# SUNNICA ENERGY FARM
# DCO EXAMINATION

# WRITTEN REPRESENTATION

## ANNEX L –BATTERY FIRE SAFETY PLANNING

SAY NO TO SUNNICA ACTION GROUP LTD

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**Report on Sunnica Energy Farm Application 18 November 2021**

**By Dr. Paul Christensen, Lithiumionsafety Ltd, 12 February 2022**

## 1. Introduction

I am an academic electrochemist with over 35 years experience in research. I have over 180 papers in international, peer reviewed journals and an H-index of 53. I am an Editorial Board member of Nature Special Reports. I serve on the Cross-government Technical Steering Group for EV fire safety, the BEIS Energy Storage Health and Safety Governance and Fire Safety Working Groups, the BEIS Steering Group for the development of PAS 63100, the Australian Building Codes Board working group on EV safety and the Tyne & Wear FRS and Envision-AESC Gigafactory fire safety working group.

I advised Nissan for 3 years on all aspects of lithium-ion battery safety during the construction and commissioning of the battery plant in Tyne & Wear. I am routinely asked for input and advice by OZEV and the DfT. I have conducted tests and experiments to research thermal runaway at module, pack and vehicle levels. I have assessed a number of LiBESS planning applications in the UK and abroad.

## 2. Executive Summary

In the main I have reviewed the following information relating to the Battery Energy Storage Systems (BESS) provided in the Sunnica Energy Farm DCO application:

SEF_7.6_Oultine Battery Fire Safety Management Plan
SEF_2.2_ Works Plans
SEF_ES_6.1_Chapter 14 Air Quality
SEF_ES_6.2_Appendix_16D_Unplanned Atmospheric Emissions from Battery Energy Storage Systems
SEF_ES_6.1_Chapter 16 Other Environmental Topics

It is disappointing to note that, at this advanced stage in the application process, the Outline Battery Fire Safety Management Plan lacks all essential detail upon which a true assessment may be made.

This defect renders it impossible to assess the Outline Battery Fire Safety Management Plan (OBFSMP), or the potential gas emissions in the event of a failure, in any meaningful way by any competent authority. For example: no indicative plans of the three BESS and substation compound layouts. The specific battery technology has not been declared. In my view, this means that it is not possible to develop the OBFSMP into a finalised version of the BFSMP without significant changes.

## 3. Outline Battery Fire Safety Management Plan (SEF_7.6)

The Outline Battery Safety Management Plan lacks all essential detail – even the total energy storage capacities of the three sites are not stated. This defect is such as to render it impossible for any true assessment to be made by any competent authority. The plan is not a Battery Fire Safety Management Plan by any reasonable definition.

Despite a lack of clarity or detail in the application, it is likely that the Sunnica BESS will be very large, perhaps GW scale. As a result, it is essential that the planning application is detailed and complete so that it may be scrutinised carefully by the planning authority.

**3.1** In Table 2 of Sunnica's OBFSMP 'BESS Design Parameters' it is stated that:
**"The batteries selected for use on the Scheme will be from tier 1 manufacturers and will utilise lithium-ion chemistry. Each battery being procured and installed will be fully sealed by design and has no free electrolyte. The lithium-ion batteries will be either NMC (Nickel Manganese Cobalt) or Lithium Iron Phosphate ($LiFePO_4$) chemistry (Ref. 3)."**

It should be noted that LG Chem/LG Energy Solutions and Samsung are examples of 'Tier 1' companies and yet defects introduced during the manufacturing stage have led to the recall of all Chevy Bolt electric vehicles[1], and recalls of Hyundai Kona[2], Ford Kuga[3] and a range of BMW models[4] over worries that the battery packs supplied by these companies are causing fires.

Further, domestic lithium-ion battery systems have also been recalled for the same reason in the UK[5], Australia[6] and the USA[7].

Simple probability suggests that failures of lithium-ion cells are inevitable, and the number of such incidents will increase as their manufacture increases. This is reflected in a statement by a DNV GL employee at a webinar in 2020 that "Over the life of a (industrial) BESS at least one failure will occur. It is unrealistic to eliminate all chance of failure"[8].

DNV GL (now DNV) are arguably world experts in the risk analysis of large lithium-ion battery systems.

Table 1 below summarises some of the recent grid-scale lithium-ion BESS (LiBESS) fires and explosions to date.

***Table 1.***

| | |
|---|---|
| 2012 | Arizona, USA |
| Aug 2016 | Wisconsin |
| Nov 2017 | Drogenbos, Belgium. VCE*. 50 reports of eye and chest irritation downwind of the site. |
| 2018 - 2019 | South Korea: around 30 LiBESS caught fire and/or exploded. All completely destroyed. |
| April 2019 | Arizona, USA. The McMicken LiBESS explodes badly injuring 2 fire fighters and severely injuring 2 more. All first responders contaminated with hydrogen cyanide. VCE. |
| March 2020 | Nathan Campus of Griffith University, Brisbane. LFP BESS explodes. VCE. |
| Sep 2020 | Carnegie Road, Merseyside: LiBESS explodes. VCE. |
| Dec 2020 | Perles-et-Castelet, Ariège France. On-top BESS configuration. Fire. |
| March 2021 | SBG-2 OVHcloud data centre in Strasbourg, France. |
| March 2021 | South Korea, North Kyungsan Province, Yeongcheon |
| April 2021 | Hongseong, South Chungcheong Province, Beijing VCE. Two firefighters killed and a third injured. VCE of LFP LiBESS. |
| July 2021 | Tesla Megapack LiBESS, container ignited during testing at the newly registered Victoria Big Battery at Moorabool, near Geelong. |
| | Invenergy storage facility, LaSalle County USA (July 2021). |
| | Märkisch-Oderland, Neuhardenberg airfield, Germany (July 2021) |
| 4 Sep 2021 | Moss Landing, California "world's biggest battery storage facility" cells go into thermal runaway, still offline. |
| 12 Jan 2022 | South Korea, Nam-gu, Ulsan 50 MW. |
| 17 Jan 2022 | South Korea, Gunwi-gun, Gyeongsangbuk-do. VCE |

VCE = Vapour Cloud Explosion.
* Confirmed by official report or my direct involvement in the investigation

The choice of Nickel Manganese Cobalt (NMC) or Lithium Iron Phosphate (LFP) cells and their form factors will have major implications for the fire sensing and suppression to be employed in the containers.

Thus, draft standards due in 2023 and likely to be employed by UK manufacturers in the absence of UK standards will require venting of LiBESS containers once off-gassing is detected from lithium-ion cells. This, in turn, demands appropriate gas sensors. However, whilst the literature suggests that prismatic and cylindrical cells vent many minutes prior to thermal runaway (depending upon the definition of this), pouch cells simply burst without such warning and there is no evidence that advance warning via venting occurs. In fact, my own research has shown this not to be the case.

The choice of chemistry can also have a major effect upon the efficacy or otherwise of e.g. sprinkler systems in containers. Thus experiments conducted under the aegis of the National Fire Prevention Association (NFPA) have shown that such systems are essentially ineffective for the suppression of fire in racks of NMC cells, but can be effective against fires involving LFP cells[9].

Overall, the above considerations are key to the fire safety aspect s of the OBFSMP and hence BFSMP.

**3.2** In the Table 2 section on Racks (in Sunnica's OBFSMP), it is stated that, **"Modules will be stacked vertically within each rack. Each rack will be separated with thermal barriers on the sides…etc"**

I am not aware of any thermal barriers that will prevent thermal propagation between cells or modules in such multi-MWh installations. The specifications of such barriers must be presented for consideration in order to assess their likely suitability. This has not been done.

It should also be noted that the side-by-side cabinets such as those involved in the Moorabool fire in Australia in July 2021[10] were separated by thermal barriers as well as by the walls of the individual cabinets, and yet the fire spread from one cabinet to another nonetheless

**3.3** In the section on BESS Enclosures (Table 2, Sunnica OBFSMP), it is stated that "**the [BESS] construction will be in the form of modified 20-foot / 40-foot ISO shipping containers OR modular premanufactured containers / enclosures."**

The exact construction of the LiBESS containers will have major implications for the required fire suppression systems and indeed their likely efficacy. Containers with racks separated by sufficient distance could allow appropriate fire suppression systems to prevent thermal runaway propagating between racks. Thermal runaway in high energy density systems such as the Tesla Megapack cabinets employed in Moorabool is unlikely to be contained: hence the purely defensive firefighting strategy of the fire services during the incident. This involved (on the advice of Tesla) allowing the affected cabinets to burn whilst cooling the surrounding cabinets to prevent propagation.

Side-by-side, on-top and side-by-side+on top configurations would bring additional and significant challenges, and it is clear that the applicants are unaware of these.

**3.4** In the section entitled 'BESS compound' (Table 2) there are no details presented about the possible BESS compound layout, or of access to and within the site.

**3.5** In section 3 of the OBFSMP the Purpose and Scope is defined as:

**"The purpose of the Outline Battery Fire Safety Management Plan is to demonstrate that the location of BESS within the Scheme does not give rise to a significant increase in fire risk and that any risk that does exist can be addressed by ensuring that the Scheme is constructed, operated and decommissioned in accordance with an appropriate Outline Battery Fire Safety Management Plan."**

The lack of all essential detail is such that this document fails absolutely in its primary purpose as stated.

**3.6** The following points are made in Table 3 of Sunnica's OBFSMP:

<u>Item 3:</u> Consideration of the release of toxic gases, including prevailing wind direction, has been undertaken.

It is not clear how this could have been achieved without explicit knowledge of the chemistry and form factor of the cells to be employed or the architecture of the modules, racks, containers/cabinets.

Item 7: Automatic fire detection systems will be provided as per risk mitigation methods RMM 17, RMM 18 and RMM 19.

**"An automatic water mist system will be considered as an alternative option to an automatic sprinkler system, with the final choice to be agreed with the Fire and Rescue Services [FRS] post-consent at detailed design stage."**

How can the water demand be assessed without knowing precisely what cell chemistry and form factors are to be employed as well as the cell capacities? This will also depend upon the precise nature of the container surrounding the cells and modules, type and positions of racks and the strategy to be adopted by the local FRS.

None of these essential details are presented yet the applicants believe the water supply will be 'sufficient.' A critical aspect of firefighting on LiBESS sites is access to sufficient water supply. The Community Fire Association of Victoria, Australia (which is leading the way in design guidance) recommends at least 288,000 L, or sufficient water to provide a flow of 20 L/s for four hours, (whichever is the greater) to contain any fire in an LiBESS. However, it should be noted that a recurrent factor in the 46 or so grid scale LiBESS fires and explosions that have occurred to date is the very large quantities of water required, despite the defensive strategy likely to be adopted by the FRS. Thus, the fire and explosion involving the considerably smaller, 1MW LiBESS container in Drogenbos, Belgium required 1.4 million litres of water to contain.

The relative efficacies of water mist and sprinkler systems is dependent upon a number of factors. These do not appear to have been considered, based on the information provided in the DCO application documents, but are known to specialists in LiBESS safety.

It is clear that the applicants are not aware of current state of the art LiBESS suppression systems.

Finally, again depending upon the chemistry of the cells, fire water run-off containment and treatment will have to be employed as, for example, fires involving NMC cells can result in run-off containing 100x the legal limit of heavy metals for disposal in drainage & sewage systems.

Item 19: It is stated that **"Details of the BESS technology has been provided in Table 1 for each element of the Scheme including cell, module, rack, BESS enclosure and BESS compound."**

No such details have been presented in the DCO application documentation. There are just (at best) broad statements suggesting alternatives (e.g. cell chemistry) or pictures (e.g. of various types of container arrangements) but nothing that indicates what the BESS entail.

The essential details of cell chemistry and form factor, container type (ISO container, cabinet etc), gas sensing system, location of sensors, type of suppression system and the layout of suppression systems etc are not given.

Item 21: **Thermal barriers or adequate fire separation will be provided in accordance with legislative code requirements available at detailed design stage.**

These details are essential at the planning stage to assess the safety and suitability of the proposed installation. Model calculations suggest propagation between containers in under 25 minutes for a separation of 3 meters.

Item 26: **The firefighting water flow of 1500 l/min for a duration of 120 minutes shall be sufficient to prevent radiant heat transfer between BESS containers.**

The water flow rate will depend upon the spacing between containers, the type of water suppression system, the density of modules, the density of cells within modules, the spacing of racks and other factors.

Their above statement betrays a complete absence of knowledge of the experiments and tests carried out on the various possible suppression systems for LiBESS. The options suggested by the applicants will simply not prevent thermal runaway or propagation between cells or, depending upon the exact structure of the surrounding container, rack-to-rack propagation.

In addition, no mention is made of the method by which the state of the batteries/environment inside the container would be conveyed to the Fire and Rescue Services in the event of thermal runaway. This communication has been identified as critical in the investigation reports into a number of fires and explosions involving LiBESS (e.g. the Liverpool fire in Sept 2020 and the two incidents in Arizona detailed in Table 1).

**3.7** Mitigation and Control measures – Section 6.1 of the OBFSMP. Table 12 highlights the following Risk Mitigation Measures (RMM):

**RMM01. Racks within the BESS enclosure shall be installed either in single row or double row arrangements with racks back to back. Each rack will be separated by non-combustible thermal barriers to prevent heat transfer. Racks will also have adequate separation from the perimeter walls and between the aisle faces of adjacent racks.**

Again, a worrying lack of essential detail. There is no explanation of what is meant by "adequate separation." The pictures of LiBESS containers in Table 2, on page 3 of the OBFSMP include designs with no separation between racks. The very low energy densities represented by the plans on p29 look to be uneconomic and unviable.

**RMM10. Thermal runaway trip will isolate the battery system when a cell is detected to have entered a thermal runaway condition.**

Disconnecting cells from the external circuit will not prevent thermal runaway.

**RMM17. Install a fire detection and alarm system using coincidence detection in accordance with BS 7273-1 and incorporating aspirating smoke detection and carbon monoxide (CO) detection within the BESS enclosure for early detection of gases produced during off-gassing and prior to thermal runaway.**

BS 7273-1 is not specific and hence relevant to lithium-ion battery fires.

The applicants are clearly unaware of the sequence of events that lead into and during thermal runaway, and the effect of cell form factor on these events or their consequences.
The applicants appear to be unaware of the uncertainty/ inadequacy of gas sensors regarding the advanced warning of thermal runaway offered by such gas sensors.

There is no explanation of what is meant by "coincidence detection"

The applicants do not seem to be aware of the deleterious effect of the type of sensing system employed in past LiBESS systems that have gone into thermal runaway (e.g. in the Carnegie Road BESS that exploded in Liverpool in September 2020 (see Table 1).

**RMM17 (continued) "The detection of gases will also allow fire and rescue services to remotely monitor for an explosive atmosphere."**

In my experience, I have never come across a means by which FRS can remotely monitor an explosive atmosphere. Further explanation is required here.

**RMM17 (continued) "The EMS for the BESS enclosure will engage the first stage alarm and will close access doors, louvres, shut down ventilation system ……."**

This is in direct opposition to accepted best practice as it would facilitate the build-up of explosive gases. The applicants do not seem to be aware of the relevant amendments to NFPA 855 requiring gas sensing and explosion avoidance via venting, or explosion control via deflagration panels. Such consideration should most certainly be included in the OBFSMP.

**3.8 General conclusions**

The conclusion set out in the OBFSMP states that "This Outline Battery Fire Safety Management Plan has demonstrated in a systematic way the mitigation of the fire safety risks posed by the BESS's in the Scheme."

In my view, this is not correct.

What parameters will be monitored? With what granularity? DNV Recommended Practice 43: "For Li-ion batteries … the voltage measurement of each cell is crucial for a reliable operation. If the voltage measurement fails, overcharging or deep discharge of certain cells in a battery module cannot be detected. In some cases, this can lead to thermal runaway. For this reason, the voltage measurement of every cell should be checked for plausibility and if this plausibility check fails, the operation must be stopped immediately."

The applicants do not appear to have any grasp of the critical difference between immediate and delayed ignition. This is essential to the design of the fire sensing and suppression system.

The applicants do not seem to be appear of the current best practice of design for failure in addition to design for safety.

The applicants should provide evidence that the cells, modules and system have passed BS EN 62619 or ULK9540A in the form of a report detailing the results of all of the thermal propagation tests and the actions taken to improve the safety of the installation based on these tests.

Given the likely very large capacity, and the proposed rural location of the Sunnica BESS close to residential areas (the Works Plans indicate that the closest dwellings, a Traveller's permanent site, are approx. 200m from the largest of the proposed BESS compounds on Elms Rd), the planning authority and all stakeholders should have access to the results of the BS EN 62619 standard tests cited in the Outline Battery Fire Safety Management Plan, and details of the actions taken by the applicant as a result of these tests.

If the applicants are indeed confident of the safety of the proposed installations, then conformity to the UL 9540A standard should also be presented, along with actions taken on the basis of the tests therein.

These to be presented as part of the application process as has been done in other planning applications by developers following best practice.

**4: Review of Chapter 16 the Environmental Statement (Other Environmental Topics)**

Section 16.5, subsection "Fire" considers only fumes arising from fire: it takes no account of thermal runaway without immediate ignition and hence the differences in terms of the composition and volume of fumes versus vapour cloud and the major hazard of vapour cloud explosion.

This is a major defect.

**Section 16.5.34 (pg 37) states that "Dispersion modelling was undertaken to help understand the minimum rates of dilution likely to occur to pollutant concentrations as they disperse from the source of the emission to receptor locations."**

There can be no valid dispersion modelling without knowing the parameters on which the model was based. The cell chemistry, the energy densities of the cells, the total energy density, the rate of thermal propagation (container type, module type, spacing, cell chemistry), the volume and composition of the gases emitted (cell chemistry)?) all need to be taken into account. On the basis of the information provided by the applicants, no conclusion can be drawn.

In addition, only fumes were considered and not the emission of the vapour cloud. Nor was the fact that the nature of the vapour cloud emitted from lithium-ion cells (e.g. density) depends upon many factors including cell chemistry (which is not stated).

The applicants are clearly unaware of the LiBESS failure incidents in Table 1 and have not acknowledged or applied the lessons learned from the investigations into these incidents.

Further, Hydrogen Fluoride (HF) is not the only toxic or dangerous gas that may be emitted during a LiBESS fire. It is not as persistent compared to some of the other toxic gases produced by immediate or delayed ignition. Other toxic gases include HCN and HCl.

**16.5.32 states that "An assessment on the potential for unplanned atmospheric emissions from BESS in the event of a fire has been undertaken and is provided in Appendix 16D of this Environmental Statement."**

Having reviewed Appendix 16D, it appears that this assessment was based on a report using a 100kWh LiBESS. It is well known that scaling-up calculations and models concerning lithium-ion batteries is wholly and completely invalid due, for example, to the volume effect. Put simply, heat is generated exponentially during thermal runaway and throughout the whole volume of a battery. In contrast, heat is dissipated only linearly and through the surfaces of the battery. As the battery capacity increases more heat will be retained.

Note there were 50 reports of eye and lung irritation downwind of the Drogenbos installation[10], which had an energy capacity only 10x larger (1 MWh) than that employed in the Fire Protection Research Foundation (FPRF) study that the applicant has referenced.

**Signed:** [redacted]

**References**

[redacted]

4. [redacted]
8. “Best practice for energy storage system safety around the globe”. DNV GL Webinar 29 October 2020.
9. [redacted]
10. K. Vollmacher, “Lessons learned: Fire in Energy Storage System”, Engie-Electrabel-Drogenbos, 11 Nov 2017.