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Dec. 16, 2024

Office of the Fire Marshal (Emergency Management Ontario)
Ministry of the Solicitor General
25 Morton Shulman Avenue
Toronto, Ontario
M3M 0B1

Subject: Safety of the Public and First Responders in the event of a Lithium Ion BESS Fire

In Ontario, the IESO (Independent Electrical System Operator) has already issued approval for the installation of over 1880 MW / 7500 MWh of Battery Energy Storage Systems (BESS) as part of the Long Term – Request for Proposals (LT1 – RFP), and is currently finalizing the next stage of the Long Term – Request for Proposals (LT2-RPF) for an even greater BESS installation.

Elected members of council of municipalities who are part of the Multi Municipal Energy Working Group, which I serve as Technical Advisor have expressed concern for the safety of members of the public and first responders in the event of a fire at a BESS facility. Such fires have occurred already at smaller BESS facilities in Ontario, and at larger facilities internationally. Some of the BESS facilities now approved by the IESO are yet larger, further increasing the risk. Through participation in the IESO RFP Community Engagement webinars, questions were asked regarding risk to public safety and safety of first responders. The IESO responded by forwarding a link to the document, "Solar Electricity and Battery Storage Systems Safety Handbook for Firefighters" (the Handbook) prepared by the Canadian Renewable Energy Association (CanREA) in collaboration with the Ontario Association of Fire Chiefs (OAFC).

Review of the Handbook identifies many concerns. These concerns will be identified in an attachment to this letter. The Handbook provides inadequate consideration of public safety related to fires in BESS facilities, and downplays the risk faced by first responders. Without intending to impugn the integrity of an industry advocacy group which has the stated objective of furthering deployment of BESS systems in preparing the Handbook, it leaves one wondering about the wisdom of the idiom of "leaving the fox guarding the henhouse."

This request is sent to the Office of the Fire Marshal, of the Ministry of the Solicitor General, charged by the Fire Protection and Prevention Act to co-operate with any body or person interested in developing and promoting the principles and practices of fire protection services, or to take action to remedy or reduce the threat to public safety. This request calls for urgent action, as installation of BESS systems such as the 400 MW / 1600 MWh Neoen Ontario Tara BESS (formerly known as the Shift Solar Grey Owl BESS) have been approved for installation in the municipality of Arran Elderslie. The approval did not even require notification of residents of the neighbouring municipality of Chatsworth, even though the nearest not-notified residence is within about 100 metres of the optioned land. Neither was consideration required of the capability of the 25 volunteer fire fighters of the Tara detachment of the Municipality of Arran Elderslie Fire Emergency Services to cope with a possible fire in this BESS facility, at 1600 MWh nearly 4 times larger than the 450 MWh Neoen "Victorian Big Battery Facility" in the State of Victoria in Australia, which required deployment of 150 firefighters when part of that BESS caught fire, and burned for 4 days. The handbook identifies, "Water is considered the preferred agent for suppressing lithium-ion battery fires." Firefighters would need to deliver water by tanker to the site, and the run-off would discharge to the Sauble river, covered by Ontario Source Water Protection, which flows through the site of the BESS.

Attachments refer to the findings of the EV FireSafe study, developed for the Defence Science and Technology Group, of the Australian Government, Department of Defence. Findings from that study, identified the risk from lithium-ion batteries (such as the 60 to 100 kWh batteries in current Tesla Electric Vehicles.) However, the risks summarized in the EV FireSafe study are relevant to the much larger battery approved for installation in the Tara BESS. For comparison, in the case of the auto carrier Felicity Ace, which sank off the coast of Portugal in Feb. 2022, an intense fire propagated through the 3,828 carried automobiles (some of which were EV's). This was only one of a number of car carrier fires on ships carrying EV's, some of which resulted in loss of life. The Tara BESS is the equivalent of 16,000 to 26,000 stacked EV batteries. In summary, the EV FireSafe study found:

- Toxic vapour cloud of flammable gases pose respiratory and explosion risk (to first responders and the neighbouring public)
- Thermal runaway makes it difficult to extinguish the fire
- Even once suppressed, there is a risk of fire re-ignition, hours or days later
- Lithium ion battery fires are not yet well understood by emergency agencies

The Office of the Fire Marshal is requested to review the concerns identified in the attachments related to the "Solar Electricity and Battery Storage Systems Safety Handbook for Firefighters" and to give direction to the IESO and impacted municipalities before the ongoing installation of Ontario BESS facilities continues. Possible resources that might be consulted in the Fire Marshal Review are identified in a further attachment.

With respect,

William K.G. Palmer P. Eng.

Attachments:

1. Concerns identified in review of the "Solar Electricity and Battery Storage Systems Safety Handbook for Firefighters."
2. Findings identified in the EV FireSafe study conducted for the Australian Government, Department of Defence.
3. Additional Resources and References for Consideration in Revision of the "Solar Electricity and Battery Storage Systems Safety Handbook for Firefighters."

Copied to:

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Steve Tiernan – Fire Chief – Arran Elderslie Fire and Emergency Services (via website)

Steve Hammell – Mayor Municipality of Arran Elderslie shammell@arran-elderslie.ca
(c/o Emily Dance – Chief Administrative Officer edance@arran-elderslie.ca)

Scott Mackey – Mayor Township of Chatsworth scott.mackey@grey.ca
(c/o Patty Sinnamon – Chief Administrative Officer patty.simmamon@chatsworth.ca)

Tom Allwood – Chair Multi-Municipal Energy Working Group
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Attachment 1 - Concerns Identified With
Solar Electricity and Battery Storage Systems
Safety Handbook for Firefighters

William K. G. Palmer P. Eng.

The "Handbook" developed by the Canadian Renewable Energy Association (CanREA) in partnership with the Ontario Association of Fire Chiefs, was announced in a September 6, 2023 press release.

https://www.oafc.on.ca/sites/default/files/MediaReleases/2023-09-06 Press Release - Solar Electricity and Battery Storage Systems Safety Handbook.pdf

The Handbook itself is available via this link.

https://www.oafc.on.ca/sites/default/files/Solar Safety/FINAL 2022 Solar Electricity and Battery Storage System Safety Handbook for Firefighters April 2023.pdf

A significant challenge is that while the press release states that the handbook, *"addresses the pressing need for up-to-date safety guidelines,"* and continues, *"the handbook prepares firefighters for potential hazards that might arise during emergency situations involving solar PV and battery storage systems,"* the descriptions, examples, and photographs deal primarily with smaller residential scale systems. Other than for a few photos of larger solar arrays of panels, and photos of BESS fires on P25 and P33, the bulk of the material and descriptive photographs of electrical disconnect equipment on Pages 6, 7, 8, 11, 12, 26, and 33 show smaller residential scale equipment. The specific electrical hazards of Battery Energy Storage Systems (BESS) connected to high voltage transmission lines, and battery arrays that may cover acres, are very poorly described. A firefighter whose training was based on the handbook would be very inadequately prepared to deal with BESS installations, in spite of what the press release says.

While the handbook definitions for BESS on page 2 defines the Battery Management System (BMS) noting that it *"monitors, controls and optimizes performance of an individual or multiple battery modules in an ESS and can control disconnection of the module(s) from the system in the event of abnormal conditions,"* there is no information on the necessity to contact the system operator to ensure BESS shutdown, and for information about hazards (such as toxic gases) before approaching the system. The closing thought of the Introduction on page 3, identifying the desirability *"for Fire Departments to be aware of existing large-scale battery and solar projects operating within their jurisdiction, and work with operators to be sure they are aware of any unique safety and emergency response procedures for projects in their area,"* is a bit understated and should be reinforced.

The handbook provides a reasonable description of individual Photovoltaic (PV) systems on Pages 4 through 13. Although it does not address the particular risks of larger scale (farm sized) solar arrays that may incorporate acres of installed PV panels, discussing those risks is not the intent of this document, focused on inadequate coverage of BESS concerns in the handbook.

Page 14 initiates the discussion of Battery Energy Storage Systems (BESS). It gives a brief description of the system building blocks of battery cells, battery modules, and battery racks. The description is incomplete as it does not explain that in a larger sized BESS, the battery racks will be typically assembled together into container sized parcels, often with their individual Battery Management Systems, charge controllers, and inverters, whose output is then paralleled to feed into (a) high voltage step up transformer(s), then to connect via appropriate switchgear to the high voltage transmission grid or distribution system.

Pages 15, 16, and 17 briefly outline three types of batteries for a BESS, as Flooded Lead Acid, Valve Regulated Lead Acid, or Lithium Based Batteries. The handbook does not identify that the Flooded Lead Acid batteries or Valve Regulated Lead Acid batteries were the system of choice in older, smaller scale installations, as might be used for starting backup generators, or supplying uninterruptible power supplies for computers or telephone systems, but that lithium Based Batteries are the more likely to be the encountered system in modern larger "utility-scale" Energy Storage Systems.

The handbook fails to identify that the significant difference between the battery types that impacts the risk of each is the stored energy density of each type. While Lead Acid batteries typically have a stored energy density of 30 to 50 Wh/kg, Lithium Based battery can have a stored energy density of 150 to 250 Wh/kg. This up to 8 times greater stored energy density impacts the release of energy (and heat) in combustion, greatly increasing the challenge of suppressing the released heat.

It is only in the last lines of the description of Lithium Based Batteries on Page 17, that the risks of these batteries, as used in BESS currently being installed under the Independent Electricity System Operator (IESO) Long Term – Request for Proposals (LT1-RFP) and (LT2-RFP) are first discussed. *"These batteries are high energy density, but have temperature limitations. There are more safety concerns with lithium-ion batteries since they contain flammable electrolytes, and if damaged or incorrectly charges can lead to explosions and fires."* The description lacks the warning that charging these batteries if too cold, or too hot increases the risk of formation of a sharp crystalline structure (dendrites) that can penetrate the separator between the anode and cathode, and result in the uncontrolled heating of thermal runaway. The description of the hazards is expanded on Page 25, in the continuation that, *"Lithium-ion batteries deliver good energy density in a small, cost-effective footprint, however that comes with a risk. When a lithium-ion cell fails, or is subjected to abuse, a potentially catastrophic event known as thermal runaway can occur, where chemical energy is converted to thermal energy. Once an ignition threshold is reached, the process will continue to propagate, or spread, from cell to cell consuming the BESS, and where adjacent structures are present, potentially facility wide."* Again, this description does not identify that this catastrophic event can be caused by charging when too cold, or if the cell gets too hot, or that the risk is enhanced if the cells are maintained at a high state of charge, as they will by design in a BESS.

The only hazard discussed in the handbook on Page 29 under the heading "Lithium-Ion Batteries" is Thermal Runaway. This significant deficiency neglects many of the risks, even more serious ones, and needs correction. A more comprehensive description of Lithium Battery hazards is found in the report of the EV FireSafe study (Attachment 2) conducted for the Australian Government, Department of Defence, intended to enhance safety for emergency responders at electric vehicle traction battery fires (but applicable to the case of many battery modules collected together in a BESS.) The listing of hazards in the EV FireSafe study includes:

- Toxic vapour cloud of flammable gases poses respiratory and explosion risks.
- Thermal runaway makes it difficult to extinguish a traction battery fire
- Even once suppressed, there is risk of fire re-ignition (hours or days later)
- EV traction battery fires are not yet well understood by emergency agencies
- A traction battery with a state of charge of under 50% is less likely to ignite *(BESS batteries are intended to be maintained at full charge, unless discharging to supply load, when the intent would be to rapidly recharge the battery to 100% as soon as excess generation is available.)*

Nowhere in the handbook is the requirement to take action to protect citizens, from either the toxic vapour cloud, or the liquid effluent from fire suppression discussed. Here are a few recent examples of fire protection services taking action to evacuate citizens, or to advise sheltering in place, with windows closed and ventilation systems isolated in a Lithium battery fire:

- Montreal port fire – September 2024, lithium battery fire in shipping container.
    - o Firefighters evacuate ~ 100 people and warn others in Hochelaga-Maisonneuve to stay in and turn off ventilation (at distance from 1.0 to 1.75 km)

Photos from Global television website:

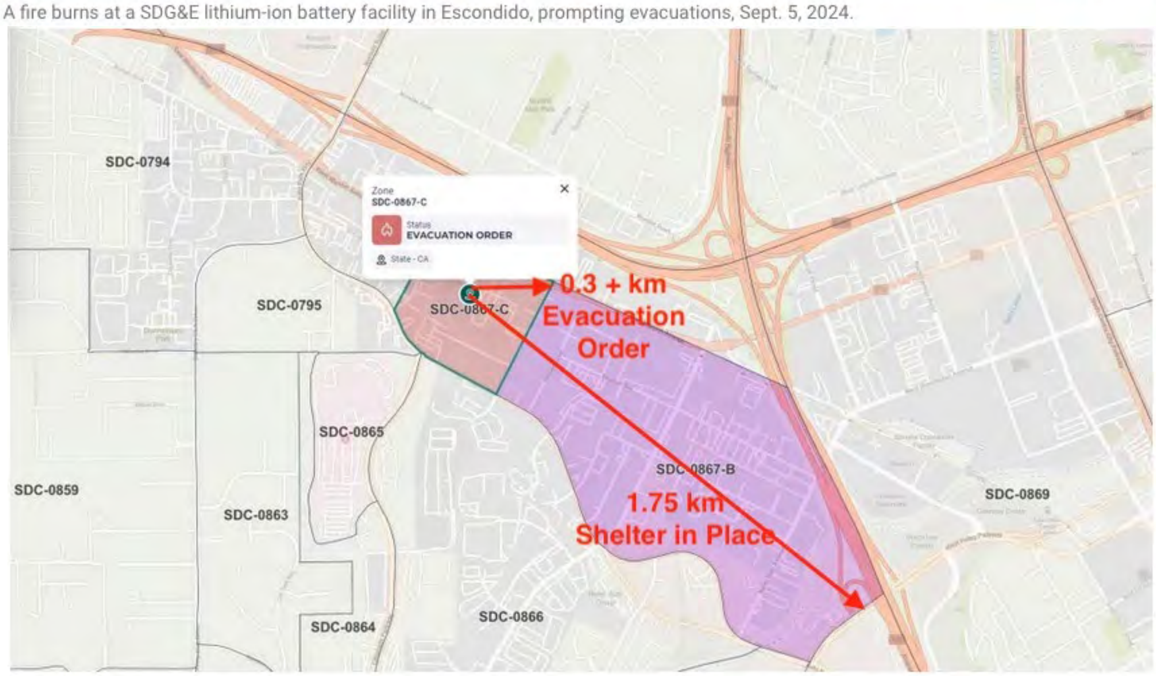
A fire at a shipping container at the Port of Montreal on Sept. 23, 2024. **Global Montreal**

Montreal's fire department goes door to door after a fire involving lithium batteries at the Port of Montreal on Sept. 23, 2024. **Global News**

- The last photo reveals a hint of the concern felt by citizens when firefighters outfitted in full bunker suits and SCBA visited their homes to advise citizens to shelter or evacuate due to toxic fumes in the air they were breathing.

- September 2024, lithium-ion battery fire at SDG&E facility in Escondido (30 MW, 150 MWh) prompted evacuations of more than 500 businesses and 1,500 SDG&E customer homes, according to the electricity agency.

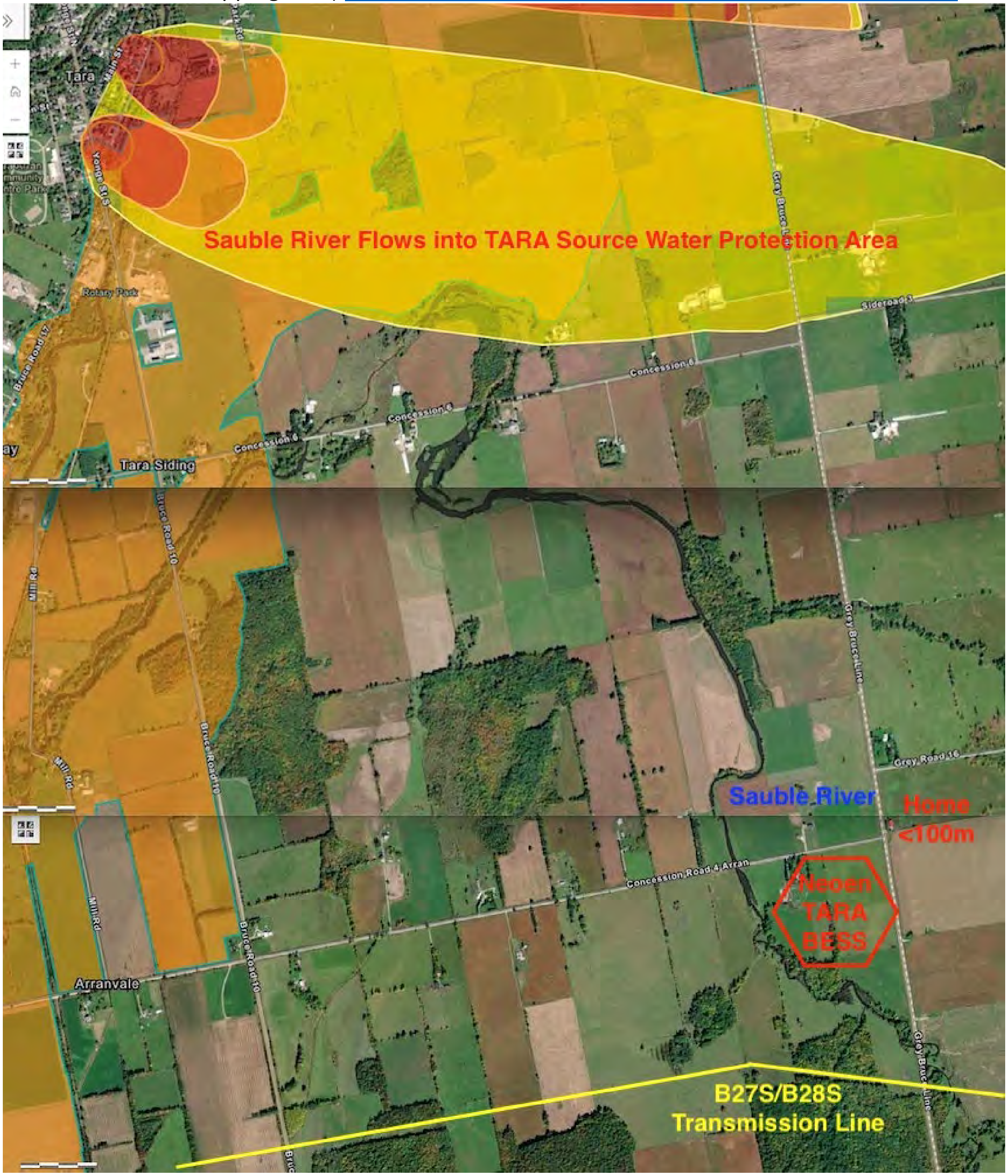
A fire burns at a SDG&E lithium-ion battery facility in Escondido, prompting evacuations, Sept. 5, 2024.



Residents in the pink highlighted area are under a mandatory evacuation order, while those in the purple area have been ordered to shelter in place.

- September 2023, as a result of a fire at the Valley Energy Storage Facility near San Diego, CA, fire officials evacuated citizens within one-quarter of a mile (400 metres) of the facility, and for those within one-quarter to one-half of a mile (800 metres) shelter in place orders were issued.

Neither does the handbook does not consider toxic liquid effluent from firefighting. Here is the NEOEN Tara BESS site (Composite Map from Drinking Water Source Protection Water - Vulnerable Areas Mapping Tool) https://home.waterprotection.ca/interactive-map-viewer/



The approved site for the Neoen TARA BESS is less than 100 m from an offsite home, and water from firefighting will drain directly into the Sauble River, upstream of a source water protected area. The site where the BESS containers will locate grew soybeans this year as an active farm.

Additional Resources and References are identified in Attachment 3 providing links and highlights from a number of relevant current publications that identify why including additional information related to hazards to firefighters and the public are required in the handbook, particularly related to toxic vapours emitted during Lithium battery fires, and to toxic effluents in the runoff water used to fight battery fires.

The handbook description of “Hazards” on Page 29 listing only “Thermal Runaway” is inadequate, as outlined in the description of Toxic gas hazards both to the firefighters and to the public. Consideration of the BESS site location, relative to neighbours, and considerations for immediate protection of downwind neighbours is an immediate concern. The recent examples shown identify evacuation of neighbours at distances in the order of 500 metres, and shelter in place for downwind neighbours, and livestock within distances in the order of 1.75 km have been used. Given that shelter in place with ventilation turned off is often not possible for livestock suggests that location of BESS installations needs to be controlled.

Neither does the handbook mention that the current design for BESS containers includes pressure relief panels. These help the containers themselves to not burst with pressure from emitted gases from the lithium ion batteries undergoing thermal runaway that usually occurs just before fire initiation. While protecting the container structure, the pressure relief panels permit immediate, unprotected release of the toxic gases to the atmosphere to impact the public, before any protective action is possible to ensure evacuation or sheltering in place.

The handbook identifies on Page 29 that “Water is considered the preferred agent for suppressing lithium-ion battery fires.” Literature based on actual Lithium-ion battery fires gives alternative opinions regarding this subject. There is general agreement that use of water to cool battery modules surrounding the module on fire may prevent the surrounding modules from heating up to also proceed to thermal runaway and fire. However, the literature identifies that in some cases, the preferred option was to permit modules actually on fire to “burn themselves out,” as adding water only extends the duration of the fire and toxic gas emission, while not actually reducing the quantity of toxic gas actually emitted. The literature also gives numerous examples of lithium battery fires which have reignited hours or even days after initially suppressed, if the battery was not fully consumed, as the fire is a result of a chemical reaction. This hazard needs to be more fully discussed in the handbook to prepare firefighters of the possibility. Both the “Best practice” of allowing a lithium battery to burn out, and the possibility of re-ignition risk are discussed in the findings of the Australian EV FireSafe study.

Literature also cautions about the consequence of lithium ion batteries that are immersed in salt water entering thermal runaway at time periods ranging from hours to weeks after the immersion. One of the referenced papers in Attachment 3 from the International Association of Fire and Rescue Services website describes that 11 EV’s and 48 lithium batteries caught fire hours or weeks after salt water wetting. The handbook does include on Page 30, under the heading BESS Tactical Considerations, that “Water from drafting or wells maybe more conductive especially if from winter roadway run-off due to contaminants, including those dissolved in water.” As water used to suppress fires in rural settings such as the Tara BESS, would be in all likelihood be derived from drafting from sources near roadways, subject to winter road salt runoff, the risk of subsequent fires in batteries not involved in the initial fire, but cooled with the drafted water needs to be expanded on in the handbook.

Although deficiencies in the handbook on Pages 29 (BESS Fire Safety Considerations) and Page 30 (BESS Tactical Considerations) have been discussed at some length, other conflicts in the material presented are also apparent.

- Page 29 identifies Suppressing Agent Choice (a subject already addressed for Lithium-ion batteries, which identifies "Water is considered the preferred agent"), while Page 30 notes, "Type of extinguishing agent – CO2 best or other inert gas, water, or dry chemical." This conflict needs to be addressed.
- Page 30 identifies, "DO NOT use foam unless electrical hazards are removed" while the literature identifies various agents, such as F-500 EA (described as an "encapsulation agent" as opposed to "foam"), added to water to enhance fire suppression. This potential item of confusion should be addressed.

In Summary:

- The "Solar Electricity and Battery Storage Systems Safety Handbook for Firefighters" does not adequately prepare firefighters for potential hazards that may be met in emergency situations involving Battery Energy Storage Systems, particularly those involving Lithium batteries
- The handbook does not adequately identify that the comparative risk in systems with Lithium batteries (compared to Lead acid batteries) is increased due to significant increase in the stored energy density
- The handbook is inadequate in describing a Lithium BESS that might be encountered by a firefighter where many "racks" of batteries are assembled into a container, and then multiple (hundreds) of containers are collected on the same site.
- The handbook is inadequate in describing that while suppressing the fire in a lithium battery is challenging, it fails to identify that the bigger challenge is to prevent the progression of the fire from module to module, and container to container by cooling batteries not involved in the initial fire.
- The handbook is inadequate at describing protective measures necessary to protect the firefighter and surrounding public from toxic gases emitted from the fire
- The handbook is inadequate at describing the hazard caused by runoff of contaminated fire protective water used to cool adjacent modules, or to suppress the active fire in modules, when that runoff water enters the environment
- The handbook is inadequate at even considering what might be identified as best practices regarding letting a battery on fire to burn itself out, while preventing fire progression to surrounding modules.
- The handbook is inadequate at describing the risk to later failure of lithium batteries if cooled with water containing contaminants, such as road salt.
- The handbook should consider additional resources and references identified in Attachment 3

Attachment 2 – Findings of the EV FireSafe Study

Relevant to the “Solar Electricity and Battery Storage Systems Safety Handbook for Firefighters”

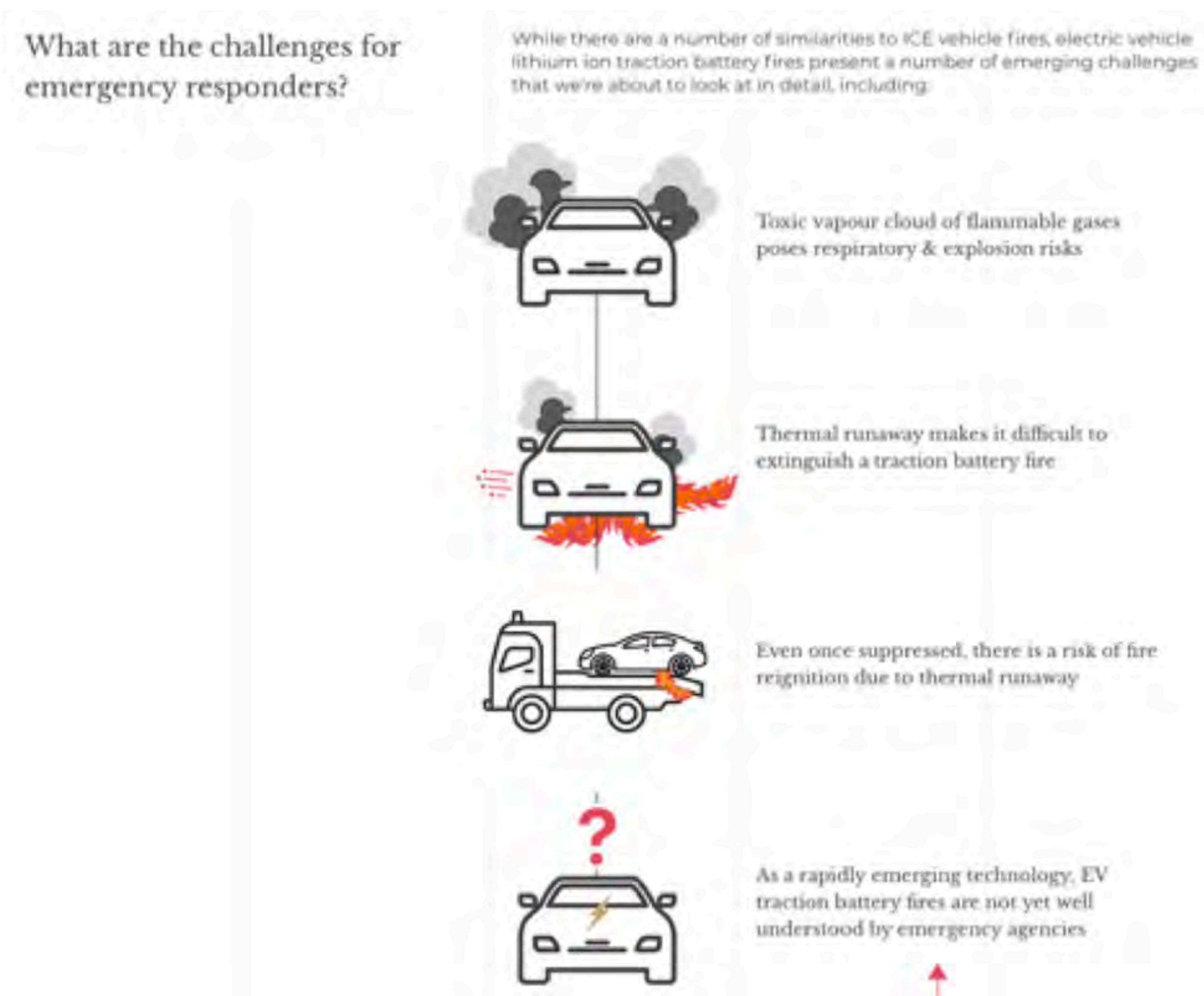
EV FireSafe – Defence Science and Technology Group, Australian Government, Department of Defence

https://www.evfiresafe.com/

Enhancing safety for emergency responders at *electric vehicle* traction battery fires

EV FireSafe is a private company that received seed funding from the Australian Department of Defence to research electric vehicle high voltage battery fires & emergency response, particularly where the EV is connected to energised charging.

https://www.evfiresafe.com/ev-fire-key-findings



02.3 What we know (so far)

Here's what our research found & what we learned from the experts*

There's a lot yet to be discovered regarding electric vehicle lithium traction battery fires - referred to here as 'traction battery fires' - but we've collated a list of the facts we think it's important for emergency responders to know now.

- **Electric vehicles are less likely to catch fire than ICE vehicles**
    a. Studies are ongoing, but evidence suggests a traction battery is less likely to ignite than ICE vehicles.
    b. Jump to EV Fire FAQs

- **Thermal runaway is how all EV battery fires start**
    a. When a battery cell experiences a short circuit, thermal runaway may occur.
    b. Jump to Thermal Runaway

- **A battery under 50% charged is less likely to ignite**
    a. Testing shows that a traction battery with a state of charge (SoC) of under 50% is less likely to ignite.
    b. Jump to Thermal Runaway

- **An EV lithium traction battery burns hotter than an ICE vehicle**
    a. A burning ICE car may reach 815-1000 degrees Celsius, an EV up to 1200 degrees Celsius.
    b. Jump to Risks - EV fires overall

- **Fire behaviour is different & presents new challenges**
    a. Recognising an EV by vapour & fire behaviour assists in early identification & management of the incident.
    b. Jump to EV Fire Behaviour

- **It's not smoke, it's a vapour cloud of highly flammable gases**
    a. When thermal runaway occurs, large clouds of flammable gases are released, primarily hydrogen.
    b. Jump to EV Fire Behaviour

- **Water is the most effective way to extinguish an EV battery fire**
    a. Lots of water to cool the battery & suppress flames is required; at least 4000 litres should be established.
    b. Jump to Suppression Methods

- **EV traction battery fires may require more resources**
    a. A longer suppression time may mean additional people, appliances & water.

- **The location of an EV battery makes fire harder to extinguish**
    a. A traction battery, located along floor pan, means the vehicle may need to be jacked up to apply water.

- **Risk of electrocution via water stream is lower than expected**
    a. An EV is not earthed, presenting low risk when using an unbroken stream of water to suppress fire.
    b. Jump to Risks - EV fires overall

- **Electrocution risk from HV cables is lower than expected**
    a. Orange cabling & components indicate high voltages, from 400V, & can pose a risk if damaged or exposed.

- **A submerged EV does not electrify a body of water**
    a. An electric vehicle underwater does not cause surrounding water to become electrically live.

- **Best practice; allow a traction battery to burn out**
    a. If location & time allow, there is a lower risk to all responders in letting the battery completely burn.
    b. Jump to EV fire reignition

- **EV traction battery fires can reignite, hours or days later**
    a. If it's not possible to allow the traction battery to 'burn out', re-ignition risk should be considered.

04.10 EV battery fire suppression

How do firefighters put out an EV battery fire?
Due to the self-sustaining nature of thermal runaway, we've moved away from using the word 'extinguish' in relation to lithium-ion battery fires and instead prefer to discuss how we suppress & contain them.

We're going to break this page down into three parts:
- Best practice methods
- Challenges of EV battery pack designs for firefighting
- Products coming to market

What are the best practice methods for putting out an EV battery fire?
There is no one method to manage an EV battery fire, rather three methods used globally that have emerged as best practice; Cool, Burn, Submerge.

Each of these EV fire incident management methods are valid options for suppressing & containing an EV in thermal runaway. The Cool or Burn options do not require fire agencies to purchase or use additional tools, which may be cost prohibitive or difficult to carry.

Cool
Burn
Submerge

EV battery fire suppression - cool

Use fog nozzles to knock down flames & provide cooling jets onto battery pack exterior to cool down the exothermic reaction of thermal runaway.

Pros:

- Recommended by all EV manufacturers
- Firefighters are 'seen' to be doing something by public

Cons:

- Doesn't get water where it needs to be
- Like 'putting out a kitchen fire by spraying water on the roof of a house'
- Water usage may be in excess of 10,000 litres *to extinguish a single EV (a typical fire department water tanker can carry 15,000 litres of water)*
- *The Tara Shift Solar BESS is rated at 1600 MWh, equivalent to 16,000 to over 26,000 Tesla EV's*
- Run off will need to be monitored & captured, particularly near waterways

Case study:

A plug-in hybrid EV was accidentally submerged in salt water at a boat ramp, with thermal runaway following removal, which was knocked down by firefighters, & secondary ignition occurring while being towed. Crews used two hose lines to cool the battery pack for an extended period. 15th May 2020, Port Moody, Canada

EV battery fire suppression - burn

Allow the lithium-ion battery pack to burn itself out, hot & fast.

Pros:

- Recommended by some EV manufacturers *(was the recommendation for the Australia Tesla BESS Fire)*

Image credits Fire Rescue Victoria

- *This Australian fire* in 2021, *affected 2 units of a 212 unit Tesla Megapack-based energy storage project in southeastern Australia. It burned for four days, prompting local authorities to send 150 firefighters and more than 30 fire trucks to the scene.*
- *This was a 300 megawatts/450 megawatt-hours capability battery. (Versus the 400 MW, 1600 MWH BESS approved by IESO for Tara, Ontario, some 3½ times larger)*

- Burns through majority of live cells, leaving scrap metal
- Removes stranded energy & secondary ignition risk

Cons:

- Time to burn will depend on battery size, state of charge, ambient temperature & other factors
- Air quality risks - monitoring & warnings for surrounding exposures
- Public / media attention; 'why aren't firefighters DOING something?'

Case study:

An EV went into thermal runaway while fast charging. The fire department opted to let the battery burn out. It was flipped onto it's side for easier monitoring with a thermal imaging camera. Time taken to burn is unknown. 22nd April 2022, Berlin, Germany.

EV battery fire suppression - submerge

Submerge EV in a containment unit that can be filled to pack level with water.

Pros:

- Contains fire spread
- Manages incident relatively quickly
- Firefighters are 'seen' to be doing something by public

Cons:

- Containment units may not be available or in close enough proximity
- Water usage may be in excess of 10,000 litres
- EV may need to remain in water for days/weeks
- Thermal runaway will continue underwater
- Time for thermal runaway to conclude depends on battery capacity & state of charge
- Water will need to be treated for disposal which can be expensive

Case study:

An EV went into thermal runaway with off-gassing, but no visible flame, while at the dealership. Fire crews organised a containment unit & the EV was submerged for several weeks. 25th March 2019, Tilburg, Netherlands.

What are the challenges of suppression using the Cool method?

There are two main challenges with firefighting an EV battery fire: position & access.

The position of the EV battery pack makes firefighting difficult:

We previously looked at how a traction battery is constructed, & how (in most EVs) it is positioned along the floor pan of an electric vehicle, between chassis rails.

If the battery pack goes into thermal runaway, the position means:

- It's difficult to locate the area in the pack thermal runaway is occurring, either visually or with a thermal imaging camera (TIC)
- Spraying water onto the outside of the pack to cool it often means firefighters have to be close to the vehicle & risk exposure to jet like flames

Lithium-ion battery pack underneath an electric vehicle

It's usually impossible to get cooling water onto the battery cells:

The construction of an EV battery pack where individual lithium-ion battery cells are contained within a module, & modules within the pack, means getting water where it needs to go to cool the cells is almost impossible.

However; we are aware of some cases where an EV has been involved in a collision, & firefighters were able to direct water into the pack where it had torn open, to directly cool the battery cells. This is safe to do & does not carry the risk of electrocution (unless the EV is connected to energised EV charging).
Cells & modules are contained within a pack, which is IP rated & essentially waterproof

What about extinguishment or suppression products?
As with all emerging industries, a range of products claiming to 'extinguish' EV battery fires are being aggressively marketed to both fire agencies & the private sector as the answer to EV battery fires.
We are often asked whether a fire agency should buy a fire blanket, cutting tool or extinguishing agent, & our answer is; no, there is no need to purchase extinguishing tools for EV battery fires.
While this response does not make us popular with those manufacturers, currently (as of 2024):

- EV battery fires are rare
- These tools are typically very expensive
- They may be too large & heavy to be comfortably carried on a truck
- Often come with no manufacturer operating procedure or training

It should also be noted that some of these products may actually increase risk to emergency responders, even when being used correctly.

Having said that, there are some scenarios in which these tools may be useful, & all considerations are outlined in the comparison table here.

Fire blanket
Fire extinguishers
Cutting tools
Underbody sprays

EV battery fire suppression - fire blankets
Large thermal fire blanket that is placed over an EV to contain flame.

Pros:

- If used in time, blanket will contain flames & stop fire spread to exposures
- Can be left on EV as it's moved from scene

Cons:

- ~25kgs for one car-sized blanket, so must be used by two firefighters in breathing apparatus
- Cannot 'extinguish' or stop thermal runaway (despite manufacturer claims!)
- Thermal runaway will continue under blanket & may slow down (as opposed to the Burn

method), the process Vapour cloud (off-gassing) will continue under the blanket

- More independent testing is required to ensure efficacy & safety for responders

Increased risk:

- Where a blanket is lifted by wind or a person, the build up of gases under the blanket may cause a localised vapour cloud explosion
- Blankets often come as single or multi use, but there are no agreed, safe decontamination procedures for multi-use blankets

For responders:

- We do not consider it necessary to buy & make space on a truck for a fire blanket for the sole purpose of EV battery fire management at this time
- Where blankets have been purchased by a high-risk site, fire blankets should be used with caution to avoid causing vapour cloud explosion
- As most thermal runaway events occur prior to fire crew arrival, fire blankets will typically be most useful post-incident to contain a potential secondary ignition

For private sector businesses:

- Sites where EVs are parked, stored or charged in normal operating conditions do not require fire blankets
- Higher risk sites such as where EV or lithium-ion battery repairs, servicing or manufacturer occur may consider purchasing a fire blanket, but;
- A standard operating procedure should be sought from the manufacturer or written by the site, including:
    - NO staff should be trained to cover an EV in active thermal runaway due to high risk of injury or death
    - Blankets should be used by attending fire crews only

Attachment 3 - Additional Resources and References
For Consideration in Revision to "Solar Electricity and Battery Storage Systems Safety Handbook for Firefighters"

CTIF – International Association of Fire and Rescue Services website:

- https://ctif.org/news/large-lithium-battery-fires-created-toxic-smoke-and-evacuations-jacksonville-and-gothenburg
- https://ctif.org/news/accident-analysis-beijing-lithium-battery-explosion-which-killed-two-firefighters
- https://ctif.org/news/large-explosion-and-fire-french-lithium-battery-warehouse
- https://ctif.org/news/900-tonnes-lithium-batteries-fire-french-recycling-plant-north-toulouse
- https://ctif.org/news/california-creates-new-emergency-response-legislation-large-lithium-based-battery-energy
- https://ctif.org/news/norwegian-shipping-company-bans-electric-cars-board-classic-ferry-route
- https://ctif.org/news/lihium-ion-battery-bank-started-offgassing-hospital-80-people-evacuated-due-toxic-fumes
- https://ctif.org/news/despite-fire-hazards-lithium-ion-battery-energy-storage-systems-are-getting-larger-and-larger
- https://ctif.org/news/ev-may-have-started-fire-onboard-cargo-ship-3000-cars-crew-had-jump-water-one-dead
- https://ctif.org/news/150-000-liters-water-needed-put-out-fire-electric-car
- https://ctif.org/news/summary-some-more-severe-lithium-battery-fires-during-last-12-months
- https://ctif.org/news/11-electric-cars-and-48-lithium-batteries-caught-fire-after-exposure-salty-flood-water

Selected relevant scientific papers: (with doi.org links to allow convenient access)

Larsson, F., Andersson, P., Blomqvist, P. et al. Toxic fluoride gas emissions from lithium-ion battery fires. Sci Rep 7, 10018 (2017). https://doi.org/10.1038/s41598-017-09784-z

Conclusions: This study covered a broad range of commercial Li-ion battery cells with different cell chemistry, cell design and size and included large-sized automotive-classed cells, undergoing fire tests. The method was successful in evaluating fluoride gas emissions for a large variety of battery types and for various test setups.

Significant amounts of HF ranging between 20 and 200 mg/Wh of nominal battery energy capacity were detected from the burning Li-ion batteries. The measured HF levels, verified using two independent measurement methods, indicate that HF can pose a serious toxic threat, especially for large Li-ion batteries and in confined environments. The amounts of HF released from burning Li-ion batteries are presented as mg/Wh. If extrapolated for large battery packs the amounts would be 2-20 kg for a 100 kWh battery system, e.g. an electric vehicle, and 20-200 kg for a 1000 kWh battery system, e.g. a small stationary engine storage. The immediate dangerous to life of health (IDLH) level for HF is 0.025 g/m^3 (30 ppm) and the lethal 10 minute toxicity value (AEGL-3) is 0.0139 g/m^3 (170 ppm). The release of hydrogen fluoride from a Li-ion battery fire can therefore be a severe risk and an even greater risk in confined or semi-confined space.

Bordes, A., Papin, A., Mariar, G. et al. Assessment of Run-Off Waters Resulting from Lithium-Ion Battery Fire-Fighting Operations, Batteries (2024), 10 (4), 118; https://doi.org/10.3390/batteries10040118

Conclusions: In the present work, the two battery modules were triggered in thermal runaway and subsequent degassing and fire. Water was applied to mock-up firefighting operations in order to analyze the composition of the extinguishing water.

The tests presented in this paper highlight that waters used for firefighting on NMC Li-ion batteries are susceptible to containing many metals, including Ni, Mn, Co, Li and Al. Those metals are mixed with other carbonaceous species (soots, tarballs). It is also important to note that particles present in the water can be nanometric or in the form of nanostructured clusters. In addition to the solid contaminants, liquid compounds can be present, especially organic carbonates coming from the electrolyte (EC and EMC in this case) and also gaseous species such as PAH. A comparison with PNEC values showed that this water could be potentially hazardous to the environment, depending on the actual situation encountered in the case of thermal runaway propagation with a Li-ion battery-based system.

As large Li-ion batteries are fast spreading (in so-called Battery Energy Storage Systems, BESS, for example), and only few data on the environmental impact of fires in those systems are available, it is crucial to further develop consolidated knowledge in this field.

Quant, M., Willstrand, O., Mallin, T., Hynynen, J., Ecotoxicity Evaluation of Fire-Extinguishing Water from Large Scale Battery and Battery Electric Vehicle Tests, ACS Publications, Environmental Science & Technology, Vol 57 (12) https://pubs.acs.org/doi/10.1021/acs.est.2c08581

Conclusions: Electrified transport has multiple benefits but has also raised some concerns, for example, the flammable formulations used in lithium-ion batteries. Fires in traction batteries can be difficult to extinguish because the battery cells are well protected and hard to reach. To control the fire, firefighters must prolong the application of extinguishing media.

In this work, extinguishing water from three vehicles and one battery pack fire test were analyzed for inorganic and organic pollutants, including particle-bound polycyclic aromatic hydrocarbons and soot content. Additionally, the acute toxicity of the collected extinguishing water on three aquatic species was determined. The vehicles used in the fire tests were both conventional petrol-fueled and battery electric.

For all of the tests, the analysis of the extinguishing water showed high toxicity toward the tested aquatic species. Several metals and ions were found in concentrations above the corresponding surface water guideline values. Per- and polyfluoroalkyl substances were detected in concentrations ranging between 200 and 1400 ng L^{-1}. Flushing the battery increased the concentration of per- and polyfluoroalkyl substances to 4700 ng L^{-1}. Extinguishing water from the battery electric vehicle and the battery pack contained a higher concentration of nickel, cobalt, lithium, manganese, and fluoride compared with the water samples analyzed from the conventional vehicle.

Jeevarajan, J.A., Joshi, T., Parhizi, M., Rauhala, T., Juarez-Robles, D., Battery Hazards for Large Energy Storage Systems, ACS Energy Letters, Vol 7 (8), https://pubs.acs.org/doi/10.1021/acsenergylett.2c01400?ref=recommended

Highlights: Hazards for Li-ion batteries can vary with the size and volume of the battery, since the tolerance of a single cell to a set of off-nominal conditions does not translate to a tolerance of the larger battery system to the same conditions. Li-ion batteries are prone to overheating, swelling, electrolyte leakage venting, fires, smoke, and explosions in worst-case scenarios involving thermal runaway. Failures associated with Li-ion batteries are described to be deflagration in nature. However, the gases produced as a result of a fire, smoke, and/or thermal runaway can accumulate to a combustible level in the installation location and cause an explosion (detonation). In general, the off-nominal conditions that can cause the occurrence of catastrophic events with Li-ion batteries can be categorized into electrical, mechanical, and environmental types. The most common electrical hazards are over-charge, over-discharge, and external and internal short circuits. Of the environmental hazards, off-nominal conditions such as temperatures beyond the manufacturer's recommended range are those that are well understood. The influence of other environmental hazard causes, such as changes in altitudes, pressures, salt fog, floods, rain, etc., are not as well understood. Mechanical hazards such as those caused by vibration, shock, and impact are understood to a certain level, especially those encountered under transportation conditions.

High and low temperatures can lead to different unsafe conditions in Li-ion cells and batteries. High temperatures can lead to decomposition of the electrolyte and the solid-electrolyte interface (SEI) layer, destabilization of the cathode and anode that eventually lead to a violent venting, fire, and thermal runaway. Low temperatures increase the viscosity of the electrolyte in a Li-ion cell, reducing the mobility of the lithium ions in the electrolyte. The reduction in ionic conductivity causes the deposition of the ions as dendritic lithium metal due to the reduced ease of intercalation into the anode. This subsequently leads to increased internal cell temperatures, and in the presence of high temperatures due to increased internal resistance, growth of lithium metal dendrites, and the organic flammable electrolytes, the inevitable thermal runaway and fire occurs. Hazardous conditions due to low-temperature charging or operation can be mitigated in large ESS battery designs by including a sensing logic that determines the temperature of the battery and provides heat to the battery and cells until it reaches a value that would be safe for charge as recommended by the battery manufacturer. When heaters are used, the power to the heaters should be controlled to prevent uncontrolled heating due to heater failures.

Yang Peng, Lizhong Yang, Xiaoyu Ju, Baisheng Liao, Kai Ye, Lun Li, Bei Cao, Yong Ni, A comprehensive investigation on the thermal and toxic hazards of large format lithium-ion batteries with LiFePO4 cathode, Journal of Hazardous Materials, Volume 381, 2020, 120916, ISSN 0304-3894, https://doi.org/10.1016/j.jhazmat.2019.120916.

Toxic gases released from lithium-ion battery (LIB) fires pose a very large threat to human health, yet they are poorly studied, and the knowledge of LIB fire toxicity is limited. In this paper, the thermal and toxic hazards resulting from the thermally-induced failure of a 68 Ah pouch LIB are systematically investigated.

The LIBs with higher state of charge (SOC) are found to have greater fire risks in terms of their burning behavior, normalized heat release rate, and fire radiation, as well as the concentration of toxic gases.

The major toxic gases detected from the online analysis are CO, HF, SO_2, NO_2, NO and HCl.

Results show that the effects of irritant gases are much more significant than those of asphyxiant gases. HF and SO_2 have much greater toxicity than the other fire gases. The maximum FEC value is approaching the critical threshold in such fire scenarios.

Larsson, F., Andersson, P., Blomqvist, P. *et al.* Toxic fluoride gas emissions from lithium-ion battery fires. *Sci Rep* **7**, 10018 (2017). https://doi.org/10.1038/s41598-017-09784-z

Lithium-ion battery fires generate intense heat and considerable amounts of gas and smoke. Although the emission of toxic gases can be a larger threat than the heat, the knowledge of such emissions is limited. This paper presents quantitative measurements of heat release and fluoride gas emissions during battery fires for seven different types of commercial lithium-ion batteries. The results have been validated using two independent measurement techniques and show that large amounts of hydrogen fluoride (HF) may be generated, ranging between 20 and 200 mg/Wh of nominal battery energy capacity. In addition, 15–22 mg/Wh of another potentially toxic gas, phosphoryl fluoride (POF_3), was measured in some of the fire tests. Gas emissions when using water mist as extinguishing agent were also investigated. Fluoride gas emission can pose a serious toxic threat and the results are crucial findings for risk assessment and management, especially for large Li-ion battery packs.

Significant amounts of HF, ranging between 20 and 200 mg/Wh of nominal battery energy capacity, were detected from the burning Li-ion batteries. The measured HF levels, verified using two independent measurement methods, indicate that HF can pose a serious toxic threat, especially for large Li-ion batteries and in confined environments. The amounts of HF released from burning Li-ion batteries are presented as mg/Wh. If extrapolated for large battery packs the amounts would be 2–20 kg for a 100 kWh battery system, e.g. an electric vehicle and 20–200 kg for a 1000 kWh battery system, e.g. a small stationary energy storage. The immediate dangerous to life or health (IDLH) level for HF is 0.025 g/m^3 (30 ppm)22 and the lethal 10 minutes HF toxicity value (AEGL-3) is 0.0139 g/m^3 (170 ppm)23. The release of hydrogen fluoride from a Li-ion battery fire can therefore be a severe risk and an even greater risk in confined or semi-confined spaces.

Using water mist resulted in a temporarily increased production rate of HF but the application of water mist had no significant effect on the total amount of released HF.

Conzen, J., Lakshmipathy, S., Kapahi, A., Kraft, S., DiDomizio, M., Lithium ion battery energy storage systems (BESS) hazards, Journal of Loss Prevention in the Process Industries, Vol 81, Feb. 2023, 104932
https://doi.org/10.1016/j.jlp.2022.104932

Highlights: There has been an increase in the development and deployment of battery energy storage systems (BESS) in recent years. In particular, BESS using lithium-ion batteries have been prevalent, which is mainly due to their power density, performance, and economical aspects. BESS have been increasingly used in residential, commercial, industrial, and utility applications for peak shaving or grid support. As the number of installed systems is increasing, the industry has also been observing more field failures that resulted in fires and explosions. Lithium-ion batteries contain flammable electrolytes, which can create unique hazards when the battery cell becomes compromised and enters thermal runaway. The initiating event is frequently a short circuit which may be a result of overcharging, overheating, or mechanical abuse. During the exothermic reaction process (i.e., thermal runaway), large amounts of flammable and potentially toxic battery gas will be generated. The released gas largely contains hydrogen, which is highly flammable under a wide range of conditions. This may create an explosive atmosphere in the battery room or storage container. As a result, a number of the recent incidents resulted in significant consequences highlighting the difficulties on how to safely deal with the hazard. This paper identifies fire and explosion hazards that exist in commercial/industrial BESS applications and presents mitigation measures.

Other relevant reference considerations:

Hydro One – BESS Fire Protection – Risk & Response Assessment Standard

- prepared by Fire & Risk Alliance, LLC, Rockville, MD for Hydro One, July 19, 2023
    - While this standard is not directly related to protection of firefighters or the public, the approach taken is relevant for reference
- goal is to ensure operation of Hydro One high voltage transmission facilities is not affected by any BESS event
- sets two step approach to achieve this:
    - first step is to design and test BESS equipment based on existing standards and industry experience to minimize the adverse effects from a BESS event, along with adequate protection and control and spatial separation within the BESS facility itself
    - second step is to establish and maintain appropriate spatial separation of BESS facility from the transmission facilities to ensure BESS facility results in minimal or no impact on the present and/or future expansion of Hydro One transmission facilities and in the event of an event is confined to the immediate BESS area.
        - setback of BESS from Hydro One – 500 kV Right of Way to be 150 metres
        - setback of BESS from Hydro One – 230 kV Right of Way to be 100 metres
        - setback of BESS from Hydro One – 115 kV Right of Way to be 60 metres
        - setback from 500 kV substation to be 300 metres, 230 kV substation to be 200 metres, 115 kV substation to be 120 metres
- these setbacks make it clear that BESS events are considered capable of causing an equipment impact at a distance from BESS equipment, and suggest consideration be made when siting BESS facilities impacting the public, which may not be as robust to injury as is transmission towers or substations when considering an impact
- what these setbacks do not consider, that is very relevant to public safety, is the issue of toxicity of vapour emissions, or of liquid emissions to waterways that may impact drinking water

- an additional fact that is not apparent from these Hydro One setbacks when considering public safety, is that a major consideration for setbacks to Hydro One equipment is the impact on the overall system on loss of the particular piece of equipment considering redundancy. Loss of a single 115 kV transmission will impact far fewer customers than loss of a 500 kV circuit. Thus, setbacks to prevent loss of a 500 kV circuit are greater than setbacks to prevent loss of a 115 kV circuit. In contrast, when considering public safety, we consider that loss of “a few lives” is still relevant, and society does not consider that we should take no protective action until considering protection against loss of an entire community. Both individual and population effects are relevant, and we would not want to tell a citizen (as for the Neoen Tara BESS site) who unfortunately lives close to the site where a BESS facility will be located, that their life does not matter.

UL Standard 9540A – Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage System

- It is of note that the UL 9540A Test Method permits certification of a battery that passes a test of charge-discharge-charge-discharge without initiating thermal runaway
- In practice, thermal runaway is unlikely to occur in 2-cycles of charge-discharge, but only after repeated cycles, particularly following damage, overcharging, or charging beyond lower or higher temperature limits
- A BESS system may experience charge and discharge cycles on a daily basis over it’s lifetime, far exceeding a 2-cycle test, and BESS batteries may be expected to be charged to their full charge value to be able to supply load for their design period (typically full load for 4-hours)
- This suggests that consideration of the test success criterion of UL 9540A may require reconsideration to assure that certification gives assurance that the BESS will not fail during normally anticipated operation