London Fire Brigade Headquarters
169 Union Street London SE1 0LL
T 020 8555 1200 **F** 020 7960 3602
Textphone 020 7960 3629
london-fire.gov.uk

Freedom of Information request reference number: 8181.1

Date of response: 22/12/2023

Request:

Under the Freedom of Information Act/Environmental Information Regulations, I would like to request the following information: 1. How may fires have your Service attended which involved electric or Hybrid vehicles powered by lithium-ion batteries between the following dates 1/1/21 – 1/11/23? 2. Of these fires attended in how many of these was the cause recorded as a fault on the lithium-ion battery? 3. Of the fires attended how many involved the lithium battery cells? 4. Have your Service developed specific operational procedures for dealing with fires involving lithium-ion batteries? 5. Have your service purchased any specific equipment/extinguishing/PPE agents to deal with fires involving lithium-ion batteries? 6. Does your Service provide specific training to operational crews who may be called to fires involving lithium-ion batteries? 7. Where lithium-ion batteries are involved in RTA's persons trapped, do you adopt any specific measures to isolate the potential battery ignition risk? 8. Have your Service initiated any specific information gathering exercise on fires attended involving lithium ion batteries?

Response:

Please see below for a response to your FOIA questions you submitted:

1. *How may fires have your Service attended which involved electric or Hybrid vehicles powered by lithium-ion batteries between the following dates 1/1/21 – 1/11/23?*
   Please see below for a table showing how many incidents LFB attended regarding electric or Hybrid vehicles powered by lithium-ion batteries between 01 January 2021 and 1 November 2023. The data is also broken down by month in each year.

2. *Of these fires attended in how many of these was the cause recorded as a fault on the lithium-ion battery?*
   There are 3 incident records of lithium powered vehicles that were recorded as due to a 'faulty appliance or supply'. These were all related to e-bikes.

3. *Of the fires attended how many involved the lithium battery cells?*
   We do not record if the fires attended involved the lithium battery cells.

Date is on or after 01 January 2021 and is before 02 November 2023
e-bike/e-scooter/Lithium is not e-cigarette or Other Lithium Battery with LFB in attendance

Year	MonthName	Number of lithium related fires	e-bike/e-scooter/Lithium
2021	January	2	e-bike
2021	January	1	e-scooter
2021	February	1	e-scooter
2021	March	1	e-scooter
2021	April	5	e-bike
2021	April	1	e-scooter
2021	May	6	e-bike
2021	May	3	e-scooter
2021	June	3	e-bike
2021	July	3	e-bike
2021	July	1	e-scooter
2021	August	3	e-bike
2021	August	3	e-scooter
2021	August	1	Road Vehicle
2021	September	2	e-bike
2021	September	1	e-scooter
2021	October	1	e-bike
2021	October	1	e-scooter
2021	November	5	e-bike
2021	November	3	e-scooter
2021	November	2	Road Vehicle
2021	December	2	e-bike
2022	January	3	e-bike
2022	January	2	e-scooter
2022	February	3	e-bike
2022	February	1	e-scooter
2022	March	6	e-bike
2022	March	1	e-scooter
2022	April	2	e-bike
2022	April	1	e-scooter
2022	May	5	e-bike
2022	May	1	e-scooter
2022	June	4	e-bike
2022	June	1	e-scooter
2022	July	2	e-bike
2022	July	1	e-scooter
2022	August	8	e-bike
2022	August	4	e-scooter
2022	September	4	e-bike
2022	September	1	e-scooter

2022	October	6	e-bike
2022	October	2	e-scooter
2022	November	6	e-bike
2022	November	3	e-scooter
2022	December	2	e-bike
2022	December	1	e-scooter
2022	December	2	Road Vehicle
2023	January	4	e-bike
2023	January	1	e-scooter
2023	February	9	e-bike
2023	February	3	e-scooter
2023	February	1	Road Vehicle
2023	March	5	e-bike
2023	March	2	e-scooter
2023	April	3	e-bike
2023	April	1	e-scooter
2023	May	4	e-bike
2023	May	1	e-scooter
2023	June	6	e-bike
2023	June	1	e-scooter
2023	July	6	e-bike
2023	July	1	Road Vehicle
2023	August	2	e-bike
2023	August	1	e-scooter
2023	August	1	Road Vehicle
2023	September	5	e-bike
2023	September	1	Road Vehicle
2023	October	1	e-bike
2023	October	1	e-scooter
2023	October	1	Road Vehicle

4. *Have your Service developed specific operational procedures for dealing with fires involving lithium-ion batteries?*
   We have a SOP (Standard operating procedure) 977a for lithium-ion batteries**.** Please see below for a copy of SOP 977a. I have also attached the section of this policy (pages 47-58 of 81) which provides further information in relation to alternative energies.

5. *Has your service purchased any specific equipment/extinguishing/PPE agents to deal with fires involving lithium-ion batteries?*
   No new equipment has been purchased although we are exploring options for deploying blankets. Our current practice has been agreed with BV as suitable at this time. We have seen several agents and specific equipment; and will continue to investigate innovation in the market but are yet to find a viable solution to the risk.

6. *Does your Service provide specific training to operational crews who may be called to fires involving lithium-ion batteries?*
   Yes, this is in the SOPS (Standard operating procedure) and operational news training (Internal training publication).

7. *Where lithium-ion batteries are involved in RTA's persons trapped, do you adopt any specific measures to isolate the potential battery ignition risk?*
   It again is referenced in the SOP (Standard operating procedure) and crews are directed to the MDT to gain Crash data for location of batteries and Chem data for advice on dealing with them. The use of a TIC is emphasised as a means for monitoring the temperature rises.

8. *Have your Service initiated any specific information gathering exercise on fires attended involving lithium-ion batteries?*
   When calls are received at control for car fires they now ask how the vehicle is fuelled and if it is electric then a HMEPO (Hazardous Materials and Environmental Protection Officer) is informed. A HMEPO is ordered to incidents where they are involved in fires. Control have prompts in place for lithium-ion fires and ask specific questions in identifying their presence which then allows for them to correctly send the required pre-determined attendance for this risk.

We have dealt with your request under the Freedom of Information Act 2000. For more information about this process please see the guidance we publish about making a request on our website: https://www.london-fire.gov.uk/about-us/transparency/request-information-from-us/

Lithium-ion batteries

Official

Lithium-ion batteries

Introduction

Lithium-ion batteries are rechargeable batteries (as opposed to non-rechargeable lithium batteries) that use lithium-ions as the primary component of their electrolyte.

The term "battery" can be used to describe an assembly of "cells" and "modules". Lithium-Ion batteries (LiB's or Li-ion) may contain cylindrical cells, slightly larger than an AA battery; prismatic cells, about the size of two cigarette packs; or pouch cells, about the area of an A4 sheet of paper and 1cm thick. The cells are packaged together into modules, and a group of modules can form a battery pack. A large battery can consist of thousands of cells grouped into many modules.

Planning

Ensure that Site-Specific Risk Information (SSRI) includes details of PV systems, including battery storage, such as details of isolation switches and updated as per Policy number 800 - Management of operational risk information.

Crews to be familiar with the location, recognition, hazards, and control measures relating to Battery Energy Storage Systems (BESS).

BESS sites and Li-ion batteries in general - (use of the interactive mapping in the links section will assist in identification of BESS sites).

BESS's are not at present notifiable sites and so may not have detailed operational risk information.

Incidents involving Lithium-ion batteries should be treated as Hazardous Materials incidents and a Hazardous Materials and Environmental Protection Officer (HEMPO) must be requested.

Hazards (Li-Ion)

General hazards of Lithium-ion batteries (LiB's)

Batteries vary in size and configuration depending on their use and application. Larger batteries may be found in Energy Storage Systems (ESS) these may contain LiBs and or traditional lead batteries or found in other methods of transportation i.e., trains etc.

Whilst smaller batteries are used in most electronic items such as laptops and mobile phones and can be dealt with relatively easier by submersion or isolation, however the larger LiB's will require an alternative approach as access is often hindered by chassis and other protective means. Batteries are arranged in series to increase voltage, and in parallel to increase capacity.

Larger batteries may contain many hundreds, even thousands of individual cells and the electrolyte is made from flammable organic solvents. Li-ion batteries can develop design or manufacturing faults; if abused through overheating, physical damage or overcharging. Battery cells may become unstable at temperatures as low as 70°C.

Hazards can include:

Thermal runaway

When Lithium-ion batteries are compromised, its normal electro-chemical processes are replaced by chemical reactions generating gases and heat. Heat speeds up the reactions, so more and more gases and heat are produced. When the (exponential) heat gains and exceeds the (linear) heat dissipation, the cells involved are in thermal runaway. Thermal runaway within a single battery cell can spread to neighbouring cells as the protective membrane in the cells are compromised resulting in an escalation of toxic vapour production, increasing fire and explosion risk.

White vapour gases

All Lithium-ion batteries produce white vapour when in thermal runaway. This vapour can easily be mistaken for steam (especially if visible flames have been extinguished) or smoke. In fact, the products are an explosive, corrosive toxic mixture of up to 50% hydrogen, plus carbon monoxide, carbon dioxide, hydrogen cyanide, acid gases, small hydrocarbons such as methane and ethane, and droplets of solvent which can be hazardous to health.

Personnel exposed may be subjected to solvent droplets from within the cloud condensing upon them. Advice should be sought from the HEMPO or Scientific Advisor (SA).

- LiB's may be pressurised under thermal runaway or fire conditions and can present a high risk of injuries from blasts and shrapnel from molten metal which can be ejected explosively over several metres.
- Large LiB fires can burn for protracted periods requiring large amounts of water to cool and extinguish. Even after extinguishment LiB are prone to re-ignition hours, days or even weeks later.
- Due to the construction of the battery cells, it is possible for the battery to retain an electrical charge during or after a fire. Therefore, a risk of electrocution or electrical arc remains throughout the incident. This is sometimes referred to as "stranded electrical energy" with an arc flash explosion producing temperatures of up to 14,000°C.
- A battery in thermal runaway and contained within chassis or other storage solutions can create conditions that lead to an explosion hazard due to the white vapour and flammable gases.

Examples of circumstances where this could occur are:

- Electric Vehicle (EV) Road Traffic Collisions (RTC's).
- Domestic and Industrial BESS.
- Fires in LiB storage warehouses.
- LiB manufacturing plants.
- Transportation of EV battery packs by road and rail.
- Underground car parks.
- Basements.
- Tunnels.
- Railway arches.

- Garages.
- Charging points (domestic and commercial).
- Any unventilated premise.

Additional hazards for crews to consider when dealing with LI-ion, LiB's

- The need to recognise LiB's are involved or likely to be involved.
- Potential for impact on any life risk i.e., fire below a flat, office, high rise.
- Uncontrolled or unpredictable vehicle movements (RTC's).
- Gases, Vapours, toxic substances, and the potential for explosive reactions.
- High-voltage systems – the residual charge in these systems may remain for up to ten minutes after isolation.
- Difficulty gaining access to safety cut offs or applying firefighting media.
- Other Hazardous materials, including liquid petroleum gas (LPG) and lithium-ion cells.
- Electrolytes leaking from battery cells.
- Damage to surrounding infrastructure and or the environment.

Operational considerations

- Potential for impact on any life risk. Incident Commander (IC) to carry out Dynamic Risk Assessment (DRA) and consider if evacuation is required.
- Crews to check Operational Risk Database (ORD) information, Mobile Data Terminal (MDT) and look for supplementary information QR, warning information notices. Check MDT for crash data and utilise. Ensure correct search term is used, i.e., "Lithium Ion". Additionally, the DVLA website can be used DVLA vehicle checker.
- Firemet, Chemdata will help identify projected vapour cloud movement, components of the vapour are heavier than air.
- Full structural PPE and RPE.
- Consider Thermal Imaging Camera (TIC) to assist situational awareness (360), identification of battery pack and continual monitoring.
- Request HMEPO, SA or onsite SME for specialist advice if available.
- LiB's are prone to thermal runaway. Do not mistake the explosive, toxic white vapour for smoke or steam.
- Establish an appropriate incident command structure and required cordon
- Confirm tactical priorities.
- Consider utilisation of defensive firefighting - taking into account building occupancy, construction, wind direction and water run-off.
- Consider if smaller batteries (phones, laptops, etc.) can be allowed to burn under control. If safe to do so they should be removed to fresh air, contained in a berm of non-flammable material i.e., open metal container, soil, sand and have a risk assessed cordon applied for 24 hours prior to disposal. Alternatively, they could be immersed in an external container of water, such as a bucket, minimum 12 hours, preferably 24 hours, this period of monitoring prior to disposal would be down to the Responsible Person (RP) once

the initial fire has been extinguished and handed over to the RP and recorded on the Key Decision Log (KDL).

- Ultimate disposal is the responsibility of the RP. HMEPO can advise on disposal of the contaminated water, but it is ultimately down to the RP. Confirm duty of care with a handover and record on the KDL.
- When in thermal runaway, one or two cells alight may give the impression of the whole module or battery being alight. Extinguishing these flames will not prevent the whole of the unit being in thermal runaway. Re-ignition can easily occur.
- Extinguishment of LiB's requires large quantities of water, crews to consider FF media, specialised equipment and the use of the MDT on CRS (CRASH data) for information required for location and access to battery packs as they may be encased in a protective casing or form part of the chassis.
- Consider water run-off to prevent environmental damage – early use of National Environmental Risk Assessment, HMEPO advice and Environment Agency liaison.
- Consider controlled burn as this will render the battery safe.
- All batteries present the risk of explosion. The size of explosion is proportional to the size of the battery and the environment it's contained within and or near.
- Danger of re-ignition batteries hours, days or even weeks later.
- Movement of a damaged battery that is not fully discharged may result in re-ignition and or damage to other items.
- Stranded electrical energy presents risk of electrocution or arc flash explosion.
- Fire suppression systems may be in place may not extinguish a LiB in thermal runaway.
- Early request for additional resources, including consideration of a Bulk Media Advisor (BMA), Hose Layers, neighbouring brigades water carriers or alternative water supplies and Light Weight Pumps (LWPs) where supplies may be poor.
- Outer cordons and 'warn and inform' media messages to the public.
- Early sharing of information with external agencies (use of METHANE).
- IC to assess if temperature monitoring of the affected units, post-extinguishment is safe to undertake

Considerations for incidents involving commercial LiB-BESS sites

- OIC to risk assess and establish a cordon and implement safety officers full structural PPE, RPE, consider electrical gloves if not involved in fire, consideration of the potential for evacuation of populated areas.
- Establish contact with on-site specialist and ascertain if containers can be flooded through fixed installation access points.
- Be aware of nearby high voltage transformers and cables (overhead, buried).
- Identify the containers in which lithium-ion cells are in thermal runaway.
- There may be flames or white vapour present.
- Thermal image cameras may show increased temperatures on one or more walls of the container if no apparent fire.
- Contact the site operator (if representative not on site) and ask if there is telemetry data available, as this can be useful if the units are secured. Inform the IC as to the situation inside the unit.
- Do not open any container doors or enter unless it is certain that any gases have ignited.

- Even if on fire, assume batteries are fully energized and present an electrocution/arc flash hazard.
- In the absence of signs of fire or obvious vapour cloud, assume there is a vapour cloud inside the container, presenting an explosion hazard. Utilise remote venting if the site has this capability. If venting, remove all personnel from the inner cordon. Consider defensive firefighting utilising fog sprays to dilute gases emitted.
- If venting is not possible, crews could flood the units via dedicated access points commonly known as dead pipes. IC to consider defensive firefighting if there are no suitable access points. Be aware of the potential massive production of hydrogen and oxygen and hence explosion hazard due to direct contact of water with high voltages.
- Post incident, the site should be secured and protected from the elements to allow post-incident investigation.
- Decommissioning of the stranded electrical energy should be carried out by experts and will take weeks or even months.

Considerations post event

- Handovers to a RP should be done on a KDL which allows the capturing of risks, hazards, and recommended actions (monitoring periods) this is important due to the potential for reignition, and the hazards associated with LiB's.

Reference information and further reading

- The Hub.
- All incidents foundation document.
- Hazardous materials.
- Policy number 808 - Hazardous materials and environmental protection - mass decontamination.
- Policy number 793 - Compartment Firefighting.
- Policy number 796 - HAZMATS; fires and incidents involving hazardous substances.
- Policy number 956 - Respiratory protective equipment – respirator – technical information.
- Policy number 839 - Incidents involving solar panels.
- Policy number 769 - Incidents involving electricity.
- Policy number 979b - Road traffic collisions - rescue - SOP.
- Roadways: Alternative fuel vehicles.
- Associated SOPS.
- Any incident involving solar panels should be managed in accordance with Policy number 839 – Incidents involving solar panels.
- For further information regarding wind turbines, see Policy number 769 – Incidents involving electricity.

Relevant National Operational Guidance

- Utilities and Fuel.
- Hazard – Rechargeable batteries.

- Control measure – Identify presence and type of rechargeable batteries.
- Control measure – Isolate rechargeable batteries.
- Control measure – Safe system of work: Rechargeable batteries.
- Scenario – Fire in Electrical Installation.

Other links:

- Renewables map: https://www.mygridgb.co.uk/map/

This Standard Operating Procedure should be read with:
PN977 - All incident considerations - NOC: Dated 6 March 2023

Alternative energy

16.38 Due to the effects of fossil fuels on the climate and the need to reduce carbon emissions whilst complying with legislative targets, alternative energy sources are being developed at an increasing pace and utilised in every aspect of power generation. These alternative energies are utilised in everything from small mobile devices, to powering vehicles or large gigawatt storage plants, which can present additional hazards to the public and operational staff dealing when dealing with them.

16.39 The five primary alternatives to fossil fuels are renewable energy, nuclear power, hydrogen, biomass, and geothermal energy. Renewable energy is defined as power derived from natural sources that can replenish themselves, such as wind, solar, tidal or hydroelectric.

16.40 Alternative energy sources can also include gaseous fuels such as hydrogen, natural gas, and propane; alcohols such as ethanol, methanol, and butanol; vegetable and waste-derived oils. All sources can be encountered in a variety of settings i.e., generation, infrastructure, transport and storage.

16.41 Additionally, radiation sources are being utilised to generate power, although these are usually encountered at the generation point and strictly controlled, see LFB Hub Utilities and fuel | NFCC CPO (ukfrs.com).

16.42 This 'context guidance' has been developed to assist fire and rescue services in identifying hazards and implementing control measures at operational incidents where alternative energy needs to be managed or controlled.

16.43 Because of similarities in the production, storage and distribution of utilities, this section of guidance also covers generic hazards for alternative energy. However, in accordance with the structure of the National Operational Guidance framework, any hazards relating to specific fuel types will be dealt with in the guidance for hazardous materials, alternative fuels, utilities and fuel sections see LFB Hub - Utilities and Fuel.

16.44 This guidance does not deal with fire and rescue service operations such as incident command, fires and firefighting, performing rescues or environmental protection, other National Operational Guidance deals with those activities.

16.45 This guidance is supported by supplementary information that provides further detail on individual subject areas see LFB hub - Utilities and Fuel Supplementary Information.

Hydrogen

16.46 Hydrogen is the lightest gas that occurs in nature and is colourless and odourless. Hydrogen atoms pair up to produce diatomic molecules. Hydrogen has the chemical formula H2 is highly flammable and a very low ignition energy. It can be ignited by a static discharge, rubbing, friction, heating or even a mechanical shock. Spontaneous ignition upon sudden release or depressurisation is possible.

Hydrogen at refuelling stations

16.47 At refuelling stations, hydrogen is stored at pressures in excess of those found in the fuel tanks of vehicles, so will therefore be above 1000 bar. The cylinder pressures in vehicles can range from around 350 to 700 bar.

16.48 After being manufactured at a remote steam reformation site, hydrogen is often transported to refuelling sites by road tankers as a cryogenic liquid.

Hydrogen fuel cells

16.49 Hydrogen fuel cells are found in:

- Fixed installations.

- Industrial sites.
- Refuelling stations.
- Vehicles.

16.50 Hydrogen fuel cells can also be found at installations such as wind farms, where they can be operated in reverse to manufacture hydrogen.

16.51 Hydrogen fuel cells chemically combine hydrogen gas supplied under pressure with oxygen, usually supplied from air at atmospheric pressure, to generate electricity. The fuel cell is linked via specialist pipework to a high-pressure hydrogen cylinder, which should be fitted with a temperature pressure relief device (TPRD).

16.52 Hydrogen fuel cells are normally stacked; hundreds of individual cells, each producing a small voltage, are combined to supply large DC voltages. These can range from around 300V to 600V. These voltages are the main hazard associated with the hydrogen fuel cell itself, although these voltages drop to zero immediately the hydrogen supply is stopped. However, high voltages may still be present in linked components, such as cabling or batteries.

16.53 Fuel cells only ever contain very small amounts of residual hydrogen, which should be treated with caution, although this is not excessively dangerous. For further information regarding fuel cells in transport, refer to LFB Hub - Transport – Roadways: Alternative fuel vehicles.

Hazards

16.54 These hazards are unique to hydrogen:

- Hydrogen burns with an almost invisible flame. When released under pressure a jet like flame several metres in length can be produced that is almost impossible to see with the naked eye.
- Very cold saturated hydrogen can pool or flow horizontally at ground level; this can be difficult to see unaided but may be detected by using thermal imaging.
- Burning hydrogen radiates far less heat than carbonaceous or hydrocarbon fuels, which can make the flames very difficult to detect. Personnel may only be able to feel these flames if in direct contact, which can cause serious harm.
- Leaking hydrogen can ignite or reignite with ease, especially if under pressure and even in the absence of an ignition source.
- Because hydrogen is the smallest molecule it can over time slowly penetrate, or travel through, container walls, resulting in 'embrittlement'. This type of damage may take many years, but can eventually affect the structural integrity of cylinders, pipework, connectors, and valves.

16.55 The following hazards relate to hydrogen and are common to many other gases under pressure:

- A leak from a high-pressure hydrogen cylinder can be loud enough to cause damage to hearing.
- Hydrogen and oxygen gas are often stored at high pressures.
- Oxygen rich atmospheres may be found where hydrogen is being manufactured using electrolysis.
- Hydrogen is often stored or transported as a cryogenic liquid.
- High-voltage equipment is used with hydrogen fuel cells and in electrolysis.
- Some electrolysis equipment may contain a high temperature alkaline potassium hydroxide solution.
- Hydrogen fuel cells are silent, and personnel may not be aware of their presence.

- It may be necessary to use thermal imaging to detect or monitor fire spread if it involves gases, such as hydrogen, that burn with an invisible flame; for further information refer to LFB Hub - Thermal imaging or scanning.

16.56 For more information refer to LFB Hub:

- Hazardous materials
- Gases under pressure
- Oxygen-enriched atmosphere
- Cryogenic materials
- Inaccurate situational awareness: Hazardous materials
- Roadways: Alternative fuel vehicles
- Policy number 979b – Road Traffic Collisions – Rescue – SOP

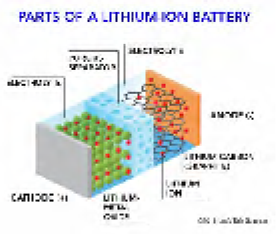
Lithium-ion Batteries

Introduction

16.57 Lithium-ion batteries are rechargeable batteries (as opposed to non-rechargeable lithium batteries) that use lithium-ions as the primary component of their electrolyte.

16.58 The term "battery" can be used to describe an assembly of "cells" and "modules". Lithium-Ion batteries (LiB's or Li-ion) may contain cylindrical cells, slightly larger than an AA battery; prismatic cells, about the size of two cigarette packs; or pouch cells, about the area of an A4 sheet of paper and 1cm thick. The cells are packaged together into modules, and a group of modules can form a battery pack. A large battery can consist of thousands of cells grouped into many modules.

16.59 For safety reasons, lithium-ion batteries include a protective membrane or separator. This prevents the electrodes of the battery's cells from touching each other. But if this separator gets ripped or damaged, the electrodes can touch. Once there are flames in one cell, they can quickly spread to others.



Background

16.60 No other battery type compares to the energy density of LiB's, resulting in a growing range of uses. These range from small mobile electronic devices, through to powering electric vehicles of all sizes including trains and Battery Energy Storage Systems (BESS).

16.61 LiB's introduce new unique hazards, requiring different responses and tactics for operational crews.

16.62 With advancements in solar-powered domestic and commercial photovoltaic systems, BESS is becoming an economically viable option for households and businesses if the surplus electricity isn't transferred to the National Grid.

16.63 There are generally two types of batteries utilised storage, lithium-ion and lead-acid batteries. Normally located near the system's inverter, often found in utility rooms, garages or similar locations.

Note: DC current is not identified by the voltage detector as this only detects AC current.

16.64 There are two main ways of linking a battery storage system into a PV system:

- **Direct Current (DC) coupled** - Batteries are installed the same side of the inverter as the PV panels, they charge from the panels, and their DC is only converted to AC when used.
- **Alternating Current (AC) coupled** - Batteries are installed grid side, where the DC from the PV panels has already been converted to AC. A separate inverter converts the AC back to DC for storing in the battery. When the battery discharges, the same separate inverter converts the DC back to AC.

16.65 BESS systems are becoming more popular, and the presence of PV panels does not always indicate if BESS are present. BESS is used to store power from the grid at cheaper rates.

16.66 If the premises owner or occupier is unsure regarding the location of the panel controls and inverter, consideration should be given to requesting a 'competent person' i.e., the system installer.

16.67 Locations of identified sites can be found at renewables map: www.mygridgb.co.uk/map/.

16.68 These images are of typical installations found in premises:

Figure 1 Small scale domestic BESS

Figure 2 DIY domestic BESS

Figure 3 Industrial scale BESS

16.69 For further information about, battery storage, refer to BRE and RECC (2016) Batteries and Solar Power: Guidance for domestic and small commercial consumers.

16.70 For further information about the components of photovoltaic systems, refer to BRE's Fire safety and solar electric/photovoltaic systems.

Thermal runaway

16.71 Lithium-ion (Li-ion) battery thermal runaway occurs when a cell(s), or area within the cell, reaches elevated temperatures due to:

- Thermal failure.
- Mechanical failure.
- Internal/external short circuiting.
- Electrochemical abuse.

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16.73 When Lithium-ion batteries are compromised, its normal electro-chemical processes are replaced by chemical reactions generating gases and heat. Heat speeds up the reactions, so more and more gases and heat are produced. When the (exponential) heat gains and exceeds the (linear) heat dissipation, the cells involved are in thermal runaway. Thermal runaway within a single battery cell can spread to neighbouring cells as the protective membrane or separator in the cells are compromised resulting in an escalation of toxic vapour production, increasing fire and explosion risk.

16.74 Impact or movement can lead to thermal runaway or deterioration in the condition of already damaged battery(s); crews should consider this when releasing a trapped casualty, stabilising a vehicle or a when a vehicle is required to be recovered.

Note: Crews may need to have a presence and agree a tactical fire plan whilst the vehicle is recovered. Additionally, crews may need to put in place watching brief(s), re inspections, and consider the need to accompany the affected vehicle to its final destination (if within London area). An in-depth handover to the Responsible Person (RP) will be required.

16.75 The presence of reactive metals, such as lithium can cause the release of explosive gases and alkaline solution, caused by chemical reduction of water, for example lithium hydroxide (LiOH) and hydrogen (H2). This can appear like steam and crews need to be mindful that this will need monitoring and advice from a HEMPO.

16.76 Sensitivity to charging and discharging regimes, mechanical shock, and localised temperature gradients which can lead to thermal runaway, rapid unexpected release.

16.77 Due to the popularity of LiB's and the need to charge and store the various uses of these systems more and more locations are being utilised often without specific notification or planning. Crews will need to recognise the surrounding risks and the control measures required to protect themselves, and the public from fire and explosion risks associated with LiB's see hazard section below.

16.78 Crews may have to evacuate buildings in close proximity and for potential extended periods, due to the thermal runaway, gases and explosion risks.

16.79 A Lithium-ion battery hazard video is available on Hotwire via Working here > Health and Safety > Lithium-ion battery hazards.

LiBESS (Lithium-ion Battery Energy Storage Systems)

16.80 Lithium-ion battery energy storage systems come in the form of one or more containers, resembling ISO shipping containers. There may not be a label identifying the contents as lithium-ion batteries. Even one container, when the lithium-ion cells inside are fully charged, contains a very large amount of energy in a relatively small space. They are often used to store grid electricity or even support the National Grid. (Note UKPN do not use LiBESS within the London area at this time see section Batteries Non Li-io). Pouch cells and prismatic cells are commonly used in LiBESS.

16.81 The McMicken LiBESS in Surprise, Arizona contained 10,584 such cells, only 392 of which went into thermal runaway. Despite that, the resulting explosion when a container door was opened severely injured two firefighters. Further reading can be found in the McMicken incident final report available online.

Figure 5 LiBESS installation on Merseyside that exploded in September 2020

16.82 The venting vapour cloud produced by cells in thermal runaway may or may not ignite; if it does it will produce jet-like flames coupled with toxic gases and fumes.

16.83 Previously fires without oxygen, would extinguish themselves. But when a Li-ion battery is on fire, one of the by-products is oxygen, so even in an enclosed environment, a battery(s) will keep burning resulting in thermal runaway often with explosive effects. In the event of ignition not occurring (e.g., the activation of fire suppressant systems, insufficient air in the container or cells having a low State of Charge [SOC]) the cascading thermal runaway will produce gases over a substantial period of time – way beyond the scope of most suppressant systems. Cells have the potential to ignite hours, days or even weeks after the initial event.

16.84 If the vapour cloud is present in a LiBESS container and the door is opened, the mixture could turn from rich to ideal, swirl and ignite resulting in a vapour cloud explosion.

16.85 The challenges posed by LiBESS are replicated in lithium-ion cell or battery manufacturing and storages facilities, large transport vehicles, goods trains, etc.

16.86 Further information can be found in the Policy number – 979a - Lithium-ion batteries - all incident considerations – SOP.

Hazard knowledge - Hazards (Li-Ion)

16.87 General Hazards of Lithium-ion Batteries:

- Batteries vary in size and configuration depending on their use and application. Larger batteries may be found in Energy Storage Systems (ESS) or vehicles including trains etc. Whilst smaller batteries are used in most electronic items such as laptops and mobile phones and can be dealt with relatively easier by submersion or isolation, however the larger LiB's will require an alternative approach as access is often hindered by chassis and other protective means.
- Batteries are arranged in series to increase voltage, and in parallel to increase capacity. Larger batteries may contain many hundreds, even thousands of individual cells.

16.88 Hazards can include:

- All Lithium-ion batteries produce white vapour when in thermal runaway. This vapour can easily be mistaken for steam (especially if visible flames have been extinguished) or smoke. In fact, it's an explosive, corrosive toxic mixture of up to 50% hydrogen, plus carbon monoxide, carbon dioxide, hydrogen cyanide, acid gases, small hydrocarbons such as methane and ethane, and droplets of solvent.

- Personnel exposed may be subjected to solvent droplets from within the cloud condensing upon them. These droplets contain a mixture of chemicals. Advice should be sought from the HEMPO.
- Li-ion batteries can develop design or manufacturing faults; if abused through overheating, physical damage or overcharging. Battery cells may become unstable at temperatures as low as 70°C. The electrolyte is made from flammable organic solvents.
- LiB's may be pressurised under thermal runaway or fire conditions and present a high risk of injuries from blasts and shrapnel. Molten metal can be ejected explosively several metres.
- Large LiB fires will burn for protracted periods requiring large amounts of water to extinguish and cool. They are then prone to re-ignition hours, days or even weeks later, and may do so several times.
- Due to the construction of the battery in cells, it is possible for the battery to retain an electrical charge during or after a fire. Therefore, a risk of electrocution or electrical arc remains throughout the incident. This is sometimes referred to as "stranded electrical energy". Arc flash explosion can produce temperatures of up to 14,000°C.
- In a confined space a battery in thermal runaway will create an explosion hazard due to the white vapour and flammable gases. Examples of circumstances where this could occur are:
    - Electric Vehicle (EV) Road Traffic Collisions (RTC's).
    - Domestic and Industrial BESS.
    - Fires in LiB storage warehouses.
    - LiB manufacturing plants.
    - Transportation of EV battery packs by road and rail.
    - Underground car parks.
    - Basements.
    - Tunnels.
    - Railway arches.
    - Garages.
    - Charging points (domestic and commercial).
    - Any unventilated premise.

16.89 Additional hazards for crews to consider when dealing with LI-ion, LiB's:

- The need to recognise LiB's are involved or likely to be involved.
- Potential for impact on any life risk i.e. fire below a flat, office, high rise.
- Uncontrolled or unpredictable vehicle movements (RTC's).
- Gases, Vapours and toxic substances.
- High-voltage systems – the residual charge in these systems may remain for up to ten minutes after isolation.

- Difficulty gaining access to safety cut offs or applying firefighting media (vehicle may need jacking).
- Fuel cell explosion.
- Other Hazardous materials, including liquid petroleum gas (LPG) and lithium-ion cells.
- Electrolytes leaking from fuel cells.
- Pressurised systems.
- Damage to surrounding infrastructure and or the environment.
- Possibility of re-ignition (hours, days after the event).

Hazard knowledge - Hazards (Alternative Fuel Vehicles)

16.90 The term 'alternative fuel vehicles' (AFV) refers to vehicles powered by fuels other than petrol or diesel. The hazards and control measures for incidents involving AFVs should be considered in conjunction with those that apply to other road vehicles. AFVs may be difficult to identify from the exterior.

16.91 The following features could also indicate the vehicle has a high voltage system:

- Registration plate with a green band (from December 2020 onwards).
- Orange cables – all high voltage cables and connectors on EVs are orange in colour.
- Large HV components, such as the battery pack, motor or invertor.
- Warning stickers on components, usually yellow with the ISO electrocution symbol.
- Electrical charging socket, this could be under the vehicle symbol on the front grille, or under a "fuel cap" cover on the side or rear of the vehicle.
- Vehicle has a charging cable stored in it.
- Lack of an exhaust pipe, although hybrids will still have an exhaust pipe.
- Electric vehicles don't use a manual gearbox, so the gear lever is likely to look more like the selector of an automatic model.

16.92 If it is safe to enter the vehicle or you can see through the windows from outside, the vehicle dashboard and instruments may show information relating to the high voltage system:

- "Ready" light or EV indicator.
- EV power mode switches.
- Rev counter replaced with a power flow indicator.
- Battery State of Charge (SOC) information.
- HV diagnostic lights.

16.93 Vehicles without any of these features may still have a high voltage system.

16.94 When a vehicle is powered by two or more fuel sources, it is referred to as a hybrid. The term most commonly refers to hybrid electric vehicles, which combine internal combustion engines, electric motors, rechargeable batteries, and high voltage systems.

16.95 AFVs can be powered by:

- High voltage fuel cells (batteries).

- Compressed natural gas (CNG).
- Liquid natural gas (LNG).
- Biofuels.
- Hydrogen fuel cells.
- High voltage systems.
- Rechargeable batteries.

16.96 Where a vehicle is powered by two or more fuel sources, it is referred to as a hybrid. The term most commonly refers to hybrid electric vehicles, which combine an internal combustion engine and one or more electric motors. However, this term includes other mechanisms to capture and use energy.

16.97 AFVs may not show signs that that the engine is running, such as engine noise or exhaust gases, emitting, particularly when stationary. Although these hazards are not unique to AFVs they are more likely to be present than in older vehicles or those powered by petrol or diesel.

16.98 AFVs affected by collision, fire or submersion may present hazards including:

- Uncontrolled or unpredictable vehicle movements.
- Gases.
- High-voltage systems – the residual charge in these systems may remain for up to ten minutes after isolation.
- Fuel cell explosion.
- Hazardous materials, including liquid petroleum gas (LPG) and lithium-ion cells.
- Electrolytes leaking from fuel cells.
- Pressurised systems.

These hazards may also result from operational activity.

Rechargeable batteries in alternatively fuelled vehicles

16.99 New style rechargeable batteries are often found in alternatively fuelled vehicles, for more information refer to LFB Hub - Rechargeable batteries. Vehicle markings vary and can be misleading if they have been modified. Designs and locations of batteries vary widely, so it is not possible to provide a guide here to all types.

16.100 Many vehicles contain interchangeable trays of batteries, and the type of battery itself can be changed so that some contain, for example, a mixture of nickel cadmium and lithium ion. Batteries can be present in their thousands in trays located under a vehicle's floor and, in total, can be as heavy as 500kg or more.

16.101 It may not be difficult to identify which individual battery, or group of batteries, has overheated or is leaking electrolyte. Access to battery trays in a vehicle that is damaged may be limited. Personnel should seek specialist advice or consider the manufacturer's handbook or guidelines for information about appropriate firefighting media, access and isolation.

Batteries (non Lithium-ion)

16.102 In addition to Lithium-ion batteries there are a number of other battery solutions widely used and continually under development. For example, UK Power Networks (UKPN) use at their grid and primary sites a combination of valve regulated sealed lead acid (VRLA) or wet cell (Plante) batteries.

The batteries are anywhere between 24 – 110V and are required for a small amount of capacity in a Blackstart or similar event to bring the network equipment back online.

16.103 The batteries are usually situated in a small, well-ventilated room on dedicated racking or designed cabinets, with SCADA linked temperature alarms fitted to the charger units.

16.104 UKPN have fire risk assessments noting the hazards that relate to these battery systems and other areas of special fire hazard, and where required specific measures put in place to control these risks. For example, fire detection and alarms may be extended/upgraded to cover these areas or air conditioning units installed to deal with peak summer temperatures that are cause temperature alarms.

16.105 Compared to other battery storage applications, such as industrial and commercial battery storage facilities or fast charging lithium battery charging stations. The VRLA and Plante systems are considered to be lower of significant and uncontrolled battery fire than other battery storage solutions.

16.106 The hazards listed below are specific to incidents involving batteries (non lithium-ion) or are generic hazards for working in or around batteries involved in incidents. The list is not exhaustive, and ICs should always be aware of additional hazards when formulating their objectives and plan.

16.107 A battery is a chemical device that stores electrical energy in the form of chemicals and by means of electrochemical reaction, it converts the stored chemical energy into direct current (DC) electric energy.

16.108 Simply speaking there are two main types of battery:

- Primary (non-rechargeable)
- Secondary (rechargeable)
  - Lead acid/nickel iron batteries
  - Nickel Cadmium batteries (Ni-Cd)
  - Nickel–Metal Hydride batteries (Ni-MH)
  - Lithium–ion batteries
  - Sodium Sulphur batteries

Characteristics and hazards of Batteries

16.109 All types of battery present significant hazards, including risk of explosion and the potential for production of corrosive and/or toxic gases if damaged through impact or fire.

Lead acid/nickel iron batteries

16.110 These are the most popular and most used type of rechargeable battery. They are available in several different configurations like small, sealed cells with capacity of 1Ah (typical AAA) to large cells with capacity of 12,000Ah. They are likely to be found in vehicles with internal combustion engines, hybrids and fully electric vehicles (EV).

16.111 Other applications include energy storage, emergency power, communication systems and emergency lighting systems.

16.112 If involved in fire the products of combustion will contain droplets of sulphuric acid which is corrosive and poisonous. Salt water should not be used on fires involving lead-acid batteries, since under certain conditions chlorine gas may be generated. Hydrogen is released during the charging of these batteries, which can lead to a risk of explosion.

Sodium Sulphur batteries

16.113 If battery is damaged sufficiently (for example in a significant road traffic collision (RTC) or involved in fire, toxic sulphur dioxide and hydrogen sulphide will be given off.

16.114 Crews should be alert to this risk and should consider deploying a gas monitor, particularly if any person reports the characteristic 'rotten egg' aroma of hydrogen sulphide, noting that this gas is heavier than air.

16.115 A fire originating inside this type of battery can take up to 30 minutes to become apparent, will be very difficult to extinguish, and can burn for up to 2 hours.

Ni-MH (Nickel-Metal Hydride) batteries

16.116 Following significant physical stress, the electrolyte (made from potassium hydroxide) may leak.

Hazard knowledge - Hazards associated with batteries

16.117 The release of:

- Hydrogen gas.
- Carbon Monoxide.
- Sulphur Dioxide.
- Sulphur Trioxide.
- Hydrogen Sulphide.
- Lead fumes and vapour.
- Corrosive acidic electrolytes, such as sulphuric acid.
- Poisonous alkaline electrolytes, such as potassium hydroxide.
- Release of stored energy.
- Toxic or irritating water based liquid electrolytes, such as copper sulphate.
- Corrosive acidic electrolytes, such as sulphuric acid.
- Poisonous alkaline electrolytes, such as potassium hydroxide.
- Very high discharge or surge currents, for example in a road vehicle battery.
- Non-precious metals like lead or copper; elevated temperatures and fires can cause these metals, when in the presence of electrolytes, to react or release vapours.
- Release of hydrogen gas or oxygen gas during charging, which can ignite or explode.

16.118 Further information can be found in:

- Policy number 808 - Hazardous materials and environmental protection - mass decontamination
- Policy number 793 - Compartment firefighting.
- Policy number 956 - Respiratory protective equipment – respirator – technical information.
- Policy number 839 – Incidents involving solar panels.
- Policy number 769 – Incidents involving electricity.
- Policy number 979b – Road traffic collisions – rescue – SOP.

- LFB Hub - Roadways: Alternative fuel vehicles.