# Red Lodge Parish Council Written Representation

Please accept the following written representation on behalf of Red Lodge Parish Council - reference: 20031138

Richard Saul, Chairman

**Executive Summary:**

Red Lodge Parish Council have a significant number of concerns about the Sunnica solar farm scheme, some totally unacceptable to many of the residents of Red Lodge and to which the Parish Council object to.

There is a real concern throughout the village over the placement of the sizeable BESS and its associated substation so close to the village. The concerns are not just around fire safety issues, they also include potential noise impact and having to live with the constant threat of being put on stand-by for an evacuation or worse - this is discussed in section **Battery Plant (BESS) Safety / Risk Management.** In fact, it has already caused some residents to consider moving away. A previous resident of Red Lodge, living on one of the estates closest to the BESS has already stated that the potential for the BESS installation at Red Lodge happening was a factor in relocating to Isleham this summer.

The Parish Council also have concerns regarding the impact on Red Lodge from the significant growth of various infrastructure developments, of which the Sunnica Solar farm is the largest. Sunnica's proposals contribute towards almost all rural aspects being removed from around our village, with the area as a whole losing its uniqueness and identity. This is dealt with in the section **Landscape / Environment**.

The roads around Elms Road and the adjacent islands presently have issues with slippery and uneven surfaces during the wetter periods and the Parish Council are concerned that the additional Sunnica traffic will create unsafe conditions in conjunction with the existing problems - this is dealt with in section **Road & Transport Infrastructure.**

Section 3 details the councils view on how residents will be impacted by changes in other areas of the Solar Farm, discussed under the sections **Health & Wellbeing** (discussing how residents use the wider area within the solar farm) **and Transport and Access** (the problems faced by deteriorating road surfaces) and the concerns of both the Parish Council and many of our residents with the loss of good agricultural land discussed in the section **Land Classification** (the fields consistently full of crops over the summer months implies that the land grading is questionable). Finally, Sunnica's proposal is projected over 40 years which is an extensive timescale given the Government's goals outlined in their 2050 plan, entitled Net Zero Strategy, Build Back Greener, discussed in the section entitled - **Decommissioning and Validity of Sunnica's Project Scope.**

## WRITTEN REPRESENTATION

## 1. Background:

Red Lodge is a village situated to the east of the A11. The village has expanded significantly since 2005, with new housing developments radiating around the 'old Red Lodge core' of approximately 200 houses that were built in the 1950's through to the 1970's.

In 2020 the population was estimated at 5950, which according to the 2001 census is an increase of approximately 3,800. The population continued to increase by 5% per annum from 2011 onwards (3,834 in 2011 census).

Although the growth rate is slowing down, there are still planned future developments of 141 dwellings in Red Lodge East; 148 dwellings in Red Lodge West and approximately 300 dwellings in Red Lodge North, with completion expected in the next four years, resulting in a population of over 7,000 by 2030.

Prior to the onset of volume new builds from 2005 onwards, the younger generation tended to move away from Red Lodge in search of work, leaving a rather skewed breakdown of age groups. The diminishing number of older generation since 2005 has resulted in just 650 over the age of 60 by 2020, while the highest count in an age range in the same year was 1,236 between the ages of 0 and 9 years old, indicating that there are now many young families (many first time buyers and single parent families) settling within Red Lodge in the last 15 years.

Upon completion of the three proposed builds in the next four years, there will be no capacity for extensive development within the Parish Boundary. A significant change in population is unlikely, unless there are changes made to the parish boundaries.

The demography for Red Lodge differs in comparison to neighbouring villages that are impacted by the Sunnica solar and battery farm and this aspect is crucial in understanding Red Lodge Parish Council's objection to Sunnica's proposals.

Red Lodge has become a popular place for the younger age groups offering 3 valuable components: to be able to afford a first-time house and set up a family requiring affordable housing; good access to a place of work (with both members of the family often working) and a healthy and pleasant environment in which to live.

Red Lodge provides these 3 components, with easy access via the A11 and A14 to Cambridge, Bury St Edmunds and other nearby sizeable towns providing employment. There is a broader range of housing types and the prices in Red Lodge tend to be more affordable whilst still allowing easy access for residents to the surrounding countryside. In essence, the village is **'rural yet affordable and accessible'**.

## 2. Objections to the Sunnica Scheme that are Specific to Red Lodge

### Landscape / Environment:

The appended map (Appendix 1) illustrates how the core of Red Lodge will be surrounded by construction and development, which in combination are almost engulfing Red Lodge. The planners continue incorporating open spaces on estates to provide areas for dog walkers, but it is a piecemeal attempt providing linked up concrete or tarmac walkways in open spaces with nothing but houses to view a short distance away.

As part of a new build planning acceptance, the SSSI environment and the surrounding countryside are protected, as planners insist on a percentage of open space within a development, with an aim to discourage residents from walking on the heathland area or out into the countryside. However, in reality dog walkers would typically remain local in the area of Red Lodge during the week (just the need to walk the dog) but use the wider facilities/areas at the weekend (to ramble, run/exercise, equestrian activities, etc.).

Residents therefore still require the rural aspects of the countryside around them, especially in their leisure time over weekends (many work all week), this is essential in maintaining both physical and mental wellbeing. Red Lodge residents' value the easy access they have to the scenic and rural landscape on their doorstep.

The proposed housing developments will result in a loss of easy accessible paths to adjoining villages to the north and east of Red Lodge. In addition, Sunnica proposals immediately render the two access routes towards Chippenham, Badlingham, Freckenham and Worlington to the west and northwest inaccessible. The visual aspects will transform from an open space to an unsightly and ill-fitting scene of deer fence along some of the paths and bridleways which may result in a claustrophobic sense of confinement.

**Red Lodge Parish Council Written Representation**

Large swathes of agricultural land and rural pathways are currently subject to a planning request for industrial units to the north of Red Lodge (on the other side of the A11 from Golf Links Road) another added depletion in both rural and agricultural land. This combined with the housing developments mentioned and the fields of solar panels, large scale battery stores, sub-stations and miles of protective fencing contribute to a feeling of imprisonment in Red Lodge and as the map shows an almost encirclement of the village.

In essence, Red Lodge will lose nearly **all** aspects of rural life and will be subjected to an industrial setting for more than 40 years. **The 'rural' will disappear from it's identity statement as being "rural yet affordable and accessible."**

For at least a decade, groups in Red Lodge have been lobbying for more rural access and routes to link up with neighbouring communities. The request for a pathway and cycle track linking Red Lodge with Worlington has been on and off projects for many years, with the lack of funding preventing progress. The project has been revisited at the Parish Council meeting agenda for September 2022, with a view to raising funding for a direct rural pathway, which would reduce road traffic and encourage a healthier lifestyle.

However, if the Sunnica project goes ahead, Red Lodge will lose the ability to connect a cycle way with Worlington and onwards to Mildenhall for the next 40 years.

Interaction with neighbouring communities is vital to Red Lodge. Many residents have friends and family close by, which binds Red Lodge with the surrounding communities, creating financial and emotional stability, especially for young families. As an example, as well as attending the local primary schools, Red Lodge children attend schools in the surrounding villages and towns (Kennett, Isleham, Fordham, Soham, Mildenhall, Newmarket, to name a few). These links reinforce our attachment to the wider area and the close ties Red Lodge has with neighbouring villages. Families with young children attend parent and toddler groups in Isleham, Newmarket etc. Families from other villages come to Red Lodge to attend toddler groups at the Millennium Center. The sharing of resources and the ability to support our neighbours is not only essential as a way of life, it is also valued and encouraged in Red Lodge. We have excellent sports facilities at the Red Lodge Sports Pavilion which are routinely used by football clubs from the the surrounding areas. The Football Fun Factory is another organisation that uses the pavilion for its regular training sessions attracting children from all over this area. The roads that link Red Lodge to surrounding villages (Elms Road, Newmarket Road, Turnpike road etc.)

are key to ensuring that these clubs and activities remain successful. The Sunnica proposal would effectively cut off a number of these routes, especially during the construction phase. Post-construction, these routes would be difficult to travel along putting the success of these clubs/ activities at risk, as people may prefer an easier route to travel elsewhere

Many of the younger generation (and some of the older ones), enjoy running, some associated with the Red Lodge Runners club (established over 11 years with around 50 members), others on their own. None of the roads out of the village have lighting or footpaths and hence are unsafe for runners. Therefore, the off road pathways (PROWs) are essential to the runners, as they are to those wishing to ramble, walk or partake in equestrian activities. This is a wider issue for the Red Lodge Runners club, in that they prefer and need to vary their routes which often start in other local villages and towns such as Mildenhall, Chippenham, etc., the club using circuits that contain parts of other PROWs within the solar farm that are going to be affected by the proposed Sunnica plant. Attached (Appendix 2) is a sample route used quite frequently, this will be closed during the construction phase.

The PROW that leads to Freckenham and Worlington from Heath Farm Road in Red Lodge is a popular walkers route as it provides a circuit for walkers taking in the rural aspects to the west of Red Lodge (Heath Farm Road also links across to Elms Road at the back of the travelers site and onwards to the Icknield Way & Bridlepath). There are two local groups of over 60's who frequently walk the circuit and recently over 20 people were counted using the circuit during one Sunday in late August over a 2.5 hour period. As well as exercise routes, these footpaths provide a treasured place for people to meet up and socialise with friends and family from nearby areas.

In essence, Sunnica's proposal will further erode that key element of "rural" in the statement '**rural, yet affordable and accessible**', taking away the opportunity to address the stresses of the working week through leisure activities in the surrounding rural areas and thus depriving residents of the opportunity to improve their physical and mental wellbeing.

**Battery Plant (BESS) Safety / Risk Management:**

Red Lodge Parish Council is very much opposed to the placement of the battery plant (BESS) so close to Red Lodge residents and village schools. Residents made this clear to Sunnica when they attended the Red Lodge Parish Council meeting in March this year. The Parish Council is aware of a number of incidents (over 38 in the last 3 years) around the world involving the use of lithium batteries and that the Sunnica BESS is of a much larger scale in comparison to those involved in the serious incidents to date. The size of the BESS (i.e. the more battery cells there are) simply increases the potential for a battery fire. We feel that even a single container battery fire is an unacceptable risk – reports from the Liverpool fire in September 2020 show that it involved a single container, and still had significant consequences (Appendix 3). Clearly, if the fire spreads to more than one container, this would result in a very serious incident close (less than 300m) to peoples' homes.

The scientific evidence (Appendix 4) is that a BESS fire could release highly toxic gases and that fire services are unable to control such events. Red Lodge Parish Council is naturally concerned about this, particularly as Sunnica have been vague as to how they can ensure the safety of these significant BESS compounds and appear to be 'naive 'in their approach to risk mitigation. There has been little if any evidence of risk prevention. Modeling of gas emissions has been limited to only one toxic gas (Hydrogen Fluoride) and not for other gases that may evolve from the different cell types that Sunnica are proposing to use.

As an example, when explaining their Outline Battery Fire Safety Management Plan at the Red Lodge Parish Council meeting in March, Sunnica stated that they had an indicative plan of the layout of the BESS compounds but which they were not prepared to share, despite being asked on several occasions by several individuals (both during and after the meeting). It was pointed out that any safety plans and models without knowing more about the technology or layout did little to re-assure our residents. To date Sunnica have not disclosed any information that would assure Red Lodge PC or our residents of the safety of the proposed BESS.

In the consultation webinar on Grid Connection (10th Oct 2022, approx. 42 mins) Sunnica stated that, *"Location of the battery storage has also been chosen in particular such that it is located well away from any potential hazard receptors."*

Sunnica have not defined what they mean by "well away from", but Red Lodge Parish Council does not consider the close proximity to our residents (less than 300m from the Travelers site on Elms Rd, 600m from a new estate and 1200m from two sizeable schools) to reflect this declaration.

As well as safety concerns, the visual and noise impacts of the BESS are likely to be significant. The transformation of Elms Road will be from rural to industrial, creating a 'tunnel' of imposing industrial equipment. To the one side fencing, large scale BESS and significant 10m high x 130m long substation, to the other side vast expanses of fencing, solar panels, inverters, etc. This would remain highly visible for well over a couple of generations and would spoil the enjoyment of travelling along this main route in and out of Red Lodge.

Although the Fire Services have serious concerns about the BESS (extracted from the latest Cambs County Council report), they could still give the go-ahead, as it is known that the BESS in other solar farms where incidents have occurred were given the go-ahead by the fire services, not because they were confident an incident wouldn't occur, but because they believe they have the ability to either contain a fire and/or evacuate the area. The incident in Liverpool is a good example of putting residents on stand-by to evacuate. The Fire Services contained the fire, however were uncertain if the run-away would still release toxic gasses. The proposed BESS on Elms Road is on a larger scale, increasing the risk of a single unit incident and therefore the possible need to evacuate. Red Lodge has a number of residents living on Elms Road (fixed site travelers park) within 300 meters of the BESS, a new estate just over 600 meters, both much closer than the area of evacuation in Liverpool and two sizeable schools at 1200 meters, a very similar distance to the residential evacuation zone created by the Fire Services in Liverpool.

A recent incident in Moss Landing, Monterey, California in September 2022, saw a lithium battery unit catch fire, resulting in the closure of the local highway. Residents were instructed to shut all windows and turn off ventilation systems due to the risks of smoke inhalation exacerbated by the emission of hazardous materials from the lithium-ion battery fires. The County Office advised that smoke may still occur in the area for several days despite the fire being fully controlled. The nearest residential area in Moss Landing of just 50 houses is located just over 1200 meters from the BESS, the same distance as the two schools in Red Lodge - once again it must be stressed that this incident involved one battery unit and such incidents are becoming increasingly common, raising the question if residents and their children should be subjected to such a real potential; risk. The likelihood is that there would be a need to evacuate the schools, or at the least subject children to smoke inhalation even if it doesn't contain toxic particulates. Furthermore, Red Lodge parish council are of the opinion that due to the close proximity of the travelers park and the new Barratt housing estate (600 meters), they will be almost impossible to protect should an incident occur.

Red Lodge Parish Council believe that electricity management systems usually create noise (hum, buzz) and there is little information about the noise levels from the BESS or substations on Elms Road - with housing estates and the fixed site travelers park in close proximity, we have concerns that the noise levels will not be acceptable to those residents. Especially since Sunnica's latest changes in scheme included the addition of a shunt reactor, which Sunnica have said will be noisier but have not, to the best of our knowledge, provided adequate assessments to ascertain the impact of these noise disturbances.

Sunnica have stated, that the BESS has been sized not only to act as a receptacle for solar energy, but also as storage for energy trading (buying in & selling out at different times of the day), or as they now refer to it as 'grid balancing'. Even labelled as grid balancing, this activity has no 'green' credentials. Red Lodge Parish Council are concerned that Sunnica appear to be over-sizing the BESS for increased profits rather than to support the energy produced from the solar panels, unnecessarily increasing the risk to the local population and environment.

The most recent changes have seen the introduction of a large transformer and a shunt-reactor. It is appreciated that both technologies are widely used and therefore likely safe introductions to the BESS environment (although certain types of shunt-reactor (oil based) are subject to fires). However, to date, Sunnica have provided no information on the proposed type or their safety when integrated into the BESS environment. The current (very basic) Sunnica risk assessment is now outdated with the introduction of the current proposed change to the BESS plans, adding another risk, which has not been fully considered.

The village should not be subjected to evacuation plans or to any risks to children, when the BESS could have been located in a more remote area of the farm, downsized in capacity or safer batteries used - the simple answer is that the location and battery type are cheaper and easier alternatives. Sunnica have openly stated (in the meeting at the Red Lodge Sports Pavilion) that they cannot guarantee zero risk from the BESS. In the early stages of scoping they moved the BESS site from the original planned position for ease of access from the A11, when questioned the use of a safer battery type (water based) instead, Sunnica stated the cost of a safer battery type was currently cost prohibitive. The statement of cost is probably correct, however, the risk is simply unacceptable to the lives and the health and well-being of the residents of Red Lodge.

Sunnica need to seriously consider the issues surrounding Battery Safety and the risk management. Red Lodge Parish Council believe that the issue should warrant a dedicated Issue Specific Hearing (ISH) devoted to Battery Safety.

**Road & Transport Infrastructure:**

The recent Sunnica change request refers to the two islands either side of the A11 (containing the feeder lanes on and off the A11, Elms Road, Newmarket Road and Warren Road); the 'Dumbbell Islands'. Sunnica are proposing to use these islands for their works traffic and exit route for their lorries.

The first of these at the junction with Elms Road is subject to mud from the quarry lorries on Elms Road. It was agreed several years ago that the quarry would be responsible for the road sweeping of this island to prevent wet mud from making the island dangerous for residential traffic and school traffic. The quarry has made it clear they will not be responsible for clearing the mud from the Sunnica traffic during wet conditions.

Although the current road clean regimen is partially successful, the mud does from time to time, carry some distance down Turnpike Road, similarly along Warren Road. Furthermore, Highways have had to contact the quarry on several occasions to request the cleaning of the slip roads, as drivers had reported dangerous driving conditions presented by the volume of mud on the slip road surface.

Sunnica are now proposing to substantially increase the volume of work traffic and heavy loads, the increase in this traffic will drag further mud in winter wet conditions onto this island and the A11 slip roads which could result in dangerous conditions in this area. Unless Sunnica take full responsibility for the frequent cleaning of these areas during wet conditions and the liability for any related incidents, this risks a potential serious accident when combining unstable road conditions (the surface is often pot-holed and breaking up, this will only get worse) with heavy loads, an uneven surface and vehicles.

**Consultation:**

Although Red Lodge Parish Council did not undertake a survey on the Sunnica consultation of residents, the council have a few general points to make about the process undertaken.

Red Lodge residents found it difficult to attend the 2 public events that were held in Cambridgeshire villages only (none in Suffolk). Aside from the lack of a more local venue to go and ask questions about the proposed changes, the timings were difficult to manage for a number of Red Lodge residents given that we have a larger proportion of working families here compared to our neighbouring villages. The timing of the mid-week events clashed on both occasions with school run times, work commitments and this, coupled with the travel time to these locations, made it less accessible. Our parish clerk relayed this to Sunnica at the time but no additional events closer to Red Lodge were scheduled.

Red Lodge Parish Council also has specific concerns about the lack of regard that Sunnica have paid to our fixed site travelers community on Elms Rd. The travelers site, which is permanent and consisting of 9 units, appears to have been regarded as uninhabited. Consequently the residents on this site had not been made aware of the scheme despite being the closest to it, with their outlook being directly onto a vast field of panels (around 10-15 m from their homes) and the largest of the BESS and substation compounds less than 300m from their property. The travelers are an ethnic minority and are protected by the Equality Act 2010, which states any discrimination against protected characteristics is unlawful.

The lack of due diligence shown by Sunnica in identifying this community and engaging with them is a serious flaw.

## 3. General Objections (in the wider area of the solar farm):

Section 2 dealt with the issues that the council felt directly impacted Red Lodge, the following section (3) lists the issues that have been discussion points by Residents and Parish Councillors of Red Lodge concerning the wider area of the solar farm:

### Land Classification:

Sunnica are currently presenting the land as classification 3b or lower. Red Lodge Parish Council believe the data being used by Sunnica as part of the justification of the location is inaccurate. Agricultural Land Classification maps by DEFRA shows a mixture of land graded from 2 to 4, growing crops such as potatoes, sugar beet, wheat and other cereals across the proposed solar plant, are crops which visible on a daily basis traveling through the area. Such crops and the wide range of other crops, is not typical of land graded 3b or lower. If the land is of such poor grade, then surely certain areas within the current plan should be de-scoped and not considered for solar use.

Red Lodge Parish Council is of the opinion that further analysis of the land grading is essential to assess the suitability of this area for this development. We believe that an Issue Specific Hearing should be held on this matter and agree with the submissions of the local authorities and Say No to Sunnica Action Group Ltd on this matter.

### Impact on Health & Wellbeing:

As previously discussed, Red Lodge has residents that use the wider area impacted by the Sunnica proposals, we also have residents involved with equine activities, some working for the stables in neighbouring villages and towns others simply owning horses and spending their leisure time riding. Many residents use the bridle paths that can be found in the wider area, with residents stabling their horses in Isleham, Fordham and Worlington. Many of these residents will lose access to the paths being closed by Sunnica during the construction phase and will certainly be affected by their significant change in aspect and possibly their safety for horses who may not easily accept caged bridlepaths when re-opened**.**

With bridlepaths closed off, riders will have to navigate roads on horseback alongside the projected large number of HGV and staff vehicles. There is a likelihood that recreational riders would have to go elsewhere to ride out, which is not easy and involves upheaval of horses and transportation of the horses to a safer location in order to exercise them. Let's not forget that some stable horses are for younger children to ride/exercise and although not in huge numbers, the increased traffic (especially heavy traffic) could mean it's far too unsafe for that ongoing practice for the children in these areas. We feel this loss of riding routes (roads, bridleways, paths) has been not been fully evaluated.

Post construction, recreational riders will be negatively affected by the significant change in visual aspect, being somewhat higher on horseback when travelling along the many roads and bridleways impacted by Sunnica. We do not feel that the safety or visual amenity of horse riders has been adequately considered, if at all.

Red Lodge has residents who use the Gallops/Limekilns for recreation. I (Red Lodge Parish Council Chair) for one have spent many hours walking the Gallops/Limekilns and have met several residents from Red Lodge there, often with their children on a Sunday afternoon. The children enjoy the search for lost horse shoes to take home, while the adults enjoy the extensive views and tranquil environment. The views are superb from the Limekilns – looking down over Chippenham park and gardens, the Avenue and spotting Ely Cathedral sitting proud on the horizon. We consider this area will be significantly impacted by field upon field of solar panels and a substantial battery store and substation also highly visible. Sunnica's proposal will alter this historic setting for over two generations and cannot be hidden at all. Not only does this affect recreational users of the Limekilns, but is likely to damage the racing industry, which is so vital to support this area economically.

Red Lodge Parish Council feel that the whole area will be poorer in many ways as a direct result of the impact of the Solar farm, transforming views and significantly affecting residents' enjoyment of their valued surrounding countryside for decades and beyond.

**Validity of the Sunnica project's scope:**

The Government's Net Zero strategy (Build Back Greener) makes no mention of solar in its investment strategy, which is laid out to deliver a net zero target by 2050. However, it does mention that solar plays it's part in filling the 'gap' in the short-term while investment in new technologies such as hydrogen, floating offshore wind, carbon capture, micro-nuclear etc. are introduced. However, solar is presented as an insignificant percentage (less than 1%) of the total energy supply by 2035 and could easily be superseded by new technologies by 2050.

Red Lodge Parish Council therefore questions why this project contains no review points, which we feel should be inbuilt to review the capability/the need for this at 15 or 20 years. This could mean that agricultural land could be re-instated sooner, rather than a loss of more than 2 generations. It is unclear why the project is geared for 40 years, when it's likely that the technology will be outdated well before that time and would impede better use of the land it stands on in years to come.

**Decommissioning:**

Red Lodge Parish Council feel the decommissioning plans fall short of any guarantee that monies will be available to clear up and return the land to its current agricultural use. Furthermore, there are no guarantees that the spent solar panels can be recycled in the future.

When considering the amount of construction needed to anchor down one solar panel so that it can withstand high winds, then consideration must be given to the amount of construction material associated with around 1 million solar panels (estimate provided by Sunnica during consultation), it cannot be concluded that there is any easy way of re-commissioning the fields to their present agricultural use again. Red Lodge Parish Council believe that future generations could still be driving through a wasteland of metal and concrete in 50 years' time and believe the current outline for decommissioning and the lack of funding to do this, is unacceptable.

Red Lodge Parish Council believe that Sunnica should have a far more robust decommissioning plan and a process by where they can guarantee monies are ring fenced for the clear up and re-instatement of the land.

**Transport & Access:**

The last major upgrade to the road system was the A11 over 20 years ago. There have been few upgrades to the road infrastructure in the intervening period and many of the roads proposed to carry the Sunnica construction traffic have no footpaths and are very narrow. The village roads being used are simply not designed to carry the heavy construction phase traffic. The roads struggle to have 2 vehicles pass each other, often 1 vehicle having to give way. The unfinished sides of the roads causing erosion, creating pot-holes and deep grooves and break away with heavier loads. These are periodically repaired by highways, but it is unclear who would assume this responsibility to ensure roads are kept in a safe order during and post construction and decommissioning.

In general, we agree with concerns raised by the local authorities regarding the inadequacies of Sunnica's traffic assessments.

**In Summary:**

Red Lodge Parish Council supports renewable energy projects and would certainly welcome proposals that are low impact, scaled, safe and sympathetic to the area. However, the Council consider, as can be seen from the sections of this Written Representation that Sunnica's proposal has the potential to cause a significant detrimental impact to both Red Lodge and the area as a whole. It seems unjust for Red Lodge and it's neighbouring communities to suffer all the negative impacts of this scheme, without any local benefit whatsoever.
In conclusion, Red Lodge Parish Council object to Sunnica's proposal of a solar farm.

# Appendix 1

DO NOT SCALE
Information Classification
PUBLIC
Information that is available to the general public and is intended for distribution outside WSP.
Legend
Red Lodge
Red Line Boundary
© Crown copyright and database rights 2020 Ordnance Survey 0100031673.
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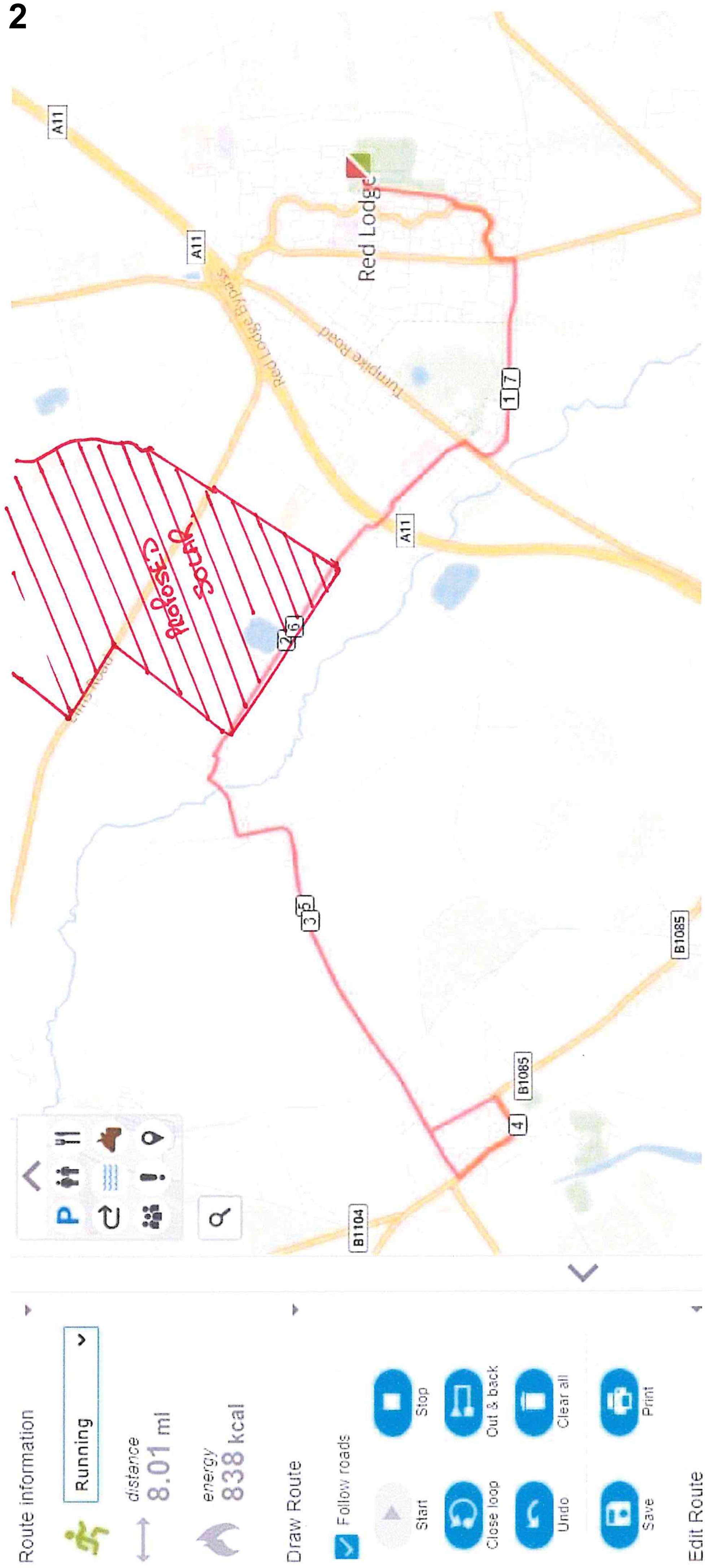
DRAFT
FOR INFORMATION
WSP House, 70 Chancery Lane, London WC2A 1AF, UK
T +44 (0)20 7314 5000
wsp.com
sunnica
Sunnica Energy Farm Development Consent Order (DCO)
Red Line Boundary Plan - Red Lodge
70050915-221004-WSP-PLN-AAA-001-LH-0
© WSP UK Ltd
LIGHT INDUSTRY DEV
PLANNING SUBMITTED
PLANNING GRANTED
Red Lodge
CURRENT SOLAR
PROPOSED
QUARRY
SSSI AREA
UNDER CONSTRUCTION
MIXED BUSINESS & TRAVELLERS SITE
PROPOSED SOLAR
0
140
280
420
560
Metres
N

# Appendix 2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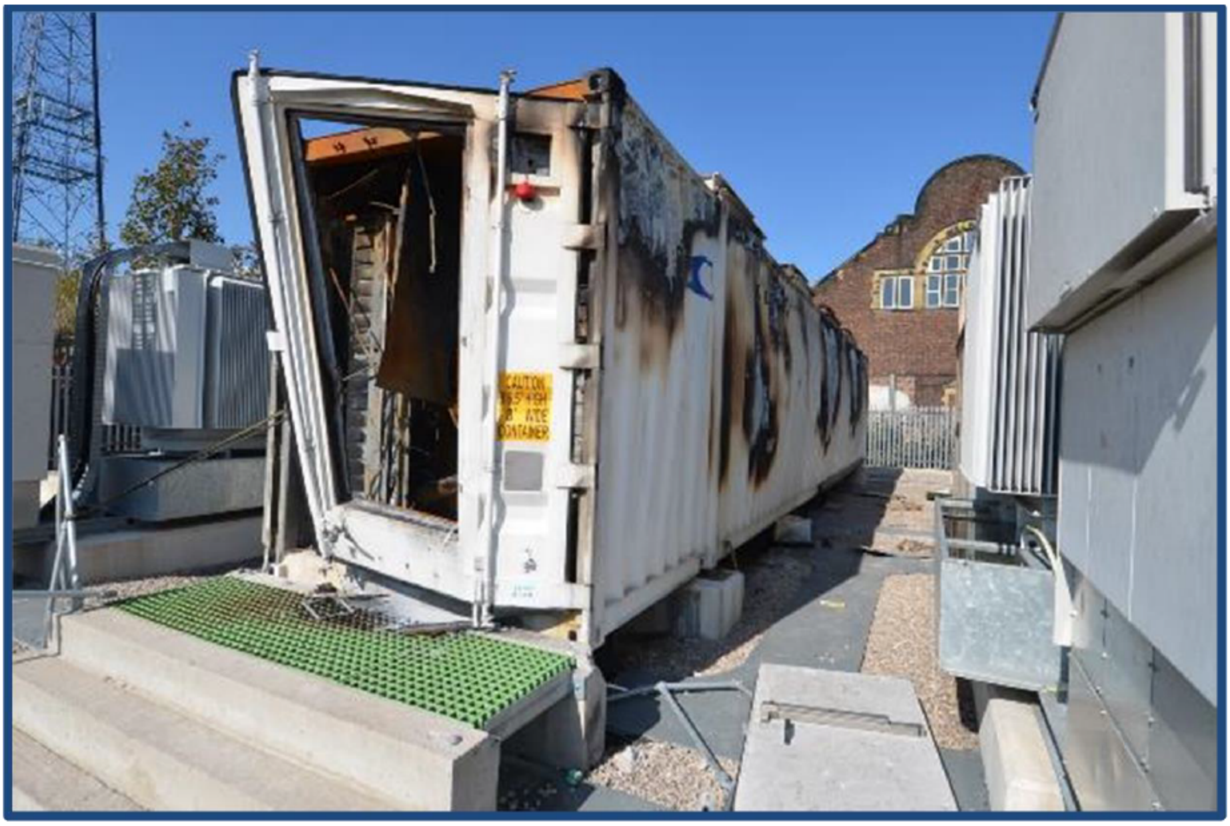
Red Lodge
Red Lodge Bypass
Turnpike Road
PROPOSED SOLAR
B1085
B1104
Route information
Running
distance
8.01 mi
energy
838 kcal
Draw Route
Follow roads
Start
Stop
Close loop
Out & back
Undo
Clear all
Save
Print
Edit Route

# Appendix 3



**Fire Investigation Report 132-20**

**Incident Number 018965**

**Ørsted BESS,**

**Carnegie Rd,**

**Liverpool,**

**L13 7HY**

Compiled by Station Manager [redacted]

Incident Investigation Team, Merseyside Fire and Rescue Service

# Contents

## MERSEYSIDE FIRE & RESCUE SERVICE

## INCIDENT INVESTIGATION TEAM

| | |
|---|---|
| PREMISES: | Ørsted BESS,<br>Carnegie Rd,<br>Liverpool,<br>L13 7HY |
| INCIDENT NUMBER | 018965 |
| DATE: | 15th September 2020 |
| TIME OF CALL: | 00:49 hrs. |
| METHOD OF CALL: | 999 |
| TYPE OF PROPERTY: | Battery energy storage site BESS |
| AUTOMATIC FIRE DETECTION: | Yes |
| BUILDING OWNER: | Ørsted Energy |
| NUMBER OF FIRE APPLIANCES: | 5 Fire Appliances, 1 High Volume Pump |
| INITIAL INCIDENT COMMANDER: | Watch Manager [redacted] |
| INCIDENT COMMANDER: | Group Manager [redacted] |
| HMEPO: | Station Manager [redacted] |
| FIRE INVESTIGATION OFFICER: | Station Manager [redacted] |

# 1 SUMMARY

1.1 At 00:49hrs on 15th September 2020, calls were received by Merseyside Fire and Rescue (MFRS) Fire Control reporting an explosion with smoke and flames visible from the Fisheries, Lister Drive, Old Swan, near to Carnegie Rd. Two appliances, [redacted] responded to the incident. They arrived within 5 minutes of the first call at a secure, double gated site, that had four 12m long shipping containers within the inner compound; one of these was alight and had signs of an explosion. Parts of this container were blown across the compound the furthest of which had travelled 23m.

1.2 The explosion was a result of a failure within Battery Zone 3-Rack 7 Module 6 (BZ3-R7M6) which led to a thermal runaway, which, in turn produced gases within the container culminating in a deflagration.

1.3 After reviewing all available evidence and the report provided by [redacted] following his review of the CT scans which were taken of the cells recovered from both the effected container and a neighbouring container, I have been unable to identify the root cause of the failure within module 6. There is evidence on the exemplar cells from the neighbouring container demonstrating that a gas build-up had occurred leading to some internal distortion within some of the cells.

# 2 PURPOSE OF REPORT

2.1 This report consists of 57 pages and outlines the details of the fire that occurred at Ørsted Battery Energy Storage Site (BESS), Carnegie Rd, and to identify the cause, origin of the fire and the subsequent fire spread. As such, I examined the scene of the fire to determine the area of origin and the most likely cause.

## 3 INVESTIGATION METHODOLOGY

3.1 *'**The Systematic Approach**: The systematic approach is based on the scientific method. This method provides an organisational and analytical process that is desirable and necessary in a successful fire investigation'*

3.2 This investigation was based around the 'scientific method' which is outlined below:[1]

- Recognise the need
- Define the problem
- Collect data
- Analyse the data
- Development of a hypothesis
- Test of the hypothesis
- Select final conclusion

3.3 To interpret and examine the scans taken of the cells, Merseyside Fire Service entered in to a consultancy agreement with [redacted] to undertake the analysis of the images. His findings have been used when forming my conclusion.

3.4 Ørsted has been cooperating closely with the MFRS both before the incident and during in the fire investigation. This has been done, from both sides, not only to carefully identify the source of the fire, but also to assist the MFRS in expanding its knowledge of batteries and further improve the fire safety standards for the whole industry. Ørsted is currently working on the rebuild of the site to the highest available safety standards, and, has and will continue to involve MFRS in the protocols and procedures to be in place before the asset is made operational again.

[1] 2020. *NFPA 921*. [S.l.]: NFPA, pp.921-20.

# 4 DESCRIPTION OF PROPERTY

4.1 Ørsted BESS, Carnegie Rd, Old Swan is a secure compound and is classed as a Battery Energy Storage Site which is used to balance the national grid load in times of high demand. This site, and others like it, are designed to store energy for longer durations to shift peaks of supply to match demand. The site is located next to a high voltage electrical substation.

*Image 1 is a Google map of the site before the BESS was in place* [2]

4.2 A company called "Ørsted" remotely manage the site, and were able to alert a key-holder that there had been an activation of the fire alarm system. The fire alarm system includes an internal and external strobe and sounder system.

The fire detection and suppression system alarms are linked to the NEC AEROS control software and the operational and maintenance interface report system alarms. This includes, related warning and alarms to site operators and NEC. *The AEROS control system measures module temperature and records the min/max of a rack. The thermistors are located in the centre of the cells, any heat radiating from a failing cell will have to pass up to six other cells before the temperature is recorded.*

4.3 The container affected by fire was at the end of the row, it exhibited clear signs of pressure building-up and deflagration. This was evident by the expansion and distortion of the sides and top of the container.

[2] BESS Site in photograph *Google Maps, 2021*


*Image 2 shows the damaged container with signs of expansion/distortion that is equal across the container and not localised to the area of the initial failure.*

4.4 The containers have four heating, ventilation, and air conditioning units (HVACs) fitted to the roof that maintain the internal temperature between $20^0$ and $35^0$ C and automatically activate when a reduction in temperature is required.

4.5 Each of the three containers had two smoke detectors fitted which cross zones with linear heat sensors (LHS) that melt at $88^0$C. The system is remotely monitored in Denmark but the suppression system (which the sensors are connected to) is not set-up to be activated remotely.

4.6 All three containers are fitted with a NOVEC 1230 fire suppression system. The system contains 3.164kg of Halocarbon media that has a discharge time of 10 seconds. The media is contained in a vessel at the end of each container, it has pipe work running along the upper parts of the container terminating at discharge nozzle(s) and is triggered by the smoke detection and linear cable activating it, or a manual break glass located beneath the fire alarm panel.

## 5 INCIDENT BACKGROUND

5.1 Merseyside Fire and Rescue Service (MFRS) were alerted by multiple calls of an explosion and smoke in the area near the Fisheries. The first call was received on Tuesday 15th September 2020 at 00:49 hrs.

5.2 On arrival, the crews arrived to find a container on fire within the site. The site has a secure compound that is spilt in two and was secured by locked gates. This area contains a rest facility for engineers and also gives access via another gate to the containers. The first container is the control unit followed by three BESS containers. There are also two empty concrete pads where two more BESS could be placed. Next to each BESS is a high voltage switch Ring Main Unit (RMU) (yellow arrow on the photograph), Transformer 33kV – 415V (red arrow on the photograph) and a cooler inverter (blue arrow on the photograph). On the top of the BESS containers are four HVAC systems.

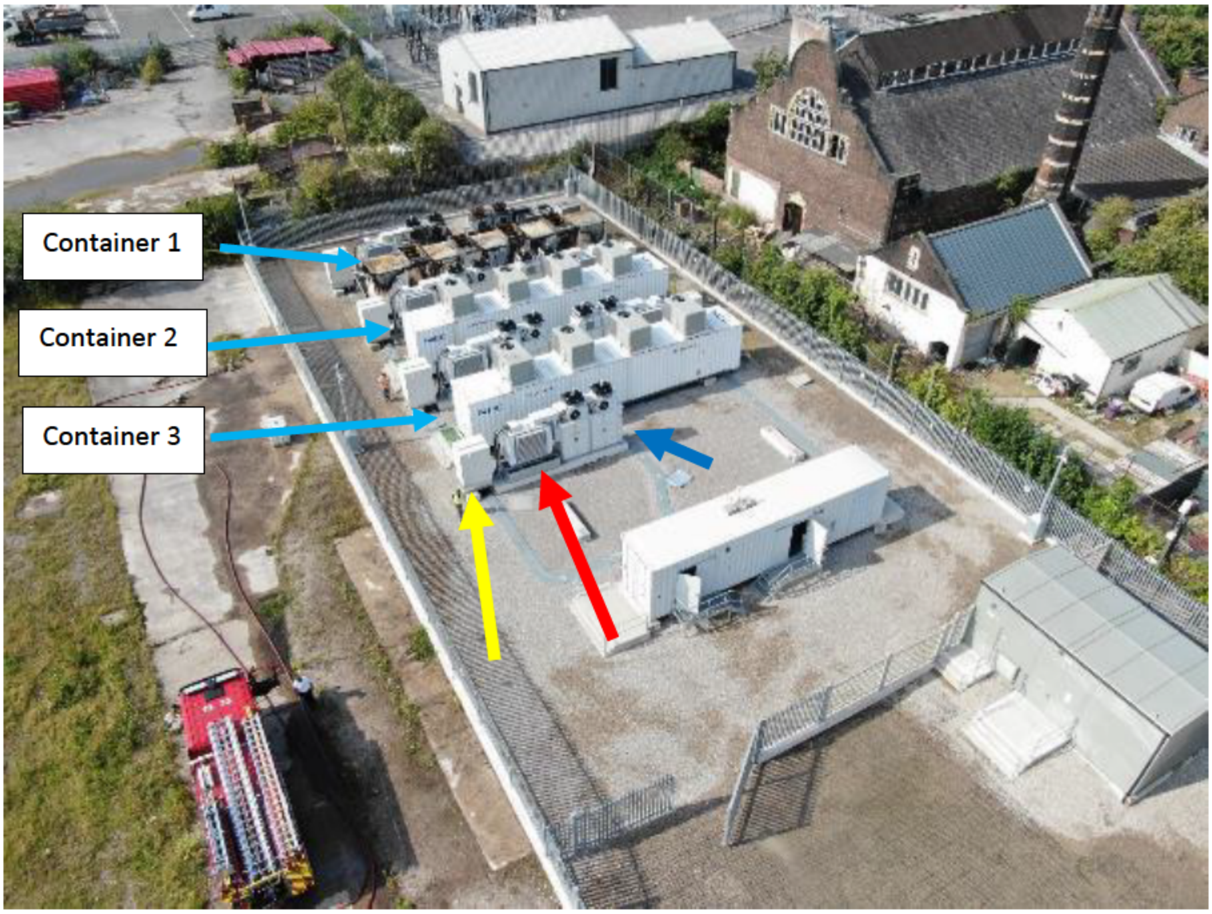



*Image 3 shows the inner compound layout*

5.3 The following time line includes partial data supplied by the responsible person and information collated as a part of my investigation. The data showed (S10 and S22 are specific NEC fault codes):

- *At 00:29:02 hrs event/fault with the rack temperature mismatch >10$^0$c S10, rack temperature spread out of range S22, module temperature above the maximum safe level S11 BZ3-Rack 7 Module 6*
- *A temperature rise of 40$^0$C in less than 2 minutes was recorded indicating a rapid independent excursion.*
- *00:29:36 Alarm for BZ3R7M6 temp above 45c max safe level*
- *00:31 hrs - Fire System Warning Zones 1-5 container 1 (Note: There is no discharge alarm). NEC received urgent alerts.*
- *00:31:02 hrs Smoke alarm went off. All communication to the rack has now stopped as the rack powered off.*
- *00:39 hrs - explosion occurs (Taken from CCTV provided by the responsible person RP)*
- *00:41 hrs - Fire system warning cleared - Ørsted control room in Denmark which monitors the site 24/7 event data shows that the user who cleared them was "kyv_adm/operator"*
- *00:49 hrs - Call received by MFRS from the public*
- *01:02 hrs - Call from Ørsted to NEC emergency line stating "Fire in control room alarm" and that emergency responders were called. This could have been a misinterpretation of location as this was a verbal conversation.*
- *01:18 hrs - Fire System Warning Zones 6-10 container 2 (no discharge alarm received regarding the Novec system)*
- *01:26 hrs (Call to Merseyside's Fire control was received from Denmark whilst crews were in attendance* [redacted]
- *01:50 hrs -* [redacted] *(NEC USA) contacts Operations desk and customer offering support.*
- *01:53 hrs - Operations desk confirms site is on fire via email to* [redacted] *and fire department is on site*
- *02:19 hrs - Entire Site goes offline*
- *02:35 hrs - Ørsted confirms Scottish Power opened breaker and National Grid was informed. Fire "seems under control" per CCTV.*
- *03:47 hrs - Notified by operations desk (Ørsted to NEC) that the "fire in the container should be out now"*

5.4 The weather records in the local area from 00:00 hrs until 01:20 hrs, shows the wind blowing East to South East and a wind speed of around 5mph with a temperature of around 16$^{O}$C.[3]

| Time | Temp | Dew Point | Humidity | Wind | Wind Speed | Wind Gust | Pressure | Precip. | Condition |
|---|---|---|---|---|---|---|---|---|---|
| 12:20 AM | 17C | 13C | 82 % | ESE | 5 mph | 0 mph | 30.00 in | 0.0 in | Fair |
| 12:50 AM | 16C | 12C | 82 % | ESE | 5 mph | 0 mph | 30.00 in | 0.0 in | Fair |
| 1:20 AM | 16C | 12C | 82 % | ENE | 5 mph | 0 mph | 30.00 in | 0.0 in | Fair |

Image 4 weather records

5.5 The temperatures within the containers prior to the system being shut down by the smoke detection system (container 1 and 2) and the site being shut down (container 3) shows that container 2 was below 25$^{0}$C and container 3 was below 27$^{0}$C.

5.6 The site was at ~86.9% state of charge and was discharging around 1.9mW. The site specification for maximum power is 20MW. The specified state of charge percentage operating range is 0 – 100%. Each rack has a power rating of +/- 224kW.

The aggregated energy throughput for the 48 hrs prior to the incident was:

- Net Energy Throughput (kWh) -21.1950362
- Discharge Energy (kWh) 332.0728309
- Charge Energy (kWh) -353.2678671

5.7 At the time of the incident the site had 3 racks off line, BZ8-R4, BZ9-R1 (Container 2) BZ12-R1 (Container 3).

[3] Weatherdata: [redacted] [Accessed 12 Oct. 2020]

## 6 FIRE INVESTIGATION / FINDINGS

6.1 I initially attended the incident scene at 10:17hrs, where I received a briefing from the Officer In Charge (OIC) before photographing the scene and making some initial notes. The firefighting plan was to cool and monitor the fire as smoke was being produced when water from firefighting hoses was turned off. The unknown state of the power supplies in the damaged container prevented an internal scene examination being carried out due to the possibility of stranded energy at this time. I documented the scene and gathered information from relevant personnel.

6.2 A number of photographs were taken by the initial officers that attended during the firefighting phase.

6.3 The responsible person for Cobalt Energy (acting for Ørsted Energy to provide technical advice) attended and explained how the site operated. He provided me with contact details for the management team in America and Denmark. A responsible person for NEC Energy Solutions was also in attendance.

6.4 He informed me that the event occurred in a purpose fitted ISO container which is used to stabilise the National Grid; for example, absorbing energy when there is less demand and feeding the National Grid when demand is high.

6.5 The affected container holds 5 Battery Zones, 9 racks per zone and 17 modules which is an assembly containing lithium ion cells. (Image 5)

6.6 Racks line both sides of the container and each rack has a vented doors. (Image 6 & 9)


*Image 5 is an example of how the containers are set up [4]*

[4] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022.

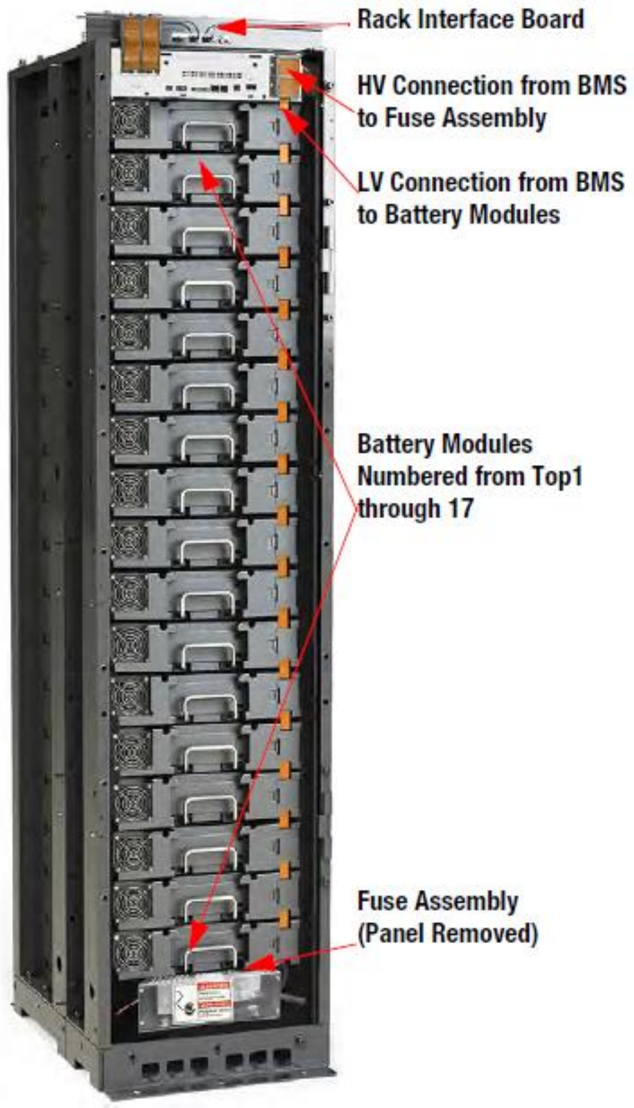



*Image 6 shows the arrangement of racks in the container which have rusted since the fire indicating they are made from a carbon steel. Fans are fitted to the racks to blow cold air that is produced by the HVAC through each module.* [5]

[5] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022.



*Image 7 is an example of the Control System Monitors at the Module, Rack, Zone, Powerblock and System Levels*[6]

[6] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022.

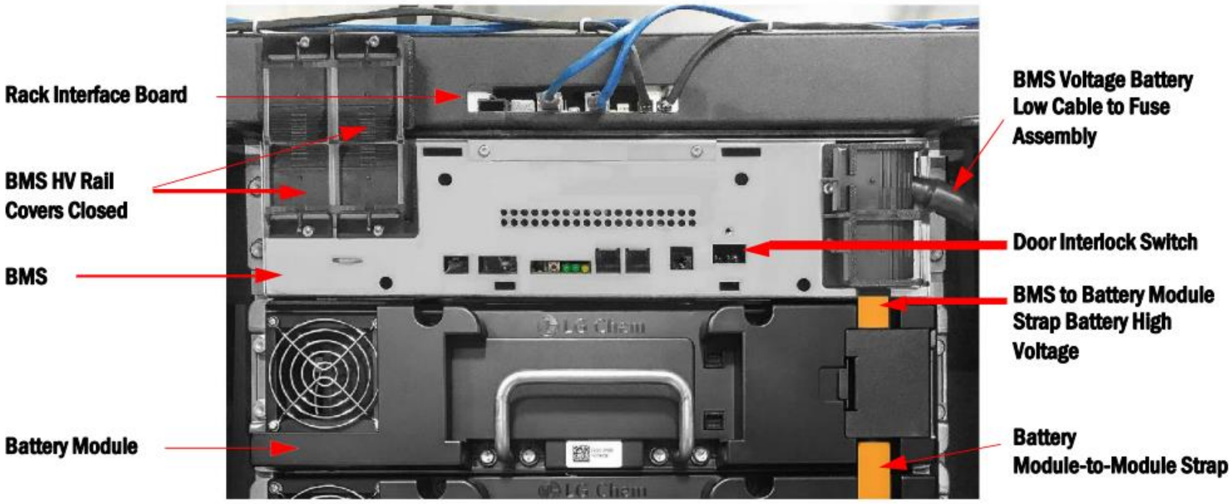



Image 8 shows the MD Rack, BMS, BMS HV strap and the battery module detailed view.[7]

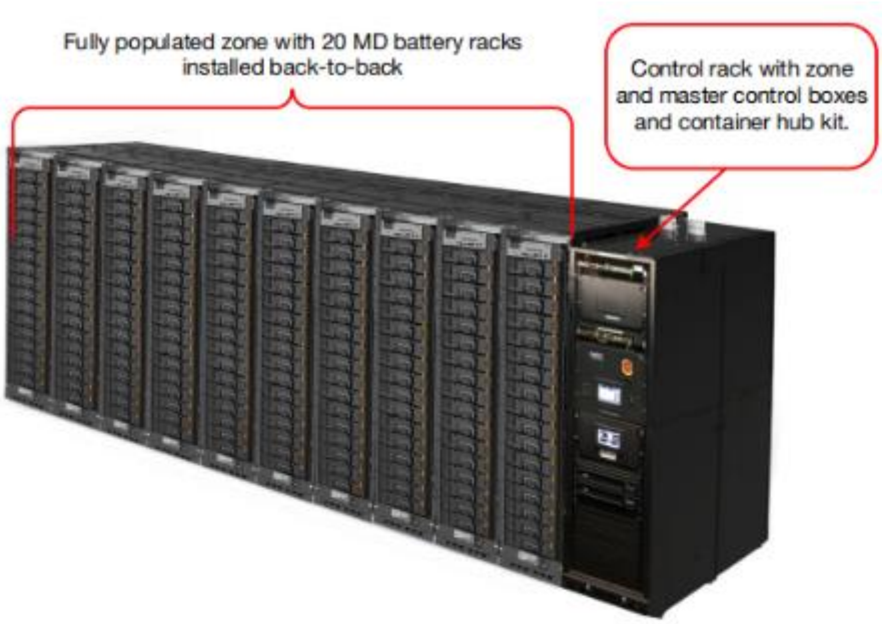



Image 9 is an example of a populated array of 20 racks (two rows of 10, installed back to back) and a control rack.[8]

6.7 Documents have been provided that show that there is a preventive maintenance (PM) plan in place: This is completed by the company service team who plan and perform the PM and provide a service report to the customer. I am in receipt of the PM which was conducted in August of 2020 and the last 3 Fire inspections paperwork covering April 13 2021, May 11 2020 and Feb 13 2020. They use a checklist that appears suitable and sufficient for reporting and customise it to represent the sites actual number of zones, HVAC, inverters, etc. The service teams' site visit reports should also include a copy of the PM checklist. The completed service report, site inventory equipment list and PM checklist are then stored in NECs service system. The last service was performed on the 26th August 2020.

[7] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022.
[8] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022

6.8 Orsted are not aware of any Industry standard for what is considered "adequate" maintenance but conduct maintenance in conjunction with the warranty agreement and what is recommended by the provider.

6.9 ASET who have conducted the inspection have stated:

***'We carry out a service on the fire alarm system installed in the LV/HV unit, this is required every 6 months. At the same time we carry out testing of the fire suppression systems in each battery unit and check operation of the firing pin using the automatic detection and MCP method. This only has to be carried out every 12 months, however we always test the suppression system whilst on site testing the fire alarm panel. (So every 6 months the full suppression system is tested).***

6.10 On 23rd July 2020, NEC issued a LG Module extended replacement Service Campaign following which a plan was put in to place to switch out any relevant modules.

This service bulletin stated that:

***LG has initiated a battery module replacement program related to a manufacture date in 2017 at a plant in Nanjing, China. LG has stated that this replacement program was prompted by the Korean Government's investigation Committee report concerning events experienced by large-scale energy storage systems in Korea in 2019. LG states this replacement program is being done out of an overabundance of caution and is voluntarily replacing batteries due to its commitment to continuous improvement for customers and industry stakeholders. LG does not acknowledge there is a defect in their modules that contributed to the Korea events. A list of recalled modules for each site is attached.***

***NEC Service Engineers will coordinate with customers to arrange the change out. Battery module replacement will be conducted according to standard procedures and NEC will handle all the logistics of getting modules to/from sites.*** [9]

6.11 On the 15th September 2020, the monitoring system recorded at 00:29 hrs: an event/fault with the rack temperature mismatch. The rack temperature spread out of range and the module temperature increased to above the maximum safe level. A temperature rise of $40^0$C in less than 2 minutes was also recorded indicating a rapid independent excursion.

[9] 2020. *LG Module Extended Replacement Service Campaign*. SRO-1220. NEC, p.1.

6.12 During the early stages of my investigation, I conducted a scene examination without entering the damaged container and, I also documented an exemplar container on the same site for comparison this was due to concerns involving stranded energy and contamination. I noted the following:

- Light weight parts of the HVAC system had been thrown up to 23m from the container towards the control room within the fence line.
- The container walls and roof had bowed outwards.
- All four HVACs had come detached from their fittings and landed in a row alongside the container and did not display much fire damage (see photo 4 & 5 in section 13).
- The door closest to The Fisheries had been blown off its hinges and had ripped through the yellow safety rails before landing in the compound. These doors are of substantial weight and it would have taken great internal pressure and force to eject them to the distance observed.
- The larger door at the opposite end to the internal CCTV camera (there are internal CCTV cameras in each container and externally in the compound) was blown open with the smaller door becoming detached and landing next to the container (see photo 2 section 13).
- The internal racking and contents had been extensively damaged and there was significant evidence that the internal container suffered weakening from the heat and the blast (see photo 6 section 13).
- On inspecting the suppression pipework, I noted that the discharge heads were missing and only appeared to have been attached by three threads. The responsible person informed me that PTFE tape and lock tight sealant was used to keep the heads in place.
- The containers are fitted with a NOVEC automatic fire detection system that operates on a double knock system which has two independent fire detection devices: 1, Automatic Smoke Detection System and 2, linear heat sensors (LHS)

6.13 Each of the containers on site had been built in China around 2018 to the NFPA 855 standard (standard for the installation of stationary energy storage systems), although this may not be the most recent edition of the NFPA standards. At the time of writing this report I am unaware of which edition of NFPA 855 was used. At the time of writing this report there were no UK equivalent standard in place.

6.14 The containers are lined with a foam insulation that is fitted for thermal insulation. Each container has a separation of approximately 5m from the next with inverters and transformers providing a barrier between them.

# 7 TESTING AND INSPECTIONS (prior to the event)

7.1 The modules were declared compliant with UL9540 (an American industry standard for safety energy storage systems and equipment) I have requested a copy of the UL9540 standard and a copy of any documentary evidence that confirms compliance to this standard. To date this evidence has not been made available to this investigation.

7.2 Ørsted informed me that they have exchanged 32 modules in the past on this site and have noted that there were no signs of swelling of the cells or any signs of failure or damage across their sites.

7.3 The responsible person, when asked, did not have any documentary confirmation to show what tests have been conducted by the manufacturer, supplier or customer regarding the safety of the cells, or if they have been tested to destruction. It has been confirmed by the responsible person for the site that, testing under the transportation regulations UN38.3 was conducted for T1-T5 and T7, I am not in possession of the results. The tests are as follows:

T1 – Altitude Simulation (Primary and Secondary Cells and Batteries)

T2 – Thermal Test (Primary and Secondary Cells and Batteries)

T3 – Vibration (Primary and Secondary Cells and Batteries)

T4 – Shock (Primary and Secondary Cells and Batteries)

T5 – External Short Circuit (Primary and Secondary Cells and Batteries)

T6 – Impact (Primary and Secondary Cells)

T7 – Overcharge (Secondary Batteries)

T8 – Forced Discharge (Primary and Secondary Cells)

7.4 Prior to the incident, data shows that none of the cells within the effected container showed signs of charging slower than normal or any other anomalies.

7.5 The site is inspected every month. The inspections are general examinations and groundwork maintenance lasting for approximately 6 to 8 hrs. This includes a basic inspection inside the containers consisting of a 15-minute visual inspection.

7.6 NEC conduct longer maintenance sessions every 6 months on the batteries which includes a thermal check of the power connections after running at full load for 20 minutes. Workers are on site for two days over this period and normally have the fire systems maintenance contractors with them at the same time.

## 8 CAUSE OF THE FIRE (Range of ignition sources)

8.1 During the course of the investigation and scene examination I considered a number of ignition sources including; deliberate ignition and cell defect. Other sources of ignition such as, smoking and fireworks were ruled out, as there was no evidence to suggest that these were likely sources of ignition due to the security of the site, the container being secured and the CCTV footage showing that no one had been on site leading up to the ignition.

8.2 I have conducted an internal examination of the container and affected rack as well as an examination of exemplar modules taken from the other containers.

8.3 Examination of the identified racks, modules and remaining cells in situ was conducted jointly in May 2021. In the time since the incident occurred there has been on site security at all times. Although some parts of the container were exposed to the elements, the area of interest was protected by the walls and roof of both the container and the rack itself.

8.4 The co-operation Ørsted and other relivant parties has aided me with my investigation. This has been through the sharing of information, research, data and joint examinations.

8.5 **Deliberate ignition**

The investigation found no evidence that the fire was caused by deliberate ignition, in drawing this conclusion I considered both the CCTV footage and that the site was secure with restricted access.

8.6 **Cell failure**

Due to the extent of the damage to the racks and modules within the container, I have relied on the information provided by the responsible people for the site and equipment, along with the data that has been captured from the sites management system and the examination of scans of both damaged and exemplar cells by [redacted] he data shows that there were issues with battery zone BZ3-R7M6 prior to [redacted]

8.6.1 When reviewing the internal CCTV, there is evidence of fumes and vapours (produced by thermal runaway of the cell) transiting through the container at low level until reaching the door closest to the Fisheries which is where the camera was positioned. Light can be seen at the opposite end of the container which appears to be the emergency lightings which was illuminating the exit signs.

8.6.2 The vapours are likely to be the result of a cell or cells venting as a consequence of overheating. The cause of which is unknown at this time but, it could be attributed to either:

- Thermal abuse – exposed to high heat from external sources; (no evidence found in data provided)
- Electrical abuse – overcharging, rapid discharging, unbalancing; (no evidence found in data provided)
- Mechanical abuse – development of an internal short circuit, leading to a high current flow with consequent local heating; (no evidence found in data provided)
- Internal defects – detritus, other contaminants; (due to the cell damage I was unable to discount any defects internally)
- Environmental abuse – seismic, flooding, absent or poorly designed HVACs. (no evidence found in data provided)

8.6.3 The failure of the cells caused it to enter thermal runaway. *The thermal runaway can be described as 3.3.20. The condition when an electro- chemical cell increases its temperature through self-heating in an uncontrollable fashion and progresses when the cell's heat generation is at a higher rate than it can dissipate, potentially leading to off-gassing, fire, or explosion.* (NFPA 855 , 2020) (NFPA 855 , 2020)

**Ørsted informed me that:** ***Some swelling is expected to occur during normal operation of a well-manufactured lithium-ion cell. Gas generation in the cell, which causes swelling, is a result of electrolyte decomposition. There is minor incompatibility between the liquid electrolyte and electrodes used in conventional, commercially available cells. As such, the electrolyte breaks down where it meets the electrode, resulting in gas generation and solid passive layer that forms over the electrode surfaces. Additionally, any external temperature increases could cause further electrolyte degradation within the cell and lead to swelling. As I have not seen the design specification I have been unable to verify if the swelling is a design feature.***

It is possible that the cells have been fitted close together in the module limiting any expansion area. This would present increased thermal contact between the cells. At this point the internal vapours and fumes would then vent which was witnessed filling the container on the internal CCTV.

The following was also noted from the CCTV footage:

- 00:37 hrs the doors appear to be in the closed position. The power is still on to the container and the racks and the lights can be seen on the alarm panel.
- 00:38 hrs camera becomes obscured with smoke/vapours gasses
- 00:39 hrs vision becomes clear and the doors are open. The smoke and vapours dissipate and items can be seen on the floor of the container.
- The external camera shows the doors being blown off and a spray of flame and sparks briefly being expelled before dying back
- 00:57 hrs Significant free burning now visible on the external camera

The module data showed as failing first was on the replacement program which was planned for changing in December 2020 and is referenced in section 6.8 page 15.

Based on my investigations, the evidence is consistent with the initial cell having suffered an exothermic reaction which then lead to a thermal runaway which resulted in flammable and toxic vapours being produced. Work conducted by Pacific Northwest National Laboratory shows that cells can give off the following toxic vapours:

Hydrogen Fluoride, Hydrogen Sulphide, Hydrogen Chloride, Hydrogen Cyanide, Hydrogen,

Propylene, Methane, Carbon Monoxide, Sulphur Dioxide, Ethylene, Ethane

The internal CCTV shows the vapours (vented gases-droplets of organic solvent from the cells) building up at low level filling the container as to started to reach their flammable limits, before coming into contact with an ignition source, the exact ignition source within the container is not known. The vapours ignited causing a deflagration which blew off both doors and caused the HVACs to come detached from the roof as well as deforming the container.

## 9 FIRE SPREAD

9.1 The thermal runaway started in module BZ3-R7M6 when the lithium ion battery cells failed. This led to a rapid rise of temperature of this cell which then caused a chain reaction of the other cells within

the module. The vapours being given off by the cells subsequently filled the compartment and activated the detection system. As the reaction remained localised, within rack three, in zone seven, and modules BZ3R7M1, BZ3R7M2, BZ3R7M3, BZ3R7M4, BZ3R7M5, BZ3R7M6, BZ3R7M7, BZ3R7M17 and run 1 to 17 from top to bottom, (data shared by Ørsted as seen in image 6 page 13). The BMS reported a maximum temperature being reached. This localised containment prevented linear heat cable being affected, which consequently led to the suppression system not activating immediately.

9.2 After attending a joint online examination of the cylinder and activator due to Covid restrictions, it indicated that the suppression system had been released electronically (the pin was in the activated position). The records from the monitoring system suggests that this was not whilst the communications were still functioning. i.e. the system did not operate due to the detection system in conjunction with the thermal wire. It is my opinion that it possibly activated as the event escalated and after communications were lost at the point when the deflagration occurred. The deflagration moving through the container would have had the force to trigger the break glass point below the fire alarm panel.

9.3 The examination of the suppression assembly also showed that the bursting disk had operated, which may be due to the cylinder discharging as the release valve resets and seals the cylinder; as the fire heated the sealed vessel, the bursting disk might have then triggered/operated. Alternatively, the activator could have triggered, but failed to release the contents, leaving it full and causing the bursting disk to operate when it was heated.

## 10 CONCLUSION

10.1 The findings of this investigation conclude that this event occurred following a failure within Battery Zone 3-Rack 7 Module 6 (BZ3-R7M6) which led to a thermal runaway. The thermal runaway caused the cell to vent vapours and, when a flame was present within the container ignited vapours/gases causing a deflagration forcing the doors off ether end and causing the HVACs to become unmounted from the roof. I have been unable to identify the root cause of the failure within module 6.

10.2 The suppression system was most likely discharged due to the deflagration which either, activated the alarm or the pressure activated the break glass media trigger below the alarm panel.

10.3 Following [redacted] review of the CT scans he has stated:

***X-ray Computed Tomography (CT) provides a non-destructive tool for 3D imaging which has been widely applied to batteries. The physical size of the object is inversely proportional to the resolution***

*that can be achieved (i.e. smaller feature sizes are observable in smaller samples); therefore owing to the large form factor of the batteries in question, the resolution that has been achieved is limited and only macroscopic features within the cell architecture are visible.*

*Furthermore, the fire damaged batteries recovered from the incident had undergone such significant failure, that the scans of these batteries have not provided substantive insight as all registration of the cell architecture has been lost. This is not uncommon in battery failures where the excessively high temperatures during thermal runaway processes can destroy the cell components.*

*X-ray images of exemplar cells recovered from neighbouring containers do provide some information relating to the state of health of the (non-failed) cells. Clearly, these cells have not undergone failure and to my understanding were in operation up until the point of the incident, after which they were recovered from the scene having not themselves failed. Within these exemplar cells, there are indication of gas generation; this has been observed both by a simple visual inspection of the cells (which shows pockets of gas immediately adjacent to the cell surface), and by X-ray CT which shows the presence of gas leading to distortion of the cell architecture in some cases.*

*Gas generation in Li-ion batteries principally occurs due to electrolyte decomposition – this can happen due to excessive heat, or over-voltage in service (which could be external or could be a result of a defect with the cell or BMS), but is more likely associated with solid electrolyte interphase (SEI) formation during formation and operation:*

*The electrolytes used in Li ion batteries are not stable across the full voltage window of operation, and they decompose to form a SEI layer at the anode. This happens in large measure during the original manufacturing process where the cells undergo a highly managed 'formation process' whereby the cells are cycled at very low rates to form a stable SEI. The accompanying gas generation can then be managed, by degassing the cell before production is finalised. Some cell geometries have hard cases and 'empty space' which can accommodate the generated gas, but pouch cells would usually require degassing as the soft casing material cannot withstand over pressure, and there is not empty volume for generated gas. After manufacture, the formation of the SEI layer will continue but at a much lower rate, and there before the accompanying gas evolution is much lower. SEI will continue to form over the lifetime of the cell, but excessive SEI*

***formation and accompanying gas evolution causing the cell to swell is of concern and has safety implications.***

***Within the exemplar cells, there is evidence of gas generation, although not to the extent that it has caused failure. Without a granular understanding of the operational history of each of these exemplar cells, it is not possible to assign the root cause of this gas generation with certainty, or to predict how this may have progressed were the cells to continue operational service. However, the presence of gassing indicates that the exemplar cell's state-of-health had degraded.***

## 11 GLOSSARY OF TERMS

**Area of Origin**

The specific location or place where the fire initially started.

**Automatic Fire Detection (AFD)**

A fire alarm system comprising components for automatically detecting a fire, initiating an alarm of fire and initiating other action as arranged; the system may include manual call points.

**BESS**

Battery Energy Storage Systems

**BMS**

Battery Management System

**Burn Pattern**

Created when applied heat flux are above the critical thresholds to scorch, melt, char or ignite a surface.

**Combustion**

Oxidisation that generates detectable heat and light.

**Deflagration**

A very rapid oxidation with the evolution of heat and light and the generation of a low-energy pressure wave that can accomplish damage. The reaction proceeds between fuel elements at subsonic speed.

**Exemplar**

A person or thing serving as a typical example or appropriate model

**Exothermic reaction**

Generating or giving off heat during a chemical reaction

**Fire**

A rapid oxidation process with the evolution of light and heat in varying intensities.

**Fire Investigation**

The process of determining the origin, cause and development of a fire or explosion.

**Fire Spread/Development**

The movement of fire from one place to another

**Flame**

The luminous portion of burning gases or vapours.

**Fire Appliance**

An appliance that is capable of carrying a multitude of equipment and firefighting media (such as water and foam) to deal with different types of emergencies.

**Fire Control**

A control room used to handle emergency calls for the fire services and mobilise resources to deal with incidents.

**GBS**

Grid balancing system

**Heat transfer**

Spread of thermal energy by convection, conduction or radiation.

**HMEPO**

Hazardous Materials and Environmental Protection Officer

**Ignition**

The process of initiating self-sustaining combustion.

**Linear heat detection**

The heat from a fire causes the LHS cable's special insulation to melt at a specific temperature, allowing the two conductors to short together, thus creating an alarm condition on the fire control panel. The LHS cable may also be used as a stand-alone contact device. The LHS normal operating state is an open circuit.

**Lithium-Ion Battery Energy Storage Systems:**

A system comprised of one or more lithium-ion batteries assembled together, capable of storing energy in order to supply electrical energy at a future time

**Point of Origin:** The physical location where a heat source and a fuel come into contact with each other and a fire begins.

**Radiated Heat:** Energy radiated by solids, liquids or gases in the form of electromagnetic waves as a result of their temperature.

**Self-heating**

An exothermic chemical or biological process that can generate enough heat to become an ignition source; spontaneous ignition.

**Stored/Stranded Energy:**

A condition where the system has been electrically isolated but there is still residual charge in the batteries.

**Suppression system**

Fire suppression systems are used to extinguish or prevent the spread of fire in a building. Suppression systems use a combination of dry chemicals and/or wet agents to suppress equipment fires.

**Scientific Method:**

The systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypothesis.

**Smoke:**

Airborne products of incomplete combustion.

**Soot:**

Black particles of carbon produced in a flame

**Thermal runaway:**

Thermal runaway is defined with in NFPA 855 3.3.20 2020 as, Thermal Runaway. The condition when an electro- chemical cell increases its temperature through self-heating in an uncontrollable fashion and progresses when the cell’s heat generation is at a higher rate than it can dissipate, potentially leading to off-gassing, fire, or explosion.

**Vapour:**

The gas phase of a substance, particularly of those that are normally liquids or solids at ordinary temperatures.

**Signed**

[redacted]

Station Manager

Incident Investigation Team

08th February 2022

## 12 AERIAL VIEW OF SITE

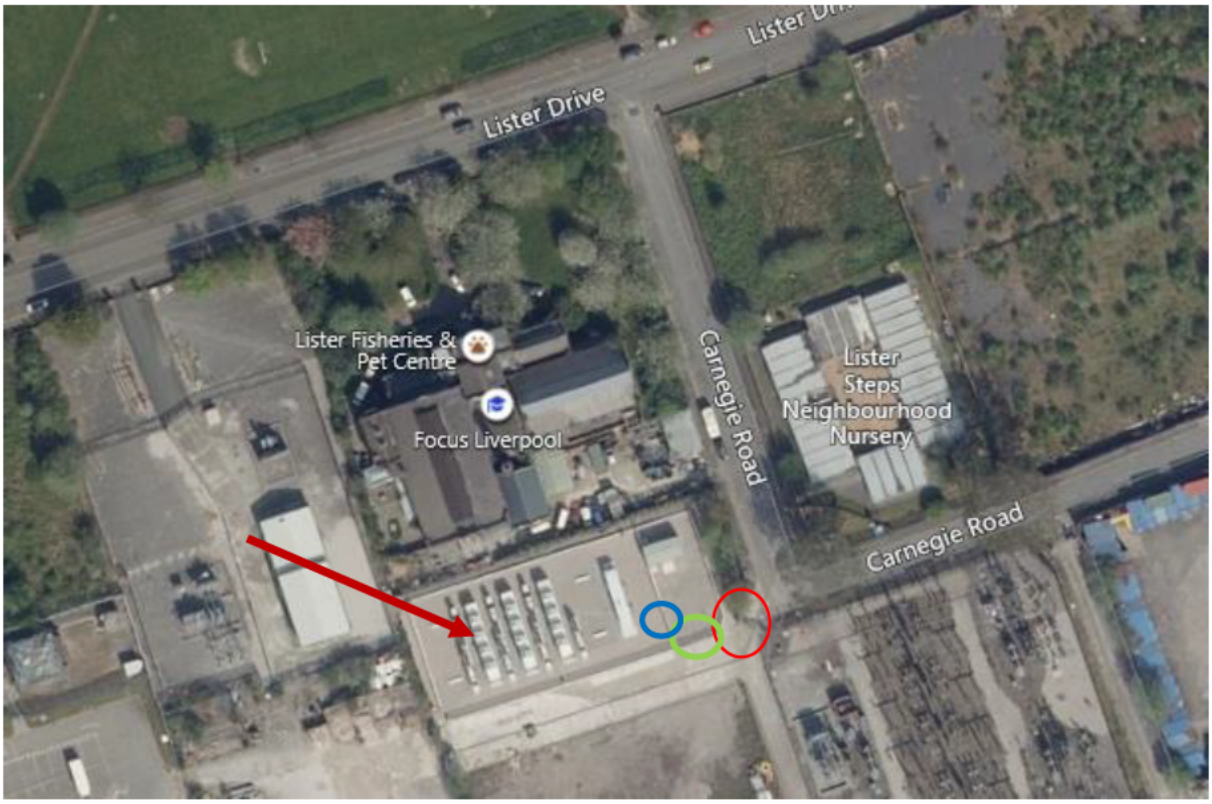



Image 15

**Main gate was secure on arrival** (red circle)

**Second gate** (green circle)

**Third gate** (blue circle)

**Affected container** (red arrow)

## 13 KEY PHOTOGRAPHS

| | Description | Frame number |
|---|---|---|
| 1 | Over view of the scene | IIT_5248 |
| 2 | Air unit overview | DJI_0237 |
| 3 | Left aspect of container one | IIT_5290 |
| 4 | Right aspect of container one | IIT_5303 |
| 5 | HVACS after coming dismounted from the container roof | IIT_5329 |
| 6 | Internal view of container one from the Fisheries side. | IIT_5519 |
| 7 | Consumer unit in container one | IIT_5518 |
| 8 | NOVEC system in container one with damaged pipe work | IIT_5516 |
| 9 | NOVEC system in unit two | IIT_5505 |
| 10 | Alarm panel, emergency activation points and consumer unit | IIT_5504 |
| 11 | External CCTV pre blast | CCTV |
| 12 | External CCTV at point of blast for the door fails | CCTV |
| 13 | External CCTV showing flaming discharge consistent with a failing Lithium cell failing | CCTV |
| 14 | External CCTV showing the door being blown open and the smaller door coming detached | CCTV |
| 15 | Internal CCTV showing the activated alarm panel to the bottom left, the NOVEC system to the bottom right and the fire exit door in the bottom centre. | CCTV |
| 16 | Internal CCTV 00:37 vision begins to become obscured | CCTV |
| 17 | Internal CCTV 00:38 vision becomes clearer and the fire exit door has failed. No power can be seen on the fire alarm panel | CCTV |
| 18 | R7 Z3 after the containers had been cut in to sections | MB0_7375 |
| 19 | Location that module 6 would have been pre fire. The modules had melted and collapsed | MB0_7397 |
| 20 | R7 after the side of the rack had been cut away | MB0_7402 |
| 21 | Close up of the module of interest before removal | MB0_7421 |
| 22 | Shows the flooring at the foot of R7. The floor had wood boarding fitted which had burnt through. | MB0_7450 |

1

Overview of the scene

## Fire Investigation

**2**

Air unit overview. The red arrows show the resting place of the doors

# Fire Investigation

**3**

Left aspect of container 1

**Fire Investigation**

4


Right aspect of container one

**5**

HVACS after coming dismounted from the container roof

6

Internal view of container one from the Fisheries side

7

Consumer unit in container one

**8**

NOVEC system in container one with damaged pipe work

**9**


NOVEC system in unit two

**10**

Alarm panel, emergency activation points and consumer unit

**11**


External CCTV pre blast

# Fire Investigation

**12**


External CCTV at point of blast for the door fails

**13**

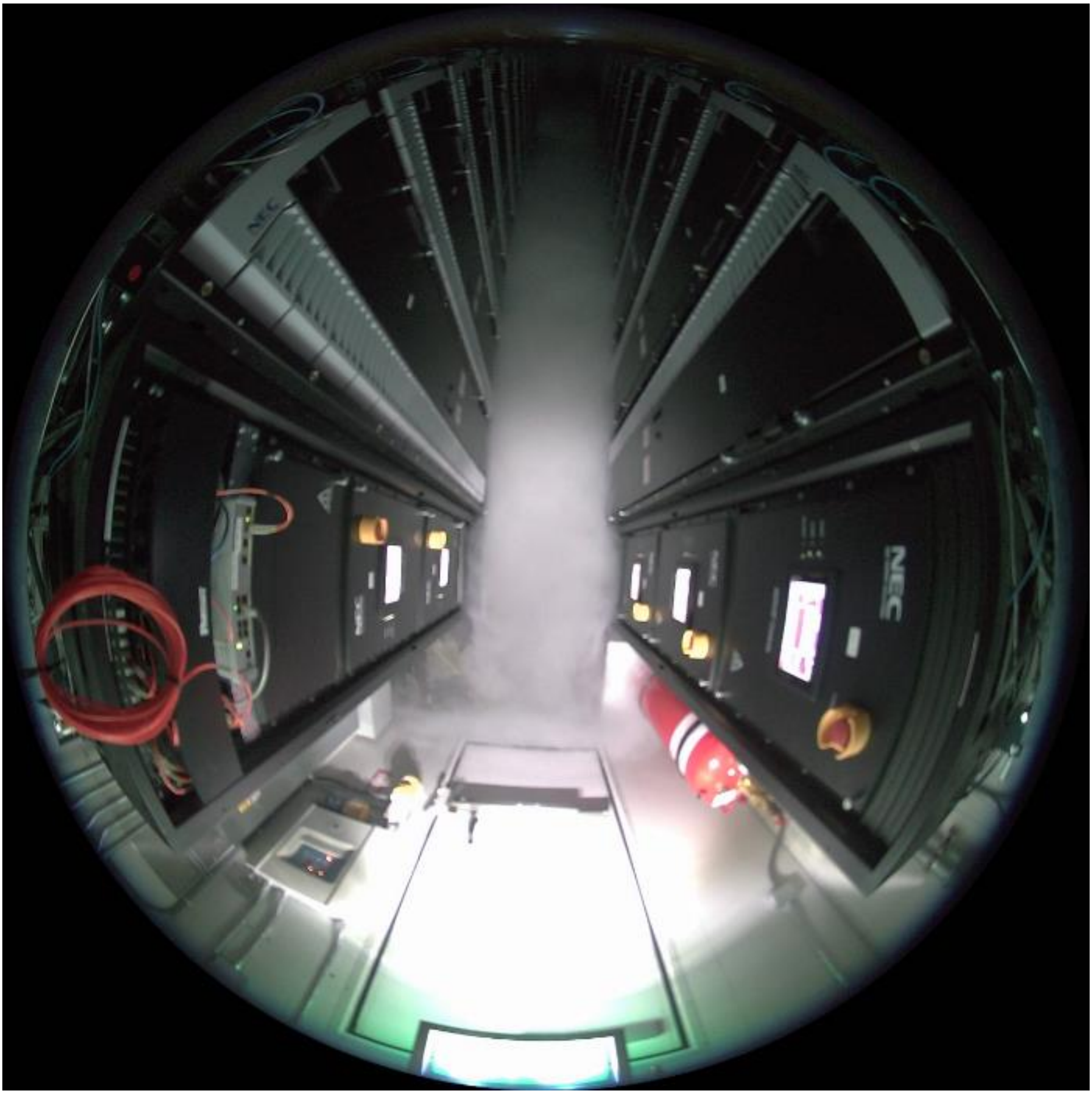

External CCTV showing flaming discharge consistent with a failing Lithium cell

**Fire Investigation**

**14**

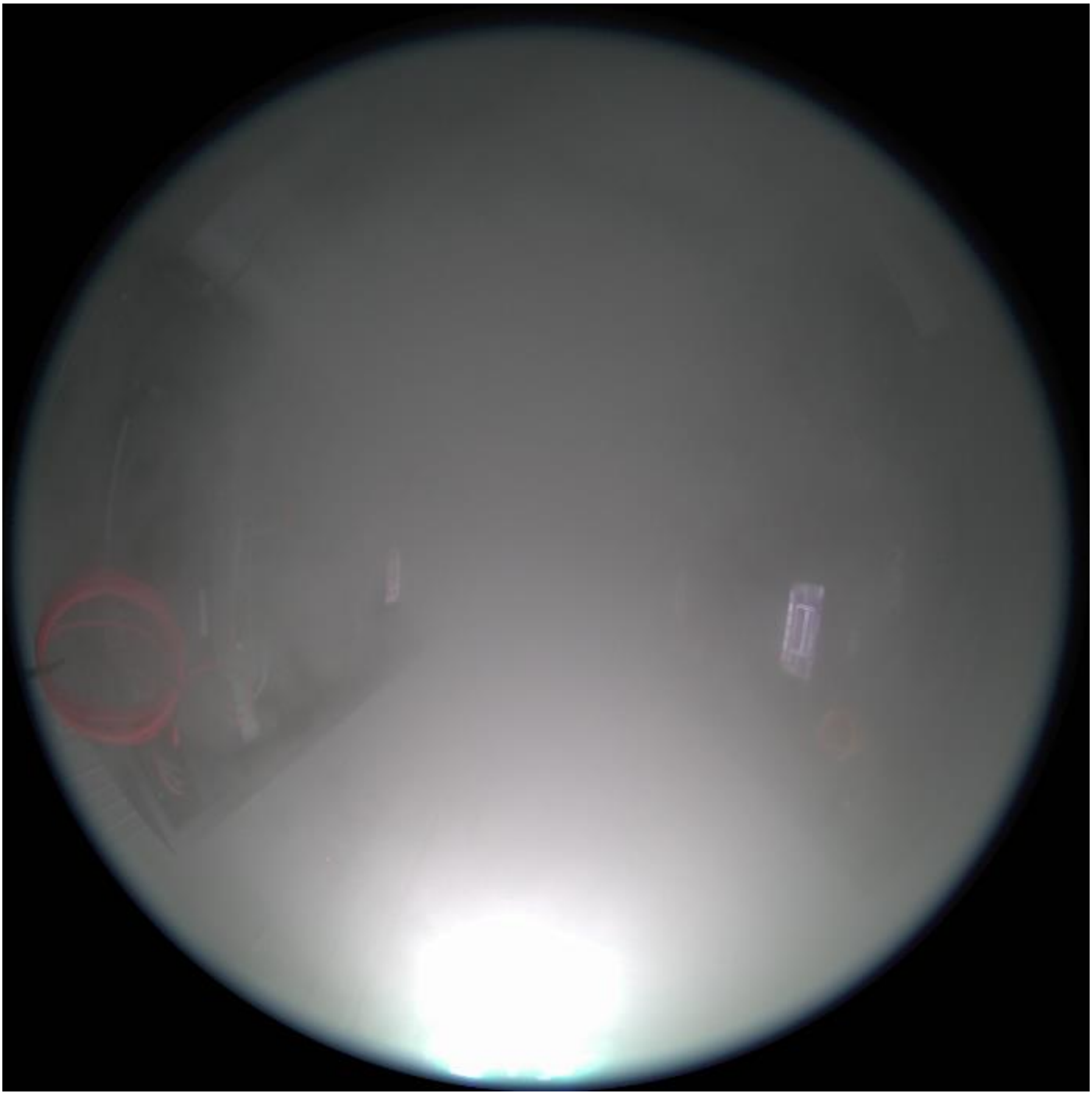

External CCTV showing the door being blown open and the smaller door coming detached

15




Internal CCTV showing the activated alarm panel to the bottom left, the NOVEC system to the bottom right and the fire exit door in the bottom centre. The fish eye view is due to the position of the CCTV camera located on the ceiling near the rear door. A vapour cloud can be scene within the container

**16**



Internal CCTV 00:37 vision begins to become obscured by the vapour cloud

17

Internal CCTV 00:38 vision becomes clearer and the fire exit door has failed. No power can be seen on the fire alarm panel

## Fire Investigation

**18**

Image MB0_7375 shows R7 Z3 after the containers had been cut in to sections.

19


Image MB0_7397 shows where module 6 would have been pre fire. The modules had melted and collapsed.

**20**


Image MB0_7402 shows the side view of R7 after the side of the rack had been cut away. This view shows how the modules have collapsed making recover difficult. To remove them through the front would have pulled the module apart so, they had to be recovered sideways.

**21**

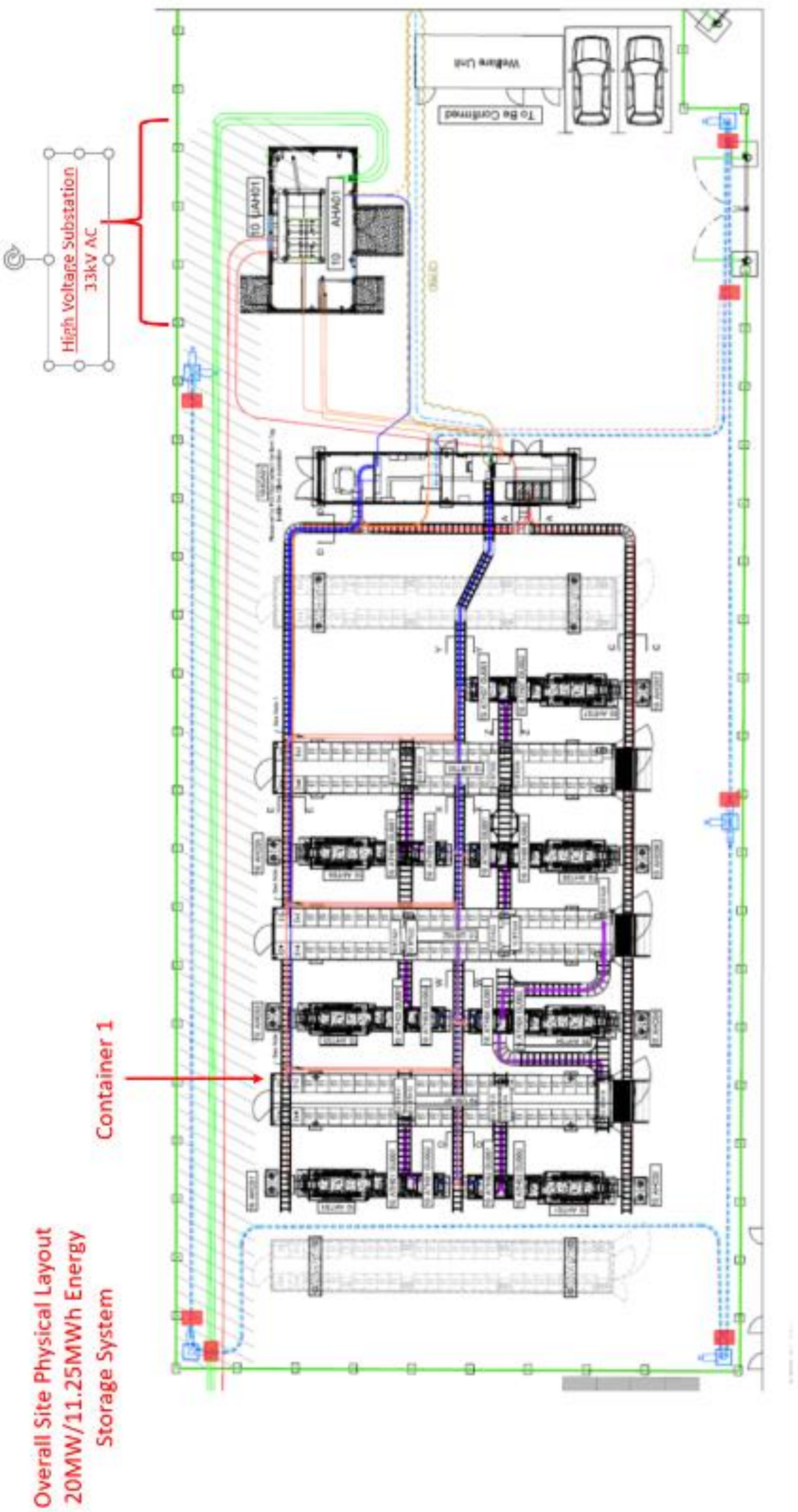
Image MB0_7421 is a close up of the module of interest before removal.

**Fire Investigation**

22

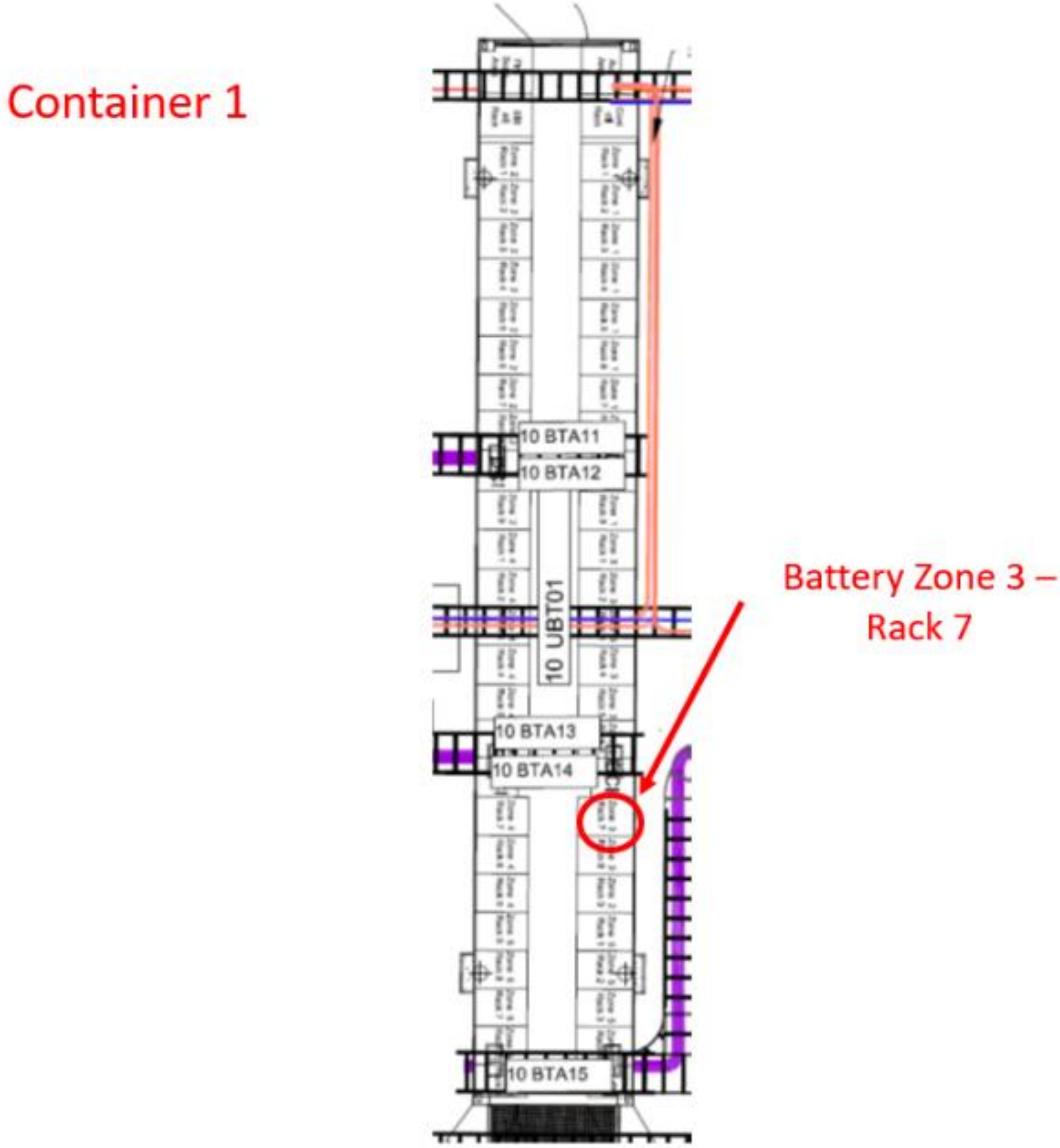
Image MB0_7450 shows the flooring at the foot of R7. The floor had wood boarding fitted which had burnt through.

APPENDIX A Plans



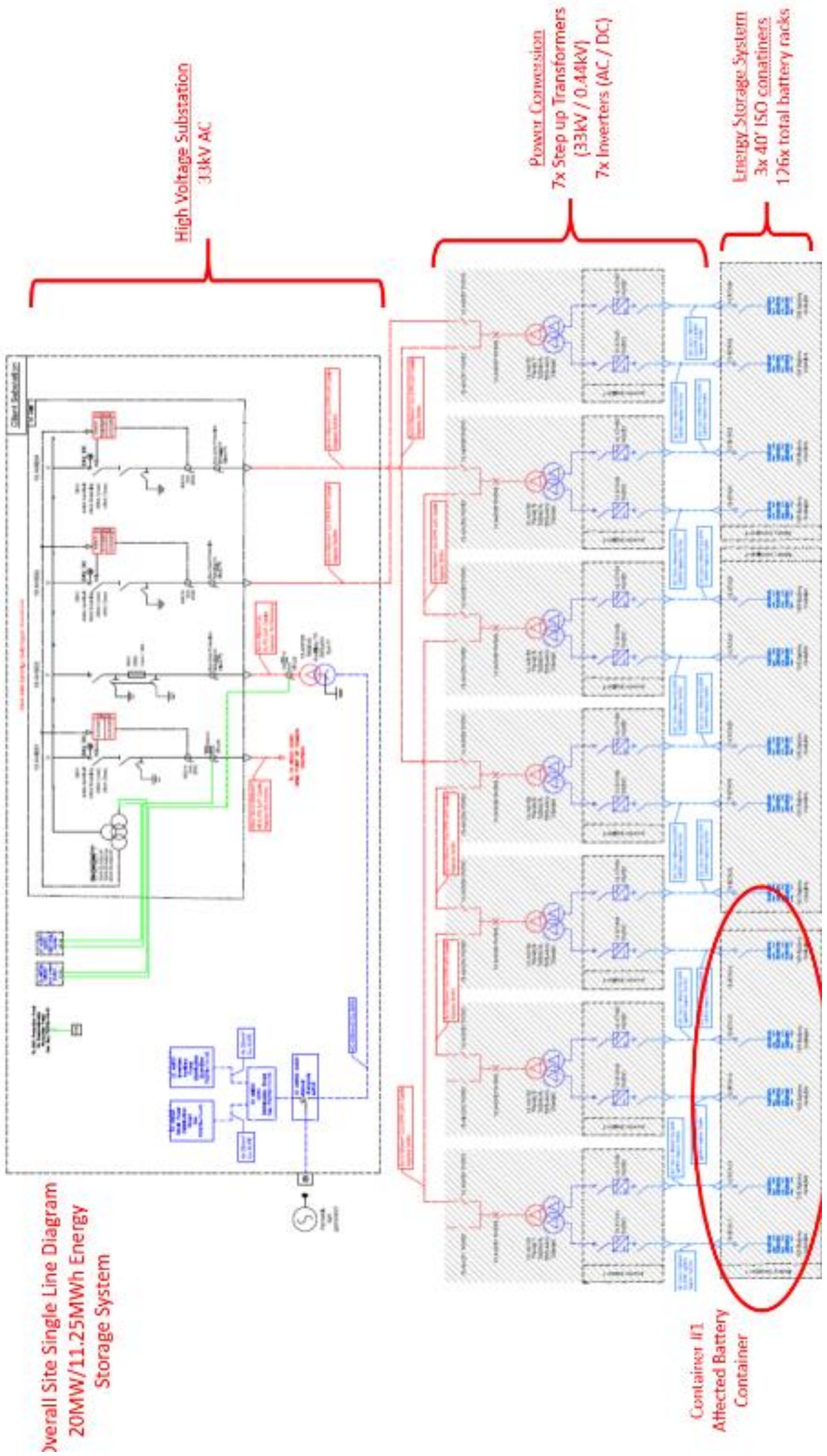

**Plan 1 shows the over view of the sites physical layout[10]**

[10] 2020. *Overall Site Physical Layout*.



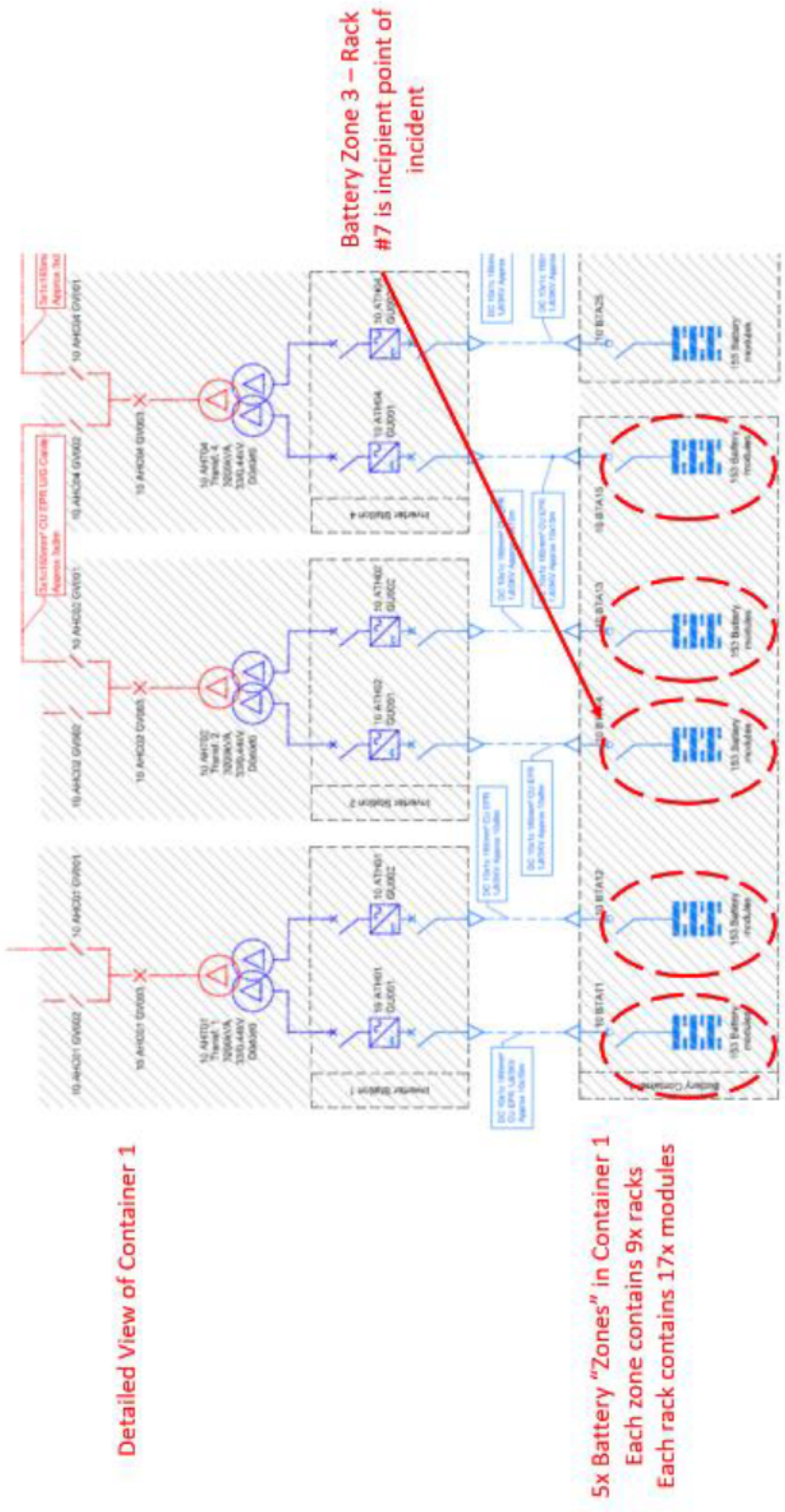

**Plan 2 shows the layout of container 1 which is the effected container**[11]

[11] 2020. *Overall Site Physical Layout*.



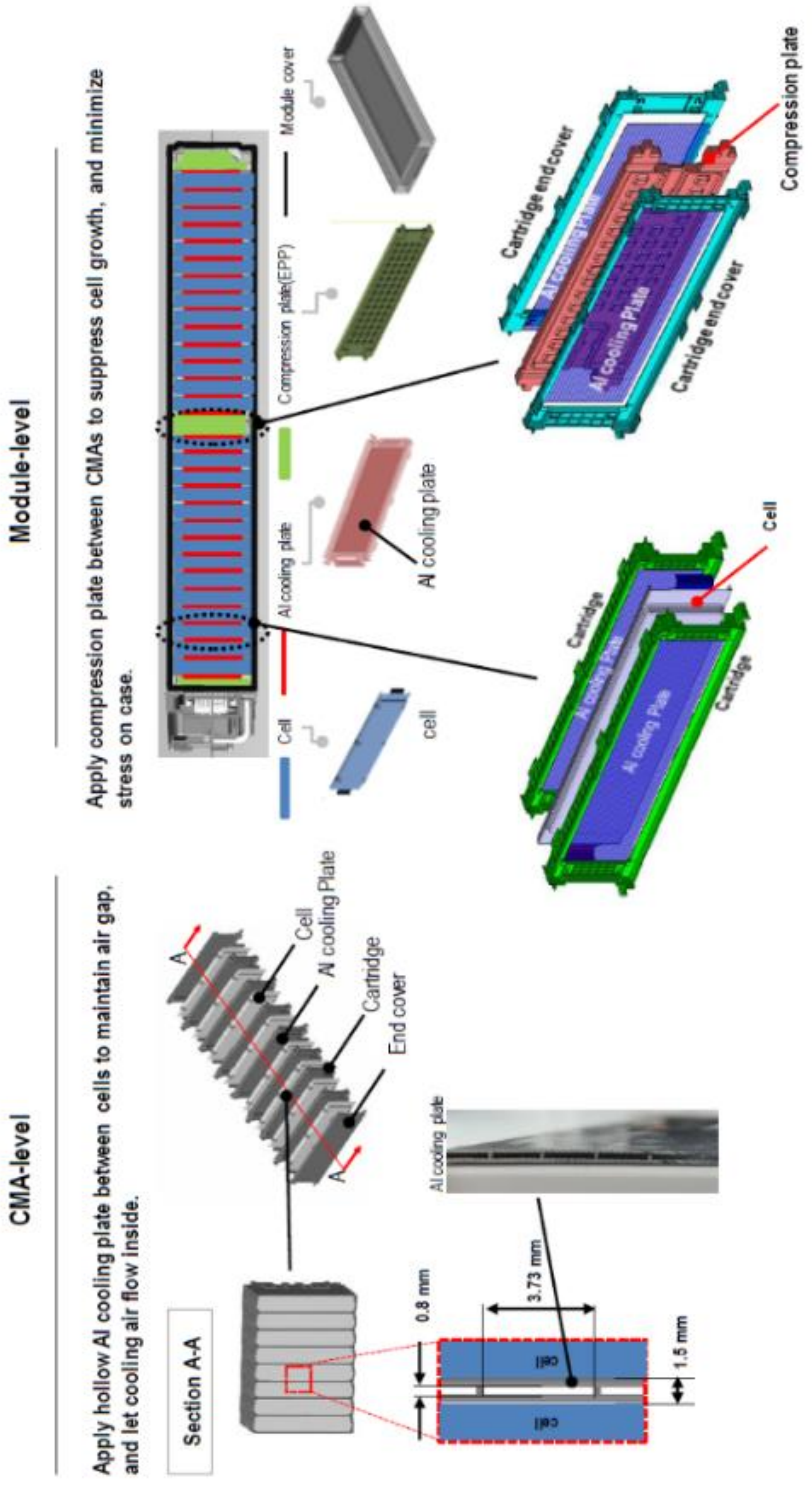

**Plan 3** [12]

[12] 2020. *Overall Site Physical Layout*.



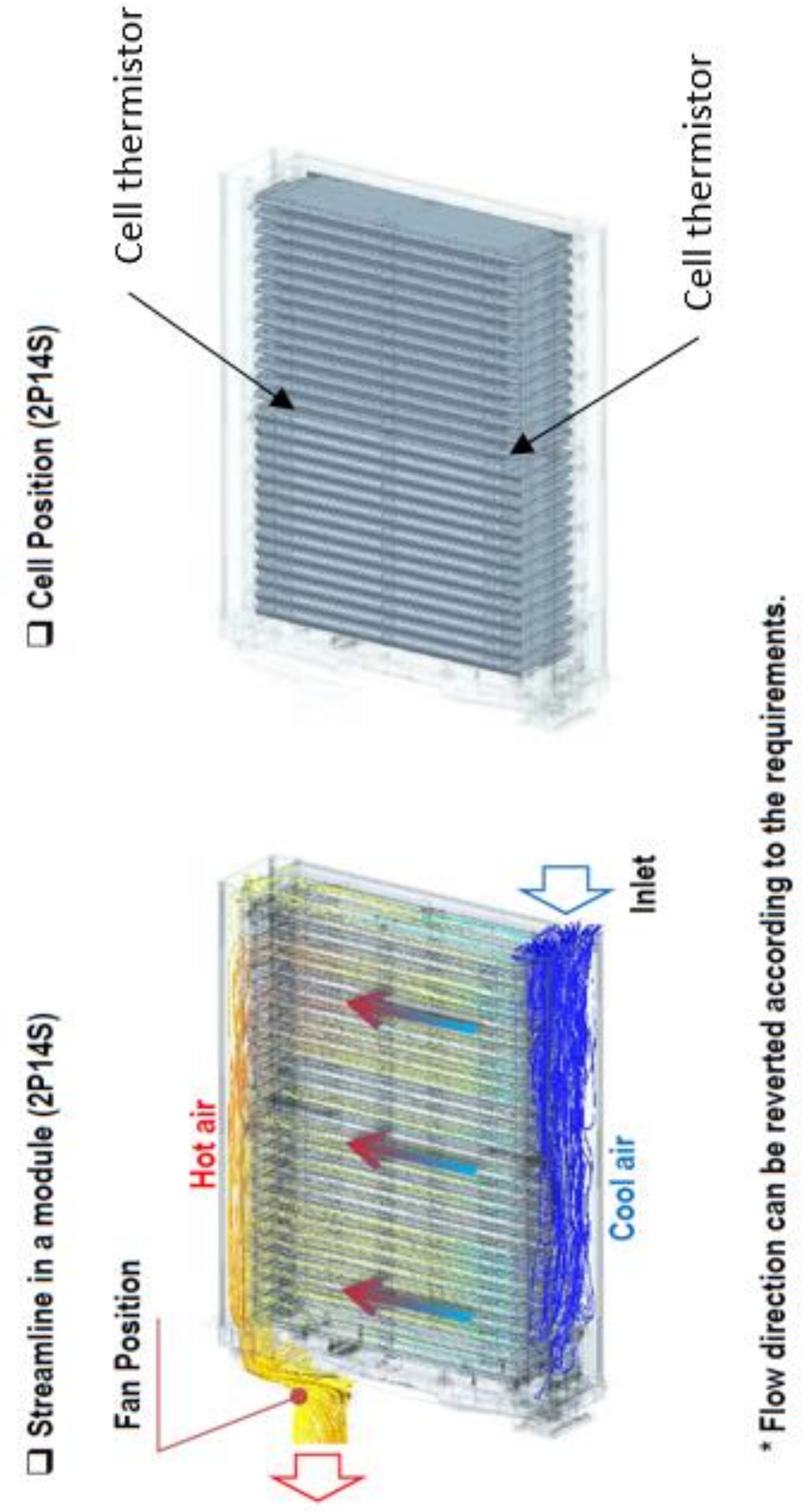

**Plan 4**[13]

13 [redacted]




**Plan 5 is JP3-2P ACP Module Disassembly[14]**

[14] 2020. NEC *Rack, Module & Cell Details*.




**Plan 6 JP3-2P ACP Module Air Flow[15]**

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15 2020. NEC *Rack, Module & Cell Details*.

## APPENDIX B Codes

During my investigation I asked the responsible person which of the following codes applied to this site.

**A, Energy Storage Systems**

| | |
|---|---|
| • UL9540, MESA | Yes |
| • ASME TES-1, | NECA Not listed |
| • NFPA 791 | Not listed |

**B, Installation/application**

| | |
|---|---|
| • NFPA855 | Yes |
| • NFPA 70 | Yes |
| • UL 9540 | Yes |
| • IEEE C2 | Yes |
| • IEEE 1635/ASHRAE 21 | Not Listed |
| • IEEE P1578 | Not listed |
| • DNVGL GRIDSTOR | Not listed |
| • FM GLOBAL 5-33 | Not listed – insurers normally reference NFPA |
| • NECA 416 | Not listed |

**C, System components**

| | |
|---|---|
| • UL 1973 | Yes |
| • UL 1974 | Not Listed |
| • UL 810A | Not listed |
| • UL1741 | Yes |
| • CSA 22.2 no 340-201 | Not listed |
| • IEEE 1547 | Yes |
| • IEEE1679 series | Not listed |

There does not seem to be any clear UK industrial standard that I have found at the time of writing this report. There has been a Domestic Battery Energy Storage System review in to safety risks published in September 2020 and I am awaiting to see if the standards will cover commercial BESS. [16]

[16] (BEIS Research Paper Number 2020/037)

# Appendix 4



# Safety of Grid Scale Lithium-ion Battery Energy Storage Systems

**Preprint** March 2022

DOI: 10.13140/RG.2.2.11566.79687



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# Safety of Grid Scale Lithium-ion Battery Energy Storage Systems

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Sources of wind and solar electrical power need large energy storage, most often provided by Lithium-Ion batteries of unprecedented capacity.

Incidents of serious fire and explosion suggest that the danger of these to the public, and emergency services, should be properly examined.

5 June 2021

**Executive Summary**

1. Li-ion batteries are dominant in large, grid-scale, Battery Energy Storage Systems (BESS) of several MWh and upwards in capacity. Several proposals for large-scale solar photovoltaic (PV) "energy farms" are current, incorporating very large capacity BESS. These "mega-scale" BESS have capacities many times the Hornsdale Power Reserve in S. Australia (193 MWh), which was the largest BESS in the world at its installation in 2017.
2. Despite storing electrochemical energy of many hundreds of tons of TNT equivalent, and several times the energy released in the August 2020 Beirut explosion, these BESS are regarded as "articles" by the Health and Safety Executive (HSE), in defiance of the Control of Major Accident Hazards Regulations (COMAH) 2015, intended to safeguard public health, property and the environment. The HSE currently makes no representations on BESS to Planning Examinations.
3. Li-ion batteries can fail by "thermal runaway" where overheating in a single faulty cell can propagate to neighbours with energy releases popularly known as "battery fires". These are not strictly "fires" at all, requiring no oxygen to propagate. They are uncontrollable except by extravagant water cooling. They evolve toxic gases such as Hydrogen Fluoride (HF) and highly inflammable gases including Hydrogen ($H_2$), Methane ($CH_4$), Ethylene ($C_2H_4$) and Carbon Monoxide (CO). These in turn may cause further explosions or fires upon ignition. The chemical energy then released can be up to 20 times the stored electrochemical energy. Acute Toxic gases and Inflammable Gases are "dangerous substances" controlled by COMAH 2015. Quantities present "*if control of the process is lost*" determine the applicability of COMAH.
4. We believe that the approach of the HSE is scientifically mistaken and legally incorrect.
5. "Battery fires" in grid scale BESS have occurred in South Korea, Belgium (2017), Arizona (2019) and in urban Liverpool (Sept 2020). The reports into the Arizona explosion [8, 9] are revelatory, and essential reading for accident planning. A report into the Liverpool "fire" though promised for New Year 2021, has not yet been released by Merseyside Fire and Rescue Service or the operator Ørsted; it is vital for public safety that it be published very soon.
6. No existing engineering standards address thermal runaway adequately, or require measures (such as those already used in EV batteries) to pre-empt propagation of runaway events.
7. Lacking oversight by the HSE, the entire responsibility for major accident planning currently lies with local Fire and Rescue Services. Current plans may be inadequate in respect of water supplies, or for protection of the local public against toxic plumes.
8. The scale of Li-ion BESS energy storage envisioned at "mega scale" energy farms is unprecedented and requires urgent review. The explosion potential and the lack of engineering standards to prevent thermal runaway may put control of "battery fires" beyond the knowledge, experience and capabilities of local Fire and Rescue Services. BESS present special hazards to fire-fighters; four sustained life-limiting injuries in the Arizona incident.
9. We identify the well-established hazards of large-scale Li-ion BESS and review authoritative accounts and analyses of BESS incidents. An internet video [10] is essential initial instruction.
10. We review engineering standards relating to Li-ion BESS and concur with other authorities that these are inadequate to prevent the known hazard of "thermal runaway". We conclude that large-scale BESS should be COMAH establishments and regulated appropriately. We respectfully request evidence from the HSE that "mega-scale" BESS are *not* within the scope of COMAH.
11. We seek the considered response of relevant Government Departments as well as senior fire safety professionals to these concerns.

## Contents

## 1. Introduction

Lithium-ion (Li-ion) batteries are currently the battery of choice in the 'electrification' of our transport, energy storage, mobile telephones, mobility scooters etc. Working as designed, their operation is uneventful, but there are growing concerns about the use of Lithium-ion batteries in large scale applications, especially as Battery Energy Storage Systems (BESS) linked to renewable energy projects and grid energy storage. These concerns arise from the simple consideration that large quantities of energy are being stored, which if released uncontrollably in fault situations could cause major damage to health, life, property and the environment.

**Table 1.** Comparison of some recent "battery fires" since 2014.
*Note: this is not a comprehensive list of all Li-ion BESS battery "fires."*

| Location | Size | "Battery fire" cause | Time to bring under control | Water needed for cooling | Comments |
|---|---|---|---|---|---|
| Houston, Texas, April 2021 | 0.1 MWh | Driverless vehicle crash | 4 hours | 30,000 (US) gallons | Tesla Model S |
| South Korea | Various; 21 fires during 2018-19 | Not known to Korean Ministry of Trade Industry and Energy | various | Not known | 522 out of 1490 ESS facilities in Korea suspended (Korea Times 2 May 2019) |
| Drogenbos, Belgium. 2017 | 1 MWh | Not known. | "rapidly extinguished" | Not known | Occurred during commissioning of system by ENGIE |
| McMicken Facility Arizona, USA. 2019 | 2 MWh | Thermal runaway in a single rack out of 27 that were in the cabin – hence 74 kWh electrochemical energy released – less than the Tesla Model S crash. | 2 hours from first report to "deflagration" | | Explosion as $H_2$ and CO mixed with air and ignited. Critically injured 4 fire-fighters. Extensive forensic report. |
| Carnegie Rd, Liverpool, UK, 2020 | 20 MWh | Not known | 11 hours | | Full report [1] delayed 4 months; still unpublished. |

Even battery electric vehicle (BEV) batteries store energy sufficient for "fires" that have taken hours to control. A Tesla Model S crashed In Texas on the weekend of 17-18 April 2021 igniting a BEV battery fire that took 4 hours to control with water quantities variously reported [2] as 23,000 (US) gallons or 30,000 gallons (87 -115 $m^3$). Yet the energy storage capacity in even the latest Tesla Model S vehicles is only 100 kWh. This is 1/20 the size of the BESS in Arizona [3] which failed in 2019, and 1/200 the size of the BESS in Liverpool [4] which caught fire [5] in September 2020, and 1/7000 the capacity of the Cleve Hill Solar Farm and Battery Store [6] approved in May 2020.

The past decade has seen a number of serious incidents in grid-scale BESS, which are summarised in Table 1. Despite these incidents, and our growing understanding of these, these large scale Li-ion BESS are not currently regarded by HSE as regulated under the COMAH

Regulations 2015. The legal basis for this attitude is unclear – simple calculations summarised in this paper argue that they should be – and the issue may yet be challenged in judicial review.

The reason the COMAH regulations should apply is the scale of evolution of toxic or inflammable gases that will arise in BESS "fires". In the Drogenbos incident (2017, Table 1), the inhabitants of Drogenbos and surrounding towns were asked to keep all windows and doors shut; 50 emergency calls were made from people with irritation of the throat and airways[1]. A chemical cloud which "initially had been enormous", was charted by helicopter. The Belgian Fire Services could not control what was described as "the chemical reaction" and filled the cabin with water. Fears of an explosion with 20 metre flames kept people confined for an hour. Although the initial visible flames were controlled quickly, cooling continued over the next 36 hours.

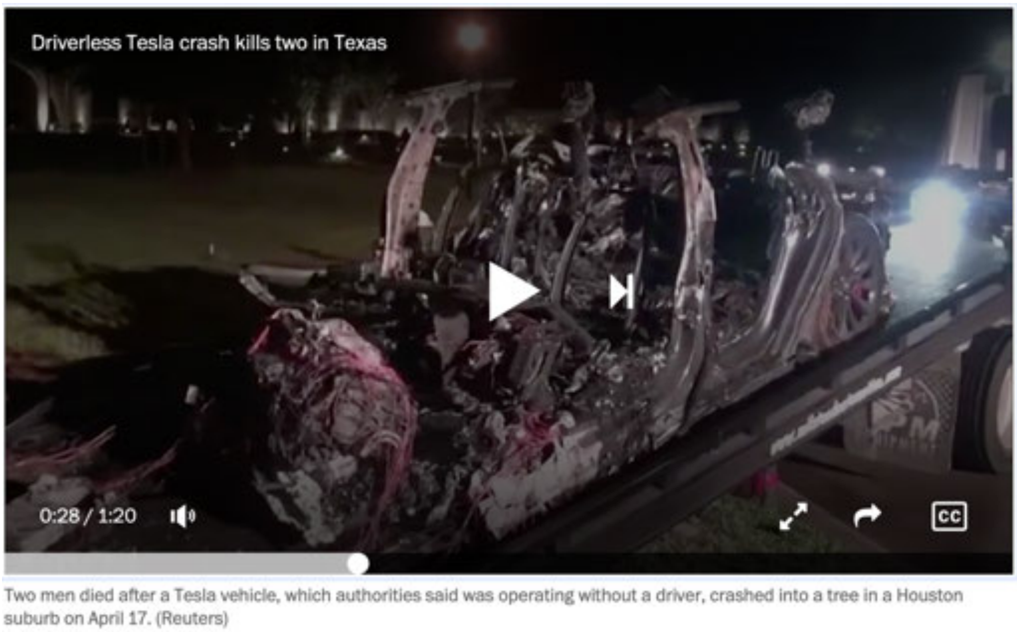



**Figure 1:** Remains of the Tesla Model S crash and fire, 17 Apr 2021, after 4 hours and 30,000 gallons. Battery capacity 100 kWh.

**Figure 2:** Remains of a Korean BESS destroyed by a "battery fire". An energy storage system was destroyed at the Asia Cement plant in Jecheon, North Chungcheong Province, on Dec. 17. Courtesy of North Chungcheong Province Fire Service Headquarters (Korea Times 2 May 2019)

[1] Tom Vierendeels (2017) "Explosiegevaar by brand in Drogenbos geweken : 50-tal oproepen van mensen die zich onwel voelen door rook." *Het Laatste Nieuws,* 11 November 2017

**Figure 3:** "Battery Fire" at Drogenbos, Belgium 11 Nov 2017. Taken at the start of the incident and 15  minutes later (eye-witness footage). 1 MWh facility; fire occurred during commissioning.

**Figure 4:** The 2 MWh McMicken (Arizona) BESS after the explosion on 19 April 2019

**Figure 5:** The 20 MWh BESS at Carnegie Rd, Liverpool. Courtesy Ørsted.

**Figure 6:** The fire at Carnegie Road, 15 Sep 2020. Liverpool Echo report, which took 11 hours to control.

The incidents recorded in Table 1 are all in relatively small BESS or a single BEV. Yet "mega-scale" BESS are now planned on a very large scale in many current proposals in the UK, listed in Table 2 and illustrated in the subsequent Figures.

And no engineering standards are currently applied to pre-empt future accidents in grid-scale BESS, the most critical of which would be design features aimed at preventing the phenomenon of "thermal runaway", the process whereby failure in single cell causes over-heating and then propagates to neighbouring cells so long as a temperature (which can be as low as 150 °C) is maintained.

BEV batteries do now include thermal barriers or liquid cooling channels between all cells to safeguard against this phenomenon, but no such engineering standards exist for grid-scale BESS. A large BESS can pass all existing engineering design and fire safety test codes and still fail in thermal runaway – by now a well-known failure mode. This must be urgently addressed.

The consequences of major BESS accidents could be significant and emergency services need adequate plans in place to handle any such incident.

**Table 2.** "Mega" scale solar plant and/or Li-ion BESS in Australia and the UK*

| Project | Location | Status | Solar PV Scheme Size | Battery Stores | Battery type | Battery capacity |
|---|---|---|---|---|---|---|
| Hornsdale Power Reserve | S. Australia | Operational | Not directly associated | Single site | Li-ion | 193 MWh |
| Cleve Hill Solar + Battery Store | Kent | Permission granted (2020) | 350 MW; land coverage 890 acres | Single site | Li-ion | 700 MWh |
| Sunnica Solar + Battery Store(2) | Cambridgeshire/ Suffolk | Pending submission | 500 MW; land coverage approx. 2792 acres | 31.5 ha of land over 3 compounds [7] of 5.2, 10.7 and 15.6 ha | Li-ion | Undeclared. Estimate 1500 – 3000 MWh |
| Longfield Solar + Battery Store | Essex | Pending statutory consultation | 500 MW; land coverage approx. 1400 acres | Stated as 3.7 acres: number of sites TBD | Li-ion | Undeclared. Estimate: 150 MWh |

* Li-ion technology has been assumed in all these proposals as Li-ion battery electrochemistry is dominant in grid-scale BESS applications (deployment at this scale is unlikely to involve technologies with lesser experience). Estimated values for Battery Capacity for the Sunnica are calculated based on the McMicken facility in Arizona (Appendix 1) and the Cleve Hill DCO. For the Longfield site it is estimated from Energy Institute guidance on energy density [25] at about 100 MWh $ha^{-1}$. The exact specification for the battery units has not been disclosed by the developers at this present time.

**Figure 7:** The Hornsdale Power Reserve (South Australia) in the process of expansion from 100 MW/129 MWh to 150 MW/193.5 MWh, as of November 2017.

Plate 3-10. Typical battery storage compound configuration (*image reproduced courtesy of Fluence Energy*).

**Figure 8:** a "typical" BESS compound (abstracted from Sunnica PEIR, Ch 3)

**Figure 9:** Artists impression of Tesla 250 MWh "Megapack".
Sunnica may have 3 ×this capacity in just one of its three BESS compounds.

## 2. Leading Concerns

The main concerns regarding large scale Li-ion BESS are:

1) The potential for failure in a single cell (out of many thousands) to propagate to neighbouring cells by the process known as "thermal runaway". Believed to be initiated by lithium metal dendrites growing internally to the cell, a cell may simply discharge internally releasing its stored energy as heat. Even sound Li-ion cells will spontaneously discharge internally if heated to temperatures which can be as low as 150 °C, releasing their stored electrical energy, thus overheating neighbouring cells and so on. Temperatures sufficient to melt aluminium (660 °C) at least have been inferred from analyses of such thermal runaway accidents. Eye-witness reports consistently speak of repeated "re-ignition" which is inevitable, even in the complete absence of oxygen, so long as the temperature anywhere exceeds the thermal runaway initiation threshold.
2) The emission of highly toxic gases – principally Hydrogen Fluoride – for prolonged periods, in the event of thermal runaway or other battery fires. At a minimum, respirators and complete skin protection would be required by any fire-fighters. Measures to protect the public from toxic plumes would also be necessary.
3) The emission of large quantities of highly inflammable gases such as Hydrogen, Methane, Ethylene and Carbon Monoxide even if a fire suppression system is deployed. These gases will be evolved from a thermal runaway accident regardless of such measures, with explosion potential as soon as they are mixed with air and in contact with hot surfaces. Such an explosion was the cause of the "deflagration event" at McMicken, Arizona in 2019 in a 2 MWh BESS, which critically injured four fire-fighters and was triggered simply by opening the cabin door.
4) The absence of any adequate engineering and regulatory standards to prevent or mitigate the consequences of "thermal runaway" accidents in Li-ion BESS.
5) The potential for thermal runaway in one cabin propagating to a neighbouring cabin. In Arizona [3] there were reports of *"fires with 10-15 feet flame lengths that grew into 50 - 75 feet flame lengths appearing to be fed by flammable liquids coming from the cabinets*".
6) The significant volumes of water required to thoroughly cool the system in the event of a "fire", and how this water will be contained and disposed of (since this will be contaminated with highly corrosive hydrofluoric acid and, therefore, must not be allowed to drain into the surrounding environment).

Such incidents are routinely and repeatedly described in the Press as "battery fires" though they are not "fires" at all in the usual sense of the word; oxygen is completely uninvolved. They represent an electrochemical discharge between chemical components that are self-reactive. They do not require air or oxygen at all to proceed.

Hence the traditional "fire triangle" of "Heat, Oxygen, Fuel" simply does not apply, and conventional fire-fighting strategies are likely to fail (Figure 10, over).

Thermal runaway events are uncontrollable except by *cooling* all parts of the structure affected – even the deepest internal parts – below 150 °C. This basically requires water, in large volumes.

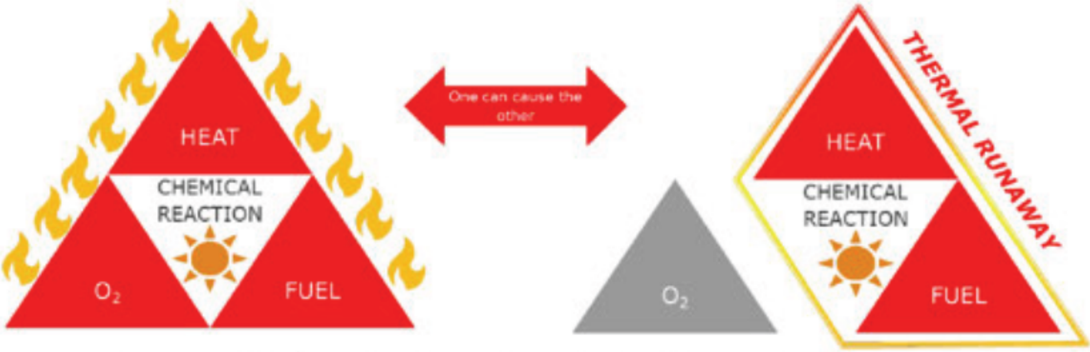



**Figure 11 The fire triangle and its relationship to thermal runaway**

**Figure 10:** The traditional "fire triangle" does not apply to "thermal runaway".

### 3. Thermal Runaway (Battery "fires")

Li-ion batteries are sensitive to mechanical damage and electrical surges, both in over-charging and discharging. Most of this can however be safeguarded by an appropriate Battery Management System (BMS) and mechanical damage (unless deliberate and malicious) should not be a hazard. Internal cell failures can arise from manufacturing defects or natural changes in electrodes over time; these must be regarded as unavoidable in principle. Subsequent escalation into major incidents can propagate from such apparently trivial initiation.

In July 2020 a thorough failure analysis by Dr Davion Hill of DNV GL [8] was prepared for the Arizona Public Service (APS), following the April 2019 thermal runaway and explosion incident in the 2 MWh Li-ion BESS facility at McMicken, Arizona. This report is revelatory and more detailed than any other failure analysis known to us. It is essential reading for any professional involved in fire safety planning for major BESS. (Figures 11 to 13).

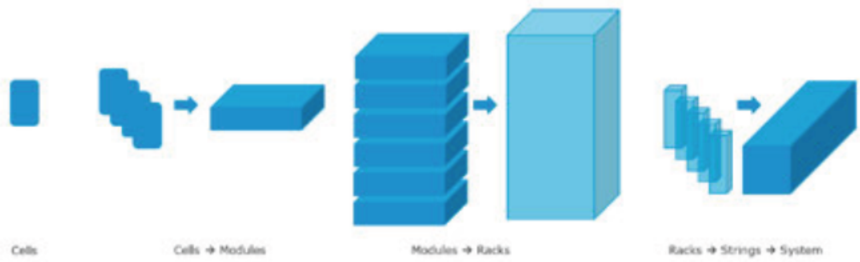



**Figure 11:** Cells stack into Modules; Modules into Racks; Racks into Strings; Strings into Systems.

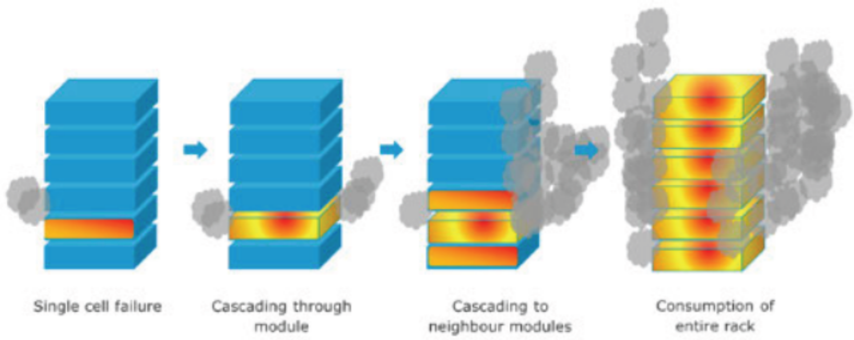
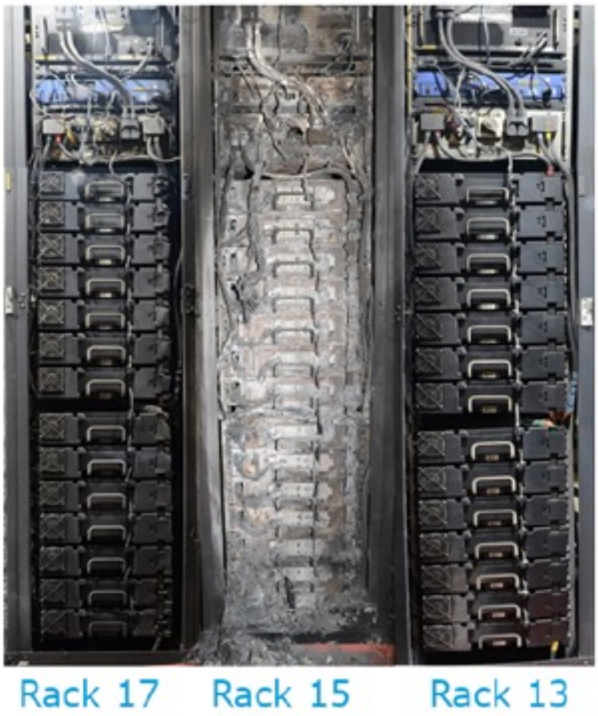



**Figure 25 A single cell failure propagated through Module 2, then consumed the whole rack, releasing a large plume of explosive gases. This process could have occurred without visible flame, which would explain why the gases were not burned as they were emitted.**

**Figure12:** Propagation of single Cell failure through Module; cascade to entire Rack.

A report by Underwriters Laboratories (UL) on the same incident [9] is less technical on the physics and engineering of the underlying causes and failure modes, but more comprehensive in terms of practical situations and consequences found, and suffered, by the “first-responders”. Two fire-fighters suffered life-limiting brain injuries, one suffered spinal damage and fourth facial lacerations. This report is similarly essential reading for any fire and emergency response planning.

**Figure 13:** Destruction of Rack at McMicken.




Detail: molten aluminium pools (exceeded 660 °C)

Figure A.1: Photograph taken during decommissioning of the ESS shows a pool of solidified aluminum on the floor in front of Rack 15 [11].

Forensic analysis [8] of the 2019 Arizona “fire” identified a failure mode different from mechanical abuse or electrical mis-management. The initiating failure was localised to a single cell at a known position in the rack. Although the cell itself was of course destroyed during the incident, the failure mode is believed to have been lithium metal deposition and abnormal growth of lithium metal dendrites. These phenomena were also found in randomly selected *undamaged* cells from the same BESS and also from a different BESS of the same manufacture elsewhere. These phenomena must be regarded as common, and inherent to the cells themselves.

The lithium metal deposits will react with air moisture, causing overheating and smoke. Battery swelling, electrolyte degradation, and internal short circuits are all possible modes of failure with internal discharge and generation of locally intense heat.

Because of the known thermal breakdown of even non-faulty cells, above a threshold temperature (which can be as low as 150 °C), the loss of even a single individual cell can rapidly cascade to surrounding cells, resulting in a larger scale “fire.” This is “thermal runaway” in which failures propagate from cell to cell within “modules” and from module to module within a “rack”.

This is what happened at McMicken [8], with temperatures sufficient to melt Aluminium (660 °C) being reached. Such “fires” can be extremely dangerous to fire fighters and other first responders because, in addition to the immediate fire and explosion risks, they would have to deal with toxic gases (principally hydrogen fluoride HF, also hydrogen cyanide HCN and other fluorine compounds such as phosphoryl fluoride $POF_3$) and exposure to other hazardous materials.

Rack to rack propagation fortunately did not happen at McMicken, though an explosion did [8]. A local conventional fire involving the plastics materials or gases evolved from them could have initiated rack-to-rack propagation; the only essential factor would have been sufficient heat to trigger thermal breakdown in just one cell in a neighbouring rack. Li-ion cells have been observed to eject molten metal during thermal runaway, another possible mode of propagation over distance. Propagation through a subsequent rack would then occur by exactly the same thermal runaway mechanisms, and potentially beyond between neighbouring cabins in large-scale BESS.

Thermal runaway is illustrated in dramatic fashion with tiny commercial Li-ion cells in a useful internet video [10] (Figure 14). The commercial cells involved in this demonstration have tiny capacities: a mere 2.6 Ah or about 10 Wh for typical terminal voltages.

A Tesla Model S would have the capacity of about ***10,000*** such cells.
A 20 MWh BESS has the capacity of about ***2 million*** such cells.

In the video, the cell is deliberately over-heated on a small electric stove. The fully charged cell goes into thermal breakdown, eventually rupturing the can. The cell flies off as a rocket and seconds later is discharged but red hot and will burn anything combustible. Although not illustrated, it is evidently hot enough to produce the same thermal breakdown in an adjacent cell within a battery.

This illustrates the damage done to a non-faulty cell, simply by overheating externally.

**Figure 14:** (a) A charged 2.6 Ah cell being deliberately overheated. (b) at the point of rupture (c) the cell takes off as a rocket (d) seconds later the discharge is complete, and the cell is red hot.

## 4. Toxic and flammable gas emissions

During a Li-ion "battery fire," multiple toxic gases including Hydrogen Fluoride (HF) [11], Hydrogen Cyanide (HCN) [13] and Phosphoryl Fluoride ($POF_3$) [11] may be evolved. The most important is Hydrogen Fluoride (HF), which may be evolved in quantities [11] up to 200 mg per Wh of energy storage capacity.

HF is toxic in ppm quantities and forms a notoriously corrosive acid (Hydrofluoric Acid) in contact with water. It is toxic or lethal by inhalation, ingestion and by skin contact. The ERPG-2 concentration (1 hour exposure causing irreversible health effects) given by Public Health England is just 20 ppm; the workplace STEL (15 minute Short-Term Exposure Limit) is just 3 ppm [12]. Major emissions of HF would form highly toxic plumes that could easily threaten nearby population centres, workplaces and schools.

Appendix 3 contains calculations of projected toxic gas quantities for 3 grid-scale battery stores that have been approved or are pending review by the Planning Inspectorate (Table 2).

The calculated capacities at the "mega-scale" sites listed in Table 2 are tens, or even hundreds, of times larger than the facilities in Table 1, which experienced significant fires or explosions.

In addition to evolution of toxic gases, even in an inert atmosphere (without Oxygen), multiple flammable gases (such as Hydrogen $H_2$, Carbon Monoxide CO, Methane $CH_4$, and Ethylene $C_2H_4$) would be evolved during thermal runaway. These are "typical of plastics fires" [8] and have been measured in sealed vessel tests [13]. As noted by Hill/DNV [8] and others [13], the proportions of $H_2$, CO, $CH_4$ and $C_2H_4$ do not in fact vary greatly between different cell technologies, simply because the chemical nature of the envelope polymers, separators, electrolyte solvents and electrolytes themselves do not differ greatly. The variations between Li-ion technologies are in the electrode systems, which are typically not polymeric.

Such inflammables can clearly create (ordinary, air-fuel) fires or explosions once mixed with air/oxygen. It is important to note that the Heats of Combustion of the inflammables may be up to 15 – 20 $\times$ the rated electrical energy storage capacity of the BESS. This has been demonstrated by the same tests which determined the quantities of HF evolved [11]. These were fire tests, not sealed vessel tests [13]. The stored electrical energy is therefore by no means a conservative estimate of the total energy release which could be released in a major (air-fuel) fire in a BESS, irrespective of whether the initiating cause was a conventional fire or Li-ion cell thermal runaway.

Appendix 2 estimates the inflammables potentially evolved from the BESS given in Table 2.

## 5. Total Energy Release Potential

Any large energy storage system has the risk that energy released in malfunction will be uncontrollable in ways that will do major damage. BESS can release electrochemical energy in the form of thermal runaway or "battery fires". In addition they can release chemical energy in the form of explosions or conventional fires of inflammable gases, or of polymer components. Many thermal runaway "fires" have now happened, as has explosion of evolved inflammable gases.

An important indicator of the foreseeable scale of a "worst credible hazard" is provided by the total stored energy in the system. For BESS, this comprises two components:

(i) The stored electrical energy which might be released in the event of thermal runaway incidents, a self-reactive electrochemical energy release not requiring oxygen at all, and

(ii) Stored chemical (fuel) energy which might be released in complete combustion of the inflammable gases which might be released by (i).

Electrochemical energy release is uncontrollable once started, by any measure except cooling – of all cells and cell parts – below about 150°C. Water is the only fire-fighting substance with the necessary heat capacity. Concurrent conventional fire would first heat cells above the thermal runaway temperature, causing more thermal runaway. Chemical energy release from inflammable gases is also uncontrollable once those gases are mixed with air and ignited: explosions result.

What might be the scale of such energy releases? The Sunnica proposal is estimated to have a stored energy between 1.5 – 3.0 GWh in total, spread across 3 separate sites called Sunnica East A, Sunnica East B and Sunnica West A (see calculations in Appendix 1). It is between 2 – 4 times the capacity projected for Cleve Hill (700 MWh). It is 8 – 15 times the capacity (193 MWh) of the "Hornsdale Power Reserve" in Australia, at installation (2017) the world's largest.

Compared to other energy storage technologies, the Dinorwig Pumped Storage Scheme in Snowdonia stores about 9 GWh [14]; the Sunnica BESS corresponds to 17 – 33 % of Dinorwig.

Compared to major explosions, the energy released in the Beirut warehouse explosion of August 2020 has been estimated [15] by Sheffield University at about 0.5 kilotons of TNT (best estimate) with a credible upper limit of 1.12 kilotons. A totally independent estimate [16] (based on seismic propagation instead of eye-witness footage) gives the same range, without specifying a "best" estimate. The popular measure of major explosions in "kilotons of TNT" has an agreed definition[2] of 1.162 GWh of released energy; in this paper we shall take "one Beirut" to be an explosive energy of 0.5 kilotons of TNT or about 580 MWh of released energy.

The projected BESS storage at Sunnica corresponds to 1.4 – 2.7 kilotons of TNT in total, across all three sites. In the "low" case, this would be "0.92 Beiruts" at the Sunnica West A site alone, or "2.7 Beiruts" over the whole scheme. In the "high" case "2.7 Beiruts" could be stored in the Sunnica East B site alone. Note that these are stored electrochemical energy only; the potential for conventional fire or explosion of evolved inflammables could be **up to 20 × larger** [11]. See Table 3, Appendix 1.

This is plainly a quantity of stored energy which, if released uncontrollably, could do major damage. Explosions and fires at individual BESS are matters of record. They can propagate from failure in a single cell out of many thousands. Cell-to-cell and module-to-module propagation occurred at McMicken. Rack-to-rack propagation was avoided, but could readily occur if continuous

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[2] See e.g. Wikipedia.

fires start. Cabin-to-cabin propagation of a major BESS “battery fire” would be the critical link that would escalate major but manageable fires into catastrophes.

Yet this propagation route remains unanalysed. Significantly, Commissioner Sandra D Kennedy of the Arizona State Commission [3] reviewed reports on the 2019 McMicken battery fire and also a 2012 battery fire at the APS Eldon substation facility in Flagstaff, AZ. She quotes the Flagstaff fire department report on the latter incident as referencing :

“*Fires with 10-15 feet flame lengths that grew into 50 - 75 feet flame lengths appearing to be fed by flammable liquids coming from the cabinets*”.

Finally, in the context of BESS, “Stranded Energy” will remain a hazard at any affected BESS cabins even assuming an initial incident is controlled. The accident investigation at McMicken required nearly 3 months, simply to discharge “stranded energy” safely [8].

‘”Mega-scale” Li-ion BESS should, in all prudence, require the highest level of regulation. The COMAH regulations are designed for this, including establishments where dangerous substances may be generated “if control of the process is lost” [17] in a thermal runaway accident.

## 6. Applicability of the COMAH (Control of Major Accident Hazard) Regulations 2015

The governing criteria for application of the COMAH Regulations [17] are:

1. The presence of hazardous materials, or their generation, "if control of the process is lost."
2. The quantity of such hazardous materials present or that could be potentially generated.

There is no doubt that hazardous substances such Hydrogen Fluoride (an Acute Toxic controlled by COMAH) would be generated in a BESS accident (i.e., in "battery fires"). Similarly highly Inflammable Gases (also controlled by COMAH) would be evolved even if the atmosphere remained oxygen-free. Depending on the size of the "establishment" these could be produced in sufficient quantities to be in the scope of COMAH. In Appendix 2 we estimate quantities guided by the literature, where fire tests have directly measured evolution of the hazardous gases.

For small capacity BESS installations, under 25 MWh capacity, the quantities ("inventory") of the evolved hazardous substances might be outside COMAH. This paper however addresses the recent trend towards "mega-scale" Li-ion BESS (Table 2) with very large quantities of stored energy, where the inventory should be large enough to bring the installation within scope.

Broadly speaking, the threshold for applicability of COMAH will be dependent on the precise BESS technology chosen, but likely to be for BESS in the region of 20 – 50 MWh. See Appendix 2.

A letter to the HSE regarding applicability of COMAH to large-scale BESS (dated 25 Nov 2020 [18]) received no reply until follow-up letters were sent addressed personally to the Chief Executive on 7 February 2021, with the intervention of Mrs Lucy Frazer MP. The reply from the Chief Executive [19] dated 22 February 2021 stated that "*Li-ion batteries are considered articles and are not in scope of COMAH*".

We believe the current attitude of the HSE – that even large-scale Li-ion BESS are "articles" best regulated by operators – is not consistent with the law.

Unless tested in the Courts however, this throws the entire responsibility for ensuring the safety of major BESS "battery fires" onto the Fire and Rescue Services. Currently the HSE makes no representation to the Planning Inspectorate in respect of BESS hazards.

## 7. Engineering standards for BESS

As with any hazard, the basic principles of Prevention and Mitigation must be applied to minimise the risk to life, property and the environment. A major contribution of the Hill/DNV report [8] is a review of current engineering and fire protection standards. This did not concern planning, siting and electrical standards, but simply addresses the question: which standards, if any, offer Prevention or Mitigation of the phenomenon of thermal runaway? The answer appears to be none.

"Thermal runaway" is an electrochemical reaction, well-known in Li-ion BESS, that is largely uncontrollable once started. Since failures in single cells (among many thousands) can be sufficient to initiate thermal runaway, the only known Prevention measure is that adopted by the BEV industry, viz. thermal isolation of neighbouring cells, so that if failure occurs in any one cell, insulation or water cooling prevents easy thermal spread to neighbouring cells. Various design strategies have been adopted in BEV Li-ion batteries, usually involving some form of thermal barrier.

However these are not widely used in grid-scale Li-ion BESS. Current practice is the assembly of stacks of cells, typically "pouch" cells which are externally flat polymer bags, that are stacked side by side in low profile modules with no thermal isolation. This is not the construction adopted in current generation BEV batteries; BEV practice *(with* thermal isolation) extended to grid-scale BESS would obviously increase costs and complexity considerably.

The engineering standards reviewed by Hill/DNV [8] included NFPA 855, UL 1973 and UL 9540/9540A. UL 9540A is a US standard that is widely used in grid-scale BESS engineering, is routinely recommended by insurance and risk consultants [20] and was appealed to by the developer of the Cleve Hill solar farm (Table 2). The problem is that UL9540A is fundamentally a test procedure. It mandates no design features. It requires absolutely nothing that would prevent thermal runaway in any BESS design. This means that an operator can say truthfully that a given BESS is "fully compliant" with UL9540A, yet this would provide no assurances at all regarding thermal runaway prevention. It is therefore wholly insufficient as a safeguard to either the operator, the public, or to emergency services.

NFPA 855 [21], uniquely, requires evaluation of thermal runaway in a single module, array or unit and recognises the need for thermal runaway protection. However, it assigns that role, with complete futility, to the Battery Management System (BMS). Thermal runaway is an electrochemical reaction which once started cannot be stopped electrically. It is uncontrollable by electronics or switchgear. A BMS can locate faults, report and trigger alarms, but it cannot stop thermal runaway.

The Hill/DNV report [8] highlights the many shortcomings of existing standards, see Appendix 4. The basic issue is simple:

(1) Thermal Runaway has very few means of Mitigation once started.
(2) It is therefore essential to address Prevention as a priority.
(3) ***No current engineering or industry standards require the Prevention of thermal runaway events by thermal isolation barriers.***

Nothing in existing standards prevents runaway incidents happening again, requiring for initiation only single-cell failures from known common defects in cell manufacture.

## 8. Fire Safety Planning for BESS "fires"

Taking the recent Sunnica BESS proposal as an example, a joint statutory consultation response has been submitted by the four Local Authorities concerned. The Local Authorities in this case are Cambridgeshire and Suffolk County Councils, and West Suffolk and East Cambridgeshire District Councils. This joint consultation response [22] included a section on Battery Safety (pp 74-75) and states as follows:

***Suffolk Fire and Rescue Service (SFRS)*** *will work and engage with the developer as this project develops to ensure it complies with the statutory responsibilities that we enforce.*

*Sunnica should produce a risk reduction strategy as the responsible person for the scheme as stated in the Regulatory Reform (Fire Safety) Order 2005. It is expected that safety measures and risk mitigation is developed in collaboration with services across both counties.*

The response also later states: *As with all new and emerging practices within UK industry, the* ***SFRS would like to work with the developers*** *to better understand any risks that may be posed and develop strategies and procedures to mitigate these risks.*

It is clear that local Fire and Rescue Services have been given the lead responsibility for independent emergency planning, in concert with the developers. Because of the attitude of the HSE refusing to exercise regulatory control over BESS safety, local Fire and Rescue Services become the sole independent public body able to influence BESS safety issues at the planning stage.

Many detailed recommendations have been made by the Local Authorities in the case of Sunnica. It is unclear how much opportunity or input Suffolk FRS has had in these. However the recommendations offered betray some serious misunderstandings and a complete lack of awareness of the lessons and recommendations made in publicly available documents such as the Hill/DNV report [8] into the McMicken explosion.

These are taken point by point in Appendix 4 but some general points are made here.

1. Thermal runaway cannot be controlled like a regular (air-fuel) fire. The only way to mitigate "re-ignition" (a regular report of eye-witnesses) is by thorough cooling. Water is the only fire-fighting material with the necessary thermal capacity. Sprinkler systems, though with good records in conventional building fires, are likely to be completely inadequate. The purpose of the water is absorbing a colossal release of energy. The Hill/DNV report [8] called for so-called "dry pipe" systems allowing first responders to connect very large water sources to the interior without having to access the interior.

It is critical to appreciate that all parts of the battery system must be cooled down. Playing water on a battery "fire" may cool the surface, but so long as Li-ion cells deep inside the battery remain above about 150°C, "re-ignition" events will continue. It is not sufficient to estimate water requirements on the basis of calculations assuming water reaches everywhere, uniformly.

For example, in the recent Tesla car fire [2] the BEV battery kept re-igniting, took 4 hours to bring under control and used 30,000 (US) gallons of water (115 $m^3$). This was for a 100 kWh BEV battery, designed with inter-cell thermal isolation barriers.

In the case of Sunnica, the Local Authorities have suggested that water supplies of 1900 litres per minute for 2 hours (228 $m^3$) will be needed [22]. But this is grossly inadequate. Using the above Tesla BEV fire experience, this amount of water would suffice for just ***two*** Tesla Model S car fires. Scaling this up to even the smallest 2 MWh BESS (such as that in McMicken [8]), which contains stored energy equivalent to ***twenty*** Tesla Model S cars, it is clear to see that a much greater amount of water would be needed.

The actual amount of water required will depend on the energy storage capacity per cabin which, in the case of Sunnica, is still unstated. Some simple estimates are, however, made below. **The requirements suggested to date by the Local Authorities for the Sunnica installation are completely inadequate and, if not addressed, would leave Suffolk FRS without the means to control a major BESS "fire".**

Taking a storage capacity of 10 MWh in just one of the Sunnica cabins (see Appendix 1), a complete thermal runaway accident in such a BESS would release that stored electrochemical energy, plus an indeterminate quantity of heat from combustion of hydrocarbon polymer materials or inflammable gases evolved from them. Such Total Heat Release may be up to twenty times the amount of the stored electrochemical energy in the BESS [11].

The thermal capacity of water is 4.2 kJ $kg^{-1}$ $K^{-1}$ or in kWh terms, about 1.17 kWh $m^{-3}$ $K^{-1}$. If heated from 25 °C to boiling point about 87.8 kWh $m^{-3}$ of thermal energy is required.

Hence the water volume required to absorb 10 MWh of released energy without boiling is about 114 $m^3$ or 30,000 US gallons, the same amount as required in practice to control a fire in a single Tesla Model S car with a mere 100 kWh battery, 100 times smaller than a 10 MWh BESS.

The quantity suggested by the Local Authorities' joint response is 228 $m^3$ (1900 L $min^{-1}$ for 2 hours), twice the above estimate, which would naively be sufficient for a 20 MWh BESS fire. **However, from the experience of recent BEV fires, it could be insufficient by a factor of 100.**

No such calculations were presented in the Examination of the 700MWh Cleve Hill BESS [6].

2. "Clean agent" fire suppression systems are a common fire suppression system in BESS, but are ***totally ineffective*** to stop "thermal runaway" accidents. The McMicken explosion was an object lesson in this: the installed "clean agent" system operated correctly, as designed, on detection of a hot fault in the cabin [8]. There was no malfunction in the fire suppression system. But it was completely useless because the problem was not a conventional fuel-air fire, it was a thermal runaway event. Only water will serve in thermal runaway.

Indeed in the McMicken explosion the "Novec 1230" clean agent arguably contributed to the explosion by creating a stratified atmosphere with an air/Novec 1230 mixture at the bottom and inflammable gases accumulating at the cabin top.

The most probable cause of the explosion was mixing caused by the opening of the door by first responders. The explosive mixture contacted hot surfaces and ignited [8].

3. A further recommendation of the Hill/DNV report [8] into the McMicken explosion is for a means of ***controlled venting*** of inflammable gases ***before*** first responders attempt access. In the Local Authority response to the Sunnica consultation, ventilation is listed as a BESS requirement [22] but the reason given, bizarrely, is "to control the temperature" – at which ventilation or air-conditioning (also listed) would be totally ineffective, lacking any significant thermal capacity.

The critical reason for controlled ventilation is the removal of inflammable gases ***before*** an explosive mixture forms. Deflagration panels (to decrease the pressure of explosions that do occur) are also recommended.

It should be noted that although controlled venting provisions would mitigate the consequence of inflammable gas evolution, they would also require simultaneous venting of Hydrogen Fluroide that would be evolved concomitantly.

Toxic gas hazard would continue to present a risk to the community and the environment for the duration of the incident. Fire-water will be contaminated with, *inter alia*, highly corrosive Hydrofluoric Acid. Contamination of water supplies and waterways ***must*** be prevented.

**It is strongly recommended that Fire Services study the Hill/DNV report [8], and the related Underwriters Labs report [9], act upon their recommendations, and make realistic, physics-based, calculations of the water quantities required to be available at every single BESS cabin. There could be as many as 150 BESS cabins at the Sunnica East B site alone – see Appendix 1; each of these would need a sufficient water supply.**

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Promised January 2021 but still not released as of May 2021.
MER 49652 is a Liverpool City Council file code.

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[17] Understanding COMAH – a Guide for new entrants
https://www.hse.gov.uk/comah/guidance/understanding-comah-new-entrants.pdf
Appendix 1 Figure 1 flowchart.

[18] Letter from Dr E J Fordham to HSE, 25 November 2020.
Addressed impersonally but sent Recorded Delivery and receipted.

[19] Letter from Ms Sarah Albon, Chief Executive of HSE, to Dr E J Fordham, 22 February 2021.

[20] Allianz Risk Consulting (2019) Battery Energy Storage Systems (BSS) using Li-ion batteries, Technical Note Vol 26.

[21] National Fire Protection Association (2020)
Standard for the Installation of Stationary Energy Storage Systems Standard 855, Table 9.2

[22] Response of affected Local Authorities
(Cambridgeshire and Suffolk County Councils, West Suffolk and East Cambridgeshire District Councils) to Sunnica Consultation.
https://democracy.westsuffolk.gov.uk/documents/s39360/Sunnica%20Statutory%20Consultation%20Response.pdf

[23] Note (2/11/20) from Councillor Andrew Douch, Freckenham Parish Council, meeting 30 October 2020

[24] *Power Engineering,* 4/18/2017, "What you need to know about energy storage".

[25] Energy Institute (2019) Battery Storage Guidance Note 1: Battery Storage Planning, Sec 4.2 page 16

[26] A guide to the COMAH regulations (2015): https://www.hse.gov.uk/pubns/books/l111.htm

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Schedule 1,Part 1, Col 2.

## Appendix 1: Battery Capacity Calculations for the Grid-scale BESS proposed at the "Sunnica" site.

The Sunnica scheme will be taken as an example of a "mega-scale" solar plant with BESS. If approved, it would cover approximately 2800 acres and will include BESS on 3 separate sites.

The proposed BESS capacity in the Sunnica scheme has not been specified. Estimates of storage capacity can be made on the basis of the land areas allocated to the BESS compounds, assuming full use (per meeting with Parish Councillors, 30 October 2020 [23]). Li-ion battery technology has also been assumed because it is the most widely used in the industry today. Li-ion batteries have a high energy density, and the costs of these have fallen significantly over the past few years [24] .

Land areas and cabin size are quoted in the Sunnica Scheme Description as:
Sunnica East A: 5.23 ha
Sunnica East B: 15.6 ha
Sunnica West A: 10.65 ha
Total: 31.48 hectares.

One storage cabin size is 15 m length × 5 m width × 6 m height. This height is *double* that of a so-called "hi-cube" shipping container and has a larger footprint (75 $m^2$ *vs* 30 $m^2$ for a standard 40-foot shipping container).

Storage capacity can be estimated based on other BESS and storage cabin volumes:

***Single cabin energy storage capacity:***

The McMicken, Arizona, Li-ion BESS was a single cabin, footprint of 60 $m^2$ and 'shipping container' height. The Sunnica BESS cabins are 75 $m^2$, with 'double shipping container' height (6 m).
Energy storage at McMicken was 2 MWh.

Scaling by footprint and height yields a *single cabin* energy storage capacity estimate of 5 MWh for each of the "Sunnica" BESS cabins.

The Arizona cabin had empty space for expansion racks, so a larger single cabin energy storage capacity, up to say 10 MWh, is entirely conceivable.

***Density of BESS cabins on allocated land***:

This is unstated by Sunnica. We assume that 7.5% of the allocated land area will be occupied by the BESS cabins themselves (this allows for safety separations, fire access routes, Battery Management Systems (BMS) and other electrical plant, bunding for firewater in the event of incidents). This implies a total of 315 BESS cabins allocated over the three sites.

***Total scheme storage capacity:***

5 MWh (single cabin capacity) x 315 cabins yields a total energy storage capacity of **1575 MWh** (or 1.574 GWh), distributed over 3 separate battery compounds of unequal size (31.48 ha total). If the single cabin capacity were 10 MWh, the total doubles to **3150 MWh.**

A storage capacity between 1500 – 3000 MWh is therefore credible for the Sunnica proposal, depending on single cabin storage and the density of cabins on the land.

The area density of storage at this cabin density would be 50 MWh $ha^{-1}$ for a single-cabin storage of 5 MWh. This figure of 50 MWh $ha^{-1}$ is independent of the total area allocated; it depends only on the assumed fraction (7.5%) occupied.

For comparison, the corresponding density at Cleve Hill [3] is a very similar 69.2 MWh $ha^{-1}$.

The Energy Institute [25] gives 100 MWh $ha^{-1}$ as 'typical' for Li-ion BESS planning. This density would be reached in our assumptions if the single cabin capacity were 10 MWh. The latter figure is entirely conceivable because the "base estimate" derives from an incompletely populated cabin. It is also readily achievable if the spacing of cabins is closer than implied by the assumption of 7.5% land occupancy.

The "base case" estimate of 315 cabins and 1574 MWh is an overestimate *only if* the project does *not* fully occupy the allocated land (i.e. BESS cabin density is less than the 7.5% assumed), but this would be contrary to advice from the developer in meetings with local Councillors.

It is also an overestimate if the single cabin storage capacity is less than 5 MWh. This is unlikely because it is estimated from a BESS cabin still incompletely populated.

These estimates are summarised in the following Table.

**Table 3. Estimates of electrical stored energy under various assumptions at Sunnica.**
Note: "1 kiloton TNT" is equivalent to 1.163 GWh. "One Beirut" is equivalent to 580 MWh.

| Compound | Area | No. of cabins at area density of 7.5% | Energy storage capacity | | Comments |
|---|---|---|---|---|---|
| ( Single cabin )<br>(per cabin land) | 75 $m^2$<br>1000 $m^2$ | 1 | 5 MWh | 10 MWh | Per cabin assumptions |
| Sunnica East A | 5. 23 ha | 52 | 260 MWh | 520 MWh | Per compound estimates of stored energy |
| Sunnica East B | 15.6 ha | 156 | 780 MWh | 1560 MWh | |
| Sunnica West A | 10.7 ha | 107 | 535 MWh | 1070 MWh | |
| Whole Scheme | 31.5 ha | 315 | 1575 MWh<br>1.575 GWh<br>1.36 kilotons<br>2.72 "Beiruts" | 3150 MWh<br>3.150 GWh<br>2.71 kilotons<br>5.44 "Beiruts" | Stored electrochemical energy only.<br><br>Does not include chemical energy from inflammables. |

## Appendix 2: Applicability of the COMAH Regulations to large-scale BESS

***The COMAH regulations (2015)***: COMAH regulates establishments with quantities of dangerous substances (categorised as toxic, flammable or environmentally damaging) that are present above defined thresholds. The substances do not need to be present in normal operation. If dangerous substances could be generated "if control of the process is lost", the likely quantity generated thereby must be considered. If the mass of dangerous substances that could be generated in loss of control exceeds the COMAH thresholds, the Regulations apply.

There are two "tiers" to COMAH, the "upper tier" imposing more stringent controls. Thresholds of hazardous substances are listed with thresholds for both tiers.

The regulations specify aggregation rules when more than one substance in a hazard category (e.g. flammables) may be present; even if all such substance are below the COMAH thresholds, others in the same hazard category must be quantified and the proportions of the threshold aggregated. If the total exceeds one, the establishment is subject to COMAH. It is also clear that the inventories of all "installations" – including pipework – must be considered as a whole.

***Extracts from COMAH Regulations*** [26] ***2(1) (definitions):***

*"establishment" means the whole location under the control of an operator where a dangerous substance is present in one or more installations, including common or related infrastructures or activities, in a quantity equal to or in excess of the quantity listed in the entry for that substance in column 2 of Part 1 or in column 2 of Part 2 of Schedule 1, where applicable using the rule laid down in note 4 in Part 3 of that Schedule;*

*"presence of a dangerous substance" means the actual or anticipated presence of a dangerous substance in an establishment, or of a dangerous substance which it is <u>reasonable to foresee may be generated during loss of control</u> of the processes, including storage activities, in any installation within the establishment, in a quantity equal to or in excess of the qualifying quantity listed in the entry for that substance in column 2 of Part 1 or in column 2 of Part 2 of Schedule 1, and "where a dangerous substance is present" is to be construed accordingly;*

***Application to grid-scale BESS:*** The Regulations refer to "*a dangerous substance which it is reasonable to foresee may be generated during loss of control of the processes*". Both Flammable Gases (P2) and Acute Toxics (H1 and H2) are certainly "*reasonable to foresee*" in thermal runaway incidents which are now well-documented. The evolution of regulated, named and categorised hazardous substances from Li-ion battery cells in thermal runaway is also well-documented. A "worst credible accident" would have to consider that the entire inventory of Li-ion cells would be destroyed in a single BESS cabin at least. Cabin-to-cabin propagation should also be considered.

The Regulations apply to the entire "establishment", controlled by a single operator. Whilst the individual BESS compounds at Sunnica might be regarded as separate establishments, it is less reasonable that individual BESS cabins should be regarded as separate "establishments". They are separate "installations" but "establishment" means the entire area under control of an "operator".

Only if the most stringent safeguards were in place to ensure that the disastrous consequences of cabin-to-cabin propagation of "battery fires" could not conceivably occur, could it be argued that dangerous substances, exceeding the COMAH thresholds in quantity, were not "*reasonable to foresee* [being] *generated during loss of control of the process*".

We believe the COMAH regulations apply to BESS and that the approach of HSE is wrong in law.

***Dangerous substances "reasonable to foresee … generated during loss of control of the processes"***: The literature and known experience of BESS accidents is clear that dangerous substances in the hazard categories H1 and H2 (Acute Toxic) and P2 (Flammable Gases) are foreseeable in the event of thermal runaway accidents. One of the Flammable Gases is Hydrogen, which is a “Named Dangerous Substance” in Part 2 of Schedule 1 of the COMAH Regulations 2015. Lower thresholds are specified for Hydrogen than for other P2 Inflammable Gases.

It remains therefore to consider the quantities of dangerous substances which could be generated if “control of the process is lost” in a thermal runaway incident. Published literature sources quantify evolution of flammable gases from tests of various Li-ion cells in sealed vessels. Open “fire tests” quantify the evolution of toxic gases particularly Hydrogen Fluoride. Many other test results exist in the records of specialist test laboratories, but here we rely upon two primary published sources.

Golubkov *et al.* (2014) [13] report quantities of evolved inflammables from Li-ion cells of three different electrode chemistries in thermal runaway situations. The proportion of Hydrogen ($H_2$), Methane ($CH_4$), Ethylene ($C_2H_4$) and Carbon Monoxide (CO) does not in fact vary greatly between different types of Li-ion cell, reflecting an underlying inventory of hydro-carbon material (plastics, electrolyte solvents etc) that remain similar in all Li-ion technologies. This is consistent with DNV/GL test data cited in the Hill/DNV report [8]. The quantitative estimates here are taken from results derived from cells with Nickel-Manganese-Cobalt (NMC) electrodes, as used in the McMicken BESS. It was not possible in the apparatus of Golubkov *et al.* to determine the concentrations of HF evolved.

Larsson *et al.* [11] report evolved quantities of Hydrogen Fluoride (HF) from Li-ion cells in open “fire tests”, and also the Total Heat Released (THR) from combustion of the inflammables. Again these vary between cell technologies and “form factors”, especially whether the cells have an outer metal cannister or are in the “pouch” format. Quantities between 20 – 200 mg / Wh are reported. The worst case figure is used in the following estimates; the lowest evolution reported for “pouch” cells was 43 mg/Wh.

Both sources report evolved gas quantities on a per Wh basis. We scale these to a Li-ion BESS cell size on the basis of stored energy since this will be roughly proportional to the electrolyte solvents and other polymer materials in the cell. Scaling on a per mass basis would be preferable, but this would require further information on the exact composition of the cells in the literature tests, and indeed those for the BESS in question. During the McMicken investigation, the cell manufacturers refused to release such data.

***H1 and H2 Acute Toxics.*** The applicability of COMAH is easiest to determine in respect of Hydrogen Fluoride (HF). This has a dual hazard classification [12] as H1 Acute Toxic (skin exposure) and H2 Acute Toxic (inhalation) and both exposure routes would apply to the general public nearby. The lower tier COMAH threshold for H1 Acute Toxics is 5 tonnes [27]; using the upper estimate of 200 mg/Wh from Larsson, the BESS capacity at which a BESS enters the scope of COMAH (lower tier) is 25 MWh.

This is far below the projected storage capacities given in Table 3 (Appendix 1). With high storage capacity cabins (of e.g. 12.5 MWh), it would require propagation of a fire from just one cabin to a second, to generate HF above the COMAH threshold. It is not necessary to foresee a major conflagration involving multiple cabin-to-cabin propagation to bring the establishment within scope of COMAH; just two cabins would suffice. If 25 MWh were stored in a single large cabin, the question of cabin-to-cabin propagation is irrelevant.

The upper tier for "H1 Acute Toxics" is entered at four times higher capacity (100 MWh), which is well below the estimated capacity of Cleve Hill, and is also below *each* of the three Sunnica BESS compounds individually.

Even on the lowest evolution figure of 43 mg/Wh reported by Larsson *et al.* for "pouch" cells, the lower tier of COMAH is entered at a storage capacity of 120 MWh, again well within the "low case" capacity of each of the Sunnica BESS compounds, and Cleve Hill.

There is little doubt that either the lower or upper tier of COMAH is applicable to Cleve Hill and all three of the Sunnica BESS compounds, on the basis of "H1 Acute Toxics" (HF, skin route) alone.

Carbon Monoxide (CO) is categorised as an H2 Acute Toxic as well as a P2 Inflammable Gas, and will also be evolved, but in application of the aggregation rule its presence does not materially alter these conclusions. It is sufficient to consider HF alone.

***P2 Inflammable Gases.*** Assessing applicability of COMAH on the basis of inflammable gases is more complicated because of the evolution of Hydrogen ($H_2$), Methane ($CH_4$), Ethylene ($C_2H_4$) and Carbon Monoxide (CO) in significant quantities, and because Hydrogen is a "named dangerous substance" for which different COMAH thresholds apply. These must be taken into account when applying the Aggregation Rule. Although proportions are generally similar, quantities do depend on the different electrode chemistries in the different Li-ion cell types.

Taking the largest evolutions reported by Golubkov *et al.* [13] for the LCO/NMC electrode type tested by them these are equivalent to 335 mg/Wh of P2 inflammables. For the NMC cells tested (the McMicken cells were NMC) the evolution was 214 mg/Wh. Taking the higher figure and applying the aggregation rule, grid-scale BESS enter the lower tier of COMAH at about 30 MWh capacity. Taking the lower figure, they enter the lower tier at 45 MWh capacity.

Hence there is little doubt that grid-scale BESS are lower tier COMAH establishments on the basis of "P2 Inflammable Gases" at storage capacities between 30 – 45 MWh.

Because of the variability between cell types, and the difficulty of scaling laboratory tests to actual BESS cells without detailed composition data, there is room for adjustment. However the calculated estimates of the thresholds for applicability of COMAH are so far below the projected capacities that it is inconceivable that the Cleve Hill and Sunnica BESS compounds would *not* be COMAH establishments, in lower tier at the very least, and probably the upper tier also.

***Conclusion:*** Grid-scale Li-ion BESS should be considered COMAH establishments in the lower tier on the basis of "H1 Acute Toxics" (HF) alone, at energy storage capacities in the region of **25 MWh**. Upper tier would apply at about **100 MWh**. They should be lower-tier COMAH establishments on the basis of "P2 inflammable gases" alone, at storage capacities between **30 – 45 MWh**. Again larger establishments could become upper tier COMAH. Laboratory closed vessel and fire tests on actual Li-ion BESS cells proposed to be deployed would be required to refine these estimates definitively.

It is difficult to see how these conclusions could be avoided if tested in litigation.

## Appendix 3: Shortcomings of Existing Engineering Standards for Li-ion BESS

The July 2020 report for the Arizona Public Service by Dr D Hill [8] provides a comprehensive discussion of existing engineering standards relating to BESS, and how they are *inadequate* to address the known hazards of "thermal runaway" incidents in Li-ion BESS. This was the failure mode leading to the explosion at McMicken, Arizona.

Unfortunately, when the UK's first "mega-scale" solar plant and battery storage site was granted approval in May 2020, this paper had not been published. The Cleve Hill solar developers cited one standard, UL 9540A [3]. This is also cited by some insurance and risk consultants [20].

It is important to be clear that nothing in UL 9540A addresses thermal runaway, and as a test method standard, it can provide no "safety certification" for Li-ion BESS.

Specific criticisms made in the Hill/DNV report include the following:

1. UL 1973 allows for the complete destruction of a BESS and the creation of an explosive atmosphere so long as no explosion or external flame is observed. An installation can do all these things but still "pass" UL 1973. At McMicken one rack was completely destroyed and an explosive atmosphere created but no flame or explosion occurred until first-responders opened the cabin door.
2. UL 9540A is merely a test method for generating data. It does not define any "pass/fail" criteria for interpreting results. Specifically, it does not address cell-to-cell cascading in thermal runaway, nor the evolution of a potentially explosive atmosphere. It does not even prescribe that the cell-to-cell cascading rate be measured.
   It allows that thermal runaway may proceed to an entire rack (as at McMicken) and offers testing of fire suppression systems (which operated correctly at McMicken but cannot prevent thermal runaway, and did not prevent an explosion).
   Presentation of data generated under UL 9540A to an "AHJ" (Authority Having Jurisdiction) does not translate to a succinct understanding of potential risks.
3. NFPA 855 [21] does require evaluation of thermal runaway in a single module, array or unit and does acknowledge the need for thermal runaway protection. However, it assigns that role to the Battery Management System (BMS). Yet thermal runaway is an electrochemical reaction that once started cannot be stopped electrically. It is uncontrollable by electronics or switchgear, only by water cooling.

**The evolution of engineering and safety standards has not yet incorporated the lessons of experience arising from the McMicken explosion** [8] **or explosion incidents in the UK like the Liverpool explosion and fire of 15 September 2020** [1]**. Compliance with existing standards does not prevent such incidents happening again.**

Articles in the industry press[3] do now recognise and discuss the problem of thermal runaway but make proposals such as: "*If off-gases can be detected and batteries shut down before thermal runaway can begin, it is possible that fire danger can be averted*".

Such statements betray a dangerous misunderstanding. Batteries cannot be "shut down", except by complete discharge, which cannot be done quickly. Taking cells "out of circuit" is useless; thermal breakdown and runaway will still occur.

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3 [redacted]

## Appendix 4 – Fire Safety Planning requirements in the Local Authorities' Joint Response to the Sunnica statutory consultation

This Appendix deals point by point with the BESS requirements in the Local Authority response (text in blue) pp 74 – 75.

Sunnica should produce a risk reduction strategy as the responsible person for the scheme as stated in the Regulatory Reform (Fire Safety) Order 2005. It is expected that safety measures and risk mitigation is developed in collaboration with services across both counties.

The Local Authorities require that the Fire Services work with Sunnica to prepare fire safety and risk mitigation measures. The Cambridgeshire and Suffolk Fire Services are therefore the only public bodies with independent oversight of BESS safety.

The use of batteries (including lithium-ion) as Energy Storage Systems (ESS) is a relatively new practice in the global renewable energy sector. As with all new and emerging practices within UK industry, the SFRS would like to work with the developers to better understand any risks that may be posed and develop strategies and procedures to mitigate these risks.

This paper is provided as input to this process, which appears to be insufficiently understood.

The promoter must ensure the risk of fire is minimised by:

- Procuring components and using construction techniques which comply with all relevant legislation.

This overlooks the points made in this paper that (i) existing legislation is being ignored by the statutory regulatory body, the HSE (ii) no adequate engineering standards exist to exercise Prevention measures over what is by now a very well-known hazard, viz. thermal runaway. Public Health and Safety cannot be assured whilst either of these situations continues.

- Developing an emergency response plan with both counties fire services to minimise the impact of an incident during construction, operation and decommissioning of the facility.
- Ensuring the BESS is located away from residential areas. Prevailing wind directions should be factored into the location of the BESS to minimise the impact of a fire involving lithium-ion batteries due to the toxic fumes produced.

This is impossible to satisfy. All the BESS compounds in the Sunnica proposal are sufficiently close to residential areas to present a major danger of toxic fumes in the event of an accident. Plume dispersal modelling should be performed to ensure that concentrations of HF cannot exceed dangerous thresholds in the event of the worst credible accident in a BESS compound.

- The emergency response plan should include details of the hazards associated with lithium-ion batteries, isolation of electrical sources to enable firefighting activities, measures to extinguish or cool batteries involved in fire, management of toxic or flammable gases, minimise the environmental impact of an incident, containment of fire water run-off, handling and responsibility for disposal of damaged batteries, establishment of regular onsite training exercises.

This requirement is very broad but insufficiently detailed. Means of cooling would require water volumes many times in excess of those requested. Management of inflammable gases is best addressed by venting, but that exacerbates the hazard of toxic gas plumes. Large water volumes may lead to unrealistic or impossible requirements for the containment, and subsequent disposal, of the contaminated water resulting from the fire-fighting activity. Other sections of this paper address these points.

- The emergency response plan should be maintained and regularly reviewed by Sunnica and any material changes notified to SFRS and CFRS.

- Environmental impact should include the prevention of ground contamination, water course pollution, and the release of toxic gases.

Preventing the release of toxic gases is all but impossible. A thermal runaway event WILL release toxic gases. If inflammables are vented to avoid /mitigate explosion risk, toxic gases WILL be vented. Ground contamination and water course pollution is almost certain to occur if sufficient water to control a major thermal runaway event is deployed. It will pose a significant challenge to contain, and safely dispose of, such large volumes of contaminated fire water.

The BESS facilities should be designed to provide:

- Automatic fire detection and suppression systems. Various types of suppression systems are available, but the Service's preferred system would be a water drenching system as fires involving Lithium-ion batteries have the potential for thermal runaway.

This is a correct precaution, but no specification is made of likely water volume requirements, nor for a "dry pipe" system allowing water to be deployed without cabin entry. We provide some water estimates elsewhere in this paper.

Other systems, such as inert gas, would be less effective in preventing reignition.

This is also a correct insight. The so-called "clean-agent" fire suppression system at McMicken was triggered correctly, but was useless to control thermal runaway. Moreover the stratified atmosphere created allowed the build-up of inflammables to a dangerous level, before the explosion occurred.

- Redundancy in the design to provide multiple layers of protection.
- Design measures to contain and restrict the spread of fire through the use of fire-resistant materials, and adequate separation between elements of the BESS.

This comment only vaguely considers the true essentials. The "elements of the BESS" could be: cells, modules, racks, strings, and the entire system. As discussed in the Hill/DNV report what is required is for the industry as a whole to accept that thermal runaway in an unacceptable hazard, and demand engineering standards that Prevent thermal runaway by design, or if it occurs, Prevent its cascade or escalation to larger system elements. This requires

a. Thermal barriers (i.e. Low thermal conductivity barriers, not merely refractory barriers, ideally with water cooling, between all cells, so that propagation from cell to cell cannot occur. This is precisely the requirement the industry has so far ***NOT*** made in the development of its engineering standards.
b. Separation of modules by similar barriers to Prevent module-to-module cascade.
c. Separation of Racks to prevent rack-to-rack cascade, even with ejection of molten metals.
d. Spacing of BESS cabins such that even with "75 foot flame lengths" cabin to cabin escalation is impossible. This is probably the most critical of all, since cabin-to-cabin escalation could turn a major fire incident into an unprecedented catastrophe, on the scale of the Beirut explosion or a small nuclear weapon.

- Provide adequate thermal barriers between switch gear and batteries,
- Install adequate ventilation or an air conditioning system to control the temperature. Ventilation is important since batteries will continue to generate flammable gas as long as they are hot. Also, carbon monoxide will be generated until the batteries are completely cooled through to their core.

This comment is very strange. There is no possibility whatsoever that air conditioning could be adequate "to control the temperature". The importance of ventilation is however recognised, as is the generation of carbon monoxide (toxic as well as inflammable). However the generation of Hydrogen Fluoride will also continue until the batteries are "completely cooled" and HF (H1 Acute Toxic by skin exposure) is much more toxic than CO (H2 Acute Toxic).

- Install a very early warning fire detection system, such as aspirating smoke detection.

The "very early warning" fire detection system required should be thermocouples to report continuously on the local temperature at every cell in the entire system. A single cell overheating can escalate via thermal runaway. By the time smoke is generated, this will be a "very late", rather than "very early" detection system. Just as thermal runaway events do not necessarily generate flame, neither do they necessarily generate smoke, until nearby combustibles are ignited.

- Install carbon monoxide (CO) detection within the BESS containers.

This is a good straightforward measure, but detectors for other gases expected (HF, $H_2$, $CH_4$) could equally well serve and multiple gas detection would provides additional security.

- Install sprinkler protection within BESS containers. The sprinkler system should be designed to adequately contain and extinguish a fire.

The excellent record of sprinkler systems in ordinary building fires shows they would help contain fire in regular combustible parts of the structure. However as discussed earlier in this paper, a mere sprinkler system would be useless to contain thermal runaway. Much larger water quantities would be needed.

- Ensure that sufficient water is available for manual firefighting. An external fire hydrant should be located in close proximity of the BESS containers. The water supply should be able to provide a minimum of 1,900 l/min for at least 2 hours. Further hydrants should be strategically located across the development. These should be tested and regularly serviced by the operator.

As discussed elsewhere, we believe these water requirements to be **under-specified by a factor of 100**, based on real experience with BEV fires. "Strategic location" is inadequate. Every single BESS cabin (potentially up to 150 of these at Sunnica East B alone) should have such a hydrant.

We remark elsewhere on the recommendation made by Hill/DNV for a "dry pipe" system to deploy water drenching inside via external connections, without cabin entry being needed.

- A safe access route for fire appliances to manoeuvre within the site (including turning circles). An alternative access point and approach route should be provided and maintained to enable appliances to approach from an up wind direction. Please note that SFRS requires a minimum carrying capacity for hardstanding for pumping/high reach appliances of 15/26 tonnes, not 12.5 tonnes as detailed in the Building Regulations 2000 Approved Document B, 2006 Edition, due to the specification of our appliances.

The requirement for safe access routes and space for appliances to manoeuvre could usefully be expanded into requirements for safe spacing of BESS cabins and thermal or flame barriers between cabins, to Prevent the "disaster scenario" of cabin-to-cabin propagation.

**Final Comment:** (over)

**Final Comment:**

**The fundamental failure mode of Li-ion batteries presenting major hazard is thermal runaway. This paper is far from the first to identify the risk which is now well-known.**

**However the BESS industry as a whole has still not agreed or implemented adequate engineering standards to address basic Prevention measures to pre-empt thermal runaway accidents.**

**Until it does, Mitigation of major accidents by the Fire Services will remain the sole recourse for public protection and safety.**