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Remarks on the Safety of Lithium -Ion Batteries for Large-Scale Battery Energy Storage Systems (BESS) in the UK

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Abstract. Large grid-scale Battery Energy Storage Systems (BESS) are becoming an essential part of the UK energy supply chain and infrastructure as the transition from electricity generation moves from fossil-based towards renewable energy. The deployment of BESS is increasing rapidly with the growing realisation that renewable energy is not always instantly available and hence dispatchable when consumers need it. This paper is a brief overview of the fundamental battery chemistry and some of the important safety issues of these large, energy—dense facilities. Our aim is to examine the potential causes of major BESS "battery fires" and explosions and the essential mitigation procedures that must be in place before their further deployment. It is strongly recommended that there is a pause to the widespread ongoing deployment of BESS installations in the UK and indeed in all countries until the necessary health and safety (H&S) standards and practice are adopted through established appropriate regulatory conditions for BESS hazards.

Keywords: Battery energy system storage, BESS, Safety, Fire, Regulations

1. Overview

There are growing and entirely reasonable public concerns about the widespread installation of large grid -scale Battery Energy Storage Systems (BESS) based on lithium- ion batteries in both urban and rural areas in the UK with little knowledge applied about the explosion, fire and pollution risks associated with them. Large BESS facilities are being employed rapidly and at very large scale because energy providers have realised that the intermittent renewable energy sources simply cannot always provide reliable electricity when it is needed. There is a worrying possibility that BESS could become the next legacy—fire safety issue with all the risks to the public from fire, explosion and toxicity and the attendant clear dangers to employees at these facilities, to First-Responders, Firefighters and the local population as well as to their impact on the environment.

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In brief:

- Lithium-ion batteries by their very nature are intrinsically fire—prone and are notoriously difficult to distinguish. In terms of their large-scale in BESS, the more lithium, the larger the fire and explosion risks.
- All the current generation of lithium-ion batteries always carry an inherent risk of so- called "Thermal Runaway" which can result in fires, explosions and off-/out- gassing of toxic and flammable gases. This Thermal Runaway (and associated) events have occurred in almost every country in which lithium-ion battery storage are being used. Even South Korea – recognised as the pioneer in the development of large-scale battery storage—experienced 23 major battery fires over a 2-year period between 2020 and 2022. There is a continuously up-dated list of such incidents in the Electric Power Research Institute (EPRI) database [1] Most recently an explosion in S Korea resulted in the death of 22 workers and injuries to 8 others.
- Recently, the UK Government through the Department for Energy Security & Net Zero has commissioned a "Health and Safety Guidance for Grid Scale Electrical Energy Storage Systems" [2]. For the first time, by highlighting existing legislation, regulations, standards and other industry guidance this acts as guidance – note, only as guidance—for the installation and relevant aspects of H&S operation of BESS facilities. In the detailed Appendices of that Report the numerous regulatory compliances are outlined, although it is not clear if these are currently mandatory. Furthermore, a recent UK House of Commons Library document "Battery energy storage systems" notes in relation to the safety regulations for BESS "There are no laws that specifically govern the safety of BESS specifically" [3].

It is widely – well, universally – recognised that such BESS installations undoubtedly pose specific – and unique – hazards in the event of fire. Any fire involving this level of large- scale lithium-ion battery storage must surely be treated as a 'Hazardous Substances or Materials Incident', so that the necessary specialist scientific and technical safety advice can be organised and implemented at the earliest opportunity.

Currently in the UK, and indeed in many other countries, not only are there are no established standards and regulations concerning the safety standards of these large BESS installations but also the guidelines to Fire and Emergency Services are at best fragmentary and lacking in substantive, detailed operational procedures in the event of fires.

This situation is without question unique and highly concerning. For example, the hazardous substances and materials constituting all known large-scale lithium-ion battery storage facilities in the UK, remarkably, do not currently come under the remit and control of the Health and Safety Executive as statutory regulatory bodies and consultees in the planning and approval process. Those sentiments and concerns were strongly highlighted by Dame Maria Miller in a recent UK parliamentary debate [4].

The present Commentary includes key aspects of the relevant background battery chemistry of Lithium-Ion Batteries (LiB) ranging from the early—generation Lithium Metal Oxide (LMO) batteries to Lithium Iron Phosphate ($LiFePO_4$; (LFP).

2. General Principles of a Working Li-ion Battery (LiB)

A LiB typically consist of 4 major constituents: the cathode, the anode, the separator and the electrolyte. The cathode and anode are the fundamental carriers of electrical charge, contributing to the energy storage and energy release.

The working mechanism for a typical LiB is shown schematically in Fig. 1 below, using the $LiCoO_2$/ graphite cell as a pro-typical example.

A separator or membrane is always incorporated in the liquid electrolyte which is an organic molecular, non-aqueous solvent. This electrolyte allows for the critical transport of 'solvated' Li + ions (Li + ions coordinated to several electrolyte molecules) as shown in Fig. 1. The separator membrane is to physically divide and (of course) separate the cathode and anode electrodes to prevent catastrophic internal short-circuits.

Critically, if the integrity of the separator membrane is compromised or damaged and fails by any process, the entire processes in the LiB transition from a controlled, to an uncontrolled series of electrochemical reactions, with significant heat generation. Importantly, if that happens, the organic electrolyte will then become a combustible fuel particularly in the presence of evolved, or additionally -admitted oxygen during any fracture of the battery.

The malfunction of any of these parts – individually or together – negates the necessary integrity, stability and safety of any LiB.

We summarise the working principles: During battery charging, the Li + ions 'de-intercalate' from the layered oxide solid cathode material and enter into the intervening non-aqueous electrolyte to finally diffuse through the liquid as solvated Li + ions through the separator nano-pores into the anode material (Fig. 1). Correspondingly, to maintain electro- neutrality, electrons (shown here as 'e') will therefore move in the opposite direction through the external circuit to generate an electric current.

During battery discharge, when the battery is delivering its stored electrical energy, Li + ions transport from the intercalated graphitic anode back through the electrolyte to the cathode, as shown in Fig. 1.

The precise charge/discharge electrochemical reactions are given below:

$$\textbf{Cathode}: \ LiCoO_2 \underset{discharge}{\overset{charge}{\rightleftharpoons}} Li_{(1-x)}CoO_2 + xLi^+ + xe^-$$

$$\textbf{Anode}: 6C + xLi^+ + xe^- \underset{discharge}{\overset{charge}{\rightleftharpoons}} Li_xC_6$$

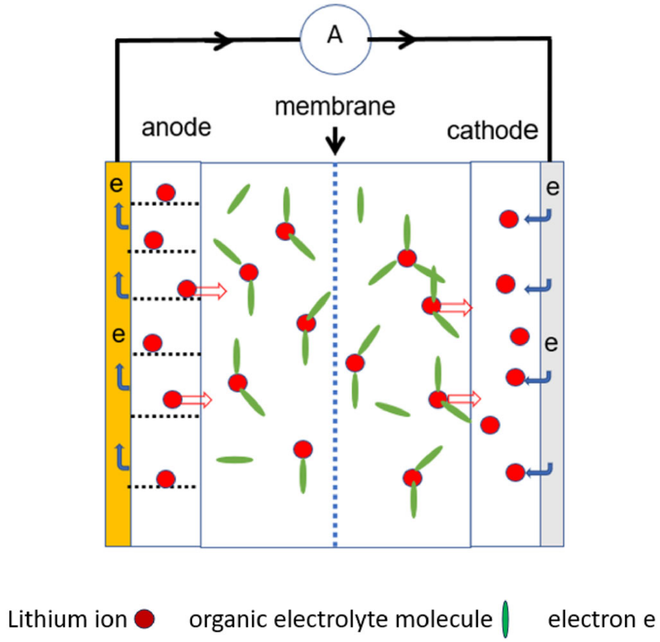

Figure 1. Schematic representation of a working Li-ion battery. The negative electrode – *the anode*- is solid, graphitic carbon that holds Li + ions in its layers, whereas the positive electrode- *the cathode*- is a Li-intercalation oxide compound (containing *both* Li + ions and electrons), often a layered (intercalated) solid-state crystal structure chosen because of their higher working potential. Both anode and cathode electrodes can reversibly insert and remove Li ions from their respective solid-state structures. Upon charging, Li + ions in the cathode are removed or deintercalated from the layered oxide compound to be transmitted through an intervening organic electrolyte and finally intercalated into the graphitic layers. The entire process is reversed on discharge. It is important to note for our present discussion that the electrodes are separated by a nonaqueous organic electrolyte that transports Li + ions between the electrodes. A corresponding solid-state electrolyte is discussed in the text. Adapted from Dunn et al. [5].

$$\textbf{Reactions}: \mathrm{LiCoO_2} + 6C \underset{discharge}{\overset{charge}{\rightleftharpoons}} \mathrm{Li}_{(1-x)}\mathrm{CoO_2} + \mathrm{Li}_x\mathrm{C_6}$$

The shuttling of Li + ions throughout the entire cell during battery operations generates a significant amount of heat; that, a perfectly normal feature of battery operation. This heat removal is usually controlled by external cooling of the entire battery. However, if this generated heat has no efficient dissipation path in either, or both, the charge/discharge states, the battery will become excessively hot – a clear compromising situation in battery safety. It is also critically important to understand that a LiB contains *not only* a powerful chemical oxidizer (the cathode material) *but also* a fuel (the anode material) and *both* are located entirely within the same sealed container! This potentially dangerous situation of a chemical oxidant and a chemical reductant in close proximity is rarely found in normal, everyday circumstances – the most obvious exceptions are high explosives and rocket propellants.

Under normal battery operating conditions, the fuel and oxidizer convert the chemical energy into electrical energy with minimal heat and gas evolution. However, if allowed to react *chemically* in such a closed electrochemical cell, the fuel and the oxidizer now convert the (latent) chemical energy into heat and gas. Once initiated, the chemical reaction will invariably proceed to completion because of the intimate contact of both the fuel and the oxidizer; this can lead to large scale explosion and fire [6]. This process will be further discussed in the "Thermal Runaway" section below.

3. Thermal Runaway

All lithium batteries can potentially transition into the dangerous condition known as Thermal Runaway. This is when local heating inside the battery initiates and/or speeds up so-called "exothermic" (heat- generating) chemical reactions which not only produce more heat and but also lead to a build-up of internal pressure from released gases, typically through the decomposition of the organic electrolyte. It is well established that the initiation of the process is caused by the chemical or electrochemical reduction of lithium ions in the battery system leading to the growth of elemental, metallic lithium dendrites or filaments of the surface of the electrodes. These highly conducting, filamentary metallic whiskers give rise to electrical short circuits and localised "hot-spots" which can produce accelerated chemical reduction and oxidation reactions at the cathode and anode which then increase the internal heat. Importantly, if localised in the liquid organic electrolyte, the hot-spots can also lead to the break-down of the electrolyte solvent, through various exothermic chemical reactions, which can produce a dramatic increase in the internal pressure of the battery as the organic electrolyte vaporises and / or decomposes to various gaseous products.

Presently, there appear to be considerable differences in the degree of lithium metal dendrite formation in the different battery chemistries and cell design. The replacement of the older -style lithium transition metal- oxide cathodes by lithium iron phosphate cathodes has led to some improvement, notably in the apparent reduction in the thermal runaway rate until higher temperatures are reached, see Fig. 2 (taken from Doughty and Roth [7]). However, it is important to stress that the suppression of this process to higher temperatures in LFP appears also lead to other, even more dangerous consequences, as we shall illustrate.

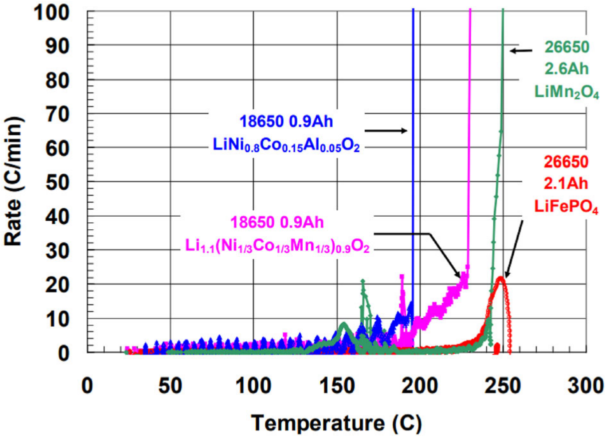

Figure 2. Onset of self-heating rate in a thermal ramp experiment on Li-ion cells. Note that the LiFePO4 (LFP) cathodes (red) show the greatest reduction in self-heating rate and also an increased onset temperature for runaway. From Doughty and Roth [7].

At present, it must be said that we lack a complete, fundamental understanding of how lithium metal dendrites form and grow and their inhibition or complete suppression has not been fully solved in current batteries. However, some progress has been made via internal design of the anode/electrolyte and cathode/electrolyte interfaces. The onset of this condition can in principle be monitored via coupled non- intrusive electrical impedance and temperature measurements. However, a particularly worrying concern to the authors is that it is not clear if the battery management systems in current BESS installations are actually configured to monitor this critical series of events. The new guidance in [2] does not discuss this critical point either.

As clearly shown in Fig. 2 LFP cathodes not only show the greatest reduction in self-heating rate but also the increased onset temperature for thermal runaway.

However, balancing this apparently attractive characteristic, it is now established that LFP batteries pose the greater explosion hazard of all LiBs; we note that the only fatal BESS explosion to-date involved LFP cells, [8]. This is clearly an extremely important consideration due to the potential risks of explosion and the obvious hazard this presents to employees at the BESS facility, First-Responders, Fire-Fighters as well as to residents in nearby houses, etc.

One of the most important chemical reactions that can occur before/after the complete thermal runaway of a lithium-ion battery is the exothermic (heat-evolving) structural collapse of the entire solid cathode material. Importantly, as part of that process, the degrading / compromised battery can produce molecular oxygen (O_2). That evolved O_2 is believed to be the primary accelerant of cell ignition/fires. This structural collapse appears to be at a higher temperature in LFP battery cells (*ca.* 310 °C) and this seems to be the major reasoning behind an emerging view that LFP are considered ‘safer’ than other lithium -ion battery systems. The LFP cathode material does not appear to generate O_2 even when fully decomposed at high temperatures; thus, going some way to explaining the lowest heating rate during thermal runaway (Fig. 2).

For this particular type of cell, thermal runaway is now dominated by anode-electrolyte reactions which show high rates of decomposition at higher temperatures; unfortunately, this has major dangerous consequences for any vapour cloud explosion.

Looking at the relative chemistries of LFP and, say, Li_xCoO_2 (the earliest and still one of the major battery materials), it may be understandable that molecular O_2 formation in the latter may be the origin of the differences in the chemistries between the cathode lattice oxide anion $(O)^{2-}$ versus the phosphate $(PO_4)^{3-}$ anions.

Such a process—the degradation of lattice oxygen, viz O^{2-}(lattice) = > ½ $O_2 + 2e^{--}$ is highly likely in the case of a lattice oxide ion located in close proximity with a readily ‘reducible’ metal cation, eg Co in oxidation state III in the oxide battery materials. In the case of LFP the phosphate anion $(PO_4)^{3-}$– the equivalent process of decomposition of the anion lattice seems less likely and oxygen evolution – leading to the ignition process – will be suppressed, though not completely eliminated. This potentially critical aspect needs further study.

However, unfortunately, the fact that this intrinsic material property of LFP cathodes can possibly delay the ignition process to higher temperatures – perhaps viewed as positive characteristic—means that these cells are also recognised to have a higher risk of so-called ‘vapour cloud explosion’ [7].

This parameter *K*, the Explosion Index, is particularly important in this present discussion. It is proportional to the maximum pressure -rise rate and is recognised as a measure of the destructiveness of an explosion. In Fig. 3 we show the experimentally-determined Explosion Index values for various battery materials. This is strong evidence that the explosion-related damage caused by the escaping gases produced from the LFP batteries will be significantly greater than that from all other Ni Co Mn oxide batteries. In the recent paper, Wang et al. [9]., report that the vapour cloud from LFP cells has a lower explosion limit, larger explosion overpressure, higher Explosion Index and, equally worrying, the ignited vent gas has a high laminar flame speed. This is suggested to be because of the higher hydrogen content in the vented gas from LFP relative to the other oxide chemistries.

4. Gas and Other Pollutant Production and Release

The previous section introduced the likelihood of an explosion almost certainly initiated by the nature and composition of gases evolved in the closed, compromised battery cells. It has been shown [10] that the combustible gases produced by a LFP module during thermal runaway can be divided into two major categories: (a) H_2 and CO produced by the chemical reactions inside the battery in the approach to/during thermal runaway, and (b) Other gases produced by the vapor-

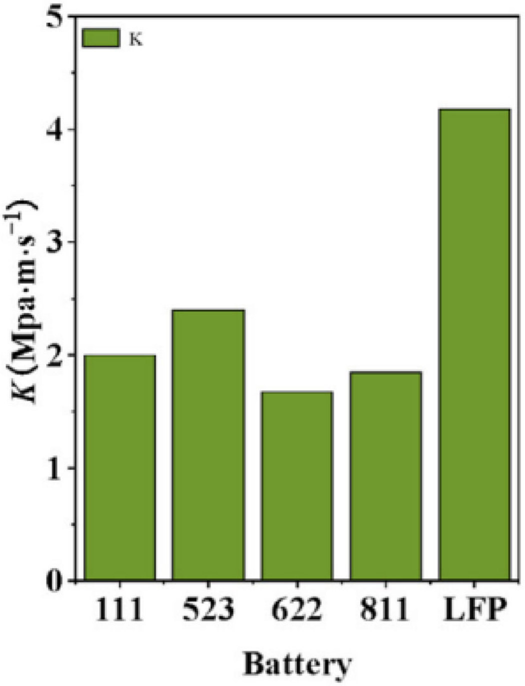

Figure 3. The measured hazard, the quantified Explosion Index *K*, of the vented thermal runaway gases from various kinds of lithium-ion batteries (Wang et al. [9]. Note that the flammability and explosive order of the vent gases thus has LFP as the highest so- called Explosion Index of all Lithium-battery materials. (Reprinted from Wang et al. ''Fire and explosion characteristics of vent gas from lithium ion batteries after thermal runaway; A comparative study''. eTransportation 13: Art 100,190 (2022) with permission from Elsevier).

ization and decomposition of liquid organic electrolytes by the high heat generated by exothermic chemical reactions inside the batteries, again in the approach to/during the thermal runaway process.

Interestingly, results show that the concentrations of H_2 and CO (although prevalent) appear *not* to be the main trigger of battery explosions in LFP. Rather, the vaporized liquid organic electrolyte is now regarded to be the main source of combustion and hence explosion. When the internal temperature of the battery rises to/above the boiling point of the liquid organic electrolytes, they obviously begin to vaporize. As expected, the vaporization rate of the electrolyte is determined by the heat accumulated in the battery. Even more concerning, when an internal short circuit occurs (eg. via hot spots initiated during the process of Li metal dendrite growth) the electrolyte vaporizes in a very short time. Important research by Christensen et al. [11] show that the vapour cloud includes the gases

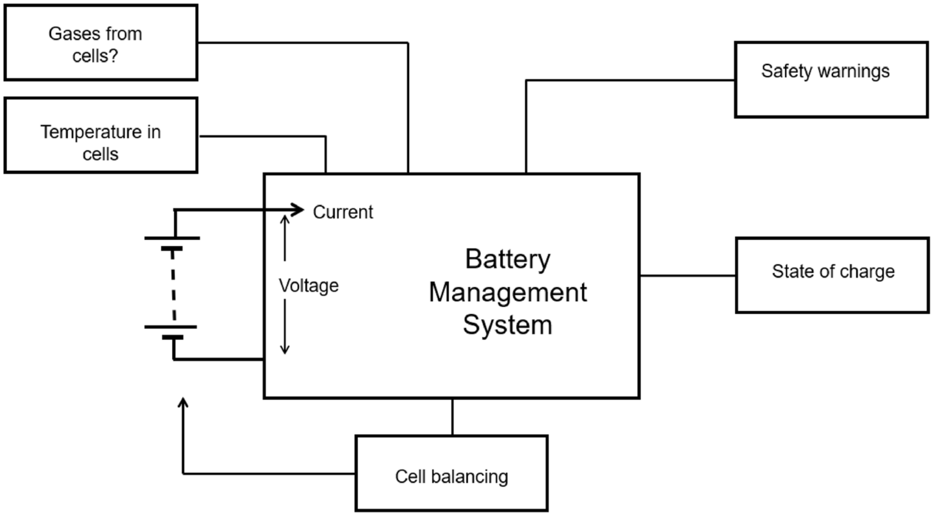

Figure 4. A very simplified representation of the main functional layout of a Battery Management System for a typical large-scale Battery Energy Storage System.

H_2, CO together with small droplets of the (thermally) vaporized organic electrolytes used in the cells. These authors highlight that First -Responders had previously mistaken such clouds as steam or smoke. The molecular composition of the vaporized electrolyte and potential decomposition products means they create the conditions for very real potential of a catastrophic vapour cloud explosion. As that work [11] illustrates, that can indeed be *much more* damaging than the initial fire itself.

The major conclusion from such careful studies is that the main content of combustible gases causing an explosion in LFP is the vapourised electrolyte, as vividly illustrated which shows the alarming process of the rapid diffusion of vaporised electrolytes in the later stages of a controlled ‘Thermal Runaway’ controlled experiment.

As is clearly evident, the current generation of batteries with their liquid organic electrolytes do pose highly significant explosion and fire hazards. There is also the serious point that the electrolytes themselves are fluorinated compounds. A study by Larsson et al. showed that fluorinated compounds were detected in the fumes emitted from lithium battery fires, including the highly dangerous hydrofluoric acid, HF [13].

There has been a comprehensive literature review by Bugryniec et al. [10] that has drawn similar conclusions to the above and it is the most comprehensive source of reference data at present. Worryingly, those workers conclude that LFP batteries emit significantly more toxic fumes than LMO ones in absolute terms.

There is also growing evidence that the "forever chemicals", the PFAs are present in the firewater and their origin could be from the fluorinated electrolytes or from the fire suppressants themselves [14].

5. Next Generation Lithium Solid-State Batteries

There is now an emerging range of batteries in which the organic liquid electrolyte is replaced by an ion—conducting solid electrolyte. Initially it was thought that these would not offer the charge/discharge rate of the liquid versions and would cost more to manufacture. Already, some of the batteries available commercially are showing charge densities and charge/discharge rates comparable to the current generation of liquid electrolyte batteries. [15, 16].

It must be noted, however, that whilst the organic liquid electrolyte and attendant vaporization and explosion issue has obviously been eliminated from these new types of solid-state battery, there is still exists The most important process of lithium dendrite formation and, of course, with that the potential also for a lithium fire. This issue, and comparisons with the liquid electrolyte batteries, has been carefully described by Zhang et al. [16]. Even in these solid-state electrolytes, lithium dendrite growth continues to be a major feature. In these batteries, the formation of lithium dendrites now appears to be linked with their formation in microcracks in the fairly brittle ceramic solid electrolytes. Ning et al. [17] have described the formation of microcracks and diffusion of lithium in these materials There are many other possible solid electrolytes, such as conducting polymeric membranes available for such batteries and it is likely that a choice of cathode, electrolyte and anode will be made that reduces – and hopefully eliminates—lithium metal dendrite formation. Until that time, lithium dendrite formation and their growth in solid-state batteries – without doubt – will still be the greatest safety issue in their widespread application [18].

The full development and commercialisation of solid- state batteries, of course, is still at an early stage, and the manufacturing process differs considerably from the liquid electrolyte types. These issues should be dealt with urgently, given the driver for safe high-density batteries both for electric vehicles and BESS facilities.

6. Battery Management Systems

So far, our emphasis has been on the way the fundamental battery chemistry influences – perhaps even dictates—the (inbuilt) hazards and performance considerations. In a real BESS installation, there will be many other factors at play with a considerable mix of hardware and software to ensure the safe operation of the facility. So-called Battery Management Systems (BMS) are absolutely essential, particularly in large scale energy storage facilities based on lithium- ion and lithium -metal battery modules, not only to monitor the state of charge, the change in electrical characteristics over time but also the temperature of the individual cells and modules. Most of the parameters being monitored also give the critical safety sensing information and this needs to be regularised and used as part of the regulations protocol.

The BMS is only a part of a complex system as described in detail by Khalid et al. [19] and is summarised simply in Fig. 4. There is also an analysis of BMS for BESS by Lawder et al. [20] which gives a more detailed description.

A well—designed BMS must be able to cope with all of the possible shortcomings of a battery system failure and provide signals to shut down operation and deliver safety warnings in the event of conditions leading to Thermal Runaway. There are such systems now appearing on the market [21].

7. Standards and Regulations

It is becoming increasingly well—known that there are highly specific and unique difficulties and grave dangers in attempting to extinguish a lithium fire, particularly so, in such large systems that form current BESS. There are really only 2 ways to deal with lithium fires. One is to smother the fire; the other is to isolate it from air. The key element is always atmospheric oxygen. The combustion product, dilithium monoxide (Li_2O) is one of the most stable compounds known, and therefore a huge thermodynamic driving force for combustion. Both fire suppression avenues are severely restricted (some would say impossible) due the physical configuration of the BESS. It is for that reason, the current advice is to allow an individual battery module to burn out whilst cooling adjacent modules.

We note also that in relation to emissions arising from lithium battery fires, Wang et al. [9] have performed a detailed analysis for the various lithium- battery chemistries and concluded that for the three agents as potential *lithium fire suppressants*: Heptafluoropropane C_3HF_7, carbon dioxide CO_2 and nitrogen N_2 The order of effectiveness is $C_3HF_7 > CO_2 > N_2$.

However, the obvious and potent downside to their use is that Heptafluoropropane, for example, can generate significant quantities of hydrofluoric (HF) acid fumes at the high temperatures one has in a LiB fire.

There have also been discussions about the effect of a water mist spray system in dealing with battery fires. The results of such studies show that this might be effective in providing some cooling effect, [22] but there is also the great concern of the risk that the presence of water increases the emission of carbon monoxide, hydrogen and hydrofluoric acid [23]. All of this points to the need for statutory National and International safety regulations. We note that the US National Fire Protection Association has taken the lead on this and its standard NFPA855 for the installation of stationary energy storage systems (2023) [24] is being adopted in the first instance. It remains to be seen how each country adopts similar standards.

Recognising these unique hazards, unfortunately, the UK, in common with many other countries, appears to lag behind in defining the critical safety standards and statutory regulations for the installation and operation of BESS. An example of the UK Govt advice, issued in 2020 is given in this link: https://www.gov.uk/government/publications/domestic-battery-energy-storage-systems. This is patently applicable only to small domestic battery storage associated with local wind/solar generation and it deals with storage capacities only up to 25KWh. In stark contrast, we note that BESS installations of *hundreds of MWh* are now routinely being installed!

Ironically, in 2023 the UK Govt did issue guidance—but only on the use of Second-Life batteries in BESS https://www.gov.uk/government/publications/safety-of-second-life-batteries-in-battery-energy-storage-systems. This document offers, however, a good summary of the situation elsewhere in the world and it is apparent that a detailed set of regulations and guidelines are urgently needed. An "independent" report to the UK Govt in 2021 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1178910/electricity-storage-health-and-safety-standards-gap-analysis.pdf also addressed the fire and explosion issues. Importantly this report (page 30) specifically admitted:

> "There is currently no national guidance on the types or sizes of system which should be notified to fire services, which may result in increased risk to firefighters or other first responders at incidents where energy storage hazards are involved."

It also highlighted other shortcomings, notably, of the lack of advice to any local Fire Services for dealing with a BESS emergency.

However, a recent (and welcome), good -practice guidance report by Fraser-Nash Consultancy- commissioned by the UK Department for Energy Security & Net Zero sets out that it is essential that (grid scale) BESS are developed in line with appropriate health & safety standards and that such regulations are adhered to across the entire electrical storage industry [2]. Although targeted primarily at lithium-ion batteries (and their variants), the dominant energy storage solutions in the market, this guidance will be applicable to other battery technologies or other grid-scale storage systems. It appears to us that this is indeed the beginnings of a good—practice guidance document.

It is also evident that part of the UK Govt does recognise these same issues because in April 2024 they issued a report [3] on BESS which gives a comprehensive snapshot of the situation in 2024 such as the numbers of installations and the safety issues. However, there were no recommendations or follow-up identified. The best advice given to—date is from a May 2024 EPRI guide [25] and this should form the basis for both regulatory guidelines and advice to first responders.

It is interesting to note that Moa and Go have looked at the safety and risk assessment for BESS in Malaysia [26]. This is a very comprehensive analysis which looks at all of the aspects covered in this paper from cell to module to whole system level making it the most detailed analysis in the literature to date.

It is interesting to compare BESS failures with fossil fuel storage failures, but it is also very difficult at this stage. Currently BESS storage is less than 1% of the magnitude of fossil fuel storage. Furthermore, fossil fuels are stored before energy generation and can easily be stored safely for long periods of months/years, whereas BESS only store electricity after generation, and then, only for a short time period. The BESS failures are well documented in [1]. Fossil fuel storage is a mature technology having undergone many decades of development, so it is not meaningful at this stage to make direct comparison. What is clear, however, is that there are fewer regulatory standards and forms of guidance regarding BESS safety compared to other energy storage industries.

8. Conclusions

- The extremely high, intrinsic stored electrochemical and chemical energy density in large battery energy storage systems (BESS) has the very real potential to cause catastrophic disasters and dangers-to = life. Industrial-scale Lithium-ion Battery Electrical Storage Systems (BESS) facilities such as are currently proposed – and indeed are being built across the entire UK—must be correctly categorised as potentially "Hazardous", that is: Defined as having the very real potential not only to create highly dangerous events but also the production of hazardous substances – all posing a real threat of injury or danger- to life to site employees, First- Responders, Fire-Fighters, and the local populous. There is also the possibility of significant damage to the natural environment both on the BESS site facility but also further afield.
- Work is urgently required to establish Statutory Health and Safety Standards for BESS facilities and to ensure that early and extensive, in-depth dialogue and communication is always formally established with the Fire Service (local and indeed national), all facility and emergency workers, all First-Responders and the public close to the facility.
- Appropriate and rigorous training of Site Operators and Workers, Emergency and First responders, but especially Fire-Fighters, need to be formally established on a national basis.
- There must now be a clear pause in allowing any BESS construction in the UK until the necessary, complete Health and Safety dangers, protocols and procedures have been established by law. These requirements are indisputable if catastrophic, safety-to-life events in BESS's facilities are to be minimised or ideally eliminated.
- Attention should be given to the design and manufacture of safe lithium -ion batteries to reduce metallic lithium dendrite formation and eliminate the volatile electrolytes that can cause explosion

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