BOCCAppeal-2025-0001

STEWARDS OF SKAGIT

Board of Directors
26717 Helmick Lane
Sedro Woolley, WA 98284

January 16,2025

Before the board of county commissioners for Skagit County

No. PL2300408

Notice of Appeal Skagit county code 14.06.120

Special Use Permit: #PL23-0408

This is an appeal of the Skagit County Hearing Examiner's approval of a Special Use Permit PL23-0408, issued January 2, 2025, for the building of a Utility Scale Battery Energy Storage Plant by NextEra Energy Resources Development LLC. The administrative appeal to the Board of County Commissioners, of the Hearing Examiner's decision, is filed within fourteen days of the decision under Skagit County Code 14.06.120(9). Under the code section, the commissioners may overturn or modify the hearing examiners decision upon a finding that it was "clearly erroneous".

In this case the Hearings examiner was "clearly erroneous" placing the burden of proof on the citizens, the record was incomplete at the time of the hearing, the conditions of the law were not met.

The Hearings examiner was "clearly erroneous" in stating in his decision, "the public did not provide credible evidence of the dangers of fires and explosion of batteries being a hazard", placing the burden of proof on the citizens, when

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SCC 14.06.160(3)(B) states In the case of open record predecision hearings for Level II or Level III decisions, the applicant for the development permit shall bear the burden of demonstrating that the project complies with applicable goals and policies of the Comprehensive Plan and the applicable criteria and requirements of the Skagit County Code and other applicable law.

Hearings examiner rule 29(A) in each hearing on an application for a permit, the Applicant shall have the burden of proof in each appeal hearing, the Appellant shall have the burden of proof.

SCC 14.02.010(14) (14) Protect and promote the public health, safety and general welfare, with respect for private property and private property rights

To place the burden of proof upon the citizens to prove otherwise is shifting the burden of proof to the citizens.

The hearings examiner stated.

> Page11 – note 2 "Albeit that there are a wide variety of Lithium-ion battery types, to which the Hearing Examiner cannot pretend to be an expert on identifying the ideal chemical compound for these specific batteries, but only adjudge the matter based on the facts in the record specific to the proposal."

Without having a full record for review there is no way for the hearing examiner to fully understand all aspects of the project. At a minimum exhibits 30 and 32 were not fully received in full prior to the hearing. A full list of parties of record is also not part of the record, the hearings examiner or interested parties had no way of calling witnesses,

researching information or questioning information when only the paid employees and paid "experts" of the applicants were the only parties of record for technical information. Without calling witnesses outside of the paid or on staff employees of the applicants the only contradictory statements provided were those provided by public comment and were dismissed without having provided the burden of proof.

The exhibit lists state the Staff report was dated December 12,2024, however when the documents were received at the hearings examiners office, some of the exhibits have modification dates of December until the date of December 13, 2024 via thumb drive due to the size of the files being transmitted. This information was not uploaded to the Examiners office website until 3:00pm on December 13th, 2024 leaving less than a full 7 days prior to the hearing for citizens and parties of record to have access to the documents. examiner had not received all the information needed to make a informed decision. Exhibits 57-59 have modification dates of 12/30/2025 on the examiners website with Exhibit having a modification date of 1/2/2025. The Hearings examiners decision was published on January 2, 2025. This does not appear give adequate time to review consider these documents prior to writing and issuing his decision. These Exhibits are also not referenced as being received post hearing.

> SCC 14.06.120(5) Before an application has been set for open record public hearing, before the Hearing Examiner and after the close of any required comment period, including any threshold determination comment period required by RCW Chapter 43.21C and SCC Chapter 16.12, the Department shall coordinate and assemble the comments and recommendations of

other County departments and governmental agencies having an interest in the subject application and shall prepare a staff report summarizing the factors involved, including the Department findings and supportive recommendations. The staff report shall be filed with the Hearing Examiner at least 7 days prior to the scheduled hearing and copies thereof shall be mailed to the applicant and shall be made available for use by any interested party at the reproduction cost.

The exhibits submitted to the hearings examiner indicate they are "draft" documents and therefore can be changed at anytime which means that the full and accurate record was not submitted to the hearings examiner for review.

Exhibits 58- 61 were filed with the hearings examiner post hearing, Exhibit O Hazard mitigation plan is a draft document, and dose not acknowledge NFPA 855 as a code or regulations they will be following, even though during testimony they stated they would be following the NFPA 855. Exhibit 59 Coffman Fire protection plan, submitted after the hearing, also does not reference NFPA 855 as a standard or code that is being referenced. The NFPA 855 is the Standards for the installation of stationary Energy Storage Systems and was referenced multiple times by the applicants "fire expert" as being a document they follow, so his statement and the documents are in conflict. Without having had these full documents prior to the hearing this could not have been an item to question about.

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I

A complete a full record was not before the hearings examiner as he stated. A public disclosure request was made on December 3, 2024 by Connie Krier for documents and has yet to be responded to by the county. We cannot verify all the documents that were not received by the hearings examiner at this time without having received response to our request. The Burden of proof for an appeal lands the appellant, but the county has hindered out ability to provide that proof.

Per Hearings examiners rules the staff report was due to the hearings examiner no less than 20 days prior to the hearing date, the hearings examiner did not received the documents in a timely manor nor was there a verification that all records were received.

The parties of record provided only shows parties who testified at the hearing and not all parties of record. There were multiple people referenced by the county and the applicant during testimony as having had input on the review process of the documents included in the staff report and none of those names were included. The Applicants documents reference documents required by JHA (jurisdiction having authority) and yet no name is associated with the JHA of the person who requested those documents and not form of request or review appears to show this request was made. Therefor the record is incomplete and the parties of record list is incomplete and not available for review.

If in fact a certified party of record list does exist a formal copy has never been published as part of a full the record.

II

The hearing examiner was "clearly erroneous" in the statement that this is a sealed system and that it would emit "No heat, noise, odors, smoke, dust nor vibration detectable offsite" no evidence or proof was provided for these statements.

There was no quantitative data presented to support this claim and in fact, even though the applicant did provide evidence of other facilities they operate similar to this one to support their other claims.

Toxic plumes do occur during fires at BESS facilities, this is why the NFPA 855 addresses this specific issue.

The statement these are completely sealed may be partially true in that while working under normal circumstances the internal workings are sealed from the outside atmosphere, however the HVAC units are not sealed inside the unit. In case of fire the unit must release any smoke or heat to avoid explosion, per NFPA 855

The only witnesses called were the applicant's staff or the single county official that prepared the staff report, the evidence submitted was that of the applicant and no testimony from experts from the county were requested or heard. There was no way for the hearings examiner to understand if more detailed information was needed, based on his statement.

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Page11 – note 2 "Albeit that there are a wide variety of Lithium-ion battery types, to which the Hearing Examiner cannot pretend to be an expert on identifying the ideal chemical compound for these specific batteries, but only adjudge the matter based on the facts in the record specific to the proposal."

The hearings examiner clearly does not fully understand the technology or the possible hazards that could arise or have arisen from other facilities of this nature.

The statement of citizens whom have researched for months and have a more thorough understanding of these systems were dismissed due to the lack of proof when the burden of proof did not lie on the the citizens. The applicants statements were taken at face value as proof in support of their claims.

It is stated that the exact nature of the gen tie lines will not be determined until the building permit will be issues, but may be underground, use existing poles infracstructure or use new poles limied in theight by the zoneing to under 50 feet.

The Hearings examiner has no way properly determining the project as whole without full knowledge of the intent, nor can citizens properly comment or appeal if the information is not provided. Above ground lines and below ground lines have different issues to address.

The contractor has not provided full detailed information of the project at this time, the applicant intended to keep items "proprietary" from the hearigns examiner and the public prior to the hearing and full documents were not submitted by the county in

agreement with this request from the applicant. Full documents were not received until after the hearing and uploaded as additional exhibits. This makes for an incomplete record being transmitted to the hearings examiner as required by law.

Many of the exhibits submitted are "draft" documents and therefore not finalized and subject to change, the examiner, the public or the commissioners cannot make decisions based on "draft" or non-confirmed information.

III

The hearings examiner was "clearly Erroneous" in his statement that Lithium-Ion batters are a type of "solid-state" battery, Lithium Ion batteries are not a completely solid state battery. The hearings examiner states that a safety hazard can exist, but then required the citizens to provide the burden of proof that these should not be used rather than requiring the burden of proof be on the applicant as to how they will ensure the safety of the community and environment knowing there is a potential for fires if the batteries are damaged.

The only "expert" testimony in regard to this was given by the applicants' internal fire engineer, no testimony was given by local fire officials, or any expert in fire sciences and firefighting. Given that the hearing examiner admitted to only being able to adjudicate based on the facts in the record the hearings examiner did not have full record for review prior to the hearing so would have been unable to properly questions this expert on the testimony he gave or subpoena the experts needed to clarify topics

specifically related to the fire safety plan and the mitigation measures documents that were unavailable to the hearings examiner or the public prior the hearing.

The hearings examiner was " clearly erroneous" in stating that the fires in CA "apparently" resulted in no groundwater or air pollution having been contained as designed. The word "apparently" is not a fact. There was no evidence submitted to support this assumption, and the statement of the applicant about a project they were not a party to is heresy. There was air pollution and evacuations that took place . The names and dates of these fires were provided as evidence. The fact that it could happen, requires that the applicant provide proof as to how they intend to keep the public and environment safe from such and event, to take the applicants word and state that "apparently" is not a proof of fact.

The hearings examiner states the batteries will be rapidly charged and discharged, this has proven to increase the risks associated with lithium ion batteries, the more frequently they are charged and discharged increases the risk of failure.

The hearings examiner was "clearly erroneous" in omitted the concerns from the public in regards to after incident testing, monitoring, clean up and liability when addressing the concerns regarding decommissioning. The decommissioning plan was a portion of the concerns and had a need to be addressed should the project last its life with no issues. The additional concern lies in what will happen if there is and incident at this site and how the citizens, environment and property will be protected from contamination, long term health effects and financial costs associated with any potential issues arising

from and emergency response at this site. The only way this is addressed in project files is to state local agencies will respond. This leaves the financial liability for everything on

the citizens to ensure testing and contamination will not affect them long term and also leave the citizens financially responsible for any costs associated with evacuation, security of evacuation areas, cost of fire services during the emergency and lack of available staff to the rest of the county as fire at a facility like this has the potential to last for days and in some cases has lasted weeks.

The hearings examiner also was also presented with evidence of a case where water was contaminated after a large scale batter fire in Wisconsin which resulted in the death of fish downstream from the site dying in large numbers due to contamination. The hearings examiner did not address this in his environmental response statement. Stating the stormwater plan would address the potential for contaminants reaching wetlands, however the examiner was presented with information regarding the quantities of water that have been used at other sites of similar size during fires, which can be millions of gallons of water, the stormwater plan does not take into account this quantity of water nor how it will affect surrounding areas when water overflow from the site.

IV

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The applicant states there are no factual or legal inaccuracies in the staff reports or findings of conclusion, and therefore cannot take a stance that the county errored in representing the information submitted as they did no correct anything in the staff report when given the opportunity.

V

The hearings examiner was "clearly erroneous" in stating that no party requested the hearing examiner to compel a witness to appear in person and the be cross examined.

Without a full list of people who participated in the review process on the county's behalf and without a completed list of parties of record and without a complete record of documents it could not be determined who should be requested to appear as a witness.

VI

The hearings examiner was "clearly erroneous" in his statement that no objections were made to the exhibits and only exhibit 61 was added post hearing.

The letter from the stewards of Skagit transmitted to the hearings examiner on December 19th clearly stated documents were not submitted in their entirety and the hearings examiner in fact had to question this and request full documents be submitted. Additional exhibits 57-61 were added to the exhibits after the date of the hearing.

VII

We reserve the right to amend our appeal based on not having received our public disclosure request response from Skagit county, having not been able to yet verify the

record transmitted to the hearings examiner was full and complete, there is not full list of parties of record and because some of the exhibits entered by the applicant as evidence are in a draft format and therefore can be changed at any time.

Examiners Conclusion of Law

I

Hearing examiner did not address

> 14.06.105 (d) A preliminary determination regarding the availability and adequacy of public facilities and services identified in the Comprehensive Plan.

One of the major concerns for the public is the availability, training and adequate services available to the rest of the county if there is an emergency situation at this facility. This was not adequately addressed by either the hearings examiner or in any of the applicants documents.

II

We reserve our rights to amend based on not having received that necessary information through exhibits or public disclosure to properly address the environmental concerns and mitigation measures.

III

For conditions under the special use permit the applicant held the burden of proof

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C. the proposed use will not create undue noise, odor, heat, vibration, air or water pollution impacts on the surrounding, existing or potential dwelling units based on performance standards of SCC 14.16.840.

E. The proposed use will not cause potential adverse effects on the general public health, safety and welfare.

G. the proposed use is not in conflict with the health and safety of the community.

H. the proposed use will be supported by adequate public facilities or services and will not adversely affect public services to the sounding areas, or conditions can be establishes to mitigate adverse impacts on such facilities.

The applicant did not provide any quantitative proof that this facility would not cause noise, heat or vibration while in normal use. No noise, heat or vibration monitoring data was supplied to prove the applicant statement they will comply with the code.

The applicant did not address in any documents that if a fire were to occur, which has been proven to be a potential based on the mitigation plan and fire plan submitted, the fire would not have adverse effects on the general safety and health of the public and has provided no measures for how they will determine any impacts from such and emergency. No quantitative measures are in place to ensure the air, water, ground and structures in surrounding areas are free from impact after a fire or emergency at this site, no trigger levels are provided for when an emergency is considered minor or major, no information is provided in case of evacuation, not information is provided about

financial support for after emergency monitoring of the environment to ensure the safety of the public.

The concern of the public in regard to health and safety revolve around if an emergency were to occur at this site, the applicant has submitted not substation planning or response information for how the public will be protected from different levels or types of emergencies that do have the potential of arising at this site.

There is a limited number of emergency services personnel in Skagit county with this being the first ever utility scale BESS facility in the state of WA, having never been trained on fighting a fire at a BESS plant and having no state regulation regarding minimum needs for a department responding to such a fire how did the applicant work with local fire authority to determine there are adequate services available to fight the fire, watch the fire for potentially multiple days, monitor for gasses and contaminates, conduct any evacuations if needed and secure sites if an evacuation is determined to be necessary. No documents were submitted showing these items had ever been addressed be the applicant or any local authority having jurisdiction and no person from the fire department or fires marshals office of Skagit county is listed as a party of record in this case.

Conclusion of facts

The main concerns of the public are the protection of their persons, property and the environment to the surrounding areas, in case of an emergency. This is real and

credible concern based on the information provided by the applicant and the numerous fires that have occurred at Utility Scale Bess plants in 2024 alone. The potential exists and therefore the burden of proof is on the applicant to show there how they intend to eliminate or mitigate that risk.

Due to the lack of regulations from the Federal Government, the State of WA and Skagit county code, due to technology outpacing the codes, the special use permit process is the only opportunity for the citizens and the county to have protections put in place for the safety and Health of the public and the environment knowingly this is an under regulated industry at this time.

The citizens are asking for very simple reassurances that they will be protected financially, physically and environmentally in the case of a fire at this facility and not left guessing if their property, air, and water is contaminate free, or that they will be required to pay additional taxes to cover the costs of the emergency response and preparedness due to the increased training, equipment, staffing needs that may arise as best practices become available and codes update.

Long term health effects in communities from contamination are usually not determined until after people or animals become sick, this is due to the lack of preventative testing when emergencies or disasters occur, the special use permit give the citizens and the county the ability to ensure proper monitoring and testing are part of a fully developed emergency response plan.

The applicant and the citizens are in a position of technology exceeding regulations. But OSHA was created after employee injuries became a problem, the NFPA 855 was

created concern and a potential risk based on the applicants plans, the NFPA, and lessons learned from other BESS facilities in the U.S. The NFPA 855 was only created after the BESS explosion in AZ that seriously injured 4 firefighters, San Diego County put a moratorium on BESS facilities while they update their regulations AFTER multiple fires in 2024.

To allow the applicant to state they will follow regulations means little in and industry where technology is outpacing building regulations, safety regulations and fire codes. The only chance to truly address preventative safety and health is to prepare for the worst in the unlikely event something does occur.

Desired Outcome or Changes to Decision

1. We respectfully request that the Commissioners revers the Decision and deny the special use permit based on the above stated issues, with appropriate findings and conclusions and "without prejudice". Denial of the project based on the record "without Prejudice" would allow the county and the applicant to negotiate over necessary safety protocols, emergency procedures, cost sharing due to project specific financial impacts to the county and post incident monitoring requirements.
2. In the alternative only, that matter should be remanded to the Hearings Examiner for the findings of fact and conclusions of law and other elements as required by SCC 14.06.160(9) and the rules of the Hearing Examiner. Appellants request that the commissioners remand include direction to

a. Allow for additional exhibits to be provided in support of the statements made in the appeal.

b. Address substantive emergency procedures and training, for the emergency service. To include local sheriffs or policing agencies if they so desire. The only training indicated by the applicant in writing for our local departments is in the Fire plan and states that fire fighters will be trained on the ERP annually. This could be a simple as a 30 minute review of a written document or more but we do not know what exactly the applicant has intended, and will be given by the applicant this is not substantial nor adequate ongoing training.

    i. We ask that the department be given an outline of the training that will be received annually to include any updates to the NFPA 855, updates to state or federal regulations, updates on best practices from the industry on fire protection, any training on equipment that may needed or be purchased, as well as at least 1 hour on any topic and or subject the local departments believe are needed for support of this facilities.

    ii. The annual training to be provided by a neutral third party, the applicant may attend the training and participate in a portion of the training for site specific information and the ERP.

    iii. The applicant to pay for at least annually for the fire Marshall and 2 other key personnel to attend a conference or training of the

department's choice within the scope of energy storage. Training must be applicable to Battery energy storage, NFPA 855, or current best practices for alternative energy firefighting. Training must within the US.

iv. All equipment shall be reviewed annually to determine if best practices have determined new equipment is necessary, or replacement of old equipment is needed. Understanding equipment is not solely used for a single facility, the fire Marshall and applicant shall work together to determine how the equipment would be used within the county and what percentage of the cost is appropriate for the applicant to cover.

v. The total cost of any and all training related specifically BESS including pay, instructors, any travel costs, over time shall be covered by the applicant.

c. Emergency procedures We ask the applicant to put into writing the response plan if an emergency effects citizens IF a fire or other emergency does occur. Currently the entire safety plan revolves around their facility and protecting their assets and not how it could potentially affect that safety and health of the surrounding citizens.

i. We ask that the applicant work together with the local emergency management to come up with a written plan for local businesses, farms, and homes within a 1- and 2-mile radius of the site. (see

toxic plume modeling and science direct information regarding evacuation zones, depending on wind)

- Evacuation plans –to include but not limited to businesses, schools, childcare, homes, farms, animals,
- Security of evacuated areas
- How crops could be affected and how that will be handled
- Cost of evacuation to be covered by Applicant.
- Post incident testing in the radius of the site of Soils, air, water at 1- and 2 mile radius and continuing outward until no contamination is detected.
- Post incident testing to take place prior to returning people or animals to their homes, at 3 months and at 6 months post incident to ensure ground and water are clear of contamination.
- Agree to supply home testing kits should citizens request one post incident for and up to 5 mile radius of the site for up to 6 months.
- Agree to cover that cost of any clean up or damages that occur as a direct result of the incident.

B. If this so "unlikely" that a details do not need to be provided, the commitment to the above emergency procedures would be of limited cost to the applicant. Having it in writing is a limited cost and if a fire never

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occurs, the follow up costs would never occur. If in the "unlikely" event a fire did occur it would ensure citizens have the appropriate safety and health protections in place.

Respectfully,

Connie Krier, SMS

President Stewards of Skagit

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Supporting sources to statements above.

Toxic Plume Modeling

Source - Science direct website and ResearchGate website

https://www.sciencedirect.com/science/article/abs/pii/S0950423023002310

https://www.researchgate.net/publication/374949246_Lagrangian_plume_rise_and_dispersion_modelling_of_the_large-scale_lithium-ion_battery_fire_in_Morris_USA_2021

Attached as separate documents Wastewater and disposal of water used during destructive testing of Lithium ion batteries in Ohio, Water was used when setting batteries on fire for testing. It is to be noted if water used on the site is not contained on the site or could leach into the ground the long term impacts to the environment, farms and people could be long term. See attached email chain from Ohio state EPA and the Energy safety response group (testing company), dated September 2023. The companies and equipment are "proprietary" so once again a secret from the public.

> "See attached data per the request in Ohio EPA's notice of violation dated September 26, 2023 for wastewater collection and disposal records from the last three years. During that time period, we have disposed of wastewater once in 2022 and once in 2023. This wastewater was tested prior to its removal from our facility, and those sample analyses are enclosed. The wastewater was removed by Buckeye Elm Contracting on

both occasions. Buckeye Elm Contracting delivered the wastewater to Valicor Environmental Services in 2022 and to the City of Piqua wastewater treatment plant in 2023. The disposal records in our possession are enclosed."

Attached as separate document Insurance needs – Please see included handout from Alliant energy.

"Given the complexity and evolving nature of the risks, it is crucial to engage a broker that understands the risks associated with BESS, that can help a company be an advocate in the marketplace. It is critical that a client with a BESS engage with industry specialists who understand the insurance and risk landscape. They can not only handle the application process, but they also have access to more specialist and competitive markets who understand and have the appetite to underwrite Wind, Solar and their BESS risks."

- Handout from WA Hazmat Symposium – From C. Todd Smith Chirstopher.Smith@atf.gov 509-342-0652
- Article by Dr Edmund Fordham, Dr Wade Allison, Prof David Melville from the website research gate
- Letter and Email from Energy Safety Response group regarding the ceasing of destructive testing of Lithium batteries in Ohio due to EPA violations to the water.
- Handout from Alliant energy instructing owner and property owners to engage insurance brokers

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Hello WA Hazmat Symposium - This handout contains some good stuff on Li-ion batteries as well as white papers for our discussion about toxicity to include the metal problem that is rarely discussed. I briefly covered a few of these in the presentation (briefly), but this format will allow you to look for yourself. Do your own searches and you will find many more. As stated, I have far more questions than answers!

I cannot vouch for all of the content so if something is wrong, please let me know. I believe the other presentations also had some valuable links and resources such as UL FSRI, RISE, NFPA, etc, that I encourage you to look at as well.

If you want to dive deeper into the white papers and various lectures they are here (and there are many more). Usually, the abstracts or conclusions are enough to get the relevance without diving too deep in the weeds, but don't take my word for this – look at it yourself. Control click the link and you are off and running.

Most importantly, please be safe and keep those around you safe!

Again, full disclosure, I am not a toxicologist, doctor, engineer, or industrial hygienist. I am a fire and explosion investigator on the tail end of a 30 year career in law enforcement. I also have a keen interest in this subject born out of my shock when we conducted our own testing when my original interest was how can I tell if a battery caused the fire or was a fire victim.

My opinions are mine and not those of my employer.

My understanding is that the immediate toxic by-products produced during a Li-ion battery (LIB) fire will depend slightly on which of the 6 main LIB chemistries is involved. Suppression water, SOC (state of charge), size of the battery system, type of batteries, geometry of the batteries within the pack, the type of containment, confined space, etc., can all impact what is produced during either venting or combustion. These things will also influence the subsequent fire behavior and the potential for a rekindle if suppression is successful.

The gases produced, both asphyxiants and irritants, are nasty, but many of these appear to dissipate quickly so the threat posed by them is more immediate to the incident so staying out of the plume, direct smoke, and remaining upwind while wearing good PPE and protecting our respiratory system should provide good protection. I know this is not always possible so if you are exposed like this please be mindful of gear contamination, consider writing an exposure report, and also consider getting blood testing from your health department or provider.

This brings us to the metals and my concerns. Keep in mind that the same recommendations to prevent hazardous exposures apply to this threat. The metals will be more persistent as particulates and may pose the larger threat in or on the burned appliance, at the fire seat, and downwind of the fire seat in the event of a fire. Remember that some of these particles can be quite small. Nanoparticles or particles less than 10 micrometers are more easily absorbed, ingested, breathed, or possibly ionized (highly reactive). Here are a few papers if you wish to look and I have included excerpts and highlighted relevant portions.

As stated, there is much we do not know about exposures or contamination of our PPE or to the scene but the amounts observed in the few published studies far exceed permissible limits. As we scale up the size of the battery system (best measured in kWh), it is reasonable to believe the threat scales up as well. I am not as concerned about smaller batteries unless you are in a confined space, vape (direct exposure), or you encounter a fire with dozens of them (add up the kWh) but caution is always our friend.

Due to the expense of testing, we are currently left with "theoretical yields" or suspicion of the same for large systems, but we are following our hazmat training to recognize this threat!

There is some research on the toxicity of cobalt dusts but very little research into how these materials behave at temperatures as high as 4000 degrees F (according to some but usually 2k or better) or in the presence of other volatile compounds such as the solvent chemistries. Manufacturers are just trying to design a better battery and not much thought is given to possible toxic combustion by-products and their impact on human health because they are designed to store energy, not for combustion. The industry is very focused on energy density and economics so don't assume they have looked at this subject comprehensively or that they would publish the information.

*side note – if these links do not open or give you access to the full paper copy the title and look it up on google, you should be able to access the full copy if all you get is a summary or excerpts – some sites charge and others do not but you can usually find it and I have access to some you may not. There are many dozens of published (peer-reviewed) white papers on this subject as you will see if you simply google lithium-ion battery toxicity, etc.

Experimental determination of metals generated during the thermal failure of lithium ion batteries - Energy Advances (RSC Publishing) DOI:10.1039/D2YA00279E

Here are excerpts from this study published in January 2023 that directly reference metal particulates as toxins produced in these fires:

"Metal residues must also be considered as a source of exposure following a battery release; potential routes of exposure could occur through both dermal uptake and any inhalation or ingestion of metals as a result of direct or indirect transfers."

"Each metal determined in this study has its own associated hazard. Nickel and cobalt are known sensitisers, both are known to cause respiratory issues including 'asthma like' allergic reactions. In addition, nickel and nickel compounds are classified Group 1 carcinogens as defined by IARC and nickel can cause skin irritation and allergic dermatitis at sometimes low concentrations.[32]

Elevated exposure to cobalt can affect heart, thyroid, liver, and kidneys. Repeated exposure to cobalt dust can cause scarring of the lungs (fibrosis) even if no symptoms are noticed.

Aluminium compounds have been linked to asthma, obstructive pulmonary disease, and heart disease, however it is better known for causing adverse neurological effects.[33]

With manganese compounds the central nervous system is the primary target of manganese toxicity, specifically causing detrimental neurological effects, since inhaled manganese is often transported directly to the brain before it is metabolised by the liver.

"The methods of analysis used here do not allow the comprehensive determination of the metal containing compounds/species; this is the subject of further work. However, it is not unreasonable to expect metal oxides to be formed from a combustion event, and some of the oxides of cobalt, manganese and in particular nickel are known to be hazardous to human health. The health impact of such an exposure depends not only on the species present, but also to the bioavailability of the compounds, influenced by solubility and, for inhaled absorption, particle size. Certainly, initial effects from exposure to the aforementioned metal oxides would present as skin and inhalation irritations. More long-term health effects can include cancer and neurological issues."

*some of these metals if inhaled can stay in your lungs for months or even years according to some toxicologists and papers (again, doublecheck anything I say if you question it), but we don't seem to have good answers on this or any understanding of potential bio-accumulation from multiple exposures.

Here is another paper from 2020 that specifically looks at LiFePO4 (LFP) or lithium iron phosphate with excerpts (the current favorite chemistry for larger systems such as EV's or ESS). Sadly, I don't think we are far ahead in our understanding than we were in 2020 when this was published and it does NOT focus on the metal particulates -

A comprehensive investigation on the thermal and toxic hazards of large format lithium-ion batteries with LiFePO4 cathode - ScienceDirect

"Toxic gases released from lithium-ion battery (LIB) fires pose a very large threat to human health, yet they are poorly studied, and the knowledge of LIB fire toxicity is limited…

"The major toxic gases detected from the online analysis are CO, HF, SO_2, NO_2, NO and HCl."

"Results show that the effects of irritant gases are much more significant than those of asphyxiant gases. HF and SO_2 have much greater toxicity than the other fire gases. The maximum FEC value is approaching the critical threshold in such fire scenarios."

"Until now, few studies have been done on evaluating the fire effluents of LIB and the knowledge of their toxicity is very limited. "

*Fractional Effective Dose (FEC) is basically the dose at which really bad stuff happens to human beings – see this link for further understanding: 130_A2016_FKT-AAA_CIReport.pdf (nfpa.org) – i.e. - we use this for fatal fires for CO or HCN when we get victim bloodwork back.

*Here is a 2017 paper on toxicity specifically looking at Cobalt – as we discussed cobalt is a key ingredient in the most popular battery chemistry NMC (nickel manganese cobalt) and two other

primary chemistries nickel cobalt aluminum (NCA) and lithium cobalt oxide (LCO) with excerpts. I don't mean to pick on cobalt because nickel, manganese, titanium, iron, aluminum, and the rest also have toxicological profiles. Again, OSHA/NIOSH and the Euros generally reference permissible limits of these metals for "dusts" and those are much larger particles than you will find in batteries. Again, the smaller the particle the more toxic it is to humans (more easily absorbed).

Cobalt toxicity in humans Leyssens et al Toxicology 2017.pdf (imperial.ac.uk)

"Although cobalt has a biologically necessary role as metal constituent of vitamin B12, excessive exposure has been shown to induce various adverse health effects."

"The systemic health effects are characterized by a complex clinical syndrome, mainly including neurological (e.g. hearing and visual impairment), cardiovascular and endocrine deficits.

"toxic reactions at lower doses have been described in several cases of malfunctioning MoM hip implants, which may be explained by certain underlying pathologies that increase the individual susceptibility for Co-induced systemic toxicity. This may be associated with a decrease in Co bound to serum proteins and an increase in free ionic Co2+. As the latter is believed to be the primary toxic form, monitoring of the free fraction of Co2+ might be advisable for future risk assessment.

*MoM refers to metal on metal joint replacements – a source of lots of class action lawsuits right now for adverse outcomes. I included a link at the end for a Ted Talk by Dr. Tower talking about his experience with a cobalt hip. It is very interesting, but keep in mind his exposure (and others) was very direct.

*a few notes here about this 56 pages of text – it is NOT specifically looking at lithium-ion batteries, only other exposures to "cobalt". The last quoted excerpt above is the scariest because these are LITHIUM-ION batteries so would it not be possible that we might have ionized cobalt emitted from the battery during venting (pre-fire) and combustion? I don't know, but it should be studied further and remember as we discussed an EV battery may contain 5, 10, 15, or more kg of cobalt along with other ingredients that have toxicological concerns such as nickel, manganese, aluminum, copper, iron, etc. There can be over 150kg of metals in the larger batteries for EV's and we now have ESS that are the equivalent of 40 EV batteries inside one vented Conex style box with buses or other appliances such as heavy equipment that will equal 5 or more large EV batteries. It is not common and best practice to evacuate downwind for these larger incidents.

***I will repeat this again, keep in mind that most of the toxicology studies are for dusts in a manufacturing setting and not ionized particles (possibly) or nanoparticles that may be encountered in a fire or present afterwards so it is reasonable to assume that metal particulates from a battery fire will be worse than metal dusts in an industrial setting.**

*Here is another paper from 2022 that looked at "contamination" post-fire. It is relevant although it's not directly applicable to contamination of humans specifically as that was not the goal of the research. This corroborates my assertion and fear that the dusts or soot (post-fire and

during the fire) are something to be concerned about. I disagree with their assertion that an ICE and EV vehicle burn at the same temperatures, but that is an argument that continues (most researchers believe it burns hotter).

*On a good note, it looks like the auto industry is beginning to engineer better separation and insulation between modules within a pack to minimize rapid fire progression with some good effect so this might reduce previously observed temperatures and rapid/violent fires.

The key take-away for me from this paper as I presented is:

Thermal runaway and fire of electric vehicle lithium-ion battery and contamination of infrastructure facility - ScienceDirect

"The results of experiment 3 indicate that with active ventilation, soot is transported over long distances and is deposited on surfaces. The amounts of soot found were much lower e.g. about 0.5 g/m^2 at 100 m distance compared to 17–20 g/m^2 in the enclosed space of experiment However, the quantities of the heavy metals nickel, cobalt and manganese as well as lithium are still high, which is why professional decontamination is also required here."

"3.1.1. Contamination of infrastructure and textiles (*PPE or turn-outs?*)

"Inorganic pollutants which are toxicological and corrosion chemical relevance were present in the form of large amounts of the elements Co, Ni and Mn, each amounting to approximately 150–400 μg/cm^2, and of the element Li amounting to around 30–70 μg/cm^2 , see Table 5. Water-soluble fluorides in amounts of 40–52 μg/cm^2 were detected on the collector plates and textile, see Table 6. Therefore, the usual background levels for non-contaminated surfaces are exceeded by factors up to approximately 2000–4000 (Co, Ni), 500–700 (Mn), 400–700 (Li) and 50 (fluorides).

"Conclusion Using the scalable experimental design, a contamination with soot in the range of 20 g/m2 can be expected when a lithium-ion battery of 32 kWh capacity burns down in an enclosed parking space for 30 cars. Thermal runaway and fire of a battery of type NMC 111 produced soot consisting mainly of heavy metal-oxides of nickel, manganese and cobalt (each 18–20% by mass) as well as, to a lesser extent, of lithium (3–4% by mass), fluorides (appr. 2.5% by mass) and chlorides (appr. 0.2% by mass)."

*30 car garage? What about a two-car garage? We don't know, but these are very high numbers for permissible exposure limits or PEL as we discussed. I will include some SDS sheets if you want to look at them below or look up your own. They don't always tell you what the exact chemistry of the battery is (proprietary special sauce).

Remember, combustion of LIB's may also cause other compounds to be formed so don't assume these are high school chemistry class questions that follow typical oxidation-reduction formulas. Again, we really don't know enough about this stuff or the long-term health consequences of exposures or contamination.

Firefighters PPE contamination PV (solar) and EV - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9566750/

It also contains test results showing that firefighters' clothes accumulate harmful substances after fighting these types of fires. Pilot tests for the presence of polycyclic aromatic hydrocarbons (PAHs) and formaldehyde showed that levels exceeded limits in all clothing samples. For example, the cobalt level was 24 times higher than that considered safe in the test carried out with car battery fire. Although it is recognized that liquid carbon dioxide (LCO_2) methods of cleaning may be more effective than traditional water washing, further research on cleaning efficiency for clothing containing substances emitted from car battery and PV modules fires is required.

Here is an old but decent representation of the "content" of a 60kWh EV battery pack (NMC chemistry) but keep in mind that the amounts of materials vary. Tesla is trying to get away from cobalt and it may contain very little but other manufacturers use more cobalt.

Visualizing an EV battery https://elements.visualcapitalist.com/the-key-minerals-in-an-ev-battery/

SDS for lithium nickel manganese cobalt oxide https://www.sigmaaldrich.com/US/en/sds/aldrich/761001

SDS for lithium nickel cobalt aluminum oxide https://loradchemical.com/data/sds/SDS-Lithium-Nickel-Cobalt-Aluminium-Oxide.pdf

SDS for lithium nickel oxide https://www.ltschem.com/msds/LiNiO2.pdf

6 most common lithium battery types https://dragonflyenergy.com/types-of-lithium-batteries-guide/

Look these up yourself simply by searching things like lithium cobalt oxide SDS – .02mg per cubic meter TWA for PEL

https://www.fishersci.com/store/msds?partNumber=AA4209022&productDescription=LITH+CBLT%28III%29+OXID+99.5%25+100G&vendorId=VN00024248&countryCode=US&language=en

*Iron is used in LFP batteries (lithium ferrous phosphate or LiFePO4) – Iron is "less toxic" than other cathode metals for LIB's but as I stated, we don't really know much about nanoparticle toxicity and most reference "not studied" when you read a straight SDS for Lithium Iron Oxide or Iron Oxide (rust) and there is possibly a threat of iron fume similar to what welders may experience. The last paper I link at the very bottom of this book states that combustion may produce other hazardous compounds with even higher toxicity, but we don't know. https://www.continentalbattery.com/assets/Lithium_Safety_Data_Sheet.pdf

* Let us break this "soot" down further from the testing above with what we discussed about SDS and OSHA/NIOSH limits…. .5g/m2 is well over .02g per cubic meter and this was measured at 100m away (! Think about the old guys like me NOT on SCBA at the end of the driveway) with 17-20g per meter squared in the enclosure for 30 cars. It is logical that this might be far worse in a two-car garage or in a smaller semi-confined space. Not to make a math lesson about this, but if permissible limits of dusts are .1mg, 5g, .02mg, .05mg per cubic meter over a 40 hour work week, that is a LONG way from 17g per square meter! As the "plume" (containing these metals) cools the particulates will drop to the ground or on you, your PPE, and your apparatus. This is the contamination that will remain present post-fire in and around the fire seat, on the appliance or container, and on our PPE. Remember, average size EV is around 60kWh and these measurements were in a far larger space than a garage so 20g per sq meter may be far lower than an incident you might respond to or less in an open parking lot.

Remember, these things are fully expelled with little to no copper or aluminum left (often just empty battery casings) so all of this stuff goes somewhere!

Another from 2017 - Toxic fluoride gas emissions from lithium-ion battery fires - PMC (nih.gov)

"Lithium-ion battery fires generate intense heat and considerable amounts of gas and smoke. Although the emission of toxic gases can be a larger threat than the heat, the knowledge of such emissions is limited."

"While the fire itself and the heat it generates may be a serious threat in many situations, the risks associated with gas and smoke emissions from malfunctioning lithium-ion batteries may in some circumstances be a **larger threat**, especially in confined environments where people are present, such as in an aircraft, a submarine, a mine shaft, a spacecraft or in a home equipped with a battery energy storage system.

Full article: Lithium-ion battery explosion aerosols: Morphology and elemental composition (tandfonline.com)

"Aerosols emitted by the explosion of lithium-ion batteries were characterized to assess potential exposures. The explosions were initiated by activating thermal runaway in three commercial batteries: (1) lithium nickel manganese cobalt oxide (NMC), (2) lithium iron phosphate (LFP), and (3) lithium titanate oxide (LTO)."

"The abundance of elements from the anode, cathode, and separator in respirable aerosols underscored the need for the selection of low-toxicity battery materials due to potential exposures in the event of battery thermal runaway."

"Aerosols emitted by lithium-ion battery thermal runaway have not been characterized to the authors' knowledge. In particular, information is lacking on the size, composition and morphology of explosion aerosols in the respirable size range (e.g., ≤4 μm). However, the powder deposited after lithium-ion battery thermal runaway has been studied for 8.5–300 μm particles (Chen, Wang, and Yan Citation2020). The study was carried out for a single battery type with an NMC cathode and showed that powder samples contained carbon, organic compounds, carbonates, and transition metals. The transition metal content of mixed aerosols can especially influence toxicity. In mixtures with carbonaceous particles, transition metals mediate the

production of reactive oxygen species that cause oxidative damage, such as **DNA strand breaks** and inflammation"

*Full disclosure, I am not a doctor, but DNA strand breaks are NOT good and we are now in the realm of cancer, birth defects, and a whole list of other bad stuff. As stated in the presentation, we don't know but until we do…….

One of my favorite papers that I referenced because it focuses on the metal particulates - Full article: Detailed characterization of particle emissions from battery fires (tandfonline.com)

"Lithium-ion (Li-ion) batteries that are becoming ubiquitous in various applications may be susceptible to thermal runaway when subjected to certain abuse factors. Fire ensuing from such a thermal runaway event results in significant release of gaseous and particle emissions that **pose a critical safety risk to human health**."

"there have been limited studies reported in the literature that examine particulate emission characteristics in detail"

"Thermal runaway resulted in very high particle emissions."

- "Battery fires emanating from thermal runaway events can result in significant particle and gaseous emissions. Both overcharge tests of LFP modules, and the nail penetration test of the NMC module resulted in PM2.5 emissions exceeding 375 g/h and total PN emissions of the order of 2E + 17 part./h. These emission rates are 5 to 6 orders of magnitude higher than those typically emitted from the exhaust of a modern heavy-duty diesel engine. It is to be noted that the aforementioned statement is primarily to provide a contextual comparison with a well-documented particle emitter.

  * my note - particles are metal particulates, oxides, etc as discussed above – gases are generally asphyxiants and irritants. Not to bore anyone with statistics but an "order of magnitude" is generally 10x more than the subject of comparison so we are talking about 50-60 times the particulates that are emitted from a diesel exhaust. Diesel can be nasty but remember that they are designed to reduce particulate emissions from the exhaust and those particulates are NOT as toxic nor are they in the same quantities (especially for metals) as batteries. My opinion.

Nickel toxicity and environmental concerns – nickel is often the main metal cathode ingredient in NMC batteries – - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7037090/

Human exposure to highly nickel-polluted environments may cause a variety of pathological effects [34,35]. Accumulation of nickel and nickel compounds in the body through chronic exposure may be responsible for a variety of adverse effects on the health of human beings, such as lung fibrosis, kidney and cardiovascular diseases and cancer of the respiratory tract [36,37]. High incidence of nasal and lung cancer in workers exposed to nickel and nickel compounds was observed [37,38,39,40,41,42]. A small fraction of nickel is dermally absorbed, and Ni^{2+} ions and nickel particles penetrate the skin at sweat ducts and hair follicles. Moreover, dermal absorption of this metal is affected by solubilizing agents, such as detergents, and clothes and gloves that behave as a barrier to the skin.

*Remember, the warmer the particle the more easily it is absorbed through your skin.

Nickel nanoparticles are associated with reproductive toxicity.

Potential toxicity of nickel and nickel compounds is dependent on their physico-chemical characteristics, as well as the amount, duration of contact and route of exposure. Nickel can enter the body via inhalation, ingestion with food and dermal absorption; however, the route for this element to enter cells is determined by its chemical form. The riskiest route of exposure to nickel is by inhalation.

Insoluble nickel sulfide (Ni_2S_3) is a carcinogen agent for the respiratory tract: When it is inhaled, particles of nickel sulfide accommodate themselves in the lungs of human beings, where they remain in contact with epithelial cells. These nickel particles are removed by macrophages in the digestive tract. Under high exposure to nickel, the macrophage activity of removal could be perturbed, and Ni_2S_3 particles may be taken into epithelial cells by endocytosis. In this way, nickel particles are delivered to the nucleus of lung epithelial cells, causing a heritable change in chromosomes, inducing lesions of both double- and single-stranded DNA in cultured human cells.

Here are the random articles, YouTube videos, and other stuff you may find interesting and educational.

A MUST WATCH is Dr. Christensen's presentation (up top). He has trained hundreds or thousands of firefighters in Europe and Australia and he specifically talks about the vapors NOT being smoke and VCE's or vapor cloud explosions being a threat like Captain Clare shared with us in the two incidents he presented. The amount of gas produced by these things is scary and I believe he now puts that at 500-3000L per kWh (I think this older presentation states 300L-3000L of gas per kWh). The potential of major explosions (like that in AZ) is definitely real!

I recommend that your family watch this too so they recognize a vapor cloud, hissing, and the sound of pressure relief caps popping.

For reference, many e-mobility devices are .5 kWh or 1 kWh, Residential ESS systems can be 10-40 kWh, and EV's and larger grid or industrial ESS systems can be much larger. He also points believes the black smoke from initial venting of the cell(s) are the cathode metals and these do NOT dissipate so we are at risk of contamination, inhalation, or ingestion while conducting a scene exam, during a fire, or post-fire.

You may see references to carbon black or black carbon in the batteries (instead of graphite) – look it up – it's also a suspected carcinogen. Yes, I am a joy to have at dinner.

Something new I learned – a CO detector may well react to a venting battery that is heating but has not or does not catch fire because CO is a big part of the vapor cloud put out to relieve pressure inside the cell when thermal runaway begins. Keep this in mind if you are running a

truck and answer a CO alarm or a witness references a CO alarm activation prior to the fire. If you have batteries in your house I would have a CO detector even if you don't have gas appliances. You should always have a smoke detector in your garage. Just a recommendation from a fire investigator!

29 minute version:

SWFRS webinar with Prof Paul Christensen. Lithium-Ion Batteries and electric vehicles - YouTube

https://www.youtube.com/watch?v=rvRCz-2zcmM 41 minute version of same presentation (mostly)

Christensen video – "the new asbestos" – 13 minutes – he makes some great points about the lack of regulations https://www.youtube.com/watch?v=GfZPNSOGjgE&t=10s

What is a lithium-ion battery? Dr. Billy Wu – great introduction and overall view of the technology - https://www.youtube.com/watch?v=DBLHaLhyo2w&t=24s

Why do they catch fire? Dr. Billy Wu – I showed part of this during the presentation but it is very good and it is not long, you can forward through the graph portion where he talks about combustion properties of specific batteries so probably 9 minutes worth and watch the conclusion - https://www.youtube.com/watch?v=VWMfeseybt4&t=689s

YT – ABC Australia EV fires – references cobalt poisoning and vapor barrier and this is where the union president mentions firefighters medically retired from exposures (to cobalt). Australia is having a lot of battery fires. https://www.youtube.com/watch?v=NWvI1daNils

YT – EV fire in garage – newer model loaner Mercedes totals a house (it was NOT charging) and I am still impressed with the knockdown on this fire - https://www.youtube.com/watch?v=SIpXkQhq1ps

YT – EV fire in driveway with not a single SCBA being used – this kills me! https://www.youtube.com/watch?v=rItu9FIBsKE

YT – E-bike battery catches fire on video in garage - https://www.youtube.com/watch?v=2ex7Qf0j7Rw

YT – Phoenix Fire puts Tesla in container with wet sand – this is not an endorsement, but just throwing it out there in case you are interested but few fire agencies have as much experience as Phoenix with these fires – batteries don't like warm temperatures? https://www.youtube.com/watch?v=LUGu30hR_kU

YT – fire blanket news story - https://www.youtube.com/watch?v=3db6Wyl9CSQ

YT – EVFireSafe – EV van on fire in London – good educational presentation https://www.youtube.com/watch?v=mIIdMkwKLp4

YT – EV fire blanket demo – short https://www.youtube.com/watch?v=n_JINtx08iA

Toxic fluoride gases from fires – white paper - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5577247/

Cobalt toxicity in humans – white paper - https://pubmed.ncbi.nlm.nih.gov/28572025/

Lithium ion battery research – storage systems – ORNL – good stuff - https://www.osti.gov/servlets/purl/1963149

ECHA SDS cobalt oxide – Europeans believe it to be a carcinogen and impact reproductive health and lungs? - https://echa.europa.eu/substance-information/-/substanceinfo/100.013.777

CDC report on manganese toxicity - https://www.atsdr.cdc.gov/toxprofiles/tp151-c2.pdf

Comprehensive investigation of thermal and toxic hazards LIBs - https://www.sciencedirect.com/science/article/abs/pii/S0304389419308696

Toxic gas emissions from damaged LIBs - https://www.mdpi.com/2313-0105/2/1/5

Ecotoxicity of extinguishment water – always consider aquatic toxicity as a major threat to your community. We have to do what we have to do, but may come in handy to explain to the public why you chose to let it burn rather than flow a lot of water - https://pubs.acs.org/doi/10.1021/acs.est.2c08581

Particle emissions from battery fires - https://www.tandfonline.com/doi/full/10.1080/02786826.2021.2018399

LIB explosion hazards/aerosols - https://www.tandfonline.com/doi/full/10.1080/02786826.2021.1938966?src=recsys

Thermal runaway and EV contamination - https://www.dora.lib4ri.ch/empa/islandora/object/empa%3A29507/datastream/PDF/Held-2022-Thermal_runaway_and_fire_of-%28published_version%29.pdf

https://www.youtube.com/watch?v=rvdb1ce7hGo – StacheD M18 battery burns down truck – this is a good one to be aware of because tool pack battery fires happen and we are moving away from 2-cycle gas powered lawn equipment or snowblowers to battery powered equipment and that is very hard usage often with temperature extremes during use or storage. We will see more fires from these in the future and most of the time these are found in the garage.

Headline – 2 firefighters killed in China https://www.pv-magazine.com/2021/04/21/two-firefighters-killed-and-one-missing-after-beijing-battery-blaze/

Rivian Factory – 3 fires in a year (believe its 4 now) for local fire dept - https://insideevs.com/news/589006/rivian-normal-fire-battery-pack/

Scooter fire and explosion – BBC - https://www.bbc.com/news/uk-england-leeds-64881631

Recall fire for vacuum battery off Amazon - https://www.nbcchicago.com/consumer/explosions-fires-and-injuries-know-the-risks-behind-lithium-ion-batteries/3133300/

AZ ESS explosion and legal fights - https://spectrum.ieee.org/dispute-erupts-over-what-sparked-an-explosive-liion-energy-storage-accident

Fire investigators have battery explode during investigation – a good one to be aware of! https://www.denver7.com/news/local-news/close-call-lithium-ion-battery-explodes-in-adams-county-fire-investigators-face

EV in China explodes during suppression https://www.dailymotion.com/video/x7vpbzl

Australia 2 firefighters cobalt poisoned https://7news.com.au/lifestyle/motoring/firefighters-union-calls-for-government-action-on-ev-fire-risks-c-8827258

Australia original source for 2 firefighters….. https://www.carexpert.com.au/car-news/firefighters-union-calls-for-government-action-on-ev-fire-risks#article_comments

*Again, I don't know what happened to these firefighters but the source of this is the President of their firefighters union and he has never retracted or corrected the quote which has been widely used in the media. I really fear stories like this may become MORE common because of a lack of training and awareness within the fire service.

Scooter battery blows out wall into hallway https://www.linkedin.com/feed/update/urn:li:activity:7108327644307353601/

Tesla into garage FF in smoke and one on the roof - https://www.nbcnews.com/business/autos/federal-regulators-warn-risks-firefighters-electrical-vehicle-fires-n1271084

Overall news story good stuff https://www.youtube.com/watch?v=WKBDNtMlRfI

Toxicity of cobalt and nickel nanoparticles https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3501377/

Heavy metals and cancer - https://www.intechopen.com/chapters/76911

Cobalt exposure white paper - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7410254/ talks about inhalation hazard and dermal absorption

Ebikes Australia rekindle https://www.youtube.com/watch?v=fyY-tnohLiY

Mutagenity/carcinogenity of cobalt dust and oxides - https://pubmed.ncbi.nlm.nih.gov/2195331/

45000g of water for a Nissan Leaf? - https://www.wkrn.com/news/local-news/electric-vehicle-fire-in-franklin-requires-thousands-of-gallons-of-water/?ipid=inline-link

Followup story talks about the US Fire Admin - https://www.wkrn.com/news/local-news/electric-vehicle-fires-continue-to-fuel-concerns-among-first-responders/

Pollution in Congo – Spina Bifida and limb abnormalities - https://www.theguardian.com/global-development/2020/may/06/pollution-causing-birth-defects-in-children-of-drc-cobalt-miners-study

UK report on e-mobility fires – good product - https://www.electricalsafetyfirst.org.uk/media/sgyikuwb/esf_batterybreakdown_report_2023_v7_-final.pdf

Waste and Recycle Fires - https://www.linkedin.com/pulse/waste-recycling-fire-report-achieving-best-case-from-ryan?trk=news-guest_share-article

Thermal imaging of overcharge failure - https://www.youtube.com/watch?v=RedHpzZesPs&t=4s

Professor Guillermo Rein Twitter thread on innovation blind spots and stats – he has some good stuff on YouTube and I will try to link others - https://twitter.com/GuillermoRein/status/1552812305242521600

Recent lecture on LIB's by Professor Rein - https://www.youtube.com/watch?v=BUVw85SZciU

E-scooter fire on London subway BBC - https://www.youtube.com/watch?v=m24ZQ0SjriQ

Tesla First Responders Guide to ESS - https://www.tesla.com/firstresponders/industrial-energy-emergency-response-video

Energy Wall Fires Oct 23 – Recalls – Europe - https://www.pv-magazine.com/2023/10/10/germany-austria-hit-by-multiple-solar-battery-fires-in-september/

Recall on LG ESS Oct 23 - https://www.news.com.au/technology/accc-urgent-recall-on-lg-solar-storage-system-battery/news-story/283a4eb58dc011ababf2da6c687fb4e9

BESS fire problem – San Diego Oct 23 - https://www.sandiegouniontribune.com/business/story/2023-10-11/battery-storage-is-a-key-piece-of-californias-clean-energy-transition-but-theres-a-problem-with-fires

Update on fighting EV fires Denmark – new design and recommendations - https://cfpa-e.eu/new-knowledge-about-battery-fires-in-electric-cars-on-ferries/#:~:text=Jul%202022-,DBI%20%E2%80%93%20The%20Danish%20Institute%20of%20Fire%20and%20Security%20Technology%20has,consisting%20of%2040%2Dfoot%20containers

Electric buses under high rise apts Europe – bad idea? - https://www.telegraph.co.uk/money/net-zero/electric-bus-fire-threat-risks-tower-blocks-volcano/

CPSC recall on 550 sets of pajamas for flammability risks – irony? - https://www.cpsc.gov/Recalls/2023/Childrens-Pajamas-and-Nightdresses-Recalled-Due-to-Violation-of-Federal-Flammability-Standards-and-Burn-Hazard-Imported-by-Little-Cotton-Clothes-Recall-Alert

*I include this recall because this is the standard we have established to keep children safe from fire(s) so this goes directly to the risk/benefit analysis of school buses or mass transit. The failure can be quite sudden and violent, the venting can generate large vapor clouds of metal particulates, and an explosion or violent fire can occur. It is reasonable to believe that airplanes, submarines, ships, and other people movers greatly increase the risk of catastrophe with this

technology from an explosion, fire, or toxic exposure regardless of "how" or "why" a fire is started. These things should require the most stringent safety engineering to prevent venting into the passenger compartment as well as stringent maintenance and monitoring.

San Diego writing local codes after losing 4 trash trucks and for BESS - https://www.activistpost.com/2023/10/city-to-write-laws-for-regulating-storage-disposal-of-lithium-ion-batteries-for-evs-etc-after-losing-4-trash-trucks-to-fires-many-injuries.html

White paper on lithium battery contents - https://www.sciencedirect.com/science/article/pii/S2405844019347012

French LIB submarine – bad idea? - https://www.navalnews.com/naval-news/2023/10/france-offers-new-scorpene-evolved-li-ion-submarine-to-indonesia

20 ton electric excavator with batteries by Proterra - https://www.mequipment.ro/en/noi-excavatoare-electrice-komatsu-cu-baterii-in-clasa-20-de-tone/

Proterra bankruptcy filed – the battery management system is apparently being updated by the company that took that portion over and I hope that continues – https://techcrunch.com/2023/08/09/what-led-to-ev-darling-proterras-bankruptcy/ This is a real concern because quality manufacturers often update the BMS to make them safer, but if a company goes bankrupt the engineers are not working on this (think transit or school buses) so if a problem exists within the BMS the software remains the same

FDNY commissioner letter to Amazon for only UL or certified products sold – this is really becoming a big problem because the discount or knock-off market is not regulated for safety with no UL testing on products. Please always pay close attention to these products in your home and follow best practices! https://twitter.com/FDNYFC/status/1712949020379803937/photo/1

Aqueous rechargeable batteries – a solution? – no flammable electrolyte – I include this because you constantly hear about new battery tech that will change the game and lower risks. This is an example as are the solid state batteries, sodium ion, silicon, and others. I think we will get there eventually, but not any time soon as it often takes a long time to field new chemistries https://thedebrief.org/lithium-ion-batteries-could-soon-be-replaced-by-new-green-aqueous-rechargeable-batteries/

IPO listing for 2022 stats – 65% growth in demand – NMC vs LFP - https://twitter.com/IPOACADEMY01/status/1713860353413759041

NSW – scooter fire with video of aftermath – blew out window - https://www.fire.nsw.gov.au/incident.php?record=rec3hvFSdo2qjZKyh

Gulf clubhouse burns down – cart batteries? - https://www.youtube.com/watch?v=GekYcU-s9YI

Best study on cobalt toxicity? Jan 23 – Agency for Toxic Substances (CDC) - tp33.pdf (cdc.gov)

Cobalt toxicity and ionized cobalt – 2012 - Cobalt metabolism and toxicology--a brief update - PubMed (nih.gov)

Scooter battery explodes on Madrid subway - https://batteriesnews.com/explosion-madrid-metro-carriage-left-destroyed-after-faulty-e-scooter-battery-causes-blast/

Francesco Retuccia lithium battery fires lecture – https://www.youtube.com/watch?v=rJsoWD0J7bQ&t=522s

Lithium batteries a clear and present danger to CT with stats - https://ctbythenumbers.news/ctnews/lithium-ion-batteries-a-clear-and-present-danger-in-connecticut

Francesco Retuccia – Fire Science Show - https://www.firescienceshow.com/118-different-batteries-different-challanges-with-francesco-restuccia/

Why Tesla, GM And Other EV Companies Have A Fire Problem – CNBC https://www.youtube.com/watch?v=XWq-Mq1Uqpw

Science and technology of battery fire safety from Imperial College – some really good stuff on this one. Discusses the importance of heat dissipation and how that impacts larger scale systems AND the FACT that most research on battery fires have been done with single cells. Behavior (and risks) change as the packs become larger and this is VERY important to understand. The bigger the battery the higher the risks due to heat dissipation influence and more failure points? https://www.youtube.com/watch?v=LVSPbbXFd5g

Cobalt hip transplant failure/poisoning? This is the one I mention above. He also references the epidemic of cobalt in beer foam in the 60's (this really happened to beer drinkers). It's an interesting Ted Talk - https://www.youtube.com/watch?v=ksuFfbic6tA

Mike Abraham's (ATF electrical engineer) presentation on DCARI (great YouTube channel for fire investigators by the way) – let's get his hits up there! https://www.youtube.com/watch?v=ZWc0Gf07MU8

London Fire Brigade scooter - https://www.youtube.com/watch?v=Ka2hMktqoCY

UL testing of scooter in news story with rapid flash and explosion - https://www.youtube.com/watch?v=cC0t7foqr8k&t=29s

"It scares the daylights out of me:' Florida's top firefighter fears more lithium-ion battery fires" - https://www.youtube.com/watch?v=CC0KyXkJPlA

https://www.youtube.com/@evfiresafe7330/videos link to the EV Fire Safe videos on YouTube

Electric bus fire in downtown Paris – this is crazy. From other sources it sounds like the bus driver thankfully reacted to warnings and he evacuated the bus earlier to the bus behind this one in the video – There were over 100 of these very expensive buses that were pulled from service after this fire and one other (I believe from other sources) – I believe they are now back in service - https://www.youtube.com/watch?v=uA7SoM2DWuM

2 mechanics hurt after VTA bus fire (Proterra) – they dispute that it was the batteries but that is not what is important – fires will happen - https://www.youtube.com/watch?v=VmK8NpstKi0

Electric bus crash in Italy – media does not use word electric, but witnesses who rescued survivors were unable to get to survivors who were screaming due to the subsequent fire – any bus can catch fire and they do, but a LIB bus may pose some unique challenges https://www.youtube.com/watch?v=Id2CvnUVtBk

Chinese parked buses catch fire – we showed this one in presentation – consider this if you have e-buses in a bus barn or parked next to one another – rapid spread but remember this video is sped up a bit https://www.youtube.com/watch?v=T71cVhxG_v4

CT transit bus fire news story – we showed this during presentation - https://www.youtube.com/watch?v=_8YClwsWTyU

Bus fire in China that we showed – it's not funny but try to count how many people were on the bus! - https://www.youtube.com/watch?v=wzwqLekgDSc

Another bus barn fire that could have been much worse! https://www.youtube.com/watch?v=O8p4JUwb680

Lithium battery fire in a backpack – a lot of backpacks now contain charging banks of questionable quality (see how cheap they are on Amazon) or people are getting on planes with charging banks - https://www.youtube.com/watch?v=2cKVgaynEuA

Battery storage system fire in Idaho recently – these are happening more frequently as the number of these systems greatly increase and more are in transportation - https://www.youtube.com/watch?v=wmVCc_nKNu8

Battery fires in London and the UK – it's not just in NYC that is having many more of these - https://www.youtube.com/watch?v=9OvkNbbHGnQ

Lithium battery fire in a hostel in Australia - https://www.youtube.com/watch?v=j15GowW5f_g

Hotel fire caused by charging battery - https://www.youtube.com/watch?v=Ho_e6cDyjvQ

Great video showing how much gas these things can put out – Australia again, New South Wales Fire is estimating 1/3 fires they run on now are batteries – remember, these are ignitable vapors! https://www.youtube.com/watch?v=2AvBs3CI8pg&t=36s

Firefighter cancer report Canada – this is an excellent product - https://www.occupationalcancer.ca/wp-content/uploads/2024/01/FFCRPW-Report-Jan-2024.pdf

How are EV batteries recycled - https://blog.ucsusa.org/jessica-dunn/how-are-ev-batteries-actually-recycled/

Concerns about e-mobility fires – very good https://www.youtube.com/watch?v=G665T8eGAn8

Toxicity of metallic nano-particles paper - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9822575/

Li-ion batteries cause scrapyard fire - https://www.newshub.co.nz/home/new-zealand/2024/02/lithium-batteries-may-have-caused-large-t-huhu-scrap-yard-fire.html

Carbon black and cancer - https://www.ncbi.nlm.nih.gov/books/NBK326509/

Metals generated during thermal failure - https://pubs.rsc.org/en/content/articlehtml/2023/ya/d2ya00279e

ESS trends global 2023/2024 - https://www.energytrend.com/research/20231218-41985.html

Toxicity, Emissions and Structural Damage from Lithium-Ion Battery Thermal Runaway

https://www.mdpi.com/2313-0105/9/6/308

GC-MS was used to qualitatively detect and analyze the thermal runaway gaseous products of the battery. Dozens of toxic substances can be detected in thermal runaway products of LIBs with different cathode materials and SOC, among which six very toxic substances such as 2-propenal, methyl vinyl ketone, propanedinitrile, propanenitrile, 1,2-dimethyl-hydrazine and thiocyanic acid ethyl ester could be detected and analyzed. For NMC and LCO, high-SOC batteries had more types of products than low-SOC batteries. For LFP, most types of toxic products were detected in 30% SOC battery samples. At the same time, it was found that certain substances used as electrolyte solvents or additives may react with electrode materials or thermal runaway products during the thermal runaway process, **generating new products with higher toxicity.** Therefore, when choosing electrolyte solvents and various functional additives containing elements such as N, S, Cl, etc., more serious concern is needed.

*Academics are the best source we have right now to define the possible threats to health and safety, but as we saw in our EV battery burn and testing you can measure a lot of stuff but it does not tell you how much is present. However, we need to demand testing to quantify our exposures and the best source may be our PPE, bloodwork, and health. The statement that is bolded above is the biggest problem I see with these batteries.

Respiratory hazards of LIB's - https://dial.uclouvain.be/pr/boreal/object/boreal%3A196570/datastream/PDF_01/view

Janus Electric converted 16 semi-trucks to electric with 2 fires - https://bigrigs.com.au/2023/12/18/why-electric-truck-caught-fire-on-the-west-gate-freeway/

Nikolai Trucks in Phoenix – semi's – 209 built with 4 fires and now recalled

https://electrek.co/2023/09/08/nikola-trucks-cant-stop-catching-fire-4th/

Hummer fire on I-405 while we were at symposium – this is a very large battery for an EV (246kWh NMCA battery or about 4 average EV's)

https://www.king5.com/video/news/local/hit-and-run-crash-causes-hummer-ev-to-reignite-three-times/281-45bcf6f3-6667-47b4-b8f7-a8bb0198d919

Morris, IL (talked about in EPA presentation) accumulator mixed battery fire suspected to be between 100-200 tons abandoned in a warehouse. EPA cleanup still active I believe.

https://www.nbcchicago.com/news/local/nearly-100-tons-of-lithium-batteries-involved-in-large-morris-industrial-fire/2543694/

Battery recycling fire in France. Fires are not uncommon at these facilities that take in large amounts of unknown and possibly damaged batteries. 900 tons present allegedly

https://www.reuters.com/world/europe/french-recycling-plant-fire-housing-900-tonnes-lithium-batteries-2024-02-18/

Toronto e-bike fire on the subway – good points from the Chief about codes and regulations

https://www.youtube.com/watch?v=J22mbd70DxU

Another e-bike fire and explosion that will really get your attention!

https://www.youtube.com/watch?v=vJ4ODDLhjvI

Lithium battery fire in Harlem high-rise kills young man – rope rescue

https://www.youtube.com/watch?v=s356Y0hX6P8

The next asbestos or PFAS? https://www.pbs.org/newshour/show/what-we-know-about-toxic-forever-chemicals-and-how-to-reduce-our-exposure

Firefighters exposure to PFAS - https://www.frontiersin.org/articles/10.3389/fmats.2023.1143411/full

This is not all inclusive, but I hope you take what you learn(ed) and pass it on to others and I apologize for sounding like Dr. Doom but we deserve better answers about these things and all of us (and our families) should be very careful until we get some.

*Again, all ***opinions*** are mine and not those of ATF but I sincerely hope you develop your own "informed" opinions and ideas based on credible science and not the prevailing narratives or "tradition". This is new technology and it is going to take us a awhile to get our feet under us with it. We need to keep pushing for answers because this is important!

Feel free to reach out if you have any specific questions and if you come across something interesting, I always appreciate a note about it or a link! I will keep my phone number when I retire if the email does not work.

Stay safe and best wishes!

C. Todd Smith

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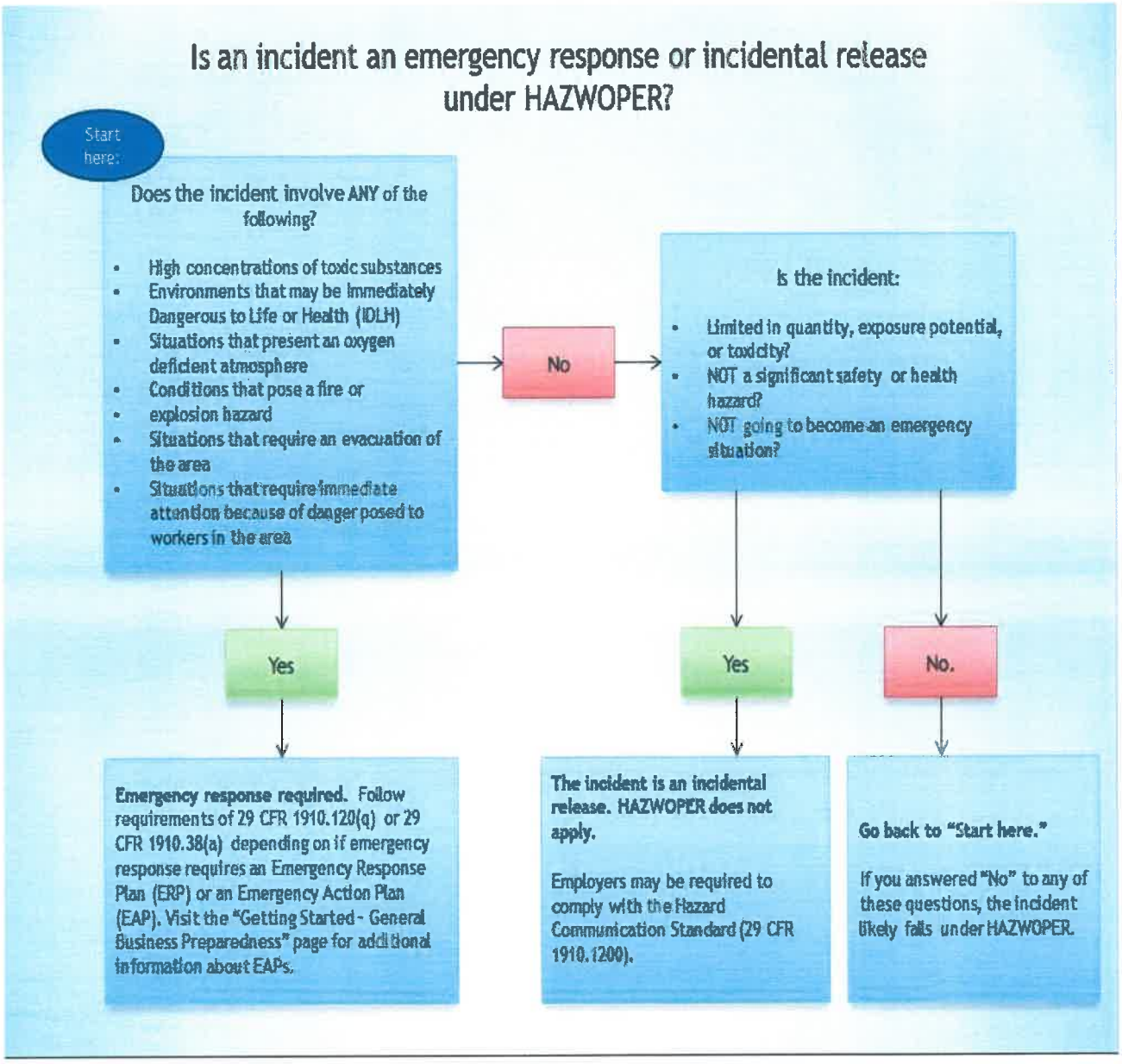
509-342-0652

"I would rather have questions that can't be answered than answers that can't be questioned." — **Richard P. Feynman**

Where is your battery fire?



Safety of Grid Scale Lithium-ion Battery Energy Storage Systems

Article · June 2021

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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."

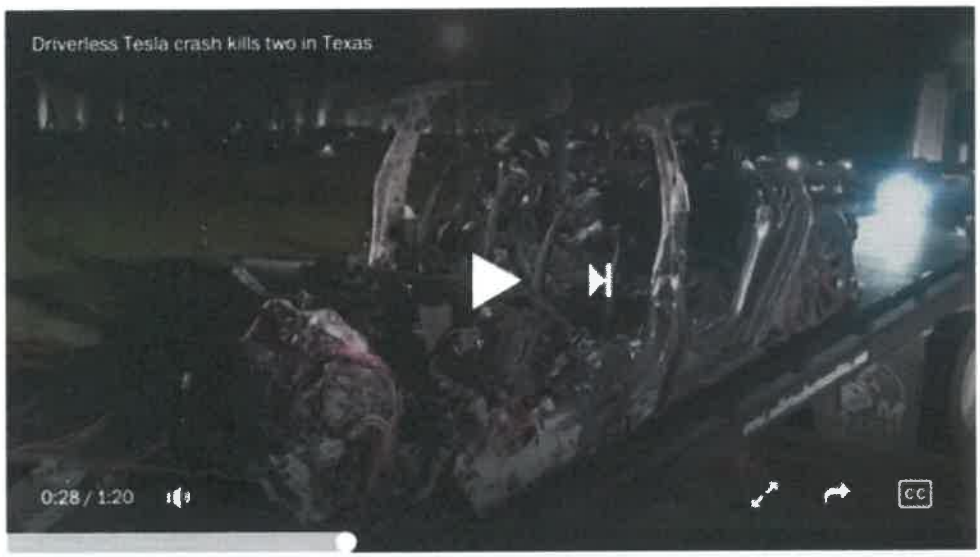
Location	Size	"Battery fire" cause	Time to bring under control	Water needed for cooling	Comments
Houston, Texas, April 2021	0.1 MWh	Driverless vehicle crash	4 hours	30,000 (US) gallons	Tesla Model S
South Korea	Various; 21 fires during 2018-19	Not known to Korean Ministry of Trade Industry and Energy	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.



Two men died after a Tesla vehicle, which authorities said was operating without a driver, crashed into a tree in a Houston suburb on April 17. (Reuters)

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.

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

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

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.

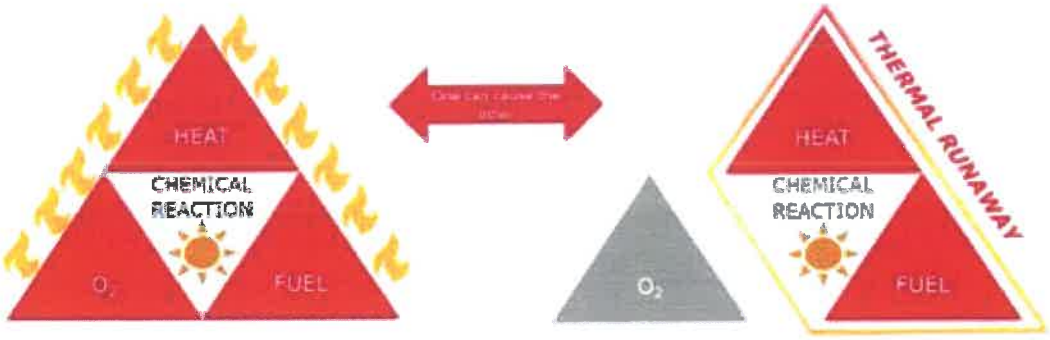


Figure 11 The fire triangle and its relationship to thermal runaway

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).

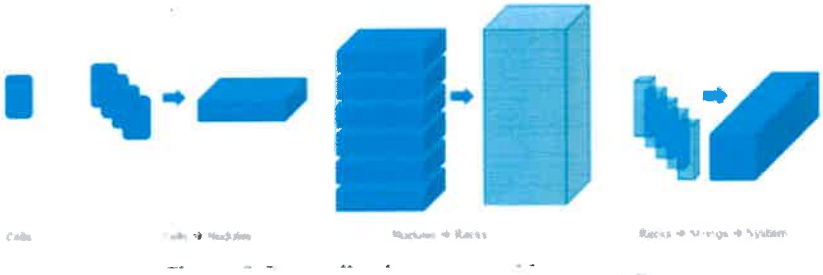


Figure 11: Cells stack into Modules; Modules into Racks; Racks into Strings; Strings into Systems.

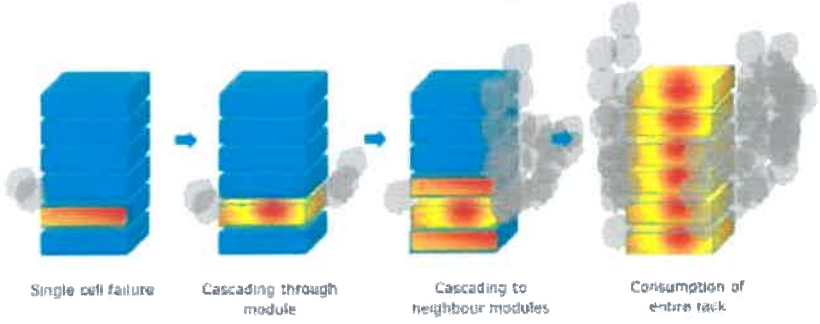
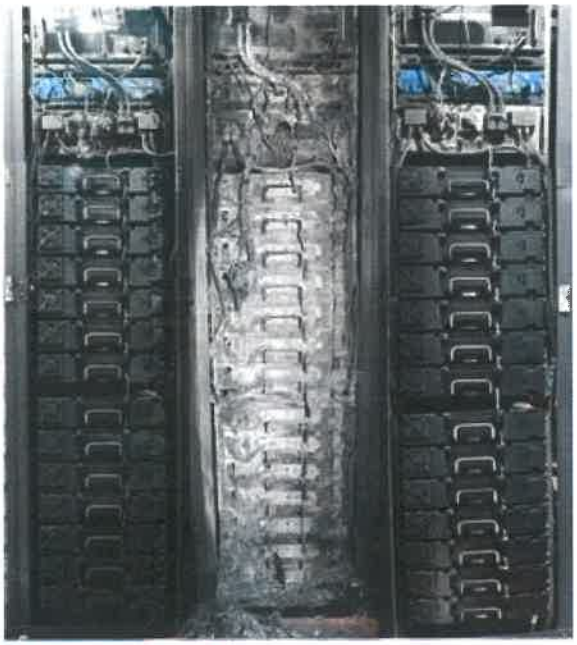


Figure 25 A single cell failure propagated through Module 2, then consumed the whole rack, releasing a large plume of explosive gases. This process could have occurred without visible flame, which would explain why the gases were not burned as they were emitted.

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 [1].

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.

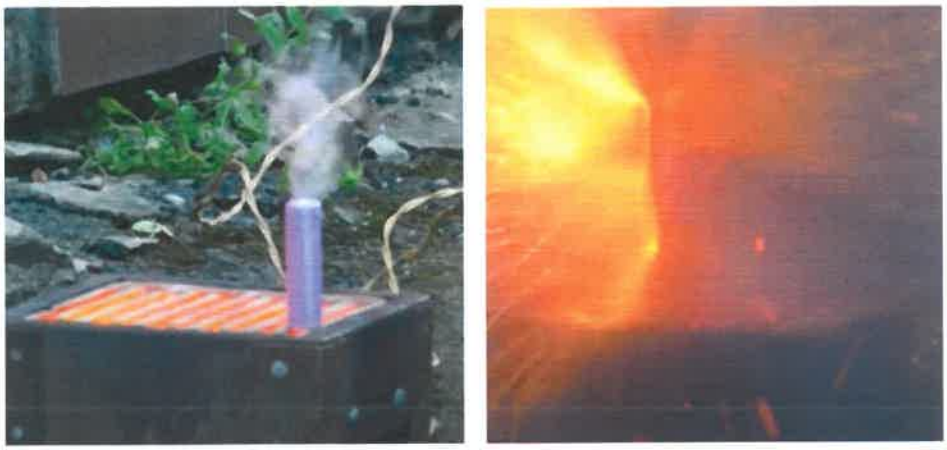


Figure 14: (a) A charged 2.6 Ah cell being deliberately overheated. (b) at the point of rupture (c) the cell takes off as a rocket (d) seconds later the discharge is complete, and the cell is red hot.

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 × 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

[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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Appendix 1 Figure 1 flowchart.

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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) (per cabin land)	75 m^2 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	3150 MWh	Stored electrochemical energy only.
			1.575 GWh	3.150 MWh	
			1.36 kilotons	2.71 kilotons	Does not include chemical energy from inflammables.
			2.72 "Beiruts"	5.44 "Beiruts"	

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 reasonable to foresee may be generated during loss of control 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.

[3] https://www.energy-storage.news/blogs/preventing-thermal-runaway-in-lithium-ion-energy-storage-systems

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.

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ESRG
ENERGY SAFETY
RESPONSE GROUP

September 26th, 2023

Mr. Paul Oberdorfer,

CC: Frank Patrizio, Brent Pohlschneider

Subject: Cessation of Testing Operations at Piqua Fire Training and Research Facility

Effective Friday, September 22nd, 2023, Energy Safety Response Group has ceased all destructive testing operations at the facility at 9300 OH-66, Piqua, Ohio. ESRG is working to re-route shipments of additional test materials slated to be received at the facility. If they cannot be re-routed in time, they will be shipped back out without performing any testing. In the immediate future, ESRG shall begin packing all equipment at the site, as well as remaining test specimens for shipment to other locations. These operations may involve the delivery of empty cargo containers to pack equipment and the use of cranes to load trucks. ESRG will remove electrical test equipment installed at their expense. ESRG shall leave in place a myriad of site improvements made at their expense as a goodwill gift to the people of Piqua.

ESRG is thankful for the opportunity to have worked with the city and their leadership team and wishes them the best of luck with the training center and all future endeavors.

Nick Warner
Principal, ESRG

Zimmer, Robert

Subject: FW: ESRG Piqua Battery Testing Site
Attachments: Re: Water Dropoff; Re: Water Disposal; Pit Vac; ESRG Water Sample Results Nov22.pdf; ESRG Water Sample Results Jun23.pdf

From: Nick Warner <nick.warner@energyresponsegroup.com>
Sent: Sunday, October 1, 2023 7:47 PM
To: Kavalec, James <James.Kavalec@epa.ohio.gov>; Brown, Russell <Russell.Brown@epa.ohio.gov>
Cc: Moran, Eileen <emoran@rapca.org>; Weisman, Andy <aweisman@rapca.org>; Buthker, Bonnie <Bonnie.Buthker@epa.ohio.gov>; Glasgow, Marcus <marcus.glasgow@epa.ohio.gov>
Subject: RE: ESRG Piqua Battery Testing Site

Mr. Kavalec,

See attached data per the request in Ohio EPA's notice of violation dated September 26, 2023 for wastewater collection and disposal records from the last three years.

During that time period, we have disposed of wastewater once in 2022 and once in 2023. This wastewater was tested prior to its removal from our facility, and those sample analyses are enclosed. The wastewater was removed by Buckeye Elm Contracting on both occasions. Buckeye Elm Contracting delivered the wastewater to Valicor Environmental Services in 2022 and to the City of Piqua wastewater treatment plant in 2023. The disposal records in our possession are enclosed.

A couple of notes when reviewing the data:

- Between the industry guidance of letting batteries burn, our need to minimize water because of containment limitations, and our desire to show that battery fires, with proper training, can be managed with minimal water; we always tried to use as little water as possible when managing these events.
    - This typically results in much higher concentrations than would be seen in normal firefighting operations where thousands of gallons are used indiscriminately.
    - This also explains why we have disposed of wastewater only twice during the last three years.
- We saw a bit of a slowdown in battery testing during COVID, coupled with increased industry guidance to not use water. Therefore, from early 2020 until now, we only had two water disposal runs. Disposal took place once we had received the results from the lab about contents.
- In February and April 2023, we performed two large outdoor tests in which some or all of the battery enclosure failed or came open after testing. This resulted in large quantities of the degraded batteries in the enclosure spilling out onto the north pad near the basin. Despite efforts to scoop everything back up into bins while dry, a lot of the particulate debris was swept or washed into the basin. I believe these two events contributed to the bulk of the nickel, manganese, and cobalt in the north basin in the 2023 disposal data as both of those tests were on lithium-ion batteries with nickel manganese cobalt oxide (NMC) electrodes.
- Samples from the holding tanks (IBCs) were combined into a composite sample with the idea that if anything came back high, we would sample them individually.
- We will be generating one more round of predisposal samples prior to disposal of the water on site currently. That water will be disposed of accordingly with basins drained to the bottom. Assuming no hazardous materials are present, ESRG will consider the pads and basins clean.

We are collecting the air emission information requested by the notice of violation and will provide that information as soon as that process is finished.

Nick

Nick Warner
Principal, Co-Founder
Cell: +1 740 981 7683
Email: nick.warner@energyresponsegroup.com

energyresponsegroup.com

From: James.Kavalec@epa.ohio.gov <James.Kavalec@epa.ohio.gov>
Sent: Thursday, September 28, 2023 7:40 AM
To: Nick Warner <nick.warner@energyresponsegroup.com>; Russell.Brown@epa.ohio.gov
Cc: emoran@rapca.org; aweisman@rapca.org; Bonnie.Buthker@epa.ohio.gov; marcus.glasgow@epa.ohio.gov
Subject: RE: ESRG Piqua Battery Testing Site

The information is attached. If you have questions you can email Marc Glasgow, he is with out legal office and can assist you with trade secret questions. I have copied him on this email

Environmental Protection Agency

James Kavalec
Assistant Chief of Compliance and Enforcement
50 W. Town Street, Suite 700
Columbus, Ohio 43215
D: 614.644.4840 C: 614.302.3587
James.Kavalec@epa.ohio.gov

From: Nick Warner <nick.warner@energyresponsegroup.com>
Sent: Thursday, September 28, 2023 2:20 AM
To: Kavalec, James <James.Kavalec@epa.ohio.gov>; Brown, Russell <Russell.Brown@epa.ohio.gov>
Cc: Moran, Eileen <emoran@rapca.org>; Weisman, Andy <aweisman@rapca.org>; Buthker, Bonnie <Bonnie.Buthker@epa.ohio.gov>
Subject: RE: ESRG Piqua Battery Testing Site

Mr. Kavalec,

Per our conversation yesterday, please connect me with your staff who can provide the information on submitting the requested data as trade secret.

Thank you,

Nick

ESRG
ENERGY SAFETY RESPONSE GROUP

Nick Warner
Principal, Co-Founder
Cell: +1 740 981 7683
Email: nick.warner@energyresponsegroup.com

energyresponsegroup.com

From: James.Kavalec@epa.ohio.gov <James.Kavalec@epa.ohio.gov>
Sent: Tuesday, September 26, 2023 2:29 PM
To: Nick Warner <nick.warner@energyresponsegroup.com>; Russell.Brown@epa.ohio.gov
Cc: emoran@rapca.org; aweisman@rapca.org; Bonnie.Buthker@epa.ohio.gov
Subject: RE: ESRG Piqua Battery Testing Site

Mr. Warner,

Attached is the Notice of Violation that was referenced in the email below, if you can please acknowledge receipt. Please feel free to reach out with questions.

Ohio Environmental Protection Agency

James Kavalec
Assistant Chief of Compliance and Enforcement
50 W. Town Street, Suite 700
Columbus, Ohio 43215
D: 614.644.4840 C: 614.302.3587
James.Kavalec@epa.ohio.gov

Alloway
Your Resource for Defensible Data

CERTIFICATE OF ANALYSIS

Reported by Alloway - Marion
Chain of Custody attached

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Lab Project #	2316958
Received:	5/17/2023
Reported:	5/30/2023
Date/Time Sampled:	05/16/2023 11:00
Sampled By:	BT
Sampled Matrix:	Surface Water
Containers:	2
Collection Method:	Grab

Project Name: ESRG House Water Disposal

Sample ID: House IBC Comp

Lab Sample # 2316958-01

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Analytical Method: EPA 300.0 Rev 2.1	**Preparation Method:**				**Validation Date:**	**5/30/2023**
Chloride	140	mg/L	5.0	DAW		05/24/2023 23:06
Analytical Method: SM 4500-F B,C-11, SM 4500-F C-97	**Preparation Method:**	**Undistilled**			**Validation Date:**	**5/30/2023**
Fluoride	152	mg/L	10.0	LGE		05/20/2023 06:30
Analytical Method: EPA 353.2 Rev. 2.0/SM4500-NO3 F-00,16	**Preparation Method:**				**Validation Date:**	**5/30/2023**
Nitrate/Nitrite-N	0.59	mg/L	0.50	TLL		05/25/2023 12:12
Analytical Method: SM 4500-H B-11	**Preparation Method:**				**Validation Date:**	**5/30/2023**
pH, Laboratory Analyzed (Estimate)	3.7	S.U.	1.0	LGE		05/18/2023 14:40
Analytical Method: SM 4500-P E-11	**Preparation Method:**	**SM 4500P-B(5)-11**			**Validation Date:**	**5/30/2023**
Phosphate, Total as P	47.1	mg/L	2.00	TLL		05/21/2023 11:32
Phosphate, Total as PO4	144	mg/L	6.00	TLL		05/21/2023 11:32
Analytical Method: EPA 300.0 Rev 2.1	**Preparation Method:**				**Validation Date:**	**5/30/2023**
Sulfate	63	mg/L	5.0	DAW		05/24/2023 23:06
Analytical Method: EPA 200.7 Rev. 4.4	**Preparation Method:**	**EPA-200.7**			**Validation Date:**	**5/30/2023**
Arsenic, Total	<15	ug/L	15	CMB		05/22/2023 08:27
Aluminum, Total	31000	ug/L	750	CMB		05/22/2023 08:27
Barium, Total	<50	ug/L	50	CMB		05/22/2023 08:27
Beryllium, Total	<2.5	ug/L	2.5	CMB		05/22/2023 08:27
Boron, Total	1300	ug/L	100	CMB		05/23/2023 12:27
Cadmium, Total	<2.5	ug/L	2.5	CMB		05/22/2023 08:27

Analysis Certified By: Rhonda C. Morris

Rhonda C Morris

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CERTIFICATE OF ANALYSIS

Reported by Alloway - Marion
Chain of Custody attached

Lab Project # 2316958
Received: 5/17/2023
Reported: 5/30/2023

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Date/Time Sampled: 05/16/2023 11:00
Sampled By: BT
Sampled Matrix: Surface Water
Containers: 2
Collection Method: Grab

Project Name: ESRG House Water Disposal

Sample ID: House IBC Comp

Lab Sample # 2316958-01

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Calcium, Total	61.2	mg/L	10.0	CMB		05/22/2023 08:27
Chromium, Total	90	ug/L	50	CMB		05/22/2023 08:27
Cobalt, Total	1400	ug/L	50	CMB		05/22/2023 08:27
Copper, Total	1200	ug/L	50	CMB		05/22/2023 08:27
Iron, Total	15000	ug/L	200	CMB		05/22/2023 08:27
Lead, Total	24	ug/L	10	CMB		05/22/2023 08:27
Magnesium, Total	22.8	mg/L	10.0	CMB		05/22/2023 08:27
Molybdenum, Total	<50	ug/L	50	CMB		05/22/2023 08:27
Manganese, Total	4700	ug/L	1000	CMB		05/22/2023 08:27
Nickel, Total	2400	ug/L	50	CMB		05/22/2023 08:27
Potassium, Total	17	mg/L	5.0	CMB		05/22/2023 08:27
Selenium, Total	<25	ug/L	25	CMB		05/22/2023 08:27
Silicon, Total	32.3	mg/L	5.00	CMB		05/22/2023 08:27
Sodium, Total	55.9	mg/L	2.00	CMB		05/22/2023 08:27
Strontium, Total	400	ug/L	50	CMB		05/22/2023 08:27
Tin, Total	120	ug/L	50	CMB		05/22/2023 08:27
Titanium, Total	350	ug/L	50	CMB		05/22/2023 08:27
Vanadium, Total	<50	ug/L	50	CMB		05/22/2023 08:27
Zinc, Total	72000	ug/L	1000	CMB		05/22/2023 08:27
Analytical Method: EPA 200.8 Rev. 5.4		**Preparation Method: EPA-200.8**			**Validation Date: 5/30/2023**	
Antimony, Total	200	ug/L	3.0	SLB		05/25/2023 22:31
Lithium, Total	200	ug/L	200	SLB		05/27/2023 23:18
Silver, Total	1.8	ug/L	1.0	SLB		05/25/2023 22:31

Analysis Certified By: Rhonda C Morris

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CERTIFICATE OF ANALYSIS

Reported by Alloway - Marion
Chain of Custody attached

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Lab Project #	2316958
Received:	5/17/2023
Reported:	5/30/2023
Date/Time Sampled:	05/16/2023 11:10
Sampled By:	BT
Sampled Matrix:	Surface Water
Containers:	1
Collection Method:	Grab

Project Name: ESRG House Water Disposal

Sample ID: House IBC Comp

Lab Sample # 2316958-01

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Thallium, Total	<1.0	ug/L	1.0	SLB		05/25/2023 22:31

Analysis Certified By: Rhonda C Morris

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Reported by Alloway - Marion
Chain of Custody attached

Lab Project # 2316958
Received: 5/17/2023
Reported: 5/30/2023

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Date/Time Sampled: 05/16/2023 11:10
Sampled By: BT
Sampled Matrix: Surface Water
Containers: 1
Collection Method: Grab

Project Name: ESRG House Water Disposal

Sample ID: House Fire Room

Lab Sample # 2316958-02

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Analytical Method: EPA 300.0 Rev 2.1	**Preparation Method:**				**Validation Date:**	**5/30/2023**
Chloride	9.1	mg/L	5.0	DAW		05/25/2023 00:32
Analytical Method: SM 4500-F B,C-11, SM 4500-F C-97	**Preparation Method:**	**Undistilled**			**Validation Date:**	**5/30/2023**
Fluoride	45.5	mg/L	2.50	LGE		05/20/2023 06:30
Analytical Method: EPA 353.2 Rev. 2.0/SM4500-NO3 F-00,16	**Preparation Method:**				**Validation Date:**	**5/30/2023**
Nitrate/Nitrite-N	<0.50	mg/L	0.50	TLL		05/25/2023 12:12
The matrix spike / matrix spike duplicate recoveries are biased below method limits.						
Analytical Method: SM 4500-H B-11	**Preparation Method:**				**Validation Date:**	**5/30/2023**
pH, Laboratory Analyzed (Estimate)	7.0	S.U.	1.0	LGE		05/18/2023 14:40
Analytical Method: SM 4500-P E-11	**Preparation Method:**	**SM 4500P-B(5)-11**			**Validation Date:**	**5/30/2023**
Phosphate, Total as P	19.6	mg/L	2.00	TLL		05/21/2023 11:32
Phosphate, Total as PO4	59.9	mg/L	6.00	TLL		05/21/2023 11:32
Analytical Method: EPA 300.0 Rev 2.1	**Preparation Method:**				**Validation Date:**	**5/30/2023**
Sulfate	160	mg/L	5.0	DAW		05/25/2023 00:32
Analytical Method: EPA 200.7 Rev. 4.4	**Preparation Method:**	**EPA-200.7**			**Validation Date:**	**5/30/2023**
Arsenic, Total	<15	ug/L	15	CMB		05/22/2023 08:27
Aluminum, Total	25000	ug/L	750	CMB		05/22/2023 08:27
Barium, Total	3400	ug/L	50	CMB		05/22/2023 08:27
Beryllium, Total	<2.5	ug/L	2.5	CMB		05/22/2023 08:27
Boron, Total	180	ug/L	100	CMB		05/23/2023 12:27

Analysis Certified By: Rhonda C Morris

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Reported by Alloway - Marion
Chain of Custody attached

Lab Project # 2316958
Received: 5/17/2023
Reported: 5/30/2023

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Date/Time Sampled: 05/16/2023 11:10
Sampled By: BT
Sampled Matrix: Surface Water
Containers: 1
Collection Method: Grab

Project Name: ESRG House Water Disposal

Sample ID: House Fire Room

Lab Sample # 2316958-02

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Cadmium, Total	<2.5	ug/L	2.5	CMB		05/22/2023 08:27
Calcium, Total	137	mg/L	10.0	CMB		05/22/2023 08:27
Chromium, Total	<50	ug/L	50	CMB		05/22/2023 08:27
Cobalt, Total	17000	ug/L	1000	CMB		05/22/2023 08:27
Copper, Total	4700	ug/L	1000	CMB		05/22/2023 08:27
Iron, Total	50000	ug/L	4000	CMB		05/22/2023 08:27
Lead, Total	70	ug/L	10	CMB		05/22/2023 08:27
Magnesium, Total	9.70	mg/L	0.50	CMB		05/22/2023 08:27
Molybdenum, Total	<50	ug/L	50	CMB		05/22/2023 08:27
Manganese, Total	17000	ug/L	1000	CMB		05/22/2023 08:27
Nickel, Total	33000	ug/L	1000	CMB		05/22/2023 08:27
Potassium, Total	9.8	mg/L	5.0	CMB		05/22/2023 08:27
Selenium, Total	<25	ug/L	25	CMB		05/22/2023 08:27
Silicon, Total	13.4	mg/L	5.00	CMB		05/22/2023 08:27
Sodium, Total	8.02	mg/L	2.00	CMB		05/22/2023 08:27
Strontium, Total	490	ug/L	50	CMB		05/22/2023 08:27
Tin, Total	280	ug/L	50	CMB		05/22/2023 08:27
Titanium, Total	390	ug/L	50	CMB		05/22/2023 08:27
Vanadium, Total	<50	ug/L	50	CMB		05/22/2023 08:27
Zinc, Total	3200	ug/L	50	CMB		05/22/2023 08:27
Analytical Method: EPA 200.8 Rev. 5.4		Preparation Method: EPA-200.8			Validation Date: 5/30/2023	
Antimony, Total	120	ug/L	3.0	SLB		05/25/2023 22:31
Lithium, Total	<500	ug/L	500	SLB		05/27/2023 23:18

Analysis Certified By: Rhonda C Morris

Rhonda C Morris

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Reported by Alloway - Marion
Chain of Custody attached

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Lab Project #	2316958
Received:	5/17/2023
Reported:	5/30/2023
Date/Time Sampled:	05/16/2023 11:10
Sampled By:	BT
Sampled Matrix:	Surface Water
Containers:	1
Collection Method:	Grab

Project Name: ESRG House Water Disposal

Sample ID: House Fire Room

Lab Sample # 2316958-02

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Silver, Total	<1.0	ug/L	1.0	SLB		05/25/2023 22:31
Thallium, Total	<1.0	ug/L	1.0	SLB		05/25/2023 22:31

Analysis Certified By: Rhonda C Morris

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Reported by Alloway - Marion
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Lab Project # 2316958
Received: 5/17/2023
Reported: 5/30/2023

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Date/Time Sampled: 05/16/2023 11:15
Sampled By: BT
Sampled Matrix: Surface Water
Containers: 1
Collection Method: Grab

Project Name: ESRG House Water Disposal

Sample ID: House Outside Pit North

Lab Sample # 2316958-03

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Analytical Method: EPA 300.0 Rev 2.1	Preparation Method:				Validation Date:	5/30/2023
Chloride	58	mg/L	5.0	DAW		05/25/2023 00:32
Analytical Method: SM 4500-F B,C-11, SM 4500-F C-97	Preparation Method:	Undistilled			Validation Date:	5/30/2023
Fluoride	194	mg/L	10.0	LGE		05/20/2023 06:30
Analytical Method: EPA 353.2 Rev. 2.0/SM4500-NO3 F-00,16	Preparation Method:				Validation Date:	5/30/2023
Nitrate/Nitrite-N	<0.50	mg/L	0.50	TLL		05/25/2023 12:12
Analytical Method: SM 4500-H B-11	Preparation Method:				Validation Date:	5/30/2023
pH, Laboratory Analyzed (Estimate)	9.9	S.U.	1.0	LGE		05/18/2023 14:40
Analytical Method: SM 4500-P E-11	Preparation Method:	SM 4500P-B(5)-11			Validation Date:	5/30/2023
Phosphate, Total as P	5.62	mg/L	0.20	TLL		05/21/2023 11:32
Phosphate, Total as PO4	17.2	mg/L	0.60	TLL		05/21/2023 11:32
Analytical Method: EPA 300.0 Rev 2.1	Preparation Method:				Validation Date:	5/30/2023
Sulfate	48	mg/L	5.0	DAW		05/25/2023 00:32
Analytical Method: EPA 200.7 Rev. 4.4	Preparation Method:	EPA-200.7			Validation Date:	5/30/2023
Arsenic, Total	<15	ug/L	15	CMB		05/22/2023 08:27
Aluminum, Total	26000	ug/L	750	CMB		05/22/2023 08:27
Barium, Total	390	ug/L	50	CMB		05/22/2023 08:27
Beryllium, Total	<2.5	ug/L	2.5	CMB		05/22/2023 08:27
Boron, Total	1900	ug/L	100	CMB		05/23/2023 12:27
Cadmium, Total	<2.5	ug/L	2.5	CMB		05/22/2023 08:27

Analysis Certified By: Rhonda C. Morris

Rhonda C Morris

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Reported by Alloway - Marion
Chain of Custody attached

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Lab Project #	2316958
Received:	5/17/2023
Reported:	5/30/2023
Date/Time Sampled:	05/16/2023 11:15
Sampled By:	BT
Sampled Matrix:	Surface Water
Containers:	1
Collection Method:	Grab

Project Name: ESRG House Water Disposal

Sample ID: House Outside Pit North

Lab Sample # 2316958-03

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Calcium, Total	21.9	mg/L	0.50	CMB		05/22/2023 08:27
Chromium, Total	<50	ug/L	50	CMB		05/22/2023 08:27
Cobalt, Total	100000	ug/L	10000	CMB		05/22/2023 08:27
Copper, Total	660	ug/L	50	CMB		05/22/2023 08:27
Iron, Total	1100	ug/L	200	CMB		05/22/2023 08:27
Lead, Total	37	ug/L	10	CMB		05/22/2023 08:27
Magnesium, Total	2.47	mg/L	0.50	CMB		05/22/2023 08:27
Molybdenum, Total	<50	ug/L	50	CMB		05/22/2023 08:27
Manganese, Total	120000	ug/L	10000	CMB		05/22/2023 08:27
Nickel, Total	220	ug/L	50	CMB		05/22/2023 08:27
Potassium, Total	19	mg/L	5.0	CMB		05/22/2023 08:27
Selenium, Total	62	ug/L	25	CMB		05/22/2023 08:27
Silicon, Total	5.46	mg/L	5.00	CMB		05/22/2023 08:27
Sodium, Total	14.0	mg/L	2.00	CMB		05/22/2023 08:27
Strontium, Total	120	ug/L	50	CMB		05/22/2023 08:27
Tin, Total	62	ug/L	50	CMB		05/22/2023 08:27
Titanium, Total	880	ug/L	50	CMB		05/22/2023 08:27
Vanadium, Total	<50	ug/L	50	CMB		05/22/2023 08:27
Zinc, Total	4800	ug/L	1000	CMB		05/22/2023 08:27
Analytical Method: EPA 200.8 Rev. 5.4		Preparation Method: EPA-200.8			Validation Date: 5/30/2023	
Antimony, Total	250	ug/L	3.0	SLB		05/25/2023 22:31
Lithium, Total	<1000	ug/L	1000	SLB		05/27/2023 23:18
Silver, Total	<1.0	ug/L	1.0	SLB		05/25/2023 22:31

Analysis Certified By: Rhonda C Morris

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Reported by Alloway - Marion
Chain of Custody attached

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Lab Project #	2316958
Received:	5/17/2023
Reported:	5/30/2023
Date/Time Sampled:	05/16/2023 11:20
Sampled By:	BT
Sampled Matrix:	Surface Water
Containers:	1
Collection Method:	Grab

Project Name: ESRG House Water Disposal

Sample ID: House Outside Pit North

Lab Sample # 2316958-03

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Thallium, Total	<1.0	ug/L	1.0	SLB		05/25/2023 22:31

Analysis Certified By: Rhonda C Morris

Rhonda C Morris

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CERTIFICATE OF ANALYSIS

Reported by Alloway - Marion
Chain of Custody attached

Lab Project # 2316958
Received: 5/17/2023
Reported: 5/30/2023

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Date/Time Sampled: 05/16/2023 11:20
Sampled By: BT
Sampled Matrix: Surface Water
Containers: 1
Collection Method: Grab

Project Name: ESRG House Water Disposal

Sample ID: House Outside Pit South

Lab Sample # 2316958-04

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Analytical Method: EPA 300.0 Rev 2.1	**Preparation Method:**				**Validation Date:**	**5/30/2023**
Chloride	5.3	mg/L	5.0	DAW		05/25/2023 00:32
Analytical Method: SM 4500-F B,C-11, SM 4500-F C-97	**Preparation Method:**		**Undistilled**		**Validation Date:**	**5/30/2023**
Fluoride	5.55	mg/L	0.100	LGE		05/20/2023 06:30
Analytical Method: EPA 353.2 Rev. 2.0/SM4500-NO3 F-00,16	**Preparation Method:**				**Validation Date:**	**5/30/2023**
Nitrate/Nitrite-N	<0.50	mg/L	0.50	TLL		05/25/2023 12:12
Analytical Method: SM 4500-H B-11	**Preparation Method:**				**Validation Date:**	**5/30/2023**
pH, Laboratory Analyzed (Estimate)	7.3	S.U.	1.0	LGE		05/18/2023 14:40
Analytical Method: SM 4500-P E-11	**Preparation Method:**		**SM 4500P-B(5)-11**		**Validation Date:**	**5/30/2023**
Phosphate, Total as P	2.29	mg/L	0.20	TLL		05/21/2023 11:32
Phosphate, Total as PO4	7.02	mg/L	0.60	TLL		05/21/2023 11:32
Analytical Method: EPA 300.0 Rev 2.1	**Preparation Method:**				**Validation Date:**	**5/30/2023**
Sulfate	5.7	mg/L	5.0	DAW		05/25/2023 00:32
Analytical Method: EPA 200.7 Rev. 4.4	**Preparation Method:**		**EPA-200.7**		**Validation Date:**	**5/30/2023**
Arsenic, Total	<3.0	ug/L	3.0	CMB		05/22/2023 08:27
Aluminum, Total	370	ug/L	150	CMB		05/22/2023 08:27
Barium, Total	27	ug/L	10	CMB		05/22/2023 08:27
Beryllium, Total	<0.5	ug/L	0.5	CMB		05/22/2023 08:27
Boron, Total	76	ug/L	10	CMB		05/23/2023 12:27
Cadmium, Total	<0.5	ug/L	0.5	CMB		05/22/2023 08:27

Analysis Certified By: Rhonda C Morris

Rhonda C Morris

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Reported by Alloway - Marion
Chain of Custody attached

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Lab Project #	2316958
Received:	5/17/2023
Reported:	5/30/2023
Date/Time Sampled:	05/16/2023 11:20
Sampled By:	BT
Sampled Matrix:	Surface Water
Containers:	1
Collection Method:	Grab

Project Name: ESRG House Water Disposal

Sample ID: House Outside Pit South

Lab Sample # 2316958-04

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Calcium, Total	18.5	mg/L	1.00	CMB		05/22/2023 08:27
Chromium, Total	<10	ug/L	10	CMB		05/22/2023 08:27
Cobalt, Total	1400	ug/L	100	CMB		05/22/2023 08:27
Copper, Total	16	ug/L	10	CMB		05/22/2023 08:27
Iron, Total	740	ug/L	40	CMB		05/22/2023 08:27
Lead, Total	4.3	ug/L	2.0	CMB		05/22/2023 08:27
Magnesium, Total	2.93	mg/L	0.10	CMB		05/22/2023 08:27
Molybdenum, Total	<10	ug/L	10	CMB		05/22/2023 08:27
Manganese, Total	5300	ug/L	100	CMB		05/22/2023 08:27
Nickel, Total	1400	ug/L	100	CMB		05/22/2023 08:27
Potassium, Total	10	mg/L	1.0	CMB		05/22/2023 08:27
Selenium, Total	<5.0	ug/L	5.0	CMB		05/22/2023 08:27
Silicon, Total	4.04	mg/L	1.00	CMB		05/22/2023 08:27
Sodium, Total	6.83	mg/L	0.40	CMB		05/22/2023 08:27
Strontium, Total	69	ug/L	10	CMB		05/22/2023 08:27
Tin, Total	<10	ug/L	10	CMB		05/22/2023 08:27
Titanium, Total	<10	ug/L	10	CMB		05/22/2023 08:27
Vanadium, Total	<10	ug/L	10	CMB		05/22/2023 08:27
Zinc, Total	820	ug/L	10	CMB		05/22/2023 08:27
Analytical Method: EPA 200.8 Rev. 5.4		Preparation Method: EPA-200.8			Validation Date:	5/30/2023
Antimony, Total	16	ug/L	3.0	SLB		05/25/2023 22:31
Lithium, Total	32	ug/L	20	SLB		05/27/2023 23:18
Silver, Total	<1.0	ug/L	1.0	SLB		05/25/2023 22:31

Analysis Certified By: Rhonda C Morris

Rhonda C Morris

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CERTIFICATE OF ANALYSIS

Reported by Alloway - Marion
Chain of Custody attached

Buckeye Elm Contracting
Attn: Bo Timmons
1333 Research Rd.
Columbus, OH 43230

Lab Project #	2316958
Received:	5/17/2023
Reported:	5/30/2023
Date/Time Sampled:	05/16/2023 11:20
Sampled By:	BT
Sampled Matrix:	Surface Water
Containers:	1
Collection Method:	Grab

Project Name: ESRG House Water Disposal

Sample ID: House Outside Pit South

Lab Sample # 2316958-04

pH was adjusted for P/NO3/Metals upon receipt.
Samples received outside of temperature requirement; analyze per client request.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Thallium, Total	<1.0	ug/L	1.0	SLB		05/25/2023 22:31

Analysis Certified By: Rhonda C Morris

Rhonda C Morris

Alloway
Your Resource for Defensible Data

CERTIFICATE OF ANALYSIS

Reported by Alloway - Marion
Chain of Custody attached

Lab Project # 2208003
Received: 11/21/2022
Reported: 12/8/2022

Buckeye Elm Contracting
Attn: Brad Timmons
782 Hartford St.
Worthington, OH 43085

Date/Time Sampled: 11/21/2022 13:30
Sampled By: BT
Sampled Matrix: Wastewater
Containers: 1
Collection Method: Grab

Project Name: ESRG Pit One

Sample ID: Fire Room Pit

Lab Sample # 2208003-01

pH was adjusted for metals upon receipt.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Analytical Method: EPA 1020A	**Preparation Method:**				**Validation Date:**	**12/8/2022**
Flashpoint	>110	o C	20	PDB		11/28/2022 13:38
Analytical Method: EPA 200.7 Rev. 4.4	**Preparation Method:**		**EPA-200.7**		**Validation Date:**	**12/8/2022**
Barium, Total	<100	ug/L	100	CMB		12/05/2022 08:41
Cadmium, Total	<5.0	ug/L	5.0	CMB		12/01/2022 13:21
Chromium, Total	<100	ug/L	100	CMB		12/01/2022 13:21
Lead, Total	39	ug/L	20	CMB		12/01/2022 13:21
Selenium, Total	<50	ug/L	50	CMB		12/05/2022 08:41
Silver, Total	<50	ug/L	50	CMB		12/05/2022 08:41
Analytical Method: EPA 200.8 Rev. 5.4	**Preparation Method:**		**EPA-200.8**		**Validation Date:**	**12/8/2022**
Arsenic, Total	<15	ug/L	15	SLB		12/01/2022 15:31
Analytical Method: EPA 245.1 Rev. 3.0	**Preparation Method:**		**EPA-245.1**		**Validation Date:**	**12/8/2022**
Mercury, Total	<0.200	ug/L	0.200	PTE	12/06/2022	12/07/2022 07:20

Analysis Certified By: Rhonda C Morris

Rhonda C Morris

Alloway
Your Resource for Defensible Data

CERTIFICATE OF ANALYSIS

Reported by Alloway - Marion
Chain of Custody attached

Lab Project # 2208003
Received: 11/21/2022
Reported: 12/8/2022

Buckeye Elm Contracting
Attn: Brad Timmons
782 Hartford St.
Worthington, OH 43085

Date/Time Sampled: 11/21/2022 13:35
Sampled By: BT
Sampled Matrix: Wastewater
Containers: 1
Collection Method: Grab

Project Name: ESRG Pit One

Sample ID: Outside Pit #1

Lab Sample # 2208003-02

pH was adjusted for metals upon receipt.

Analyte	Results	Units	PQL	Analyst	Extraction Date	Analysis Start Date/Time
Analytical Method: EPA 1020A	**Preparation Method:**				**Validation Date:**	**12/8/2022**
Flashpoint	>110	o C	20	PDB		11/28/2022 13:38
Analytical Method: EPA 200.7 Rev. 4.4	**Preparation Method:**	**EPA-200.7**			**Validation Date:**	**12/8/2022**
Barium, Total	1800	ug/L	100	CMB		12/05/2022 08:41
Cadmium, Total	<5.0	ug/L	5.0	CMB		12/01/2022 13:21
Chromium, Total	<100	ug/L	100	CMB		12/01/2022 13:21
Lead, Total	120	ug/L	20	CMB		12/01/2022 13:21
Selenium, Total	<50	ug/L	50	CMB		12/05/2022 08:41
Silver, Total	<50	ug/L	50	CMB		12/05/2022 08:41
Analytical Method: EPA 200.8 Rev. 5.4	**Preparation Method:**	**EPA-200.8**			**Validation Date:**	**12/8/2022**
Arsenic, Total	23	ug/L	15	SLB		12/01/2022 15:31
Analytical Method: EPA 245.1 Rev. 3.0	**Preparation Method:**	**EPA-245.1**			**Validation Date:**	**12/8/2022**
Mercury, Total	<0.200	ug/L	0.200	PTE	12/06/2022	12/07/2022 07:20

Analysis Certified By: Rhonda C Morris

Rhonda C Morris

Alliant

Power

Battery Energy Storage Systems Overview

As Wind and Solar power generation sources become more popular, these generators are turning to Battery Energy Storage Systems (BESS) as a cost-effective means to harness and deliver the power created from these renewable sources.

Battery Energy Storage Systems Overview

BESS is essentially a large collection of batteries where the power created can be stored and then released when needed. This allows storage and disbursement to happen in a more regulated way, which is also gaining popularity as a way to adapt to the changing demands of the grid. It is an important way to ensure energy sources like solar and wind, that are not able to capture power all the time, can still be a consistent source of energy. Their reliability and versatility allow for broad application, from utility-scale to residential-scale.

The current state of BESS growth continues to be exponential, with no end in sight. As manufacturers develop batteries with greater storage capacity and the costs of materials continue to decline, the global demand for batteries has soared. Additionally, the recently signed Inflation Reduction Act has created more incentives for a variety of industries to use battery technology.

Common Risks

While BESS is an attractive option in many ways, potential hazards remain in the vicinity of their installation and for the people who work around them. The number of losses in the installed base of BESS is already significant. The batteries themself can be an area of concern. Things like a manufacturing defect, design flaw, improper use or a charging issue can cause battery failure. One can expect that a fire in the enclosure will also have the same effect. When batteries fail, they often release combustible gases, which if not properly dissipated, can lead to an explosion.

Additionally, given a BESS is sometimes set up in a warehouse type environment, a big concern is that the overheating of one cell can overheat an adjacent cell, resulting in a cascading failure.

The current industry norm for BESS systems is lithium-ion technology. There are multiple battery technologies that fall under the lithium-ion battery classification, but there is now a clear and welcome trend within the lithium-ion market segment toward the use of Lithium Iron Phosphate (LFP) cells, which will reduce the risk profile of these systems. This technology continues to evolve, and new storage systems will need to be evaluated as they become available.

Another area of concern is BESS are often found in rural areas. If there is a fire or explosion, firefighting operations may not be able to respond quickly and there may not be a readily available water supply.

Current Market

While more renewable power generators are exploring BESS options, the insurance market is working to adequately address this area of risk. Renewable Energy companies face unique challenges to insure this risk as this is a new and often unfamiliar technology for underwriters. BESS has a high concentration of high-value assets in a single location, so chances or a total loss are higher. The battery technology is also constantly evolving, and underwriters may not always be up to date on the latest technology.

Given the complexity and evolving nature of the risks, it is crucial to engage a broker that understands the risks associated with BESS, that can help a company be an advocate in the marketplace. It is critical that a client with a BESS engage with industry specialists who understand the insurance and risk landscape. They can not only handle the application process, but they also have access to more specialist and competitive markets who understand and have the appetite to underwrite Wind, Solar and their BESS risks.

Alliant Renewable Energy

Alliant's dedicated Renewable Energy team is well-versed in this area of risk and is leading the charge in developing creative solutions for our clients. Our team will:

- Screen the risk by conducting more granular natural catastrophe modeling
- Capture relevant information, accurately and concisely, to better inform underwriters
- Review contracts and documents to ensure that finance and lending requirements are met and discrepancies are avoided early
- Provide loss control and safety support to make sure risks are being properly mitigated
- Keep clients informed of current trends and emerging issues

Ultimately, Alliant knows that BESS is going to continue to grow and be the dominate way to store power. Our team is committed to staying at the forefront of this industry and developing solutions to address risks as they continue to evolve.