Comments on Applicant Responses to ExA Questions: Dr Edmund Fordham

Dated: 28th November 2022

Annexes EF34 through to EF36 uploaded separately

THE PLANNING INSPECTORATE

EN010106 – Sunnica Energy Farm

APPLICATION BY SUNNICA Ltd for an Order Granting Development Consent for the Sunnica Energy Farm Project pursuant to The Planning Act 2008

To the Examining Authority (ExA)

COMMENTS on Applicant Responses to ExA Questions

EurIng Dr Edmund John Fordham MA PhD CPhys CEng FInstP

Interested Party – Unique Reference: 20030698

Please note:

1. These comments are being submitted as required by Deadline 3A (28 November 2022) being revised from the Deadline 3 set for receipt of Comments on Responses to the ExA questions. They are largely confined to questions of BESS Safety and Air Quality.

SUMMARY

(*per Guidance, being 10% of the main submission*)

[*Please refer to the Glossary following, for a list of abbreviations.*]

1. It is not true that there are few differences between Li-ion cell chemistries from a fire risk perspective. Speed of progression in thermal runaway, toxic gases evolved, and fire water run-off contaminants will all depend on cell chemical type. Relative risks of immediate Fire, versus delayed ignition in a Vapour Cloud Explosion, will depend on cell chemistry as well as SoC and fire suppression systems.

2. Water sprinkler systems have been shown to be likely effective against fires in cells of the LFP type, but not in cells of various mixed oxide types (NMC falls in this class). A key report is Annexed.

3. Explosion hazard has been demonstrated in several actual BESS incidents and represents a Physical Hazard related to Fire, but presents different problems. The interplay between factors tending to immediate ignition (Fire) and delayed ignition (typically producing Explosion) is complex.

Explosion of its nature cannot be Mitigated, only a consequent Fire can be. A Battery Fire Safety Management Plan should really be a Battery Fire and Explosion Prevention and Mitigation Plan.

4. Hazards to the Aquatic Environment may be generated by sprinkler or other fire-fighting activity and should be considered as part of any effective BFSMP.

5. The likelihood of a single cell failure somewhere in the establishment increases in proportion to the total size (in MWh) of the system. For very large systems, a single cell failure somewhere may become a routine event. Because even a single cell failure may propagate into a thermal runaway accident, Prevention measures assume ever-larger importance.

6. The maximum possible scale of a BESS accident also increases in proportion to the total size of the system. The Applicant's claim that BESS accidents will be confined to a single container is not credible when fires escalating to neighbouring containers have occurred in reality, or have been averted only by strenuous efforts by FRSs. Moreover escalation to spatially separated containers was reported in the Beijing incident.

Unless and until cabin-to-cabin escalation is demonstrated to be functionally impossible by preventive measures, demonstrated by full scale tests, the possibility of multi-cabin BESS accidents must remain a serious concern.

7. An unreasonable degree of responsibility is being placed on local FRSs for "fire safety" which is only one aspect of the Physical Hazards presented by giant BESS (the other being Explosion).

Health Hazards (toxic gases and smokes) and Hazards to the Aquatic Environment are presented in addition.

The complex nature of the hazards presented by giant BESS in failure can only be properly evaluated by active engagement of the COMAH Competent Authority, as Policy in NPS EN-1 clearly envisions.

8. The current OBFSMP and the Applicant's ES Appendix 16D on unplanned atmospheric emissions are inadequate.

9. Specifically, the water volumes allowed for in the BESS compound tanks would be wholly insufficient to control a fire even in a small 1 MWh BESS, based on the experience at Drogenbos (Belgium, 2017) and at Moorabool (Victoria, Australia, 2021).

10. Many toxic gases and particulates have been ignored in the air quality assessment. Only Hydrogen Fluoride has been analysed.

11. Even if restricted to HF alone, the Appendix 16D analysis is completely inconsistent with alternative analyses by Atkins for HSE(NI), and wholly inconsistent with reliable literature data on aggregate HF emissions per unit Wh of energy storage capacity, including peer-reviewed data published by the same author team as cited in Appendix 16D.

12. The Appendix 16D analysis under-states credible HF emissions by about 70-fold on its own terms (reference case accident 5 racks out of 35).

On the more prudent reference case of complete destruction of a 5 MWh BESS cabin, the Appendix 16D analysis under-states credible HF emissions by about 500-fold.

These figures for aggregate HF emissions are so completely at variance with other analyses and peer-reviewed published data that no credence can be attached to Appendix 16D.

(Summary 640 words)

EJF, 28/11/22

GLOSSARY

Abbreviations used in the interests of brevity.

Legislation and statutory permissions:

CLP	– the Classification, Labelling and Packaging Regulation
COMAH Regs 2015	– the Control of Major Accident Hazards Regulations 2015
CQ	– Controlled Quantity (of a HS as defined in P(HS)Regs 2015)
DCO	– Development Consent Order
dDCO	– draft Development Consent Order
HS	– Hazardous Substance (as defined in the Schedule to P(HS)Regs 2015)
HSC	– Hazardous Substances Consent
PA 2008	– The Planning Act 2008
P(HS)A 1990	– The Planning (Hazardous Substances) Act 1990
P(HS)Regs 2015	– The Planning (Hazardous Substances) Regulations 2015
QQ	– Qualifying Quantity (of a "dangerous" substance) in the COMAH Regs 2015; similar to CQ in the P(HS)Reg 2015
S or "S"	– any "substance used in processes" which on its own or in combination with others may generate HS defined in Parts 1 or 2 of the Schedule to the P(HS)Regs 2015
Seveso	– the "Seveso III Directive" 2012/18/EU of 4 July 2012
UN MTC	– United Nations Manual of Tests and Criteria

Direct quotations from legislation are shown in blue

Policy documents:

NPPF	– National Planning Policy Framework
NPS	– National Policy Statement
EN-1	– Overarching National Policy Statement for Energy (EN-1)

Direct quotations from policy documents are shown in magenta

Competent authorities:

CA	– COMAH Competent Authority	
DHCLG	– Department for Housing Communities and Local Government	
EA	– Environment Agency	
ECDC	– East Cambridgeshire District Council	(LPA)
ExA	– Examining Authority	
FRS	– Fire and Rescue Service	
HSA	– Hazardous Substances Authority	
HSE	– Health and Safety Executive	
HSE(NI)	– Health and Safety Executive for Northern Ireland	
LPA	– Local Planning Authority	
SoS	– Secretary of State	
WSC	– West Suffolk Council	(LPA)

GLOSSARY (cont.)

Parties:

Sunnica – the Applicant, or the proposal under Examination

SNTSAG – Say No To Sunnica Action Group Ltd (continued)

Documents

OBFSMP – Outline Battery Fire Safety Management Plan

BFSMP – Battery Fire Safety Management Plan

LIR – Local Impact Report

Technical:

BESS – Battery Energy Storage System(s)

Li-ion – Lithium-ion

M-factor – Multiplying Factor used for certain substances Toxic to the Aquatic Environment in eco-toxicity classifications

SoC – State Of Charge of cells, usually given as percentage, between fully charged (100%) and completely discharged (0%)

STEL – Short Term Exposure Limit, i.e. limiting allowed concentration for short-term exposures (typically 15 minutes)

VCE – Vapour Cloud Explosion

IUPAC – International Union of Pure and Applied Chemistry

GCMS – Gas Chromatography Mass Spectrometry

CAS – Chemical Abstracts Service, maintains a catalogue of unique chemical substances with reference numbers

IDLH – Imminent Danger to Life and Health

AEGL-3 – Acute Exposure Guideline Levels

SLOT – Specified Level of Toxicity

SLOD – Significant Likelihood of Death

Chemical substances:

CH_4 – Methane

C_2H_4 – Ethylene

C_2H_6 – Ethane

CO – Carbon Monoxide

CO_2 – Carbon Dioxide

Co – Cobalt (as metal) (not to be confused with CO)

CoO – Cobalt (II) Oxide

Cu – Copper (as metal)

CuO – Cupric (or Copper (II)) Oxide

Cu_2O – Cuprous (or Copper (I)) Oxide
H_2 – Hydrogen
HCN – Hydrogen Cyanide
HF – Hydrogen Fluoride
Mn – Manganese (as metal)
MnO – Manganese (II) Oxide
Ni – Nickel (as metal)
NiO – Nickel Monoxide
ONiO – Nickel Dioxide
Ni_2O_3 – diNickel triOxide
POF_3 – Phosphoryl Fluoride

Li-ion cell types:

NMC – Nickel – Manganese – Cobalt; a popular Li-ion cell type, with cathodes based on complex oxides of those elements
LFP – Lithium – Iron [chemical symbol Fe, hence “F”] – Phosphate; another type of Li-ion cathode chemistry
LCO, NCA, LATP – other cell cathode chemistries mentioned in text
LMO – Lithium Manganese Oxide
LNO – Lithium Nickel Oxide

Measurement units:

MW – megawatt, or one million watts, a unit of *power*, i.e. *rate* of transfer of *energy*
MWh – megawatt-*hour*, or one million watt-hours, a unit of *energy* e.g. the *energy* transferred by a *power* of 1 MW acting for 1 *hour*
m^2 – square metre (area)
ha – 1 hectare = 10,000 m^2
MWh ha^{-1} – energy storage density (on the land) in the BESS compounds, as MWh energy storage capacity, per hectare of land allocated
MWh / tonne or MWh $tonne^{-1}$ – energy density of the BESS cells themselves, as MWh energy storage capacity, per tonne of cells
Wh / kg or Wh kg^{-1} – energy density of the BESS cells themselves, as Wh energy storage capacity, per kg of cells
1 MWh / tonne = 1000 Wh / kg
mg / Wh or mg $(Wh)^{-1}$ – gas generation from cells in failure, in milligrams gas per watt-hours of energy storage capacity
tonne – 1 metric tonne or 1000 kg or 1 Mg
$\mu g\ m^{-3}$ – trace concentrations of highly toxic gases, in micrograms of toxic contaminant per cubic metre of air

Scope of these Comments

1. These Comments comprise various observations on the responses made by the Applicant to the first Questions put by the ExA and are largely confined to the issue of BESS safety and consequent Air Quality assessments.

Qu 1.1.4

2. The Applicant states:

(i) "*The fire risk is not anticipated to generate a likely significant effect.*" [on atmospheric emissions]

(ii) "*The report* [SCC report on OBFSMP] *was also copied to HSE but this did not constitute consultation.*"

3. The first comment is assertion unsupported by any evidence.

Historical BESS thermal runaway incidents certainly generated toxic gases and smokes and the generation of toxics is confirmed in multiple laboratory and model scale tests confirmed repeatedly throughout the technical literature. Quantification is attempted in my WR with reference to Annex EF16 drawn from technical literature offering quantitative estimates.

The Applicant needs to present an equivalent, or superior, level of evidence, or accept that unplanned emissions are a significant concern and propose Mitigation measures.

4. As set out in my WR, I believe that a full appraisal of Hazardous Substances generated in loss of control of the processes would have indicated a need for HSC.

This in turn would have indicated a need for early consultation with the COMAH Competent Authority (the HSE plus EA acting jointly) as required by Sect 1.11 NPS EN-1, which has not a taken place.

Early consultation with the relevant HSAs would have indicated the need to consider "loss of control of the processes" under Part 3 of the Schedule to the P(HS)Regs 2015. This advice given by the HSE appears to have been ignored.

Qu 1.1.6

5. The Applicant states: "*from a fire risk perspective there is relatively little to distinguish between lithium ion battery chemistries as they share common hazard parameters during thermal runaway reactions and chemistry is in fact a very small part.*"

6. This is completely untrue.

Generally speaking, the metal-oxide cathode chemistries (of which NMC is one) fail more aggressively in terms of the speed of temperature rise and the maximum temperatures reached. An example paper from the technical literature contrasting the two cell types was already Annexed[1].

[1] Annex EF27

The LFP chemistry is often asserted to be "safer" for this reason, and moreover has a higher threshold temperature for thermal runaway than the metal-oxide (including NMC) types. Thermal runaway incidents may be expected to progress more slowly in LFP cells for this reason, though they certainly can occur, and have done, the Beijing accident[2] being the most widely reported.

7. Moreover the cell chemistry has strong effect on the actual toxic emissions expected and in what quantities. These are emphasised in my WR and Annex EF16. For example, the generation of inhalable Nickel Oxide smokes (which are potent carcinogens) is not possible from LFP cells which do not contain significant quantities of Nickel compounds. Similarly the related Cobalt and Manganese oxides cannot be generated from LFP cells. However the literature shows that LFP cells also appear to generate the largest quantities of Hydrogen Fluoride (HF) gas in thermal runaway. The dominant concerns (regarding toxics) are clearly different.

8. In the report[3] on the (original) OBFSMP Li-ion BESS safety expert Professor Paul Christensen repeatedly states that the cell chemistry is an essential and critical parameter for a BFSMP which is fit for purpose: "*The choice of Nickel Manganese Cobalt (NMC) or Lithium Iron Phosphate (LFP) cells and their form factors will have major implications for the fire sensing and suppression to be employed in the containers.*"

9. Aspects of the fire safety and air quality considerations which *are* common to the two cell types in question (NMC vs LFP) include: (i) generation of Hydrogen Cyanide (HCN), which almost always comes from ancillary plastics so not dependent on cell type; neither cell chemistry contains significant Nitrogen compounds which would be required for the formation of Cyanides; (ii) generation of Carbon Monoxide CO, which is both a flammable gas and a toxic one; this depends strongly on air supply to fire, since CO will burning an excess of air forming the non-combustible and non-toxic Carbon Dioxide (CO_2).

The Applicant does not appear to have assessed HCN emissions though cyanide is a well-known potently toxic gas, a common hazard in plastics fires, was an operational concern in the McMicken, Arizona incident[4], and would necessitate breathing apparatus for first-responders.

Qu 1.1.6 – Fire versus Explosion

10. A further distinction between cell chemistry types need to be made in distinguishing Fire hazard from Explosion hazard. BESS safety is not just a matter of "Fire Safety" and the very concept of a "Fire Safety Management Plan" addresses only a subset of the hazards presented; it is necessary but by no means sufficient.

11. One may ask: How exactly does one "manage" an Explosion? Of course an explosion may be the initiating event of an actual fire, but major damage will already have been done, possibly unexpectedly, as in the Beijing explosion leading to two

[2] Annex EF13
[3] Annexed to the WR of the SNTSAG Ltd
[4] Annexes EF11 and EF12

fatalities among the fire crew, and the McMicken Arizona incident leading to life-limiting injuries for three.

Vapour Cloud Explosions (VCEs) are a serious risk with BESS and have occurred in the catalogue of heavily analysed BESS incidents, including Drogenbos (2017), Arizona (2019), Liverpool (2020), and Beijing (2021)[5]. The most heavily analysed incident is probably that in McMicken, Arizona (2019) where it is critical to note that the thermal runaway incident *involved no flame* until the final "deflagration" – though temperatures sufficient to melt Aluminium (660 °C) were realised during the thermal runaway[6], before the appearance of flames "*up to 75 feet in length*"[7].

12. The risk of Explosion versus Fire is a complex matter probably dependent on the *rate* of generation of flammable gases and aerosols as well as on the availability of air for actual combustion. Professor Christensen's large-scale experiments[8] show examples of both behaviours, with a synopsis of possible behaviour routes (immediate *versus* delayed ignition).

In correspondence with Professor Christensen he comments[9]: *"Cathode chemistry has a major effect* [on the hazards associated with thermal runaway] *eg LFP hazard is more explosion than fire. More energetic chemistries eg NMC, NCA more prone to fire.*

Higher SoC favours ignition and hence fire, lower SoC hazard switches to explosion.

These insights are consistent with the speed of generation of flammable gases and aerosols in thermal runaway: a faster generation is expected with (i) NMC cells *versus* LFP cells (ii) cells (either type) in higher State of Charge (SoC) *versus* lower SoC.

13. Fire suppression systems will also have a major impact. The McMicken, Arizona BESS was NMC but had a "clean-agent" (inert gas or aerosol) fire-suppression system (which deployed correctly). The analysis concluded that the fire-suppression system (designed to "smother" a fire) actually contributed to the explosion by creating a stratified atmosphere in which flammable gases could build up unhindered by actual burning, until mixed with air caused by first responders opening a door, when immediate ignition resulted.

14. Generally speaking, slow generation of flammables will tend to promote conditions for a VCE, rapid generation will promote immediate ignition.

Cell chemistry has a critical role in the relative risk for Fire *vs* Explosion (immediate *vs* delayed ignition), with NMC cells tending fail with immediate flame (unless "smothered" by inappropriate fire-suppression systems), LFP cells tending to promote conditions for a VCE.

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[5] See Professor Christensen's report Annexed to WR of SNTSAG
[6] See Annex EF12
[7] Eye-witness reports in Annexes EF12 and EF21
[8] Abstracted in my Annex EF16 with Professor Sir David Melville
[9] Email 21 November 2022 re Qu 1.1.6

Qu 1.1.6 – Fire suppression systems

15. The inappropriate use of "clean agent", dry powder, or Aerosol Forming Composite fire suppression systems is noted above by reference to the McMicken, Arizona incident where such systems actively contributed to the extent of the accident.

No fire-suppression strategy based on "smothering" a fire can possibly work to suppress thermal runaway, which requires no oxygen. They are of value only once an actual fire (sustained by air flow) has developed.

16. Water-based systems (reliant on cooling, utilising the exceptionally large specific heat capacity of water) are more likely to be effective but the Applicant appears unaware once again of the differences in efficacy between metal-oxide cells (including NMC) and LFP cells.

A major study managed by the National Fire Prevention Association (NFPA) found that water-sprinkler systems were almost completely ineffective in fires involving metal-oxide cells, although they could be effective in fires from LFP cells. A report by the insurer *FM Global* is Annexed[10], [11].

17. In view of this major work the efficacy of a sprinkler system with NMC cells must be questioned, although it could be a positive measure with LFP cells.

With the latter choice however, the dominant risk may be Vapor Cloud Explosion, (*per* Professor Christensen's comments) rather than immediate Fire.

Qu 1.1.6 – Hazards to the Aquatic Environment:

18. The question relates primarily to the Physical Hazard of Fire or Explosion and also to Air Quality, but it must be remembered that if water from sprinkler systems or from external fire-fighting is used to control fire, then contaminants in fire water may represent a significant Hazard to the Aquatic Environment (particularly where so close to Ramsar-designated natural wetland habitats).

Again the likely contaminants may be dependent on cell chemistry. Cobalt compounds represent a significant hazard to the Aquatic Environment but would be a risk only with NMC cells. One paper showing fire-water run-off (from NMC cells) exceeding 100-fold the permitted levels[12] of Nickel and Cobalt compounds for industrial effluent is already Annexed[13]. This point is made also by Professor Christensen[14]. Copper compounds would a be risk from all cell types[15].

19. A thorough Hazard Analysis cannot continue to maintain that there is no difference between the available cell types in Fire.

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[10] Annex EF34, a new Annex with this submission.

[11] The report is careful to note that the metal oxide cells used were of the LNO (Lithium Nickel Oxide) and LMO (Lithium Manganese Oxide) types. However as remarked elsewhere the metal-oxide types (including NMC) have qualitatively similar behaviours in failure; the distinction to be made is between metal-oxide and the completely different chemistry of LFP.

[12] Under Swiss law.

[13] Annex EF26

[14] Report Annexed to WR of SNTSAG.

[15] Detailed discussion in my WR and in Annex EF16

Qu 1.1.6 – Historical accidents and necessity for robust BFSMP

20. Under "Bullet 4" the Applicant refers to causes of historic incidents. I agree entirely that any Fire (or Explosion) Prevention / Mitigation measures must be appropriate to the likely behaviour. Any "smothering" system will likely only escalate the risk of VCE. Water-sprinkler systems may be effective against actual fires in LFP cells[16] but questionable with NMC.

21. The forensic investigation of the 2019 McMicken Arizona incident identified plating of lithium metal, or growth of lithium dendrites, in one single cell (identified from detailed voltage records) as being the most likely proximate cause (initiating event) of the thermal runaway. Manufacturing Quality Control can never be perfect and cell working life is never infinite.

Over the working life of any BESS failures must be expected. Professor Christensen's report[17] re-iterates this: "*Simple probability suggests that failures of lithium-ion cells are inevitable, and the number of such incidents will increase as their manufacture increases. This is reflected in a statement by a DNV GL employee at a webinar in 2020 that "Over the life of a (industrial) BESS at least one failure will occur. It is unrealistic to eliminate all chance of failure"* [18]

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

22. It should be noted that on a statistical basis even if the probability of cell failure, per cell, per year, is kept very low by excellent quality control, as the number of cells in the system becomes larger and larger, the probability of a single cell single failure, somewhere in the total system, per year, necessarily increases, to the point where a failure somewhere, must be accepted as routine within any realistic time period. So long as engineering controls fail to provide *effective prevention* of propagation of thermal runaway initiated by single cell failures (as at McMicken) then the larger the total system, the greater the risk that a significant Fire or Explosion will become a routine event.

23. Any Battery Fire Safety Management Plan really should be a "Battery Fire *and Explosion Prevention and* Management Plan", taking full account of the forensic engineering failure analyses available, including Arizona (2019), Liverpool (2020) and Moorabool (2021), and Beijing (2021), and analyse the differences to be expected when deploying NMC *vs* LFP cells.

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[16] On the evidence of the *FM Global* report, Annex EF34

[17] Annex to WR of SNTSAG

[18] "*Best practice for energy storage system safety around the globe".* DNV GL Webinar 29 October 2020.

Qu 1.1.9

24. The Applicant states: *"The amount of power the BESS can store, and for how long, has no direct relationship to its environmental and social impacts. The only technical topic this affects is safety; although because any fire is likely to be associated with a single battery enclosure, safety is affected by the power energy rating of an individual battery enclosure rather than the BESS compound as a whole."*

25. This statement betrays the regrettably customary confusion between power and energy. BESS do *not* "store power", at all. They store *energy.* The closing comment betrays the same conceptual muddle: "*The ExA should note that the export capacity is limited to 500MW for the solar farm and BESS; the BESS will therefore never exceed 500MW peak export."*

This may be true, but irrelevant to the question of BESS safety, where it is the total stored energy that reflects the maximum possible scale of the hazard (and, as discussed above, the probability of accident-initiating events).

26. Elsewhere the Applicant states: "*The impacts of a BESS are not directly related to its capacity*".

I reject this contention (and the related claim in the first extract) as unconditionally wrong, for the reasons already given: the scale of the maximum possible accident, and the probability of initiating events, both increase (without limit) as the system becomes larger and larger (in term of *energy* storage, *not* power).

27. The claims that safety is determined by the "*power energy* [which ?] *rating of an individual battery enclosure*" and "*any fire is likely to be associated with a single battery enclosure*" are unsupported by any evidence. They are pure assertion.

28. Cabin-to-cabin propagation of BESS accidents has occurred in reality. In the case of the Big Battery fire in Australia in 2021 (Moorabool, near Geelong), one Tesla megapack went into thermal runaway and despite firefighting measures to cool the surrounding area and despite thermal barriers, the adjacent megapack also went into thermal runaway[19] (ref: Paul Christensen report). In Beijing there was a propagation to a second cabin, spatially separated, thus apparently not from a thermal mechanism. An electrical surge cause may be conjectured, and presents a further accident escalation mode requiring examination. "Remote propagation" to a non-adjacent cabin in Beijing was what killed two firemen in a surprise explosion[20].

In a "near-miss" incident, cabin-to-cabin escalation was narrowly forestalled in Liverpool only by the continuous presence of Merseyside FRS for 56 hours cooling the neighbouring cabin with uninterrupted hydrant water in an urban setting[21].

29. Eye-witness reports from fire service professionals in two separate incidents in Arizona (2012 fire and the 2019 "deflagration") both reported flame lengths up to 75 feet [22 9 metres] laterally[22]. These were single-cabin installations, so no

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[19] Professor Christensen report Annexed to WR of SNTSAG
[20] Reports in Annex EF13
[21] Reports in Annex EF14
[22] Reports in Annexes EF11, EF12 and EF21

escalation was there possible, but if 23 metre flame lengths are recorded, then absent any other measures, with performance data, this suggests minimum safety separation of 23 metres, in all directions, to pre-empt the possibility of cabin-to-cabin escalation.

Even this would not prevent cabin-to-cabin escalation by an electrical fault mode, as conjectured from the Beijing incident.

30. The Applicant's response is thus another case of "unknowns based on unknowns". Until we know the energy storage capacities of the BESS containers we don't know the level of risk posed by even a single-cabin accident. Until we know the final layouts of the BESS compounds and any preventative measures proposed to limit escalation of a thermal runaway incident in one container to a nearby container, we can *not* know that fire safety concerns are limited to one single battery enclosure.

31. Given the known records of cabin-to-cabin escalation, it is irresponsible in the extreme to suggest that what has already happened in reality has now somehow become impossible, without specifying in detail the engineering control measures effecting the claimed impossibility, and demonstrating their effectiveness by full-scale tests to destruction.

32. On the contrary, cabin-to-cabin escalation is now a demonstrable fact, so the concern should rather be the consequences of a major escalation where an incident in Cabin 1 propagates to Cabin 2 and thence to Cabin 3 and so on. The overall energy storage capacity is the only factor limiting the scale of such an accident, and the larger the scale of the potential accident the stronger should be the level of control measures designed to render such escalation not merely improbable but in all credible circumstances functionally impossible.

No such control measures (demonstrated by full scale test data) have been offered within the OBFSMP, so the presumption of cabin-to-cabin escalation remains a necessary and prudent presumption for any responsible safety engineering.

33. It is thus completely untrue that the storage capacity "*has no direct relationship to environmental or social impacts*". Emergency Response Plans for communities close to a major BESS accident could involve sealing doors and windows, up to mass evacuation. The social impact of living with such a level of hazard would be extreme for the affected communities.

Similarly a major BESS accident could have lasting environmental impact for example if bunding of contaminated fire water were breached or its capacity exceeded.

Qu 1.1.9 – "Environmental and Social Impacts"

34. "The EIA process and resultant ES has considered the maximum parameters of the BESS, as a worst case approach to the EIA. These parameters are set out in the design principles and comprise the assumption that the entire Works Nos 2A, 2B and 2C (as shown on the Works Plans [APP-007] will be covered with BESS containers 6m in height, with no spacing between containers. Should the BESS be built smaller, it is logical that the impacts would be the same or lower than what is presented in the ES."

"The EIA has therefore assessed the maximum and worst-case parameters for the BESS. Limiting the energy and power rating of the BESS would not change the assessment of the environmental and social impacts assessed within the ES."

35. These claims appear be limited to matters of visual appearance and interruption of landscape.

However "Environmental Impacts" certainly include toxic emissions in the event of BESS accidents. These most certainly do depend on the energy storage capacity, and the limiting case of *"covered with BESS containers 6m in height, with no spacing between containers"* would represent a colossal energy storage capacity, inventory of high-technology functional chemicals, and of potential emissions of toxics (both atmospheric and water-borne) in the event of a major accident.

Hence the idea that "*Limiting the energy and power rating of the BESS would not change the assessment of the environmental and social impacts*" is simply preposterous, in the context of possible major accidents in BESS.

Qu 1.1.9 – "Impacts on Safety"

36. *"The design of the BESS and its impacts are controlled in several ways. Prior to commencement of construction of the BESS, a Battery Fire Safety Management Plan (in accordance with the Outline Battery Fire Safety Management Plan (BSMP) [APP-267] submitted with the Application) is required to be submitted to the relevant local planning authority and approved, in consultation with the Cambridgeshire Fire and Rescue Service and the Suffolk Fire and Rescue Service. The Applicant must operate the BESS in accordance with the approved plan. Further, pursuant to the detailed design requirement of the draft DCO [APP-019], the detailed design of the BESS must be in accordance with the Design Principles [Appendix B of APP-264]. The Design Principles [APP-264] contain controls over the BESS which restrict the area, height, external finish and some design features of the BESS. The controls in the Design Principles also include: (i) that the chemistry of the BESS will be lithium ion, and (ii) that an assessment will be undertaken, based on the detailed design for the BESS to demonstrate that the environmental and social impacts from such a fire will be no worse than as assessed in ES Appendix 16D: Unplanned Atmospheric Emissions from Battery Storage Systems [APP-124]."*

37. These are largely reactive measures, involve "passing the buck" of responsibility to the local FRSs, and design according to inadequate principles: – "*area, height and external finish*" are unlikely to Prevent or Mitigate a BESS accident.

38. A responsible Hazard Analysis and Risk Control exercise will always involve two broad headings: (i) Prevention and (ii) Mitigation. Mitigation is always necessary and prudent, but Prevention is always to be preferred. For instance, how exactly does one “manage” an Explosion hazard ? On may Mitigate its consequences, but the only really effective “management” lies in Preventing it happening at all.

39. Even before one begins, one must first understand the nature of the hazard. The emphasis on a OBFSMP is to misunderstand the nature of the hazards presented by Li-ion BESS. “Fire” is certainly one of them, but the hazards presented by Li-ion BESS are unfortunately not limited to “Fire”. Even under the broad class of “Physical Hazards” one must consider Explosion in addition, as discussed above.

40. Moreover the OBFSMP/BFSMP by their very nature are essentially Mitigation measures, are reactive and not proactive, and cannot Mitigate an Explosion. A BFSMP fails to pay adequate attention to the Health Hazards (except as operational constraints on first responders e.g. requiring breathing apparatus) and may actually generate Environmental Hazards during response to Fire, in the form of contaminated fire-water run-off. They do not address Prevention (except in the limited sense of detection systems, sprinklers, etc).

41. The Health Hazards presented by “*ES Appendix 16D: Unplanned Atmospheric Emissions from Battery Storage Systems”* will be dealt with in more detail below, but we note from Prof Christensen’s report[23]:

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

In other words, a single test report on a fire from a 100 kWh system has no relevance, at all, to fires in much larger systems.

Qu 1.1.9 – Conclusion

42. The responses to this Question exemplify the importance of detailed technical input from the HSE and EA, not just the local FRS. It is not simply a “fire safety” matter, and the local FRSs cannot be expected to shoulder the responsibility for assessing the effectiveness of suppression systems for controlling thermal runaway (which is *not* a “fire” in the conventional sense), nor for issues such as the eco-toxicity of unplanned discharges of contaminated fire water close to Ramsar-designated wetlands.

43. The hazards presented by Li-ion BESS are shared by other large scale industrial plant involving dangerous or hazardous substances for which the existing regulatory regime comprises the P(HS)Regs 2015 (at the Planning stage) and the COMAH Regs 2015 (at the operational stage).

[23] Annex to WR from SNTSAG

It should be noted that these are wholly agnostic as to technology and explicitly cover “loss of control of the processes”. Policy in NPS EN-1 clearly envisions, where dangerous substances above prescribed thresholds may be present, or foreseeably generated, the early involvement of the COMAH Competent Authority, comprising the HSE and the EA “acting jointly”. The involvement of HSE, or of the EA, alone does not constitute “acting jointly”.

44. The systematic safety appraisal from the COMAH Competent Authority required by Sect 4.11.4 of NPS EN-1 is the appropriate level of safety appraisal, but regrettably has not so far happened. It is an unreasonable burden to place responsibility for these major issues on two local FRSs.

Qu 1.1.14

45. *“The length and width of each individual infrastructure within the BESS compounds will not exceed the maximum parameters in the application. The fire / explosion risk is directly related to MWh energy contained in each BESS enclosure and the volume of free air, not necessarily its physical dimensions. The dimensions are influenced by the MWh energy stored in the BESS enclosure i.e. number of battery modules & racks, and therefore will be determined at detailed design state, ensuring minimum spacing widths and sufficient space for the fire services to access the compounds are achieved in line with the outline Battery Fire Safety Management Plan [APP-267]. “*

46. I agree that the fire/explosion risk in a single container is dependent on the MWh of energy storage in such BESS container.

I do not agree, for reasons given under Qu 1.1.9, that the hazard can be regarded as limited to a single container, unless extreme measures, supported by actual full scale tests, are taken to prevent cabin-to-cabin escalation. No such measures are detailed.

It is not why clear volume of free air is relevant when thermal runaway accidents require no air to proceed, although it might well affect the development of a stratified atmosphere likely to lead eventually to Vapour Cloud Explosion.

47. The ExA question regarding “minimising risk of fire” does not appear to have been answered. The scenario of complete coverage to 6 metres high would not minimise risk of fire, on the contrary it represents a hazard so large that no responsible operator would consider it.

It is not good enough to determine the MWh capacity “at detailed design stage” where major safety issues are concerned.

Also, in the routine reference to the UL 9540A standard should be clearly understood that UL 9540A is a test specification i.e. something that can be legitimately compared to other UL 9540A tests on a *ceteris paribus* [other things equal] basis. UL 9540A has no concept of pass/fail and is therefore in no sense a “certification” of anything.

Qu 1.1.17

48. The Applicant refers to '*resiliency*' if one of the water tanks were to fail there would be additional capability for firefighting through the second tank.

49. However, both the joint Councils and BESS expert Professor Christensen fear that the Applicant has considerably underestimated the likely water capacity that would be required in the event of a thermal runaway incident. As such, there is currently no 'resiliency.'

50. Professor Christensen[24] cites the Community Fire Association of Victoria, Australia as leading the way in design guidance, and they recommend a minimum of 288 m^3 or flow of 20 L/s for four hours. However even this may not be sufficient. The joint Councils' LIR cites the 900 m^3 of water required for the 2021 fire at Moorabool. The 2017 explosion and fire at Drogenbos (Belgium) (itself a very small BESS of only 1 MWh capacity) required 1400 m^3 of water to contain. The 2020 explosion and fire in Liverpool occupied Merseyside FRS for over 56 hours to prevent cabin-to-cabin escalation by water cooling, with access to urban hydrants.

51. If the Drogenbos incident needed 1400 m^3 to control, then the current plans for tanks of 242 m^3 are undersized by a factor of nearly 6 even for a 1 MWh BESS.

There is no credible assessment of water volumes needed for even a single container incident in a 5 MWh BESS. A second tank is completely beside the point. You would need at least 5 more tanks to control even a 1 MWh BESS. How many more would be needed for a single container incident in a 5 MWh BESS ?

There is simply no appraisal; however, we do *know* that two tanks are demonstrated to be *completely insufficient* by the experience at Drogenbos (2017) and at Moorabool (2021).

Qu 1.1.19

52. The applicant asserts, without basis, that local residents are situated "*outside the life safety critical zones*". It is not clear what these critical zones are. They do not appear in the OBFSMP or the Unplanned Emissions documentation, and if reliant on the latter, may seriously under-estimate the extent of a major BESS accident.

53. How have Sunnica concluded that residents lie outside these critical zones and have the Traveller community on Elms Road been considered? What parameters have been *calculated* to inform their view that residents lie outside critical zones?

54. A report by the engineering consultancy Atkins for the HSE for Northern Ireland (HSE(NI))[25] NI assesses hazards such as Explosion risk by reference to estimated explosion overpressures in mbar, and references HSE (Great Britain) codes defining Inner, Middle and Outer land use planning zones for Explosion hazards. The Outer zone is defined by an explosion overpressure of 70 mbar which is still considered to risk "partial demolition of houses – rendered uninhabitable". This

[24] Annex to WR of SNTSAG
[25] Annex EF28

zone extends up to 45 metres in the Atkins illustration[26]. It must be remembered however that even at 1-3 mbar overpressure this is sufficient to break 5% of exposed glass panes[27] and there is a Travellers' site at Elms Road less than 200m from the BESS compound at East B.

No Explosion Hazard analysis at all has been provided by the Applicant.

55. With regard to toxic emissions, the same report provides plume dispersal modelling for an example but relevant and rational "reference case" (single container 5 MWh BESS), and provides contours based on the HF concentrations reached at various distances, for concentrations assessed by reputable agencies in the UK and elsewhere corresponding to the following levels:

IDLH = Imminent Danger to Life and Health
AEGL-3 (30 min) = Acute Exposure Guideline Levels (30 minute exposure)
AEGL-3 (10 min) = Acute Exposure Guideline Levels (10 minute exposure)
SLOT = Specified Level of Toxicity (used by HSE in relation to Planning advice)
SLOD = Significant Likelihood of Death

Again this represents rational risk analysis against concentrations known (e.g.) to risk death in highly susceptible people (SLOT) or 50% mortality (SLOD).

In the Atkins illustration, the IDLH level of HF is reached 240 m downwind of the source, sufficient to reach the Elms Rd Travellers' site.

There is no rational risk assessment by Sunnica, on the lines provided by Atkins to the HSE for Northern Ireland.

Once again this demonstrates the critical need for full engagement by the HSE and the EA in respect of the Sunnica proposal.

Qu 1.1.21

56. The Applicant states that learning points from historical accidents have been taken into account in current legislation and guidelines.

57. Unfortunately there is often a lengthy time delay between an incident occurring and an investigation report being published. This was the case with the Liverpool BESS fire which happened in September 2020 and the report was suppressed for litigation reasons and only disclosed in March 2022.

As such learning points from historical battery fires are not often captured in current guidelines so it is essential that applicants consider these and obtain expert input.

As an example the Arizona fire in 2019 the report into the fire concluded that the aerosol fire suppression system contributed towards the explosion and yet in Burwell, Cambridgeshire, this year a BESS was commissioned with an aerosol based fire suppression system.

[26] Section 5 of Annex EF28
[27] Atkins report, Annex EF28, page 15, citing HSE sources.

58. With regard to legislation, whilst a Bill on BESS safety passed its First Reading in September[28], the Second Reading will not take place until March 2023.

59. I remain of the view that the regulatory regime represented by the P(HS)Regs 2015 and the COMAH Regs 2015 remains robust for addressing BESS safety, placing the burden of responsibility squarely upon the operator (at the operational stage) and the Applicant (at the Planning stage) to perform all necessary investigations and tests, including those in "loss of control" situations. The engagement with the COMAH CA provides a dialogue with disinterested technical experts on what is prudent and acceptable from a public safety perspective.

60. However, the effect of consenting regimes represented by the P(HS)A 1990 and P(HS)Regs 2015 obviously only has its effect if the Applicant is prepared to engage with them, as both law requires and policy clearly intends.

Qu 1.1.21 – Fire Safety Plan

61. The applicant claims: "*As noted above, Section 5 of the Outline Battery Fire Safety Management Plan presents a comprehensive list of mitigation and control measures*"

62. Professor Christensen does not agree; in his report[29] a number of these mitigation measures (OBFSMP Section 5 , Table 13) will not mitigate thermal runaway. As examples:

RMM10 – Disconnecting cells from the external circuit will not prevent thermal runaway.

RMM17 – there is uncertainty/ inadequacy of gas sensors regarding the advanced warning of thermal runaway offered by such gas sensors.

Prof Christensen is not aware of a means by which FRS can remotely monitor an explosive atmosphere. He also remarks: "*The engagement of the first stage alarm and closure of access doors louvres etc is in direct opposition to accepted best practice as it would facilitate the build-up of explosive gases. The applicants do not seem to be aware of the relevant amendments to NFPA 855 requiring gas sensing and explosion avoidance via venting, or explosion control via deflagration panels. Such consideration should most certainly be included in the OBFSMP."*

63. The removal of the term 'reasonably practicable' is welcome. The replacement with the intention to reduce all foreseeable risks to "as low as reasonably practicable" (ALARP) has however to be weighed against possible consequences, with a bias in favour of health and safety[30].

In my view the scale of the maximum possible accident with multi-cabin involvement is so large that the likelihood of cabin-to-cabin escalation should be reduced by proven Prevention measures to be "functionally impossible". This is far from the case at present.

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[28] Report from *Hansard* in Annex EF9
[29] Annex to WR of SNTSAG
[30] Edwards v NCB [1949] 1 All ER 743 quoted in https://www.hse.gov.uk/managing/theory/alarpglance.htm with further guidance.

Qu 1.1.22

64. I agree entirely with the ExA that any effective BFSMP should encompass an Emergency Response Plan in addition, which should take account of the worst credible accident likely to occur.

65. It should be noted that in any application for HSC made to local HSAs, the Applicant would be required under R. 5(1)(d)(viii) P(HS)Regs 2015 to provide details of "*the measures taken or proposed to be taken to limit the consequences of a major accident"* exemplifying the value of observing these features of regulatory law (regarding Hazardous Substances Consent) at the DCO stage.

Qu 1.1.27

66. I agree entirely with the ExA that insufficient detail has been provided in the Application. Without a full specification, including cell type, energy storage per container, number of containers, and site layout, such an appraisal cannot even begin.

67. As I contend in my WR, policy in NPS EN-1 requires this to be assessed at the Planning stage.

68. I do not see how the Planning doctrine of the "Rochdale envelope" applies appropriately to health and safety analyses. A worst credible accident analysis is needed for both cell types under consideration, fully analysed for Fire, Explosion, Atmospheric Emissions, and Hazards to the Aquatic Environment.

The OBFSMP represents an inadequate approach to just one of these aspects.

Qu 1.1.28

69. "If the separation distances can't be maintained, thermal barriers shall be provided in accordance with FM Global Datasheet 1-21 for Fire Resistance of Building Assemblies. This will allow containers to be located directly next to each other. Cable and pipe penetrations into each BESS enclosure will be sealed and provided with rating equal to that required for the BESS enclosure."

70. This is a most irresponsible proposal and if allowed would amount to extensive in-filling of BESS compound land, escalating both the likelihood of cabin-to-cabin spread and the scale of the worst case accident. According to Professor Christensen, side-by-side cabinets such as those involved in the Moorabool "Big Battery" fire in Australia in July 2021 were separated by thermal barriers as well as by the walls of the individual cabinets, and yet the fire spread from one cabinet to another.[31]

71. The FM Global datasheet cited is a valuable design guide on fire resistance of classic building elements but has no direct relevance to BESS. Without a design basis (temperature, heat output, duration, rate of propagation etc) this data sheet cannot provide any materials selection. It is in no sense a "design chart" for an acceptable thermal barrier, even using the 1 hour recommendation of NFPA 855

[31] Annex EF20

(2023) which may not be adequate given the evidence of BESS fires (Liverpool, Moorabool) sustained for much longer periods.

72. “*The separation between containers has no bearing on thermal runaway*”.

73. This is quite wrong. Thermal runaway can be initiated even in “healthy” cells once heated past a threshold temperature, which can be as low as 150 °C in NMC cells somewhat higher (200 °C typical) in LFP cells.

74. Eye witness reports from Arizona[32] contain independent reports from two incidents in different installations having the common feature of “*flames up to 75 feet in length*” [22.9 metres]. If that is the flame length known to have been generated at least twice in recorded incidents, then in the absence of any other data this represents an entirely credible accident. Absent other measures, it implies a minimum cabin separation of at least 23 metres in all directions should be required.

75. Moreover, because the Applicant has not assessed Explosion risk, the question of blast protection has not been raised. Any thermal barriers would also have to be designed to withstand explosion damage from an adjacent BESS container. Blast walls were explicitly recommended in the Significant Incident Report on the 2020 Liverpool explosion.[33]

The Atkins report[34] to HSE(NI) provides credible explosion overpressures at even 10 metres distance which would approach the “*complete destruction of a house*”. It does not appear likely that such blast-resistant barriers could be designed without significant development work and proof of concept by full scale tests.

76. Even without the required blast resistance a full scale thermal barrier would need to be proven by extensive modelling and full scale tests. The NFPA 855 recommendations cited should be revisited given the evidence of BESS fires lasting much longer than 1-2 hours.

77. “*BESS containers located closer together and with thermal barriers will lead to the volume of free air quickly diminishing therefore any fire reducing.*”

78. The inappropriate use of the word “fire” for thermal runaway incidents leads to this kind of erroneous reasoning. Thermal runaway incidents do not require oxygen to develop, heat is enough. Hence free air will have no bearing on whether or not the thermal runaway incident propagates to an adjacent container.

Qu 1.1.38

79. The ExA rightly question the categorisation of loss of life in tables 7 to 11 of the OBFSMP. The Applicant replies saying that the probability of a major severity impact reduces following the implementation of the measures in the OBFSMP. That assumes that the OBFSMP is adequate. Professor Christensen’s report[35] does not agree that it is.

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32 Annex EF21
33 See Annex EF14, REP2-129c, 3rd item, page 30
34 Annex EF28
35 Annex to WR of SNTSAG

Qu 1.1.40

80. A major defect of this Application has been the failure to consult adequately with the HSE and EA (comprising the COMAH Competent Authority). The Policy requirements to do so are set out in detail in my WR. It appears that the HSE has been copied on plans but this does not necessarily constitute consultation and it certainly does not constitute the "safety assessment" required by Policy in Sect. 4.11.4 of NPS EN-1.

81. The Applicant admits under Qu 1.1.35 that "*there are no current UK laws or regulations specifically covering BESS enclosure fire safety*". This exemplifies the need for early engagement with the statutory regulators. The public is entitled to the protection offered by close scrutiny, by the regulators, of detailed plans, given the relative novelty of the technology being deployed at unprecedented scale.

Qu 1.1.46 – 1.1.49 (Major Accidents and Disasters)

82. The ExA have raised absolutely pertinent questions regarding major accidents.

83. However as pointed out in multiple places it is not possible to assess safety of such a major installation except against a detailed specification, which the Applicant has consistently failed to provide.

84. Moreover, I must question the adequacy of the current process for assessing "Major Accident Prevention and Mitigation". The regulatory regime for doing so is represented by the COMAH Regs 2015 and the P(HS)A 1990 and P(HS)Regs 2015.

The Applicant has declined to apply for HSC, though my WR makes the case that HSC is almost certainly a legal requirement, implying *prima facie* that BESS at this scale should be regulated as a COMAH site, and that in the NSIP / DCO process, a safety assessment by the COMAH CA is required.

The regulatory regime would assess hazards under the headings of Physical Hazards (Fire and Explosion), Health Hazards (typically airborne pollutants including particulate smokes as well as toxic gases) and Hazards to the Aquatic Environment.

85. Engagement with the statutory regulators would produce active input from independent technical experts e.g. on matters of explosion risk, blast protection, air quality, toxic fire water run-off etc. In particular where recognised standards demonstrated as effective by experience do not exist[36], the public is entitled to expect the protection offered by independent scrutiny of detailed plans by those with a duty to serve the public interest in health, safety and environmental protection.

86. To date the only safety appraisal by a statutory regulator is the Atkins report to HSE(NI)[37], which is itself generic, does not appraise any particular proposal, but does cover Explosion as well as toxic gas plume dispersal against a far more credible reference case than offered by the Applicant in their ES Appendix D.

It is surely important that HSE in Great Britain becomes engaged at least as much as HSE(NI) with what could be one of the largest BESS in the world.

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[36] See e.g. Applicant's admissions under Qu 1.1.35

[37] Annex EF28

Qu 1.1.50 – 1.1.63 (Unplanned Atmospheric Emissions from BESS)

87. Again the ExA have raised very pertinent questions.

88. The Applicant's ES Volume 6 ES Appendix 16D has been reviewed unfavourably by independent experts (i) for the joint Councils' LIR[38], and (ii) by the UK's leading expert in Li-ion battery safety, Professor Paul Christensen, for the SNTSAG[39].

Inapplicability of a 100 kWh fire to a large BESS accident

89. Professor Christensen comments:

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

Neglect of toxic pollutants other than HF

90. Professor Christensen again:

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

91. The Davion Hill analysis of the McMicken, Arizona explosion[40] reports:

Toxic gases are also present in a Li-ion battery thermal runaway event. HCl, HF, and HCN are all emitted from common plastics fires. HCl evolves from Polyvinyl Chloride at temperatures above 100 °C. [2] By 200 °C HCl evolution is strongly evident, becoming rapid at 230 °C and dehydrochlorination is very rapid at 300 °C. Carbon dioxide (CO_2), carbon monoxide (CO), and water form from the dehydrochlorinated residue at high temperatures. In fact, a common signature of a suspected battery thermal runaway event is the presence of HCN, HCl, or HF.

92. The Applicant claims that the toxic hazards are "*not particulate*". This is not so: in my WR and Annex EF16 we review the literature on Nickel Oxides in "inhalable powder form" which are potent carcinogens and have been shown to be transported large distances in simulated Electric Vehicle fires[41] .

93. Carbon Monoxide (CO) is an Acute Toxic gas known to be generated in Li-ion battery fires[42] and (dependent on air availability) could be a significant contributor to a toxic gas hazard[43].

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[38] Their Appendix 26
[39] Annex to WR of SNTSAG
[40] Annex EF11
[41] Annex EF26
[42] Annex EF18
[43] E.g. Annex EF22, a paper commissioned by a BESS Applicant in Northern Ireland.

Defects in the Appendix 16D Analysis

94. Even disregarding the neglect of all atmospheric contaminants other than HF, the modelling exercise reported is defective on the following grounds.

(i) The accident scenario, whilst conceivable, is wholly arbitrary, "plucked out of thin air". An accident limited to 5 racks out of 35 is certainly *not* conservative[44] where BESS accidents resulting in complete destruction of a whole container have occurred and are matters of record. The joint Councils' LIR makes the same criticism.

(ii) Any computer model is only as good as its input data, or the exercise reduces to what is known colloquially as a "GIGO" (Garbage In, Garbage Out). Credible input data is therefore fundamental. The input data (emission rate, and aggregate mass of HF) are not credible, for reasons discussed below.

(iii) Similarly a sensitivity analysis is required to determine which input parameters have large effects on outputs if varied, and which are only weak contributors to a result. No sensitivity analysis is reported.

(iv) The question of what atmospheric conditions should be chosen is beside the point when only one or two scenarios are presented. The whole point of a rational computer model is to be able to model with ease a variety of circumstances. The selection of which situations represent a "worst credible accident" is then a judgment to be made by the users.

(v) The authors note (correctly) that a "*standardised set of emission factors is not currently available from the Environment Agency for BESS, and therefore equivalent data must be sourced from manufacturers and the research literature*". Unfortunately the two sources cited betray such a cursory survey of the research literature that no credence can be placed on the results.

In particular the report by Andersson et al.[45] dated 2013 has long been superseded by a peer-reviewed paper in the *Nature* portfolio (*Scientific Reports*) by the *same authors*, published in 2017[46], which quantifies properly the aggregate quantity of HF and other toxic fluoride gases in terms of mg HF per unit energy storage in Wh. The scale-up exercise reported by Andersson in the older paper[47] is redundant.

It is inexplicable that the authors of Appendix 16D are apparently unaware of this widely cited and peer-reviewed paper.

(vI) There is little explanation for the origin of the assumed emission rate of 1 $\mu g\ m^{-3} s^{-1}$ and in response to the ExA questions this appears to be yet another "fluid" parameter.

[44] Though claimed to be, Para 2.1.7 page 16D-3
[45] Now provided as Annex EF35
[46] Larsson *et al.* (2017) Annex EF15. Submission date was 11 April 2017.
[47] And relied upon in Appendix 16D, Para. 2.1.6(d) page 16D-3

Inconsistency with aggregate quantities of HF reported elsewhere

95. The Atkins report for HSE(NI)[48] reports a much more thorough plume dispersal analysis than provided in Appendix 16D and moreover assumes credible values for fire load, heat flux, and aggregate quantities of possible HF emissions, from a credible whole-container accident in a 5 MWh BESS.

Emissions at the IDLH level are found for entirely typical weather conditions at up to 240 m from a single-cabin BESS accident.

96. Atkins' report first notes that a full stoichiometric decomposition of the Fluorine-containing compounds in the BESS cells would generate 2033.2 kg of HF per ISO container, whilst the upper figure of 200 mg/Wh reported by Larsson *et al* [49] would correspond to 738 kg HF from the same ISO container[50].

Therefore, the upper figure of Larsson (200 mg/Wh) is about 36% of a full stoichiometric decomposition of all fluorine-containing components of the cells. The significance of this is that 200 mg/Wh represents a significant proportion of all fluorine-containing chemicals in the cells, but by no means the maximum possible generation.

97. The representative nature of the 200 mg/Wh figure is endorsed (for LFP cells) by independent literature sources[51] reviewed in Annex EF16.

98. Applied to a 5 MWh BESS container this represents a credible emission of 1,000 kg of HF, that is 1 tonne of Hydrogen Fluoride gas.

99. Yet in the Appendix 16D model, we see as assumption of 2.07 kg HF from a 5-rack fire[52], and a range between 1 and 3 kg HF has been taken in section 4.[53]

As in many places in this Application, exact figures are not stated for energy storage capacity of the 5 racks assumed, but on the assumption of a 5 MWh BESS, then 5 racks out of 35 would correspond to 0.714 MWh, from which on the Larsson figure of 200 mg/Wh, a total emission of 142.9 kg of HF.

100. The Appendix 16D model therefore under-states credible HF emissions by 71-fold, (taking the central figure of 2 kg HF).

101. Applied to a more realistic "base case" of total destruction of a cabin of 5 MWh, the Appendix 16D would results therefore under-state credible HF emissions by 500-fold (2 kg *vs* 1000 kg)

102. It should be obvious that the Appendix 16D results cannot be reconciled with data and independent plume dispersal models elsewhere, by a very wide margin.

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[48] Annex EF28
[49] Annex EF15
[50] Each container in their example was 3.7 MWh energy storage capacity.
[51] E.g. Sturk D, Hoffmann L & Tidblad AA (2015) Fire Tests on E-vehicle Battery Cells and Packs, *Traffic Injury Prevention*, **16**:sup1, S159-S164, DOI: 10.1080/15389588.2015.1015117
[52] From the Leclanche SA study cited, para 2.1.7 page 16D-3
[53] Table 4, page 16D-10, para 4.1.5, same page.

103. The input assumptions are simply not credible against independent analyses and literature data elsewhere, based on very simple parameters such as the aggregate HF emissions to be expected.

104. Appendix 16D is simply not credible as a realistic HF dispersion model.

(8,039 words) EJF 28/11/22

List of Annexes referred to follows; Annexes uploaded separately

List of Annexes referred to: – Comments on Responses to ExA Questions of Dr Edmund Fordham (dated 28th November 2022)

EF1 – Personal details

EF2 – "Safety of Grid Scale Lithium-ion Battery Energy Storage Systems"
by E J Fordham (Interested Party), with
Professor Wade Allison DPhil and
Professor Sir David Melville CBE CPhys FInstP

EF3 – "Hazardous substances (Planning) Common Framework"
CP 508 Presented to Parliament by the SoS for DHCLG August 2021

EF4 – Directive 2012/18/EU of the European Parliament and of the Council
on the Control of Major-Accident Hazards involving dangerous substances
commonly known as the "Seveso III Directive"

EF5 – The Planning (Hazardous Substances) Regulations 2015

EF6 – Explanatory Memorandum to the P(HS)Regs 2015

EF7 – The Planning (Hazardous Substances) Act 1990

EF8 – Overarching National Policy Statement for Energy (NPS EN-1)

EF9 – Speech of Dame Maria Miller MP, House of Commons, 7 September 2022
Hansard, (House of Commons) Volume 719, Columns 275-277

EF10 – Battery Storage Guidance Note 1: Battery Storage Planning. Energy Institute, August 2019, ISBN 978 1 78725 122 9

EF11 – D. Hill (2020).
"McMicken BESS event: Technical Analysis and Recommendations"
Technical support for APS related to McMicken thermal runaway and explosion.
Arizona Public Service. Document 10209302-HOU-R-01
Report by DNV-GL to Arizona Public Service, 18 July 2020.

EF12 – Underwriters Laboratories incident report into McMicken explosion

EF13 – (5 items) News items and English translation from Chinese of official accident investigation into April 2021 BESS fire and explosion in Beijing

EF14 – (3 items) Reports from Merseyside Fire and Rescue Service into September 2020 BESS fire and explosion in urban Liverpool

EF15 – Larsson *et al.* (2017), *Scientific Reports*, **7**, 10018,
DOI 10.1038/s41598-017-09784-z

EF16 – Paper with Professor Sir David Melville CBE: “Hazardous Substances potentially generated in “loss of control” accidents in Li-ion Battery Energy Storage systems (BESS): storage capacities implying Hazardous Substances Consent obligations.

In public domain on *Research Gate* preprint server
DOI 10.13140/RG.2.2.35893.76005

EF17 – Golubkov *et al* (2014) *RSC Advances* DOI 10.1039/c3ra4578f

EF18 – Research Technical Report by *FM Global:* Flammability characterization of Li-ion batteries in bulk storage”

EF19 – Bergström *et al* (2015) Vented Gases and Aerosol of Automotive Li-ion LFP and NMC Batteries in Humidified Nitrogen under Thermal Load

EF20 – (2 items) Victorian Big Battery Fire, July 2021. Report of technical findings. Also compendium of news items with aerial photography.

EF21 – (2 items) Letter from Commissioner Sandra D. Kennedy, Arizona Public Service Company, August 2019, regarding McMicken explosion.

Also letter with Fire Department report into earlier 2012 BESS fire with eye-witness reports on flame length.

EF22 – Technical Memorandum from Golder Associates re composition of BESS at Kells, Northern Ireland

EF23 – Ouyang *et al.* (2018), *J. Thermal Analysis and Calorimetry,*
DOI: 10.1007/s10973-018-7891-6

EF24 – Essl *et al.* (2020), *Batteries*, **6**, 30 DOI: 10.3390/batteries6020030

EF25 – Chen *et al.* (2020), *J. Hazardous Materials*, **400,** 123169
DOI: 10.1016/j.jhazmat.2020.123169 (Citation only: article copyright)

EF26 – Held *et al.* (2022) *Renewable and Sustainable Energy Reviews,* **165***,* 112474
DOI: 10.1016/j.rser.2022.112474

EF27 – Wang *et al.* (2019) *Energy Science and Engineering*, **7**, 411-419
DOI: 10.1002/ese3.283

EF28 – Hazard Assessment of BESS, Technical Report by Atkins (Consulting Engineers) for Health and Safety Executive for Northern Ireland HSE(NI)

EF29 – Letter 13/05/2022 from HSE(NI) to Ards and North Down Borough Council

EF30 – Letter 22/09/2022 from HSE(NI) to Derry City and Strabane District Council

EF31 – Letter 10/09/2021 from HSE(NI) to Armagh City, Banbridge & Craigavon Local Planning Office

EF32 – Letter 18/07/2022 from HSE(NI) to Derry City and Strabane District Council

EF33 – Letter 20/05/2021 from HSE(NI) to to Armagh City, Banbridge & Craigavon Local Planning Office

New Annexes added this submission (28 November 2022)

EF34 – Research Technical Report by *FM Global*: “Development of sprinkler protection guidance for Lithium-ion based energy storage systems”

EF35 – P. Andersson *et alia*, “Investigation of fire emissions from Li-ion batteries”, SP Technical Research Institute of Sweden, 2013.