BRIEFING NOTE: LITHIUM-ION BATTERY ENERGY STORAGE SYSTEMS (LiBs)

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Battery Energy Storage Systems (BESS) – the issues **APPENDIX B**

The currently adopted renewable energy drive has created major issues for power distribution and energy security. Not only is there a requirement for massive changes to cable and sub-station infrastructure to distribute the electricity from these additional sources, but because renewable power is intermittent and not very predictable it is now necessary to install very large electricity storage systems. This poses a new problem.

When fossil fuels were dominant the energy was stored in coal heaps, oil and gas tanks *before* combustion and electricity generation. Now, however, we need to store the energy (electricity) *after* it has been generated by the wind and sun. This had not been properly anticipated hence, rather belatedly, energy storage has become an issue. And, as we all know, storing energy is not especially easy or risk-free. Currently, the only viable solution in the short/medium term is to exploit lithium-ion batteries to store energy on an unprecedented scale. The deployment of large-scale lithium-ion BESS has begun at pace – but with no adequate standards or adequate safety regulations being applied. A summary of BESS in the UK was recently published by the Faraday Institute [1].

What is in a lithium-ion BESS (LiB)?

A LiB site is a collection of containers that look like shipping containers. Each of these contain hundreds of individual lithium-ion battery cells packed into modules and the modules are packed into racks within the outer cabinet. There is usually provision in the container for liquid cooling of the batteries and a battery management system (BMS) that can monitor the state of charge (SOC) of the battery cells, their temperature and any gas release. Built-in fire suppression systems may also feature, although there are no regulatory standards for these. There are also power conditioning units to convert the incoming alternating current to direct current and to take the outgoing direct current and convert it to alternating current (invertors). These are often sited outside in separate containers. A typical example is the 20 foot (ca. 6m) CATL BESS container: https://www.evlithium.com/energy-storagesystemsolutions/catl-enerc-plus-306-bess-container.html

The current LiB situation:

- Battery storage is critical for renewable energy to store the electricity that intermittent solar/wind produce and to trade electricity using the excess capacity the BESS have. Trading electricity (*i.e.* buying cheap electricity and storing it at times of peak output, ready for selling back to the National Grid at a higher price at times of peak demand) makes large-scale renewable schemes with BESS a particularly attractive proposition for investors.
- A typical modern BESS container will store around 4-5MWh of energy for a relatively short period of time. The batteries are usually charged and then discharged over a 2-4 hr cycle. The whole BESS installation should be specified by two numbers to designate the maximum *power* (in MW) that can be supplied and the total *energy stored* (in MWh). So, for example, a 200MW/400MWh system can deliver up to 200MW power for 2 hours.
- Most BESS today use lithium-ion batteries. The main chemistries in use today are: NMC, Nickel Manganese Cobalt and Lithium Iron Phosphate, LFP.
- Over 70% of all BESS units and components are made in China. The remainder come from the US (e.g. Tesla) and South Korea and Japan. There is no European manufacturer of significance.
- Currently the expected lifetime of the lithium-ion battery cells in these modules is between 8-13 years. So, for a 40-year LiB site there will have to be several (expensive) battery replacements during its operational lifetime.

- At present there are very few recycling centres anywhere in the world for the recovery of the materials used in LiBs and none of the present generation of lithium-ion batteries were designed to make recycling easier. It is hoped that this situation will change but estimates on current processes are that it is 2-3 times more costly to recover the metals for re-use as opposed to using new raw materials. Mining for lithium ore and extraction of the metal from this also have major environmental consequences. China is the main source of processed lithium; substantial lithium deposits are also found in Latin America and Australia.

What are the concerns about LiBs?

Lithium-ion batteries have many attributes for rapid charging and discharging - clearly a vital part of the transformation to electric vehicles, as well as for our mobile phones, laptops, etc. However, they are not considered ideal for long-term energy storage and even for short term application their inherent instability is a cause for concern. There have been many well-publicised explosions, fires and toxic emissions resulting from this instability [26]. Whilst many of these have been in cheap and relatively badly controlled situations (such as in e-scooters and ebikes), there have also been a number of LiB fires and explosions, some of which have resulted in deaths and lifechanging injuries to first responders who were called out to handle the incident, as well as wider environmental contamination.

The main cause of these appears to be ‘thermal runaway’ which can result from metallic lithium dendrite formation in the lithium-ion battery cell – a problem that has not yet been fully solved. These dendrites or ‘whiskers’ of metal create an internal short circuit or ‘hot spot’ in the cell, which causes heating, vaporisation and ignition of the organic electrolyte, which in turn ruptures the cell via a vapour cloud explosion. The usual result is a self-propagating fire, fed initially by the organic electrolyte but subsequently the lithium metal itself can ignite and is almost impossible to extinguish. Such fires and explosions cannot be handled like a ‘normal’ fire – they cannot be extinguished by smothering, for example, as they do not require oxygen to sustain them. As such these incidents often last for extended periods of time (days and weeks) and re-ignition is not uncommon. During a thermal runaway incident many toxic and harmful gaseous and particulate emissions are released, usually requiring evacuation of surrounding areas. Further environmental hazards result not only from these toxic emissions to air and ground, but also from the millions of litres of water cooling which is applied to the affected area to help prevent the fire spreading. This results in toxic compounds in the firewater run-off. Fluorinated compounds in the fumes and the firewater are toxic - even in small amounts - and have a long lifetime in the environment, which could last for decades.

Even the slightly newer, lithium ferro-phosphate (LFP) batteries, which some developers consider slightly safer as they require higher temperatures before thermal runaway occurs, can and do experience thermal runaway. They also carry a higher explosion risk and higher concentrations of fluorinated compound emissions.

To summarise:

- **Lithium-ion batteries have exceptional ability to charge/discharge quickly but are inherently unstable.**
- **There have been many well publicised LiB failures, some of which have led to deaths and serious (life changing) injuries to first responders called to handle the incident.**
- **Failure is usually by thermal runaway. This can lead to explosion, fire and the release of highly toxic emissions to air and ground, with a risk of wider environmental contamination to water, soil etc.**
- **Fires are intense and self-propagating; they cannot be managed like a 'regular' fire. Most advice by Fire Services is simply to allow them to burn out (several days, sometimes weeks) and to keep surroundings cool using millions of litres of water (‘drenching’ takes place of surrounding buildings and areas). Reignition is not uncommon.**

- **Firewater run-off is toxic and needs to be contained and properly disposed. If this contaminated firewater was to get into aquifers, farming irrigation, crops or local streams or rivers it could have detrimental environmental impacts for decades.**

Lack of adequate legislation for lithium-ion BESS

The rapid deployment of LiBs in the UK has *not* been accompanied by the application of any adequate safety standards or regulation. This is astonishing given the publicity surrounding the Grenfell Tower fire which, tragically, could have been avoided had the known risks been properly acted on. The roll-out of LiBs appears to come under the remit of Ofgem who class these as “energy generators” – yet they are not generators at all but, critically, rather “energy stores.” One might expect that the Health and Safety Executive would have a say in the regulation of LiBs like they do, for example, in the case of hydrogen for energy applications and other gas storage operations. However, this does not seem to be the case. The Government recognises the risks with LiBs and indeed acknowledges the lack of adequate regulations to govern these [7]. However, the Government currently appears to be relying on the Fire Service to recommend guidance [8] which does not seem logical because the preventative safety aspects and planning considerations for BESS do not necessarily fall within their remit. Government regulation aimed at preventing thermal runaway in LiBs is urgently needed, as is clear Government instruction for planning authorities.

To summarise:

- **There is no clear legislation for LiBs in the UK**
- **There are no British Standards or other adequate government regulations being applied to ensure the safe manufacture, installation, operation and decommissioning of LiBs.**
- **There is no legislation preventing the use of second-life lithium-ion batteries being re-used in LiBs. Secondlife lithium-ion batteries are considered to pose a much greater safety risk, since less would be known about their previous use, which could include previous damage/abuse that can make them more prone to failure.**
- **It has been suggested that LiBs should come under the Control of Major Accident Hazards (COMAH) legislation to ensure they are suitably regulated. This would appear sensible.**
- **Hazardous Substances Consents (HSC) are most likely required for the transportation of LiB units. HSC are almost certainly required for large scale LiB installations [9,10].**
- **Battery Management Systems vary – there are no statutory requirements or engineering specifications, so not all current safety features are present in all sites.**
- **There are no Government regulations on appropriate locations for LiBs, depriving planning decision makers of instructions on appropriate safety distances from occupied buildings, sensitive receptors and environmentally sensitive sites. Nor are there regulations on how to deal with LiB fires and explosions. The National Fire Chiefs Council have issued their own guidance notes for Fire and Rescue Services on dealing with LiB failures, but these are not legal requirements, nor are they specifically aimed at *prevention* of failures to avoid a major accident [11].**
- **Given the known risks, and potentially disastrous consequences of LiB failures, it is essential that the Government applies appropriate safety regulations to LiBs as a matter of urgency. Until they do this, such installations are being installed without adequate safety measures in place and in unsuitable locations.**
- **Some cities and regions in other countries have issued a moratorium on LiBs until adequate safety regulations are in place. This must surely be the most sensible approach in the immediate term.**

References:

1. Batteries in Stationary Storage Applications https://www.faraday.ac.uk/wpcontent/uploads/2024/11/Faraday_Insights_21_FINAL.pdf
2. EPRI BESS Failure Event Database https://storagewiki.epri.com/index.php/BESS_Failure_Incident_Database 3. EPRI White Paper distributed in May 2024 provides an Analysis of Failure Root Causes: https://www.epri.com/research/products/000000003002030360
4. https://www.britsafe.org/safety-management/2024/lithium-ion-batteries-a-growing-fire-risk
5. https://www.gov.uk/government/publications/grid-scale-electrical-energy-storage-systems-health-and-safety
6. https://www.thefpa.co.uk/news/mp-calls-for-fire-service-input-to-li-ion-batterystoragesites#:~:text=If%20you%20put%20water%20on,recent%20House%20of%20Commons%20debate .
7. Ranki F, Walker A, Rowe G, "Battery Energy Storage Systems" UK House of Commons Library (April 2024) available at https://researchbriefings.files.parliament.uk/documents/CBP-7621/CBP-7621.pdf. Section 4, pg 25, highlights the lack of regulation
8. In the US, the NFPA has some guidance: National Fire Protection Association (2023) Standard for the installation of stationary energy storage systems https://www.nfpa.org/codes-and-standards/8/5/5/nfpa-855
9. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23
10. https://www.researchgate.net/publication/359203817_Hazardous_Substances_potentially_generated_in_loss_of_control_accidents_in_Liion_Battery_Energy_Storage_Systems_BESS_storage_capacities_implying_Hazardous_Substances_Consent_oblig ations
11. National Fire Chief Council guidance to first responders: https://nfcc.org.uk/wpcontent/uploads/2023/10/GridScale-Battery-Energy-Storage-System-planning-Guidance-for-FRS.pdf

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