the atmosphere, or other external moisture) to form HF gas. HF gas is water soluble and forms hydrofluoric acid when it comes into contact with water, including water used to extinguish a fire, and importantly, mucosal tissue in the eyes, nose, mouth, throat and lungs. The liquid electrolyte also reacts with water to form hydrofluoric acid.

29. A study conducted in 2017 concluded that a burning li-ion battery pack produces between 20 to 200 mg per watt hour of nominal battery energy capacity. That study extrapolated that between 2 and 20 kilograms of HF gas would be produced by a burning 100 kilowatt hour battery pack (which is at the larger end of EV batteries) and between 20 and 200 kilograms of HF gas for a 1,000 kilowatt hour battery system (such as a small stationary battery energy storage system).[5]

30. HF gas and hydrofluoric acid present serious risks to the safety of first responders, workers and the general public. The current Safe Work Australia exposure standard states that the peak limitation value for hydrogen fluoride is 3 parts per million, or 2.6

[5] F Larsson, et al, *Toxic fluoride gas emissions from lithium-ion battery fires* (2017) 7 Scientific Reports 10018 (https://www.nature.com/articles/s41598-017-09784-z).

mg per cubic metre.[6] That is, workers should not be exposed to levels of hydrogen fluoride in excess of those amounts, even instantaneously.

31. In brief terms, when a person comes into contact with hydrofluoric acid, two things occur. Firstly, in higher concentrations, hydrogen ions cause a corrosive burn and tissue destruction similar to other acids. In lower concentrations, an immediate corrosive burn may not occur or may not be apparent. Secondly, HF acid easily penetrates deep into tissue and reacts with calcium and magnesium. When that reaction occurs, it can cause liquefactive necrosis of deep tissue, extreme pain and systemic toxicity. Fluoride ions in the body can bind calcium and magnesium at a rate faster than the body can mobilise it – the result of which may present as hypocalcaemia, hypomagnesemia, and hyperkalaemia.[7] It is generally accepted that when hydrofluoric acid at a concentration of greater than 50% is spilled onto skin, a spill with an area the size of a hand is sufficient to have fatal effects.

32. In 2021, a study was conducted in Singapore into known burn injuries caused by personal mobility device fires, the root cause of which was thermal runaway in Li-ion batteries. The study was concerned with 30 patients, both adult and paediatric, and found a 10% mortality rate. When examining the cases of 3 adult males who died, it was hypothesised that HF toxicity could be a critically overlooked component contributing to the mortality rate. The study went on to argue that, *inter alia*, it is crucial to be highly suspicious systemic fluoride toxicity in the presence of blast pattern type traumatic injuries and shrapnel injuries; and as a standard approach, there should be a high suspicion of fluoride toxicity in the case of mixed thermal and chemical burn injuries (including inhalation injury). As a further feature, there should be an extremely low threshold for suspecting fluoride toxicity when a patient presents with a history of collapse at the scene, or re-entry into the fire scene.[8]

33. In 2021, the Burns Unit at Concord Hospital published a retrospective review of the NSW Statewide Burn Injury Service database for the period January 2005 to December 2019 in relation to Li-ion battery burns. The data for the relevant period

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[6] https://hcis.safeworkaustralia.gov.au/ExposureStandards/Document?exposureStandardID=324; https://www.safeworkaustralia.gov.au/system/files/documents/1702/hydrogenfluoride_1989pdf.pdf
[7] D McKee, et al, *A review of hydrofluoric acid burn management*, (2014) 22 Plast Surg (Oakv) 95-98 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4116323).
[8] M.K.H. Hsieh, et al, *Electric Scooter Battery Detonation: A Case Series and Review of Literature*, (2021) 34 *Annals of Burns and Fire Disasters*, 264 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8534310/)

(Jan 2009 to Jan 2019) recorded that all burn injuries treated by the Service were related to mobile telephones, e-cigarettes and portable battery charging devices.[9]

Pollution and Contamination

34. Surfaces and textiles are the subject of contamination with toxic metal oxides (such as cobalt, nickel, manganese and lithium); polycyclic aromatic hydrocarbons; and water-soluble fluorides.[10] Early studies have shown that surface decontamination was no more difficult when compared to decontamination after an ICEV fire (provided adequate PPE and safe working methods are used), however, the contamination of firefighting water runoff and storage water was a critical issue worthy of a chemical incident type response.[11]

35. A number of studies have been conducted on the levels of contamination of water used in fire-fighting water runoff and water used to store damaged batteries. In the case of runoff water, investigations have found that fluoride and lithium levels exceed relevant drinking water standards.[12] In the case of storage water, significant levels of water-soluble fluorides; lithium ions; and acid soluble heavy metals (such as cobalt, nickel and manganese) were detected, and such levels were found the exceed relevant drinking water quality and sewer discharge standards.[13]

36. Data is currently emerging to the effect that when LIBs are abused, vent or catch fire, toxic particulate matter including cobalt, nickel, aluminium, lithium and fluorine is released. The amount of settleable particulate matter equates to between 1.67% to 11.2% of battery cell mass. Approximately 40% of the settleable particulate matter is comprised of metallic elements. The toxic settleable particulate matter has the potential to pollute crops, waterways and groundwater; enter the food chain; and, affect

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[9] (https://ajops.com/article/32019-exploding-power-a-statewide-review-of-lithium-battery-related-burns)

[10] M Held, et al., *Thermal runaway and fire of electric vehicle lithium-ion battery and contamination of infrastructure facility* (2022) 165 Renewable and Sustainable Energy Reviews 112474, [3.1.1] (https://www.sciencedirect.com/science/article/pii/S1364032122003793).

[11] Held, et al., [5].

[12] Held, at al., [3.2.1].

[13] Held, et al., [3.2.2].

human health.[14] There is also early data which suggests lithium-ion batteries are an emerging source of polyfluoroalkyl and perfluoroalkyl substances in the environment.[15]

Other Safety Risks

37. Based on our inquiries and research, we have identified a non-exhaustive list of risks posed to emergency services personnel and automotive workers. It is anticipated that as EVs and LEVs become more common, further risks will be identified. Unfortunately, some risks will only be identified after the fact. Specific identified risks include:

37.1 Lack of standardisation of battery placement – each EV and LEV has a different battery configuration and batteries are placed in different parts of the vehicles. Responding agencies are able to have reference to the ANCAP app, which contains details of battery placement and other details relevant to fire suppression and rescue. We have observed in some cases that there can be a lag between a new EV (or variation) being introduced to the market, and listing on the ANCAP app. The ANCAP app is an invaluable resource to first responders, however, it does not cover the field. In particular, where ICEVs have been converted to EVs, they are not listed on the ANCAP app, nor is there any way for responding agencies to have advance notice of where the battery has been placed.

37.2 Virtually any car can be converted to an EV. That can be done by professionals, or by vehicle owners using conversion kits. Older converted vehicles without appropriate labels affixed are apt to add a layer of confusion in an emergency situation. For instance, emergency services personnel could be lulled into a false sense of security that they are dealing with an ICEV when attending a fire

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[14] H Wang, et al, *Particles released by abused prismatic Ni-rich automotive lithium-ion batteries* (2020) WSEAS Transactions on Systems and Control, 30 (https://www.wseas.org/multimedia/journals/control/2020/a085103-063.pdf); Y Zhang, et al, *Size distribution and elemental composition of vent particles from abused prismatic Ni-rich automotive lithium-ion batteries*, (2019) 26 Journal of Energy Storage 100991 (https://www.sciencedirect.com/science/article/abs/pii/S2352152X19307820); W Mrozik, et al, *Environmental impacts, pollution sources and pathways of spent lithium-ion batteries* (2021) 14 Energy Environ. Sci 6099 (https://pubs.rsc.org/en/content/articlepdf/2021/ee/d1ee00691f).

[15] A Rensmo, et al, *Lithium-ion battery recycling: a source of per- and polyfluoroalkyl substances (PFAS) to the environment?* (2023) 25 Environ. Sci.: Processes Impacts, 1015 (https://pubs.rsc.org/en/content/articlelanding/2023/em/d2em00511e); J Guelfo, et al, *The dirty side of clean energy: Lithium ion batteries as a source of PFAS in the environment*, 1 August 2023, Preprint (Version 1) (https://www.researchsquare.com/article/rs-3150504/v1); W Gao, et al, *A review on the impacts of fluorinated organic additives in lithium battery industry – an emerging source of per- and polyfluoroalkyl substances* (2024) Critical Reviews in Environmental Science and technology (https://www.tandfonline.com/doi/full/10.1080/10643389.2024.2306093?src=).

or collision involving a classic car or a vehicle well known to have been manufactured in the 1970s or 1980s, when in fact the car contains a lithium-ion battery pack. Further, it might not be apparent that the car contains a lithium-ion battery due to the physical damage done to the car. An example would be where a battery pack is placed into the front of a vehicle, which has been destroyed by a head-on collision.

37.3 Lack of standardisation of isolation process – each manufacturer offers a different method and means of isolating the battery pack from the high voltage cables in the vehicle. The isolation points are placed in different areas of the vehicles. It is impossible to expect that emergency personnel will remember each and every possible configuration. The isolation process also presents its own complications. In the main, EVs can be isolated by disconnecting the 12 volt battery system within a vehicle. The effect of that, however, is that the doors, windows and other systems powered by the 12 volt battery system become inoperable. Emergency personnel should ensure that all of the windows of an EV are down and all of the doors are open, prior to effecting a rescue. It is also important to recall that "isolation" does not mean "deenergised". Whilst the battery pack can be isolated, reducing the risk of electrocution when cutting into an EV, the battery pack retains its energy and is still capable of causing injury during a rescue, transport or repair. The effect of isolation differs between vehicles. Some vehicles are immediately isolated by whatever method is provided. In other cases, a person isolating the battery pack needs to wait up to 15 minutes after isolation for the energy within the vehicle's electrical system to discharge. There is also no guarantee that isolation points will be accessible to emergency personnel in every EV or LEV incident.

37.4 There is very limited research and data relating to the extrication of occupants from EVs. In particular, research gaps exist in areas such as how to protect trapped occupants and emergency services personnel from risks such as spontaneous or unexpected thermal runaway events or toxic and/or explosive gas venting that might occur during a protracted rescue.

37.5 Accepted methods of extrication from vehicles may increase risks during a rescue. For instance, the removal of a dashboard from a trapped occupant often involves the use of jacks or other devices that are supported pillars or parts of the floor of a vehicle. In the case of EVs, where battery packs are mainly located under the floor, there is a risk that the battery pack will be dented, deformed or punctured during an extrication – carrying with it the risk of a thermal runaway event and fire during the course of a rescue.

37.6 A proportion of EVs are sold with heavily laminated windows, sunroofs or other glass panels. The use of laminated glass, particularly for driver and passenger windows, as opposed to tempered glass means that it is more difficult to break a window for the purpose of extricating a trapped occupant or ventilating a vehicle that is collecting gas within its cabin.

37.7 Risk of gas explosion or deflagration – some of the gas products emitted during a thermal runaway of fire event can cause explosion or deflagration. Hydrogen gas is one of those products. So to are the organic carbonates contained in Li-ion battery electrolytes, which have similar explosion characteristics to propane.[16] Generally when the gaseous products are released within a room or a building, they can cause what is known as a "confined vapour cloud explosion". If the gaseous products are allowed to escape into the atmosphere, they can cause an "unconfined vapour cloud explosion". There are, however, two aspects to the vapour cloud explosions that are worth noting. Firstly, where there is an unconfined vapour cloud explosion, the cloud that explodes can be lighter than air (in the case of hydrogen) or heavier than air (in the case of the organic carbonates). That is to say, there are in fact two separate clouds that can cause an explosion that need to be managed. Secondly, the concept of confinement is not limited to rooms and buildings. Where an EV or HV are involved in a fire or a thermal runaway event, the gaseous products can be discharged into the vehicle's cabin, where pressure increases, and the effects of the explosion are "magnified". There are two overseas examples of such a confined gas cloud explosion, and its effects. Footage of a Belgian incident can be viewed here: https://www.youtube.com/watch?v=aLtkTp4GVuE (from 2.43 mins to 3.16 mins). Photographs of a German incident can be viewed here: https://www.youtube.com/watch?v=dc6CIITqW20 (at 0.49-0.57, 2.48-3.11 and 4.06-4.38). With respect to the incident in Neuss, Germany, the

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[16] M Henricksen, *Explosion characteristics for Li-ion battery electrolytes at elevated temperatures* (2019) 371 Journal of Hazardous Materials 1 (https://www.sciencedirect.com/science/article/pii/S0304389419302511)

District Police confirmed that the fire and explosion was caused by a defect in the EV's battery.[17]

37.8 There are well documented risks associated with delayed ignition and re-ignition of Li-ion battery fires. The ignition risk can arise in two ways. Firstly, a battery may be damaged but not immediately ignite or eject gases. In the case of a road crash, there is a risk that the battery may begin to vent or ignite during an extrication. Where a battery has been on fire and the fire has been suppressed, there is a risk that the chemicals and energy in the battery have not been fully combusted or discharged. That poses a risk to automotive workers in the course of towing, storing and reparing EVs and HVs. The risk of reignition can remain for days or weeks after a fire event.

37.9 We are yet to see the full spectrum of what can occur in the course of collisions, accordingly, there is a degree of uncertainty as to what risks are likely to be posed. For instance, battery packs can be torn by the force of a collision and expel their battery cells onto roads;[18] battery packs themselves can be damaged so as to expose the energised cells within them; electrical insulation protection can be damaged by the forces associated with a collision;[19] parts of the high voltage electrical system can be crushed or exposed; isolation methods can be irreparably damaged. Examples of some of the possibilities referred to above were the subject of a presentation by Underwriters Laboratories in 2021, which can be viewed here: https://ul.org/sites/default/files/2021-04/UL_FF_Issues_20210416WEB.pdf. Data capture, information sharing and training can only anticipate so far, and some risks will only be capable of identification in the moment.

37.10 Current domestic and commercial firefighting operations, in particular methods of entry, have limitations due to the behaviour of Li-ion battery fires. For instance, in the case of a domestic fire, upon entry one can see the "neutral plane". Hot smoke and gases will usually be in the upper part of the room, and cooler air being drawn into a room will be in the lower part of the room. The

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[17] Media report: https://www.spiegel.de/panorama/neuss-defekter-e-auto-akku-loeste-explosion-aus-a-f0533b58-90cf-4cf1-91d6-816f8fa39416; District Police press release: https://www.presseportal.de/blaulicht/pm/65851/5591426

[18] https://www.nfpa.org/news-blogs-and-articles/nfpa-journal/2020/01/01/ev-stranded-energy?l=866.

[19] T Werling, et al, *On a Dynamic Electro-Mechanical Failure Behaviour of Automotive High-Voltage Busbars Using a Split Hopkinson Pressure Bar* (2021) 14 *Materials (Basel)* 6320 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8585170/).

layer between the floor and the start of the smoke layer is the area firefighters use to see into a room as visibility is generally good. In the case of a Li-ion battery fire, where gases are released that are both heavier and lighter than air, visibility at floor level is significantly reduced or zero. Further, the gases at the lower level are highly toxic. Prior to entering a room, it will generally be cooled by water mist. If hydrogen fluoride gas is in the upper level of the room, the gas will dissolve into the water mist spray and become aqueous hydrofluoric acid. There are also serious risks of deflagration or explosion of gases in confined space firefighting operations. There are analogous examples where firefighters have sustained injury when entering or suppressing fires within Battery Energy Storage Systems. One example having occurred in Arizona, USA;[20] and, another having occurred in Brisbane, Qld.[21]

Adequacy of training and equipment for automotive workers and emergency services

38. The current state of training and equipment is inadequate to protect against the potential hazards of EVs and HVs. The inadequacy can partly be explained by the lag between the emergence of a new technology at a rapid rate and the time it takes to react to the potential hazards posed by the technology. It takes time to develop training packages, assess risks and account for the types of hazardous situations that might arise. A partial explanation may also be the sheer complexity and amount of information that is available, and the concomitant time it takes to properly assess and understand it. Those matters do not amount to a complete explanation. There are inadequacies that can only be explained by a lack of understanding, a lack of curiosity, a failure to make proper inquiries with appropriate specialists, a lack of research or data, the absence of rigorous examination of current practices and ignorance.

39. During our research and development phase, we have identified a number of those inadequacies. Our research has extended to an examination of photographs, videos, incident reports and media reports of EV and HV fire responses and hazmat clean up; a review of international regulatory reports on EV and HV incidents; a review of academic literature; discussions with emergency services personnel; a review of international literature and instructional material relating to EVs, HVs, and emergency

[20] M McKinnon, et al, *Four Firefighters Injured in Lithium-ion Battery Energy Storage System Explosion – Arizona*, UL Firefighter Safety Research Institute (https://cdn.bfldr.com/D35SAQ1Q/as/m7chrn9wg6kxbq39k3bc/Four_Firefighters_Injured_in_Lithium-Ion_Battery_Energy_Storage_System_Explosion_-_Arizona)

[21] NSW Association of Fire Investigators, *Case Study: Griffith University Battery Energy Storage System (BESS) Thermal Incident* (https://www.youtube.com/watch?v=CDTbdZwBNXg).

responses including rescue; and, a review of publicly available response guidelines issued by emergency response agencies throughout Australia.

40. We have identified a number of pressing matters that are relevant to the safety of automotive workers and emergency services personnel. Those matters include, but are not limited to, the following:

40.1 A number of responding agencies currently use nitrile gloves during and after responses to Li-ion battery fires to protect against skin contact with toxic chemicals. Presumably, nitrile gloves are used because it has been identified that hydrofluoric acid poses a serious risk to human health, and nitrile gloves are capable of protecting against hydrofluoric acid. It may also be that agencies have relied upon MSDSs issued by manufacturers of products powered by Li-ion batteries, some of which recommend the use of nitrile gloves. Nitrile gloves provide adequate protection against aqueous hydrofluoric acid in its pure form. Nitrile gloves have been proven to offer little to no protection against the most common electrolyte mixture contained in Li-ion batteries, which in turn permits the permeation of hydrofluoric acid through the gloves to occur.

40.2 A number of training packages, instructions and MSDSs recommend the use of sand to absorb electrolyte spills or the reaction products of electrolyte spills and fires. Whilst sand is generally considered to be an inert sorbent for a number of chemical spills, sand reacts with hydrofluoric acid to form highly toxic silicon tetrafluoride gas.

40.3 Training and instruction about the hazards of gases and particulates discharged by Li-ion battery fires is rudimentary at best. So far as we have been able to gather, it amounts to identification of the fact that expelled gases and the electrolyte might be toxic or dangerous, and contact with the gases and electrolyte should be avoided. The real risks of acute exposure to fluoride products and heavy metals are not sufficiently brought home to automotive workers or emergency services personnel. Nor are the real risks of chronic exposure sufficiently explained.

40.4 There is very limited research, information and training related to rescue operations and extrication of persons from EVs and HVs, and the risks posed by those operations. Similarly, training packages offered to automotive workers need to extend to instruction on high voltage electrical safety and co-worker rescue and first aid operations. Those training packages are not offered to all participants in the industry, particularly all participants who will be dealing with EVs and HVs after a fire or an accident.

40.5 So far as we have been able to ascertain, FRNSW is the only agency in NSW that has centralised uniform washing and decontamination systems for most PPE used by firefighters. That system does not appear to be available to other accredited road crash rescue units. Nor does it appear to be available to RFS firefighters, notwithstanding that a number of RFS brigades are responsible for village and car firefighting operations. Rescue units and firefighters (other than those employed or retained by FRNSW) are expected to wash their own uniforms and PPE. Those arrangements pose risks that: uniforms and PPE will not be properly laundered after a contamination event; improperly laundered uniforms and PPE will retain hazardous chemicals, and become an agent for chronic exposure; and, persons living in the same household as emergency services personnel who wash contaminated uniforms and PPE at home will be chronically exposed to toxic chemicals whether by the uniform being brought into the home or being laundered in shared machines.

40.6 A number of training packages and instructions suggest that EV and HV high voltage battery packs can be isolated by disconnecting the negative terminal of the 12-volt battery system. The logic behind that instruction is that disconnecting the 12-volt battery will cause the high voltage connectors/relay to open, thereby isolating the battery. That is inaccurate. Some EVs and HVs have multiple 12-volt or auxiliary batteries. Some EVs required synchronous disconnection of multiple 12-volt battery systems. Some HVs do not have 12-volt batteries. Instruction to the above effect is contrary to manufacturers' recommendations in many cases. The instruction also doesn't take into account the many different (and non-standardised) methods for battery isolation, such as the use of cut-loops, fireman's loops, pull fuses, kill switches and "manual service disconnect" removal. In the latter case, the "manual service disconnect" is a method by which mechanics isolate the high voltage battery when servicing a vehicle. Some training instructions make reference to using the "manual service disconnect" method in emergency settings, however, do not sufficiently inform emergency services personnel that the method should only be used by qualified automotive workers who have training in high voltage operations, and are wearing or utilising appropriate high voltage PPE.

40.7 There has been little to no published data relating to injuries sustained by automotive workers while working on EVs and HVs. Similarly, there are few studies or research papers addressing the issue. The absence of evidence or research in the area should not be taken to be evidence of absent risk. The area is developing and has not assumed the same importance as other areas of research relating to EVs and HVs. It has been inferred, based on data relating to injuries sustained by battery energy storage system workers, that the risk of automotive worker injury by arc flash is more probable than injury by electric shock.[22]

40.8 A number of responding agencies do not have the ability to measure the full suite of gases that can be discharged during a thermal runaway event or a fire. Of most concern is that a number of responding agencies do not have the ability to measure for the presence of hydrogen fluoride gas, nor test for the presence of hydrofluoric acid.

40.9 Some post-fire instructions refer to immersing a damaged Li-ion battery in water to cool it in order to arrest or slow thermal runway, without sufficient warnings as to the risks of: fire occurring while the battery is immersed, given batteries capable of producing their own oxygen; reaction between the electrolyte and water causing the formation of hydrogen case; continued emission of hydrogen gas and other gases capable of causing an explosion; and, the generation of hydrogen gas by the process of electrolysis.

Risk Mitigation

41. There are a number of practical steps that can be taken to ensure risks are properly being identified, characterised and managed. We respectfully submit that such steps could include:

41.1 Ongoing monitoring of FRNSW and RFS officers who have attended, or attend, EV, HV and Li-ion battery fires for the presence of heavy metals, PFAS and fluoride in blood and urine.

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[22] V Linja-aho, *Electrical accident risks in electric vehicle service and repair – accidents in Finland and a review on research*, April 2020, 2020 Transport Research Areana Conference (https://www.researchgate.net/publication/339875411_Electrical_accident_risks_in_electric_vehicle_service_and_repair_-_accidents_in_Finland_and_a_review_on_research)

41.2 Review by State Rescue Board Accredited Rescue Units having responsibility for road crash rescue to ascertain whether PPE, SOPs, decontamination procedures, pollution management controls and PPE laundry procedures are fit for purpose.

41.3 FRNSW, NSWRFS and NSW Ambulance to consider whether current PPE provisions are appropriate to the risks of injury (including by contamination by patients)

41.4 Review by FRNSW and RFS to ascertain whether SOPs, decontamination procedures, pollution management controls and PPE laundry procedures are fit for purpose.

41.5 Review by all State Rescue Board Accredited Rescue Units having responsibility for road crash rescue to ascertain whether extrication techniques, equipment and SOPs are fit for purpose.

41.6 NSW Health and NSW Ambulance to consider whether current clinical guidelines sufficiently set out the risks associated with HF exposure and fluoride toxicity, and the possibility of delayed effects of exposure, in circumstances where patients have been exposed to a burning Li-ion battery or Li-ion battery electrolyte.

41.7 NSW EPA and LGAs to consider whether fire fighting runoff pollution management techniques, procedures and regulations are fit for purpose, given the additional hazards posed by runoff associated with Li-ion battery fires.

41.8 Review by all State Rescue Board Accredited Rescue Units having responsibility for road crash rescue, FRNSW and NSWRFS as to whether gas detection and measurement devices are sufficiently deployed and fit for purpose.

41.9 SafeWork NSW to consider whether it is appropriate to issue a Code of Practice under Part 14, Div 2 of the *Work Health and Safety Act 2011* (NSW), or other guide or resource, specifically dealing with the management of risks associated with Li-ion batteries in EVs, HVs and other mobile plant powered by Li-ion batteries.

41.10 SafeWork NSW, TAFE and any other relevant organisation to consider whether and to what extent training packages provided to emergency services personnel, automotive workers, waste disposal workers, battery recycling workers, towing and salvage workers, and the like contain sufficient education and warnings about the risks of hazardous chemicals and gases, in particular hydrogen fluoride gas and gases capable of causing an explosion.

41.11 Consideration be given to:

41.11.1 Amending r 144B of the *Road Transport (Vehicle Registration) Regulation 2017* (NSW), requiring the fixing of a conspicuous label to all electric and hybrid vehicles, regardless of date of manufacture or conversion, rather than limiting the application of the regulation to electric vehicles manufactured or converted after 1 January 2019.

41.11.2 Amending the *Road Transport (Vehicle Registration) Regulation 2017* (NSW); *Vehicle Safety Compliance Certification Scheme Declaration of Modification or Class of Modification Order 2013* (NSW); or, any other relevant legislation, mandating the registration (with ServiceNSW, ANCAP or both) of emergency response information (in the case of manufacturers) or design schematics (in the case of conversions) for all registered electric or hybrid vehicles, regardless of age.

Other related matters

42. There are a number of other matters that are relevant to the issued raised by the Committee’s Terms of Reference.

43. The technology is emerging and changing rapidly. The state of knowledge and research is also developing rapidly. The Committee’s inquiry into the issues presents an opportunity to develop a firm base upon which the risks associated with EVs, HVs and related technologies might be understood and managed. The safety and management issues associated with EVs and HVs are equally relevant to the emergence of large Battery Energy Storage Systems, home and solar panel batteries, and other Li-ion powered devices, plant and other technology. The nub of the issue is that EVs, HVs and other Li-ion battery powered technologies carry the risk of serious

harm. ICEVs and other devices powered by more “traditional” fuel types also carry risks of serious harm. However, the risks posed by EVs, HVs, and other Li-ion powered plant and devices are different to those posed by ICEVs and the like. Accordingly, they need to be managed differently.

Other and Emerging Risks

44. There are aspects of the technology, its use, and the industry that pose risks which may not be immediately apparent, are developing, or have not yet occurred in Australia.

45. One circumstance that has arisen internationally involves the provision of e-bikes and e-scooters to the public. In the main, there is no infrastructure for charging such devices at street-level pickup and drop off points. A business practice has arisen whereby businesses remove batteries from LEVs at night when use is low, and replace them with fully charged batteries. The removed batteries are then taken to a central point, which can be residential or industrial, and large amounts of batteries are charged. Repairs are also undertaken at such sites.

46. Closer to home, on 31 May 2021, fire crews responded to an e-scooter recharging facility in Fyshwick, ACT (see: https://www.youtube.com/watch?v=l-shpX3QNm8). A review of media reports relating to e-scooter trials in NSW suggests that a majority of the e-scooters provided in the trials contain swappable batteries. A search for “e-scooter” related jobs on www.seek.com.au returns a number of roles that involve the swapping of e-scooter batteries. There is little to no publicly available information (or, at least information available to emergency services personnel) about where batteries are in fact charged, or repairs are conducted. There is little to no publicly available information as to the fire protection measures taken by such businesses, or whether local fire brigades are in fact aware of the presence of such facilities in their areas of responsibility.

47. An example of the materialisation of risks posed by LEVs occurred in a Manhattan apartment block on 5 November 2022. In that case, residents were carrying on an e-bike and e-scooter repair business within their apartment. Whilst charging, an e-bike caught fire causing an intense blaze within the apartment. The seat of the fire was near the entry door to the apartment, accordingly, the residents were not able to escape via the door and firefighters were prevented from entering the apartment through the door to effect a rescue. In the result, the residents were rescued from their twentieth

floor apartment by way of a rope rescue, and thirty-six patients (including four firefighters) were conveyed to hospital. The Fire Department, City of New York prepared a short video relating to the fire response, which can be found at: https://www.youtube.com/watch?v=nPmlF36yP0U.

48. The exposure to risk is not limited to emergency services personnel and automotive workers. At present, there are a number of businesses who provide EV conversion services. It also may be expected that owners of EVs and HVs will conduct repairs, upgrades, conversions and make other additions in their own homes. It is likely that a second-hand market for EVs, HVs, and their battery packs will emerge in a manner referable to the number of EVs and HVs in the market.

Heavy Vehicles, Plant and Other Vehicle Types

49. Putting aside EVs, HVs and LEVs, there are a number of other vehicles that will become relevant as they enter the market. At present, Li-ion powered buses, trucks, prime movers, refrigeration trucks and other heavy vehicles are being introduced into the Australian market. Li-ion powered mining vehicles, industrial forklifts and other heavy plant also exist within the market.

50. In Finland, there are businesses who offer autonomous delivery vehicles that are powered by Li-ion batteries to deliver groceries and food. Only a few weeks ago, BMW signed a commercial agreement for a milestone-based introduction of Li-ion battery powered humanoid robots into its production line, commencing in Spartanburg, South Carolina, USA. Offroad EVs and Li-ion battery powered ride-on lawn mowers and slashers are available in the Australian market. Agricultural equipment manufacturers are in the process of developing Li-ion batter powered tractors, heavy duty ploughs and other farm equipment.

51. Understanding the issues now, and setting safety and response standards now, will provide a strong base from which the government, industry and the public can manage risk as new products emerge.

Charging and Use Risks

52. A technology that is currently available in Australia for Li-ion battery powered trucks, and will likely become more widely available for EVs, is a “swap-in swap-out” battery system. Rather than charging a single battery pack in an EV or truck at a charging point, swap-in swap-out technology allows the driver to (in the case of EVs) drive into

a site, have their old battery pack removed and replaced with a fully charged battery pack by a machine. A similar technology is currently available in the Australian market for certain trucks. In that case, the batteries are extremely large and heavy, and can only be removed and replaced by a forklift (which carries its own dangers of puncture or damage). We understand that there are systems whereby removed batteries are charged, and then used with other batteries as a Battery Energy Storage System to power industrial sites, until such time as they are swapped back into a truck. There is limited information available to responding agencies as to the location, configuration and fire suppression methods at such sites.

53. A number of EVs in the market contain V2L (Vehicle to Load) systems, which are connected to AC power points, not dissimilar to a domestic power point. We understand from our inquiries and research that there have been instances where people have been found cooking food in their cars or powering other appliances while the car is in motion. We also understand that there have been instances where worksites and tools have been powered by plugging them in to EV battery systems. It must be said that those reports were anecdotal and not subject to independent verification. However, they are examples of risks to persons who, for instance, may assume that a worksite is not energised due to the absence of a mains power connection.

54. It is anticipated that risks associated with charging stations will start to materialise in the near future. Based on our own observations and research, there are a number of safety issues that are unaddressed. ICEVs are generally filled with petrol at a central site. Those sites, such as service stations, have a number of safety features to mitigate the risk of fire and spills. For instance, there are generally multiple shut off points located well away from bowsers. There is fire suppression equipment located around service stations. There is generally bunding and spill response kits to prevent the discharge of petrol into stormwater and waterways. They are generally configured in such a way that access to a burning bowser, car or building is relatively easy. A small car fire is capable of being extinguished completely by a hand held fire extinguisher.

55. In contradistinction, the risk profile associated with emergency responses to EV and HV fires has changed. Charging stations can be located in apartment buildings, hotels, airports, and other public places. There are approximately 1,000 public charging points in NSW, and it is current policy to expand to 30,000 sites by 2026. We have observed that there are currently charging sites in NSW that: do not have collision prevention

bollards to prevent cars from colliding with them; do not have any fire suppression equipment in their vicinity; do not have emergency shut off switches; have emergency shut off switches on the charging point, rather than at a more remote point where it can actually be accessed in the event of fire; do not have insulating material around them to protect against electrical leakage; are attached, or immediately adjacent, to power poles; and, have no indication of the voltage or other electrical risks associated with them, despite a lack of standardisation. There are products in the market that allow users to padlock charging cables to their cars to prevent theft. Some EVs also have a function whereby they "grip" the charging plug when it is connected and the car is locked.

56. It is important that these matters are addressed in the interests of public safety and utility. By way of example, if a responding agency is called to an EV fire, and the EV is connected to a charging point that does not have an emergency shut off switch or an accessible shut off switch, water will generally not be applied until such time as the charging point has been de-energised. That process involves calling the relevant electricity supplier, arranging for a technician to attend, and having them isolate the electricity supply in the area. In the case of charging points located on streets, isolation of the power supply would necessarily involve the shutting down of power to the block or blocks adjacent to the charging station.

Regulatory Powers

57. The regulatory environment appears to be sufficient to deal with mitigating risks associated with environmental and public health in the aftermath of a fire. The provisions contained in section 91 of the *Protection of the Environment Operations Act 1997* (NSW) and section 124 of the *Local Government Act 1993* (NSW) are two examples of such powers. Having said that, there are two ways in which those powers might be supported.

58. Firstly, it would be prudent to establish a reporting mechanism, whereby responding agencies are required to notify Environmental Health Officers within local councils, or the NSW Environment Protection Authority where appropriate, of EV and LEV fires.

59. Secondly, it would be prudent for NSW Health, Safe Work NSW and/or the NSW Environment Protection Authority consider whether remediation guidelines should be issued in a form similar to the *NSW Remediation Guidelines for Clandestine Drug*

Laboratories and Hydroponic Drug Plantation[23] to assist relevant agencies and remediation consultants in the assessment and management of potentially contaminated sites.

60. The State Coroner is seized with the jurisdiction to hold an inquiry into the cause and origin of a fire or explosion, where the fire or explosion has destroyed or damaged property in NSW (*Coroners Act 2009* (NSW), Pt 3.3). There are also powers capable of being exercised by the Commissioner of New South Wales Fire Brigades and the Commissioner of the NSW Rural Fire Service to, in effect, compel a general coronial inquiry into a fire or explosion in NSW (see: *Coroners Act 2009* (NSW), s 32(4)(a)).

61. Part 9 of the *Environmental Planning and Assessment Act 1979* (NSW) contains a number of inspection, entry, information request and enforcement powers that are capable of being exercised by public officers and agencies, including local councils, the NSW Environment Protection Authority and the Commissioner of NSW Fire Brigades. Parts 9 and 10 of the *Work Health and Safety Act 2011* (NSW) also confer powers capable of being exercised to regulate work practices in the industry.

62. It would be appropriate for relevant enforcement agencies to consider whether their existing powers are being properly exercised to mitigate against the risks posed to emergency services personnel, automotive workers and the general public.

[redacted]

Matthew Davis
Director, Encap Fire & Safety Pty Ltd
Ph: [redacted]
Email: [redacted]

[redacted]

Adam Davis
Director, Encap Fire & Safety Pty Ltd
Ph: [redacted]
Email: [redacted]

[23] https://www.health.nsw.gov.au/environment/hazard/Documents/clan-lab-guidelines.pdf