HIGH LEVEL SAFETY HEALTH AND ENVIRONMENTAL RISK ASSESSMENT FOR THE PROPOSED DEVELOPMENT OF BATTERY ENERGY STORAGE SYSTEMS ASSOCIATED WITH THE PROPOSED BETHEL SOLAR PV FACILITY NEAR BANDELIERKOP IN THE LIMPOPO PROVINCE

17th August 2025

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ASSIGNMENT NO:	J3939M - 1
REPORT DATE:	17th August 2025
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REPORT ADMINISTRATIVE RECORD

LIST OF ASSESSMENTS

Assessment	Rev	Assessment Date	Description
SHE Risk Assessment	1	17th August 2025	J3939M – High Level Safety Health and Environmental Risk Assessment for The Proposed Development of Battery Energy Storage Systems associated with the Proposed Bethel Solar PV Facility near Bandelierkop Limpopo Province - issued by ISHECON

CONTRIBUTORS

The validity, results and conclusions of this assessment are based on the expertise, skills and information provided by the following contributing team members:

NAME	ORGANISATION	DISCIPLINE
Dale Holder	Cape EAPrac	Environmental Assessment Practitioner

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Although every effort has been made by ISHECON to obtain the correct information and to carry out an appropriate, independent, impartial and competent study, it remains the responsibility of the Contractor to ensure suitable Process Safety Measures are in place. ISHECON cannot be held liable for any accident or incident, due to negligence by the owner/operator, which directly or indirectly relates to the plant, equipment, facilities and systems analysed in this document and which may have an effect on the client or any other third party.

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RISK ASSESSMENT APPROVAL

This report is approved for issue by the undersigned Technical Signatory as per the ISHECON.

NAME	CAPACITY	REPORT DATE	SIGNATURE
D.C. Mitchell	Risk Assessment, Report preparation, Technical signatory	17th August 2025	

EXECUTIVE SUMMARY

Bethel Solar PV (Pty) Ltd propose to develop an energy facility, the Bethel Solar PV, to be located approximately 11km west of the town of Bandelierkop in the Makhado Local Municipality, Vhembe District, Limpopo Province of South Africa. Site access is via gravel roads off of the N1 which runs north-south through Bandelierkop.

The proposed Bethel Solar PV is not located within one of the promulgated Renewable Energy Development Zones (REDZ) and is subject to a Scoping and Environmental Impact Assessment (S&EIA) process.

It is proposed that the Bethel Solar PV will have a capacity of up to 240MW and will connect via new powerlines (132kV) into the National Grid via the Tabor Main Transmission Substation. The proposed Bethel Solar PV will have a Battery Energy Storage Systems (BESS) of up to 240MW / 960MWh. For the BESS there is only one proposed location. Solid state technologies will be used, with chemistries such as Lithium-ion or Sodium-sulphide, however, the specific technology will only be determined following Engineering, Procurement and Construction (EPC) procurement.

In 2019, the Department of Forestry, Fisheries and the Environment (DFFE) requested that EIA applications for BESSs, either on their own or as part of a power generation (e.g., PV or wind) application, should include a high-level Risk Assessment of the BESS considering all applicable risks (e.g., fire, explosion, contamination, end-of life disposal etc).

This report summaries the high-level Safety, Health and Environmental (SHE) Risk Assessment conducted by ISHECON for the BESS at the proposed Bethel Solar PV.

1. METHODOLOGY

This assessment of risk comprises:

- Identification of the likely hazards and hazardous events related to the construction, operation and decommissioning of the installation using a checklist approach.
- Estimation of the likelihood/probability of these hazardous events occurring.
- Estimation of the consequences of these hazardous events.
- Estimation of the risk and comparison against certain acceptability criteria.

For the purpose of this high-level Risk Assessment a desktop study of the available information, preliminary layout of the facility and associated BESS alternative locations, reports of related incidents and various literature sources was undertaken and no physical site visit was conducted. The facility and the project were divided into the sections/phases and using a checklist approach the hazards in each section/phase were identified. Each identified hazard was then analysed in terms of causes, consequences, expected and suggested preventive and mitigative measures to be in place. Each hazard was qualitatively assessed using a qualitative risk ranking system.

2. FINDINGS

2.1 GENERAL

- This Risk Assessment has found that with suitable preventative and mitigative measures in place, none of the identified potential risks are excessively high, i.e., from a Safety, Health and Environment (SHE) perspective no fatal flaws were found with either type of technology for the BESS installation at the proposed Bethel Solar PV near Bandelierkop.

- At a large facility, without installation of the state-of-the art battery technology that includes protective features, there can be significant risks to employees and first responders. The latest battery designs include many preventative and mitigative measures to reduce these risks to tolerable levels. (Refer to tables in section 4 under preventative and mitigative measures). State-of-the-art technology should be used, i.e., not old technology, such as liquid phase lithium ion batteries, that may have been prone to fire and explosion risks.

- The design should be subject to a full Hazard and Operability Study (HAZOP) prior to commencement of procurement. A HAZOP is a detailed technical systematic study that looks at the intricacies of the design, the control system, the emergency system etc. and how these may fail under abnormal operating conditions. Additional safeguards may be suggested by the team doing the study.

- For most projects, from an acute health and safety point of view, the No-Go option will usually be a preferred option since there are no immediate health and safety risks associated with not doing a project, i.e. no one can get hurt if something does not exist. However, some projects aim to reduce adverse effects elsewhere and can be viewed at offsetting either current or future risks. In this case, renewable energy projects should help to mitigate possible adverse impacts of climate change, create jobs and contribute to sustainable energy, i.e. the project risks are offset against future social risk reduction

2.2 LITHIUM SOLID STATE CONTAINERIZED BATTERIES

- With lithium solid-state batteries, the most significant hazard with battery units is the possibility of thermal runaway and the generation of toxic and flammable gases. There have been numerous such incidents around the world with lithium-ion batteries at all scales and modern technology providers include many preventative and mitigative features in their designs, e.g. solid state electrolytes being one of these improvements. This type of event also generates heat which may possibly propagate the thermal runaway event to neighbouring batteries if suitable state of the art technology is not employed.

- The flammable gases generated may ignite leading to a fire which accelerates the runaway process and may spread the fire to other parts of the BESS or other equipment located near-by.

- If the flammable gases accumulate within the container before they ignite, they may eventually ignite with explosive force. This type of event is unusual with solid state batteries, but has happened with an older technology container installed at McMicken in the USA in 2019.

- Due to a variety of causes, thermal runaway could happen at any point during transport to the facility, during construction or operation / maintenance at the facility or during decommissioning and safe making for disposal.

- Due to the containerized approach as well as the usual good practice of separation between containers, which should be applied on this project, and therefore the likely restriction of events to one container at a time, the main risks are close to the containers i.e., to transport drivers, employees at the facilities and first responders to incidents.

- In terms of a worst conceivable case container fires, the significant impact zone is likely to be limited to within 10m of the container and mild impacts to 20m. Based on the current proposed layouts, radiation impacts at the closest isolated farmhouses are not expected.

- In terms of a worst conceivable case explosion, the major impact zone is likely to be limited to with 10m of the container, noticeable damage within 25m and minor impacts such as debris within 50m. Based on the current proposed layouts, explosion impacts at the closest isolated farmhouses are not expected.

- In terms of a worst reasonably conceivable toxic smoke scenario, provided the units are placed suitably far apart to prevent propagation from one unit to another and large external fires are prevented, the amount of material burning should be limited to one container at any one time. In this case, beyond the immediate vicinity of the fire, the concentrations of harmful gases within the smoke should be low.

- For the Bethel Solar PV, the BESS location is over 500m from any occupied farmhouse and in this context the location is therefore considered suitable in terms of toxic gas risks.

2.3 SODIUM-SULPHIDE SOLID STATE CONTAINERIZED BATTERIES

- With sodium-sulphide solid-state batteries, the most significant hazard with battery units is the presence of sodium and the possibility of some failure (mechanical or electrical) leading to a sodium and sulphur fire. In addition to an intense localized fire there could be generation of toxic gases. There have been a few such incidents in the early days of these batteries. Modern technology providers include many preventative and mitigative features in their designs. This type of event also generates heat which may possibly thermal instability neighbouring batteries propagate if suitable state of the art technology is not employed.

- The fire, explosion and toxic smoke events are not expected to be significantly worse than those estimated for the lithium batteries and similar on site separation distances should be applied, e.g. to occupied buildings, electrical infrastructure etc.

- For the Bethel Solar PV, the BESS location is over 500m from any occupied farmhouse and in this context the location is therefore considered suitable in terms of fire, explosion and toxic gas risks to the public outside the site.

- Suitable Battery Management System (BMS), safety procedures, operating instructions, maintenance procedures, trips, alarms and interlocks should be in place. (Refer to tables in section 4 under preventative and mitigative measures).

2.4 TECHNOLOGY AND LOCATION OF BESS FACILITIES

- Overall, from a SHE RA points of view, there is no specific preference for a type of technology.

- From a SHE risk assessment point of view, where there is a choice of location that is further from public roads, water courses, isolated farmhouses or other occupied facilities, this would be preferred. The current chosen location is suitably far from the above with a very low risk of any significant impacts.

2.5 CUMULATIVE IMPACTS

- Unless another BESS is installed within 500m of the BESS location proposed for this project, cumulative impacts of other developments in the greater area do not affect the safety and health of employees, contractors of members of the public within the BESS impact zone. The same can be said for the BESS electrical infrastructure and grid connection.

3. RECOMMENDATIONS

The following recommendations have been made:

- There are numerous different battery technologies, but using one consistent battery technology system for the BESS installations associated with all the developments in the Bandelierkop Area would allow for ease of training, maintenance, emergency response and could significantly reduce risks.

- Where reasonably practicable, state-of-the-art battery technology should be used with all the necessary protective features e.g., draining of cells during shutdown and standby-mode, full BMS with deviation monitoring and trips, leak detection systems.

- There are no fatal flaws associated with the proposed Bethel battery installation for either technology type.

- The tables in Section 4 of this report contains technical and systems suggestions for managing and reducing risks. Ensure the items listed in these tables under preventative and mitigative measures are included in the design.

- The overall design should be subject to a full Hazop prior to finalization of the design.

- Prior to bringing any solid-state battery containers into the country, the contractor should ensure that:
    - An Emergency Response Plan is in place that would be applicable for the full route from the ship to the site. This plan would include details of the most appropriate emergency response to fires both while the units are in transit and once they are installed and operating.
    - An End-of-Life plan is in place for the handling, repurposing or disposal of dysfunctional, severely damaged batteries, modules and containers.

- The site layout and spacing between solid-state containers should be such that it mitigates the risk of a fire or explosion event spreading from one container to another. The battery supplier should be able to provide guidance as well as technical proof that the proposed container to container separation distances are adequate.

- Suitable separation must also be ensured between the BESS containers and other onsite facilities such as transformers, any high voltage overhead powerlines etc. In this regard there are National Fire Protection Agency (NFPA - USA) and Eskom guidelines. Suitable separation must also be ensured between the BESS containers and other onsite facilities such as transformers, any high voltage overhead powerlines etc. In this regard there are National Fire Protection Agency (NFPA - USA) and Eskom guidelines.

- Separation from offices (O&M) areas should be at least 25m to avoid direct damage from possible explosions and fires and possibly be 50m to avoid minor impacts explosion debris.

- Under certain weather conditions, the noxious smoke from a fire in a lithium battery container or a sodium-sulphide battery container could travel some distance from the unit. The smoke will most likely be acrid and could cause irritation, coughing, distress etc. Close to the source of the smoke, the concentration of toxic gases may be high enough to cause irreversible harmful effects. Location of the facilities needs to ensure a suitable separation distance from public facilities/residences etc. The current proposed BESS location is over 500m from isolated farmhouses / other occupied facilities and is therefore suitable. The risks of significant impacts is very low.

- Where there is a choice of alternative locations for the BESS, those that are further from water courses would be preferred. The buffer distance between water bodies and the facilities containing chemicals should be set in consultation with a water specialist and is therefore not specified in this SHE RA. It should be noted that the location is well over 100m from the closest stream and will likely be suitable.

- Finally, it is suggested once the technology has been chosen and more details of the actual design are available, the necessary updated Risk Assessments should be in place.

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GLOSSARY OF SOME TERMS POSSIBLY USED IN THIS REPORT

Units, acronyms, abbreviations	Definition
BA	Basic Assessment or Breathing Apparatus
BEI	Biological Exposure Index (Refers to values in blood or urine, etc., as per to OHS Act)
BESS	Battery Energy Storage System
BMS	Battery Management System
°C	Degrees Celsius
dB	Decibels
DC / AC	Direct Current / Alternating Current
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and the Environment
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
ERPG	Emergency Response Planning Guideline (a series of values in ppm or mg/m^3 that indicates various levels health effects if exposed to this concentration for more than 60 minutes)
E-stop	Emergency stop button
FP	Flash Point
HAZOP	Hazard and Operability Study
HBA	Hazardous Biological Agents (Refers to pathogens, parasites, cell cultures, etc., - Refer to the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993) as amended
HCS	Hazardous Chemical Substances (Refers to a list of hazardous chemicals - Refer to the OHS Act)
HV / MV	High Voltage / Medium Voltage
IDLH	Immediately Dangerous to Life and Health (a value in ppm or mg/m^3 that indicates serious health effects if exposed to this concentration for more than 30 minutes)
IMDG	International Marine Dangerous Good
km	Kilometres
kPa	Kilopascal
kW	Kilowatts
kWh	Kilowatt hour
m^3	Metres cubed
MW	Megawatts
MWh	Megawatt hour
NASA	National Aeronautics and Space Administration
NEMA	National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended
NFPA	National Fire Protection Agency
NRT Act	National Road Traffic Act, 1996 (Act No. 93 of 1996) as amended (Chapter 8 deals with transportation of dangerous goods) Note various South African National Standards are incorporated into the regulations.
OEL	Occupational Exposure Limit (usually in ppm or mg/m3 in the air for each HCS as defined in the Hazardous Chemical Substances Regulations of the OHS Act)
OHS Act	Occupational Health and Safety Act, 1993 (Act No. 85 of 1993)
PPE	Personal Protective Equipment
ppm	Parts Per Million
PV	Photovoltaic
RA	Risk Assessment
RQ	Reportable Quantity in terms of NEMA to DFFE
QC / QA	Quality Control or Quality Assurance
SANS	South African National Standards
SDS	Safety Data Sheet

Units, acronyms, abbreviations	**Definition**
SHE (Q)	Safety, Health, Environment (Quality)
SSLB	Solid State Lithium Batteries
TWA (8 hrs)	Time weighted average of 8 hrs
VOC	Volatile Organic Carbons
VRFB	Vanadium redox flow battery
USA	United States of America
WEF	Wind Energy Facility
WBGT Index	An index in degrees Celsius composed of fractions of the Wet Bulb, Globe and Dry Bulb Temperatures (Refer to Environmental Regulations under the OHS Act)

1. INTRODUCTION

1.1 SCOPE OF ASSESSMENT

Bethel Solar PV (Pty) Ltd propose to develop an energy facility the Bethel Solar PV to be located approximately 11km west of the town of Bandelierkop in the Makhado Local Municipality, Vhembe District, Limpopo Province of South Africa. Site access is via gravel roads off of the N1 which runs north-south through Bandelierkop.

The proposed Bethel Solar PV is not located within one of the promulgated Renewable Energy Development Zones (REDZ) and is subject to a Scoping and Environmental Impact Assessment (S&EIA) process.

It is proposed that the Bethel Solar PV will have a capacity of up to 240MW and will connect into the National Grid via the Tabor Main Transmission Substation. The proposed Bethel Solar PV will have a Battery Energy Storage Systems (BESS) of up to 240MW / 960MWh. For the BESS there is only one proposed location. Solid state technologies will be used, with chemistries such as Lithium-ion or Sodium-sulphide, however, the specific technology will only be determined following Engineering, Procurement and Construction (EPC) procurement.

In 2019, the Department of Forestry, Fisheries and the Environment (DFFE) requested that EIA applications for BESSs, either on their own or as part of a power generation (e.g., PV or wind) application, should include a high-level Risk Assessment of the BESS considering all applicable risks (e.g., fire, explosion, contamination, end-of life disposal etc).

This report summaries the high-level Safety, Health and Environmental (SHE) Risk Assessment conducted by ISHECON for the BESS at the proposed Bethel Solar PV.

Although this assessment is based on the best available information and expertise, ISHECON cc cannot be held liable for any incident that may occur on this installation and associated equipment which directly or indirectly relate to the work in this report.

1.2 EIA REGULATION SCOPE OF APPLICATION

This Risk Assessment is conducted as a technical input into the EIA process for the proposed Bethel Solar PV to comply with the requirement for a high-level Health and Safety Assessment, and it does not necessarily comply with all the requirements of a specialist study as defined in Appendix 6 of the Environmental Impact Assessment Regulations of 2014, as amended, under the National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended (NEMA).

1.3 RISK ASSESSMENT METHODOLOGY

This Risk Assessment will consider the technology in detail. However, considering the general risks posed by the technology, each of the possible locations will be assessed with respect to advising on preferred locations from a SHE perspective.

Risk is made up of two components:

- The probability of a certain hazardous event or incident occurring.
- The severity of the consequences of that hazardous event / incident.

Therefore, this assessment of risk comprises:

- Identification of the likely hazards and hazardous events related to the operation of the installation.
- Estimation of the likelihood/probability of these hazardous events occurring.
- Estimation of the consequences of these hazardous events.
- Estimation of the risk and comparison against certain acceptability criteria.

For the purpose of this high-level Risk Assessment a desktop study of the available information, preliminary layout of the facility and associated BESS alternative locations, reports of related incidents and various literature sources was undertaken and no physical site visit was conducted. Based on this information the facility and the project were divided into the following phases:

- construction,
- operation,
- decommissioning (end of life).

This study makes use of a qualitative risk ranking system framework[1]. The method considers the nature of what causes the effect, what will be affected and how it will be affected.

TABLE 1.3.1 NATURE OF POSSIBLE IMPACTS

NATURE OF IMPACT	DEFINITION
Beneficial / Positive	An impact that is considered to represent an improvement on the baseline or introduces a positive change.
Adverse / Negative	An impact that is considered to represent an adverse change from the baseline, or introduces a new undesirable factor.
Direct	Impacts that arise directly from activities that form an integral part of the Project (e.g., new infrastructure).
Indirect	Impacts that arise indirectly from activities not explicitly forming part of the Project (e.g., noise changes due to changes in road or rail traffic resulting from the operation of Project).
Secondary	Secondary or induced impacts caused by a change in the Project environment (e.g., employment opportunities created by the supply chain requirements).
Cumulative	Impacts are those impacts arising from the combination of multiple impacts from existing projects, the Project and/or future projects.

A Health and Safety Risk Assessment is focussed on hazards arising from the construction, operation and decommissioning of a facility and their impact on humans, either employees or members of the public outside the site. By definition the nature of the chemical and machine hazards is negative, i.e., adverse impact on health and safety. Some of the impacts are immediate and direct such as effects of fires and explosions or exposure to high concentrations of chemicals (in health and safety we refer to these as acute impacts). Other impacts are longer term such as repeated exposure to low concentrations of harmful chemicals, noise etc. (in health and safety we refer to these as chronic impacts).

[1] Adapted from a method developed by WSP to meet the combined requirements of international best practice and NEMA, Environmental Assessment Regulations, 2014, as amended (GN No.326) (the “EIA Regulations”).

Using the checklist detailed in Table 1.3.1 the hazards in each section/phase were identified. Each identified hazard was then described by the assessor in terms of causes, consequences, preventive and mitigative measures in place.

Each hazard was qualitatively dimensioned and assessed using the method as per Table 1.3.2. There are five dimensioning criteria in this method:

- The magnitude of impact on the processes of interest (i.e., human health and safety) e.g., no impact, moderate impact and will alter the operation of the process (e.g., injuries), very high impact and will destroy the process (e.g., fatalities).
- The physical extent, e.g., will it be limited to the site or not.
- The duration, i.e., how long will the person bear the brunt of the impact.
- Reversibility: an impact may either be reversible or irreversible, e.g., fatalities are permanent, while it may be possible to recover from injuries.
- The probability of occurrence of the impact.

After dimensioning these aspects, a combined overall risk / significance was calculated for each hazard, see Table 1.3.3.

The impact significance without design controls, preventative and mitigation measures will be assessed. Impacts without mitigation measures in place are not representative of the proposed development's actual extent of impact and are included to facilitate understanding of how and why mitigation measures were identified.

The residual impact is what remains following the application of mitigation and management measures and is thus the final level of impact associated with the development. Residual impacts also serve as the focus of management and monitoring activities during Project implementation to verify that actual impacts are the same as those predicted in this Report.

There are other specialist assessments being carried out as part of the S&EIA process, for example assessments in the field of impacts on terrestrial biodiversity, including fauna and flora, aquatic biodiversity, avifauna etc. The focus of this study is on human health and safety with possible impacts from chemicals, fires, explosions etc. and on broad issues of chemical pollution, emissions and waste of resources.

Also note that in the realm of occupational health and safety the aspects of exposure, irreversible harm, cumulative impacts are all grouped into the broad term consequence. Clearly, if the possible consequence is death of an employee, then the impact is irreversible, the person irreplaceable and the effects are not cumulative. Unless a facility is classified under the Occupational Health and Safety Act, 1998 (Act 85 of 1993) as amended (OHS Act) as a Major Hazard Installation (MHI) with offsite impacts that can be cumulative (domino effects), which the BESS installation is not, or if one BESS is located within 500m of another independently assessed BESS, cumulative impacts are not relevant. Cumulative impacts that increase risks to employees can usually be mitigated by improved process safety management.

For most projects, from an acute health and safety point of view, the No-Go option will usually be a preferred option since there are no immediate health and safety risks associated with not doing a project, i.e. no one can get hurt if something does not exist. However, some projects aim to reduce adverse effects elsewhere and can be viewed at offsetting either current or future risks. In this case, renewable energy projects should help to mitigate possible adverse impacts of climate change, create jobs and contribute to sustainable energy, i.e. the project risks are offset against future social risk reduction.

TABLE 1.3.1 SAFETY, HEALTH AND ENVIRONMENTAL RISK ASSESSMENT CHECKLIST

NO	RISKS	DESCRIPTION OF TYPICAL HAZARDS	TYPICAL STANDARD (OHS ACT) OR KEY ISSUES
	HEALTH RISKS		
H1	Chronic Chemical or Biological Toxic Exposure	Continuous releases of toxic materials (Chemical or biological) Long term exposure to low concentrations Unsanitary or unhygienic conditions Diseases Harmful animals/insects	Do not exceed Occupational Exposure Limits (OEL's) and Biological Exposure Indices (BEI's – OHS Act Hazardous Chemical Substances (HCS) and Hazardous Biological Agents (HBA) Regulations)) for continuous work time exposure to hazardous chemical substances and materials. Awareness of HBA.
H2	Noise	Continuous and peak exposure to high levels of noise	Continuous noise not to exceed 85dB at workstation (OHS Act Noise-Induced Hearing Loss Regulations) and 61dB at boundary of the site.
H3	Environmental	High temperatures in work areas Low temperatures in work areas High humidity in work areas	Wet Bulb Globe Temperature (WBGT) index above 30 in summer and/or very cold less than 6 °C in winter (OHS Act Environmental Regulations for Workplaces)
H4	Psychological	Inherently dangerous tasks Monotonous tasks High production pressure	
H5	Ergonomics	Bad ergonomic design, chronic or acute impact Vibration, repetitive impact	Maximum weight to lift 20 – 25kg
	SAFETY RISKS		
S1	Fire	Internal and external fire Small fire Large fires	Upper and lower flammability limits for materials. 12.5 kW/m^2 for 1-minute leads to 1% fatalities. 37.5 kW/m^2 leads to >90% fatalities and probable structural failure.
S2	Explosion	Internal explosions inside equipment Confined explosion inside structures Unconfined explosions outside	7 kPa overpressure leads to minor structural damage. 70 kPa leads to 90 % fatalities and probable structural failure.
S3	Acute Chemical or Biological Toxic Exposure	Large releases of toxic gases Exposure to high concentrations of harmful materials Asphyxiation inside a vessel Exposure to corrosive materials, burns	Immediately Dangerous to Life and Health values (IDLH) and Emergency Response Planning Guidelines (ERPG's) for all materials. Minimum oxygen levels.

NO	RISKS	DESCRIPTION OF TYPICAL HAZARDS	TYPICAL STANDARD (OHS ACT) OR KEY ISSUES
		Ingestion of poisonous materials	Low or high pH.
S4	Acute physical Impact or violent release of energy	Slips and trips Working at heights Moving equipment, objects or personnel	Any work above 1.5m is considered working at height.
S5	Generation impact	Electrocution Radiation sources Lasers Static Lightning	
	ENVIRONMENTAL RISKS		
E1	Emissions	Continuous emissions	Exceeding permitted emission levels
E2	Pollution	Unplanned pollution incidents causing immediate damage	Not transporting as per legislation (SANS10228/0229 and Haz. Subs. Act – Road Tanker Regs.) Hazmat requirements Reportable spill quantities NEMA Section 30
E3	Waste of resources	Water Power Other non-renewable resources (minerals) Biodiversity	Exceeding water consumption permits Peak demand requirements
	GENERAL RISKS		
G1	Aesthetics	Tall unsightly structures Glaring glass Odours	
G2	Financial	Risks of litigation Business collapse – recovery after emergency Sustainability	Business continuity Std SANS22301
G3	Security	Theft Hi-jacking Looting	
G4	Emergencies	Emergencies originating off-site (neighbours) Natural disasters	MHI Emergency Response Planning SANS1514
G5	Legal compliance		

TABLE 1.3.2 – SHE QUALITATIVE RISK ASSESSMENT MATRIX

a) The magnitude of impact on human health and safety and environmental pollution, quantified on a scale from 0-5, where a score is assigned.

SCORE	DESCRIPTION
0	small and will have no effect on the environment.
1	minor and will not result in an impact on processes.
2	low and will cause a slight impact on processes.
3	moderate and will result in processes continuing but in a modified way.
4	high (processes are altered to the extent that they temporarily cease).
5	very high and results in complete destruction of patterns and permanent cessation of processes.

b) The physical extent.

SCORE	DESCRIPTION
1	the impact will be limited to the site;
2	the impact will be limited to the local area;
3	the impact will be limited to the region;
4	the impact will be national; or
5	the impact will be international.

c) The duration, wherein it is indicated whether the lifetime of the impact will be:

SCORE	DESCRIPTION
1	of a very short duration (0 to 1 years)
2	of a short duration (2 to 5 years)
3	medium term (5–15 years)
4	long term (> 15 years)
5	permanent

d) Reversibility: An impact is either reversible or irreversible. How long before impacts on receptors cease to be evident.

SCORE	DESCRIPTION
1	The impact is immediately reversible.
3	The impact is reversible within 2 years after the cause or stress is removed; or
5	The activity will lead to an impact that is in all practical terms permanent.

e) The probability of occurrence, which describes the likelihood of the impact actually occurring.

SCORE	DESCRIPTION
1	very improbable (probably will not happen).
2	improbable (some possibility, but low likelihood).
3	probable (distinct possibility).
4	highly probable (most likely).
5	definite (impact will occur regardless of any prevention measures).

TABLE 1.3.3 – CALCULATION AND INTERPRETATION OF RISK / SIGNIFICANCE

The final assessment of the risk, i.e., the significance, of a particular impact is determined through combination of the characteristics described above (refer formula below)

Risk	=	Consequence	x	Likelihood
Significance	=	(Extent + Duration + Reversibility + Magnitude)	x	Probability

The risk (significance) can then be assessed as very low, low, medium, high or very high as follows:

OVERALL SCORE	SIGNIFICANCE RATING (NEGATIVE)	SIGNIFICANCE RATING (POSITIVE)	DESCRIPTION
4-15	Very Low	Very Low	Where the impact in negligible
16-30	Low	Low	Where this impact would not have a direct influence on the decision to develop in the area
31-60	Moderate	Moderate	Where the impact could influence the decision to develop in the area unless it is effectively mitigated
61-80	High	High	Where the impact must have an influence on the decision process to develop in the area
81-100	Very High	Very High	Where the impact would indicate a potentail fatal flaw

2. DESCRIPTIONS

2.1 ORGANISATION, SITE LOCATION AND SURROUNDING AREAS

2.1.1 ORGANIZATION

Bethel Solar PV (Pty) Ltd is a company created solely for the purposes of developing, owning and operating the proposed Bethel Solar PV facility.

2.1.2 LOCATION AND PHYSICAL ADDRESS

Bethel Solar PV BESS

Location:

Affected properties for the BESS only: Remaining Portion of Farm 466 Makhado Local Municipality, Vhembe District, Limpopo Province. GPS co-ordinates: 23^{0}22’52.07” S 29^{0}41’17.87” E

2.1.3 DESCRIPTION OF SITE AND SURROUNDINGS

The maps below show that the BESS facilities are planned in relatively isolated locations.

Figure 2.1.1 is a map of South Africa showing the location of the proposed Bethel Solar PV facility.
Figure 2.1.2 is the development area showing the location of the Bethel facilities.
Figures 2.1.3 shows 500m circles around the proposed BESS Facilities (blue) as well as local farmsteads / occupied facilities with (red) and near-by water courses/bodies (green).

Figure 2.1.1 - Map showing the location of the proposed Bethel Solar PV near Bandelierkop within Limpopo Province South Africa.

Figure 2.1.2 - The general area of interest for the Bethel Solar PV

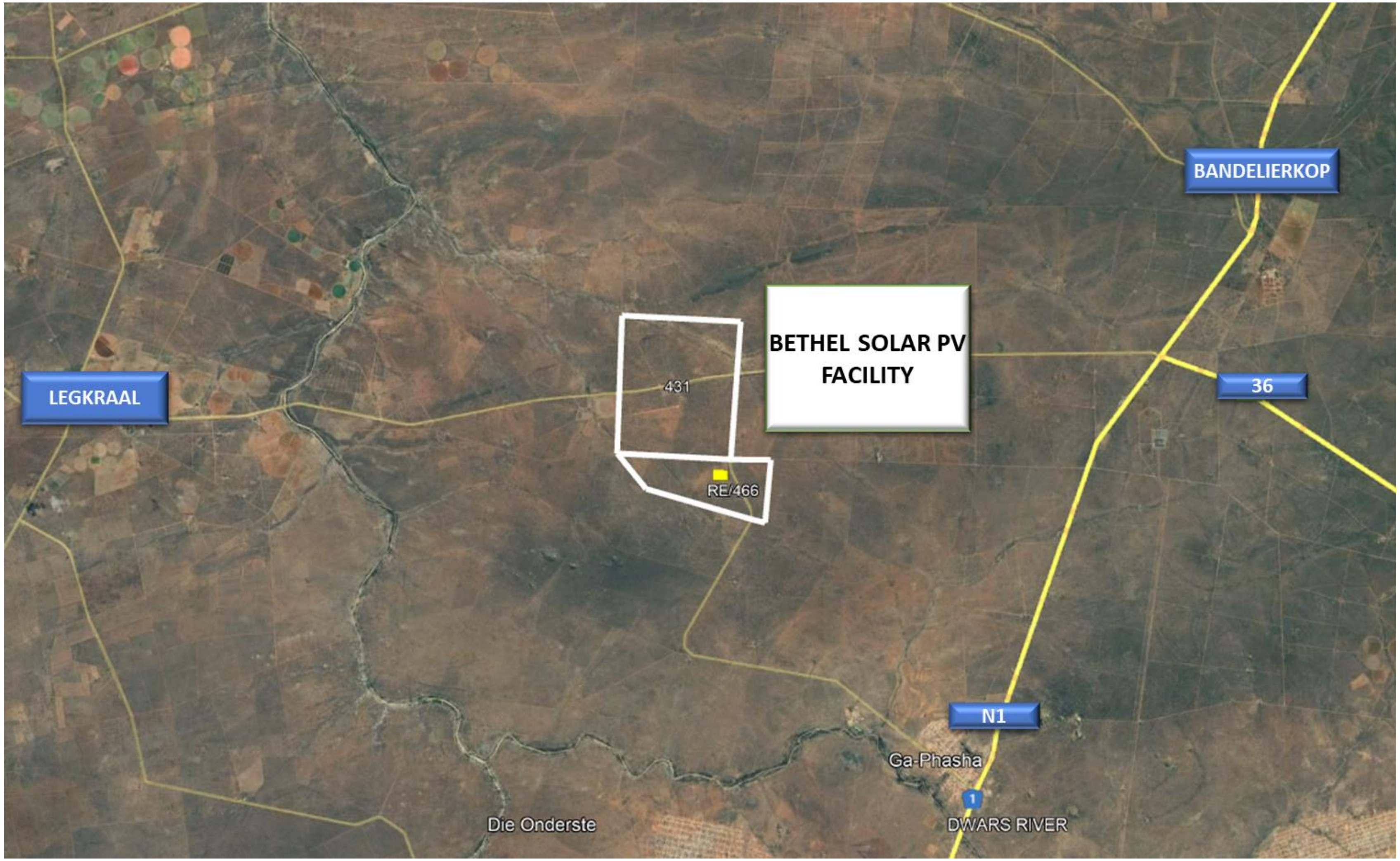
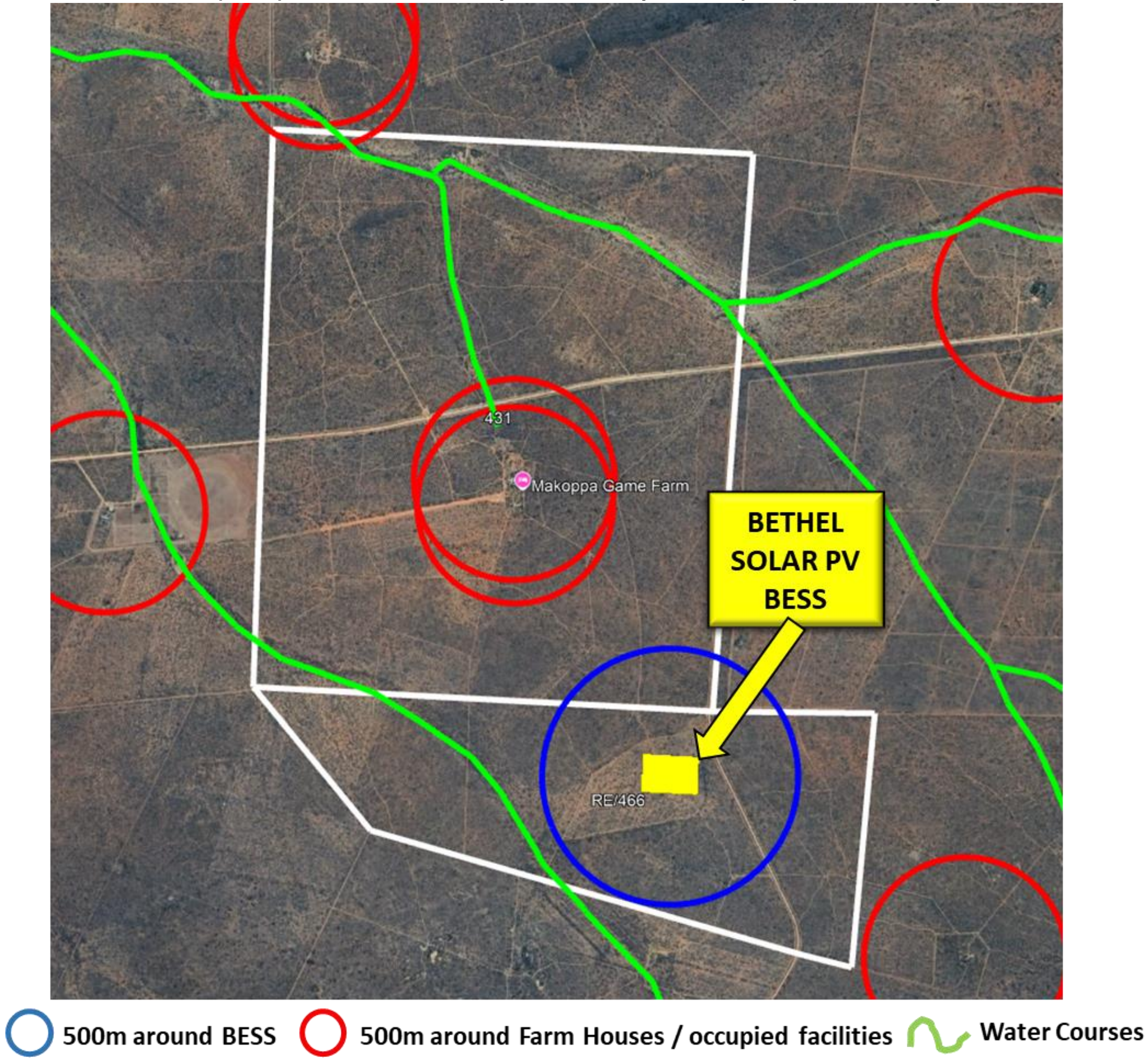


Figure 2.1.3 – 500m circles around the BESS Facilities (Blue), Location of Occupied Developments (Red) and Nearby Water Courses/Bodies (Green) in the immediate area



2.2 TOPOGRAPHY, LAND-USE AND METEOROLOGY

2.2.1 TOPOGRAPHY

Refer to the relevant EIA specialist studies for details of flora and fauna as well as water resources in the area. Vegetation in the area is mostly farmlands with some natural grass and bushes close to water courses.

The proposed site is on relatively flat high ground. The areas selected for the BESS facilities (and other significant infrastructure such as transformers) are flatter sections within the greater areas.

There are no major rivers located close to the proposed BESS location. However, approximately 600m to the south and 1500m to the north of the BESS location are small streams that eventually joins the Limpopo River to the far north. The proposed BESS location is not near any borehole/water reservoir.

2.2.2 LAND-USE

Refer to the relevant EIA specialist studies for details of the agricultural activities and cultural aspects in the area. The BESS facilities will not use large amounts of land, typically 6 ha.

The area is used sparsely for agricultural activity. There is no mining, industrial, commercial or urban activity in the proposed development area.

There are a few farm house complexes in the general area but none located within 500m of the BESS, in fact the closest is approximately 1500m north west of the proposed BESS Location.

Across South Africa seismic activity is conceivable with the Free State / Gauteng (man-made activity) and the Western Cape (natural activity) being relatively higher risk areas. However, compared with aspects such as corrosion, human error etc. seismic activity is not usually a highly likely risk factor, refer to SANS 10160:2011, part 4. [Ref 24]. The proposed area is a low seismic activity area and civil / structural design of the BESS facilities would not normally need to take major additional seismic protection into account.

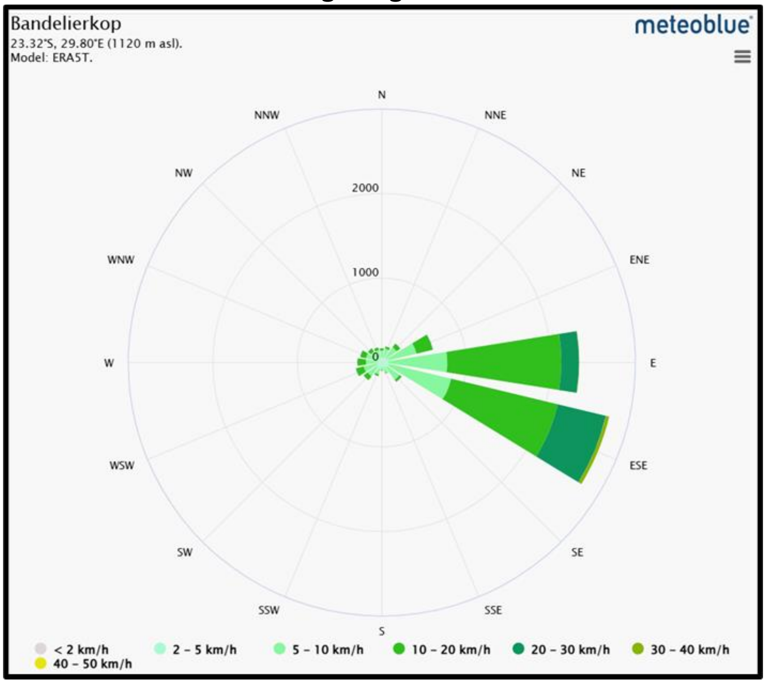
2.2.3 METEOROLOGY

The site is located on the highveld. Weather conditions for the closest town of Bandelierkop, for which only simulated data is available, could be applied for the site.

Refer to a wind rose below in Figure 2.2.1 and temperature and precipitation in Figure 2.2.2 (simulated historical climate and weather data from MeteoBlue).

Across South Africa, lightning strikes are conceivable as a source of ignition of major hazards, refer to SANS10313:2012 lightning strike density table where Polokwane closest major town to Bandelierkop (4.5 strikes/km^2/y) is moderate. Nevertheless, ignition from on-plant sources is much more likely than lightning, but lightning cannot be ignored as a source of risk particularly for tall structures in wide open flat areas.

Figure 2.2.1 Wind rose indicating the general wind conditions for the area

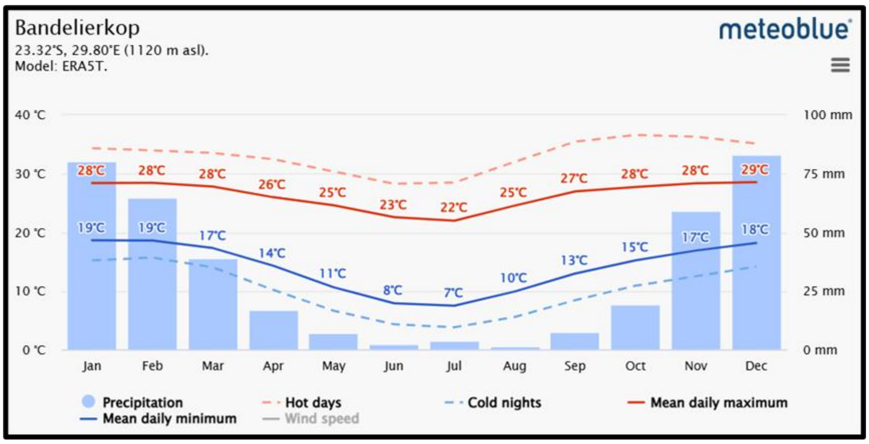


Source MeteoBlue

The key features of the weather patterns are:

- Winds which blow mostly from the east and east south east.
- Winds very seldom blow from south or north.
- Moderate temperature conditions in summer during the day.
- Rainfall, is in the summer.
- Cool conditions in winter with limited precipitation, possibly in the form of frost.
- Temperature inversions, which trap air in a stagnant layer near the earth surface, occur on cold nights and early mornings.
- Day night variations are typically 9 - 15 degrees Celsius.

Figure 2.2.2 Temperatures and Precipitation for the area



Source MeteoBlue

2.3 PLANT AND PROCESSES

All battery systems have an anode and a cathode with electrons migrating through an electrolyte to one electrode during charging and then towards the other during discharge. There are many different types of electrode arrangements, electrode and electrolyte chemistries and sizes of the installations, i.e. a myriad of technologies.

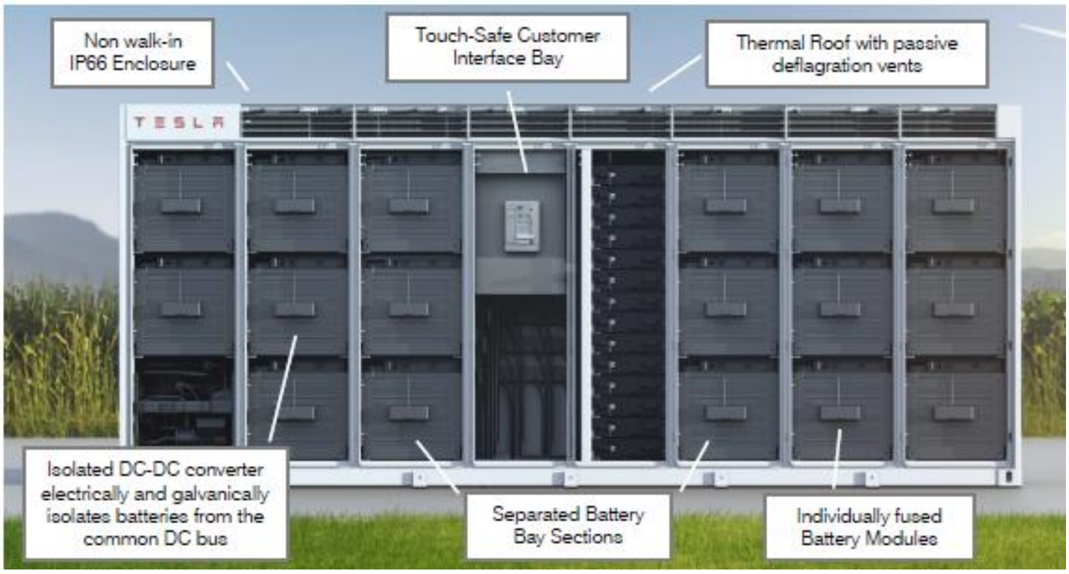
2.3.1 PROPOSED DESIGN - SOLID STATE BATTERIES – TYPICALLY LITHIUM-ION OR SODIUM SULPHIDE

This type of battery technology being considered for the BESS would be a Solid-State Battery which consists of multiple battery cells that are assembled together to form modules. Each cell contains a positive electrode, a negative electrode and an electrolyte which is mostly solid but can contain a small amount of liquid/polymer. The BESS will comprise of multiple battery units or modules housed in shipping containers and/or an applicable housing structure which is delivered pre-assembled to the project site. Containers are usually raised slightly off the ground and laid out is rows. They can be stacked if required although this may increase the risk of events in one container spreading to another container. Supplementary infrastructure and equipment may include substations, power cables, transformers, power converters, substation buildings & offices, HV/MV switch gear, inverters and temperature control equipment that may be positioned between the battery containers.

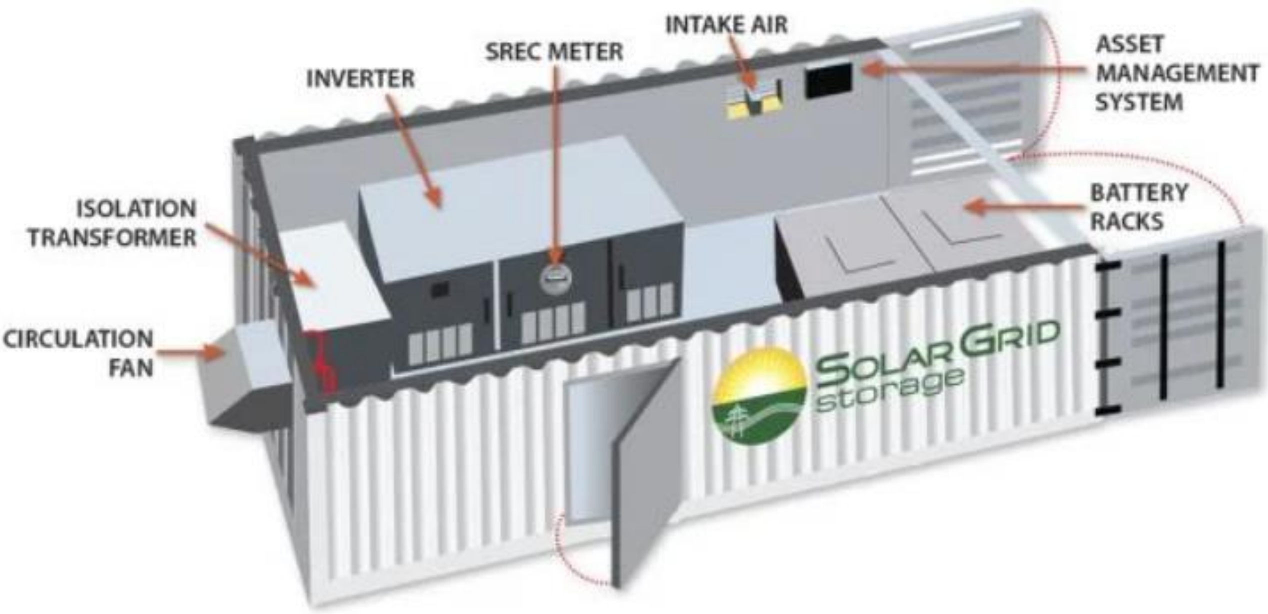
The solid-state batteries that are being considered are Lithium-ion or Sodium-sulphide systems. The pictures in Figure 2.3.1.1 are typical BESS installations servicing renewable power farms (in this case depicted as solar but could be wind and arrangement of BESS would be similar). Figures 2.3.1.2 & 2.3.1.3 show typical battery modules in the BESS facility.

FIGURE 2.3.1.1 – Images of Typical BESS Systems Servicing Renewable Power Farms
(depicted as solar but could be wind)

FIGURE 2.3.1.2 – Typical Battery Modules in a BESS with the Separated Sections

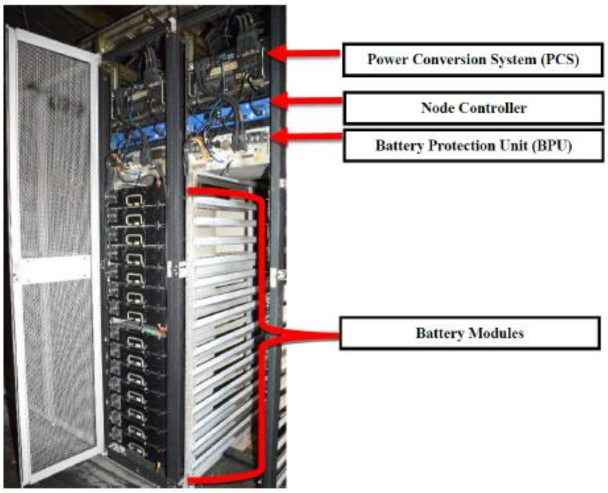


Source – Tesla MegaPack – Safety Overview



Source – Tesla MegaPack – Safety Overview

FIGURE 2.3.1.3 – Typical Battery Modules in a BESS with the Power Conversion Systems in with the Batteries



Source – DNV-GL McMicken Event Analysis

2.3.2 STAFF AND SHIFT ARRANGEMENT

The BESS facilities will run 7 days a week for 24 hours a day. Although the system will be largely automated with a battery management system and electronic operator interface etc, it will still require attention from operators and maintenance staff. The facility will need routine checking / preventative and breakdown maintenance / grass cutting / security etc. During normal operations there are assumed to be approximately 10 persons on site during the day depending on the activities taking place and possibly one or two operators as well as security personnel at night.

2.3.3 OPERATIONS AT THE BESS FACILITY AND PHASES OF THE BESS PROJECT

The BESS facilities can be considered to have three main phases:

- Construction including transport to site and storage prior to installation,
- Operation including commissioning, maintenance, shutdown – restart,
- Decommissioning including repurposing and disposal.

The main processes undertaken in each of these stages can be summarized as follows together with some details:

TABLE 2.3.4.1 – Project Phase with Main Processes/Activities and Some Details of Likely Elements

No	PHASE	MAIN PROCESSES	DETAILS
1.1	Construction of both types of battery technology	Construction machines e.g., cranes, graders, cement trucks, diesel and oil storage	Graders to clear ground make roads, diggers for trenches foundations, cement mixers for civil works, cranes to place containers, diesel bowser for fuel for machines, oil for machines
1.2		Materials for the construction of the O&M buildings, civil supports for containers and electrical equipment	Building materials such as bricks, cement, re-bar, I-beams, roof sheeting etc. BESS equipment such as tanks, pumps, piping etc. Electrical equipment such as transformers, pylons, cabling.
1.3		Equipment items for containerized installation e.g., lithium battery containers	Battery containers Electrical equipment such as transformers, pylons, cabling.
1.4		Waste e.g., packaging materials, paint	Connections, transformers, switches etc will likely have protective coverings (Plastic, paper, cable ties etc) to remove during installation, paint waste (cans, brushes, solvents), building rubble
1.5		Construction camp	Temporary offices, accommodation, ablutions
2.1	Lithium-ion or Sodium-sulphide based Solid State Operation	Chemical electrolyte and electrode materials in the battery cell	Will be solid state lithium-ion or sodium-sulphide batteries with limited liquid electrolyte quantities contained within the solid phase electrolyte
2.2		Battery cells, modules and racks typically in shipping containers	The facilities are designed for 960MWh having typically up to 300 containers (for example, each Tesla Lithium-ion Megapack has up to 3 megawatt hours (MWhs) of storage and 1.5 MW of inverter capacity, sodium-sulphide NGK 4*6 trailer ~3MWh at 1MW inverter)
2.3		Electronic equipment in container	Battery management system for monitoring of the battery condition and control of the loading and unloading cycles
2.4		Electrical equipment in container or separate container	Power conversion system, connections, switches, cabling
2.5		Mechanical equipment in container(s)	Air conditioners, fans, filters, coolant
2.6		Electrical equipment outside the containers	Network interconnection equipment, switchgear, transformers
2.7		Site office and workshop	Including potable water, 220V power, kitchen, sewage, tools and parts store etc
2.8		Support services	Dirt roads, access control fences, lights inside the container and outside for general access lighting, fire suppression/fighting systems, grass cutting, communication systems
2.9		Waste	Broken parts, storm water run-off, hot air from battery and PCS cooling systems
3.1	Decommissioning both types of battery technology	Liquid chemical waste	Transformer oils, coolants
		Solid State Lithium or Sodium-sulphide chemical waste	Batteries, air filters, transformer oils, coolants
3.2		Electronic waste	Circuit boards, HMI screens
3.3		Building rubble - non-hazardous waste	Steel, copper, cement, equipment and structures
3.4		Solid hazardous waste	Contaminated equipment such as pumps, pipes, bund linings
3.5		Batteries Shipping Containers/Trailers	Shipping containers / trailers

3. HAZARD IDENTIFICATION

3.1 LITHIUM-ION BATTERY HAZARDS

3.1.1 LITHIUM BATTERIES IN GENERAL

One of the battery types being considered by the project proponent is lithium-ion based batteries.

Lithium-ion based battery systems are becoming one of the dominant technologies for utility systems in Europe and America. For this reason, this assessment assumes that lithium-based batteries will be used in the BESS facilities. Should sodium-based batteries be used, the hazards are likely to be similar at a high level but different in their details, and therefore the Risk Assessment may need to be reviewed.

Primary (non-rechargeable) batteries use lithium metal anodes. Lithium is one of the lightest and most reactive metallic elements and is highly reactive towards water and oxygen. Exposure of lithium metal to water even as humidity can decompose exothermically to produce flammable hydrogen gas and heat. These lithium metal batteries are not used in BESS systems. However, if secondary batteries discussed below are charged at temperatures below 0 °C, then lithium can plate out onto the anode surface and in this manner lithium metal could be present even in lithium-ion batteries.

Secondary, rechargeable lithium batteries, as used in bulk BESSs, use cathodes that contain lithium in the crystal structure of the cathode coating and/or lithium salts in an electrolyte that is in the battery. These are called lithium-ion batteries. Lithium-ion batteries operate at room temperature and have significant limitations outside the 0 – 50 °C range. The exact lithium-ion composition of the batteries can vary with suppliers. In addition, the technology allows for many combinations of chemistry to suit the particular application.

3.1.2 LITHIUM BATTERY CHEMISTRY

Generally, for all lithium-ion based batteries the anode is made of solid carbon (graphite) and the cathode of a solid lithium metal oxide or phosphate. So the cathode can be for example lithium iron phosphate or lithium nickel manganese cobalt.

In between the cathode and anode is an electrolyte through which the electrons migrate. This electrolyte can come in many different forms.

Lithium-ion liquid batteries generally have a liquid electrolyte that is typically a lithium salt in an organic solvent. The electrolytes are typically ethylene carbonate or di-ethyl carbonate. The flash points of these carbonates can vary from 18 – 145 °C which means they can be highly flammable (FP < 60 °C) or merely combustible if involved in an external fire (FP > 60 °C). They may produce toxic and flammable gasses if involved in a fire.

Lithium-polymer batteries have a gel-like electrolyte that contains the lithium-ions in a flexible polymer, which is less flammable than the liquid solvent based system.

Lithium-solid state batteries have an electrolyte that contains the lithium-ions in a solid matrix that can be either an inorganic solid, solid polymer, polymer ceramic composite or a metal organic framework. These solid electrolyte have the advantage that they cannot leak out if the battery is damaged and that they can be made of non-flammable materials reducing the fire hazards. Some of the lithium compound in the electrolyte include lithium hexafluorophosphate, lithium perchlorate, lithium cobalt oxide etc.

3.1.3 HAZARD - THERMAL DECOMPOSITION

Upon heating of the contents of a battery due to shorting (e.g. due to dendrite formation, physical damage, water ingress etc), contaminants, external heat or exposure to water and reaction heat, the lithium salts in batteries can begin to break down exothermically to release either oxygen (oxidants) that enhances combustion, possibly leading to explosion, or fumes such as hydrogen fluoride or chlorine that are toxic.

These exothermic break down reactions are self-sustaining above a certain temperature (typically 70 °C for liquid batteries and) and can lead to thermal run away. In this process the battery gets hotter and hotter, the decomposition reactions happen faster and faster and excessive hot fumes are generated in the battery. Eventually the pressure in the battery builds up to the point where those gases need to be vented, usually via the weakest point in the system. These vented fumes can be flammable due to vaporization of the electrolyte (especially if liquid solvents but generally if hydrocarbon based) and can ignite as a flash fire or fire ball (if large amounts) leading to the fire spreading to any surrounding combustible materials, e.g., plastic insulation on cables, the electrolyte, the electrodes and possibly even the plastic parts of the battery casing etc. If the vented flammable vapours do not ignite immediately, they can accumulate within the surrounding structures. If this flammable mixture is ignited later, e.g., due to a spark, this can lead to a violent explosion of the module, cabinet, room, container etc.

In addition to being flammable the vented gases will contain toxic components. These could include:

- the products of combustion such as carbon dioxide/monoxide, hydrogen cyanide,
- VOCs like benzene and ethylene,
- Depending on the exact battery chemical composition, decomposition products such as hydrogen fluoride, hydrogen chloride, phosphorous pentafluoride, phosphoryl fluoride and oxides of aluminium, cobalt, copper etc.

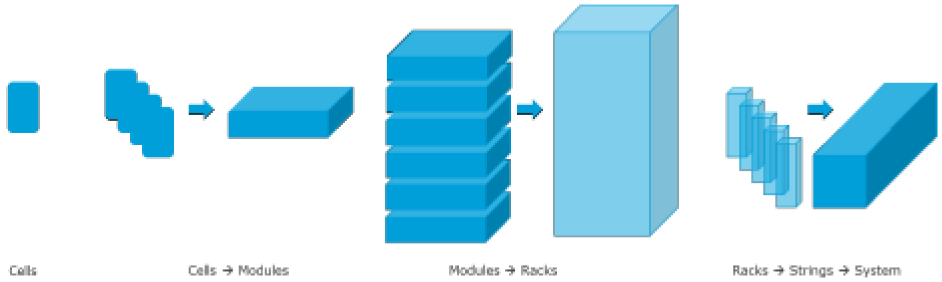
The temperature in the batteries and of these vented gases can be extremely high, e.g., > 600 °C.

In the situation where oxygen is released internally as part of the decomposition (e.g., lithium perchlorate) the oxygen is available to react with the combustible electrolyte and if all this happens extremely fast in a self-sustaining manner within the confines of the device, an explosion of the device can occur with only localized impacts.

3.1.4 HAZARD - PROPAGATION

A BESS is composed of individual batteries which are combined into different size packs such as modules and racks, as illustrated on the diagram below.

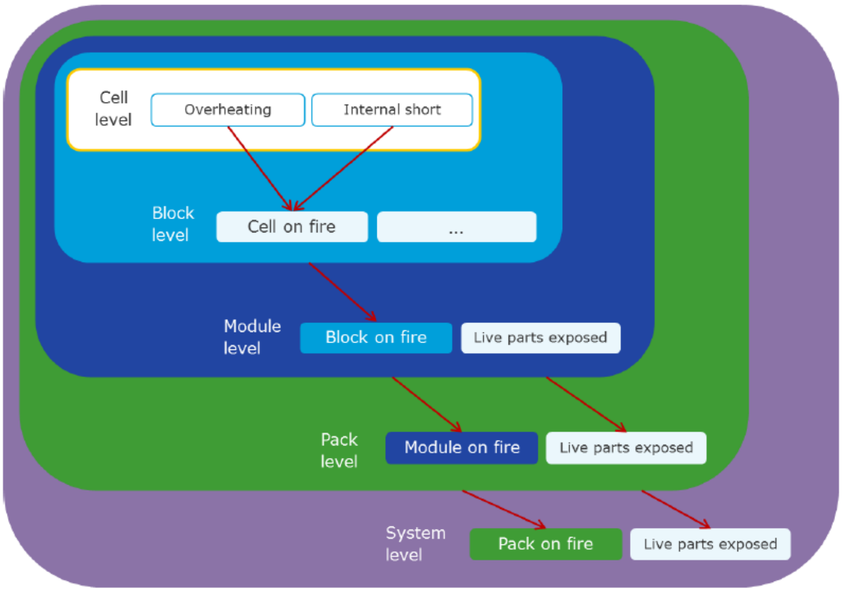
Figure 3.1.4.1 - Diagram of battery structure



Source DNV-GL McMicken Event Analysis

The very high temperature generated by one battery cell in thermal runaway could lead to overheating of adjacent cells. This cell in turn then starts thermal decomposition and so the process propagates through the entire system, as illustrated on the diagram below.

Figure 3.1.4.2 - Diagram of battery fire propagation



Source – STALLION Report

In order to prevent propagation, there are separation requirements between cells, modules etc. Separation could be with physical space or insulating materials.

3.1.5 HAZARD - ELECTROLYTE LEAKS FROM LIQUID PHASE BATTERIES

In the case of liquid or polymer batteries, although extremely unlikely due to the structure of the batteries, should electrolyte liquid leak out of the batteries, it can be potentially flammable as well as corrosive or toxic. If ignited as fire, or explosion, the smoke would contain toxic components. If unignited it can still be extremely harmful especially if its decomposition products include hydrofluoric acid.

One of the main safety advantages of solid state batteries is that flammable electrolyte leaks are not possible.

3.1.6 HAZARD – ELECTRICAL SHOCK/ARC

Electrical shock presents a risk to workers and emergency responders, if the energy storage system cannot be “turned off”. This is referred to as “stranded energy” and presents unique hazards. Arc flash or blast is possible for systems operating above 100 V. Lithium-ion systems operate from 48 - 1000 V, depending on the battery design.

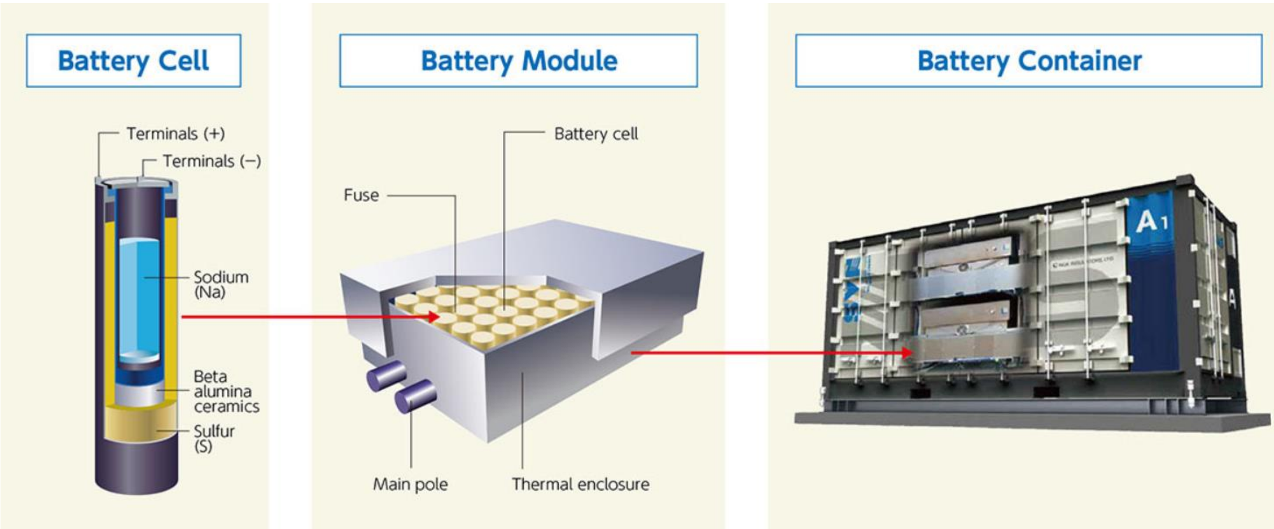
3.2 SODIUM SULPHIDE BATTERY HAZARDS

3.2.1 SODIUM-SULPHIDE BATTERIES IN GENERAL

Sodium-sulphide (NaS) batteries are similar in principle to other solid state batteries such as lithium-ion batteries. They are a different chemistry and are a type of molten-salt battery that uses liquid sodium and liquid sulfur electrodes. This type of battery has a similar energy density to lithium-ion batteries, but the chemicals are more readily available and therefore cheaper than lithium. Worldwide there have been about 200 Sodium–sulphur batteries installations, with a combined energy of 5 GWh and power of 0.72 GW. This is a fraction of the 948 GWh installed lithium-ion batteries.

The battery cell is usually made in a cylindrical configuration. The entire cell is enclosed by a steel casing that is protected from corrosion on the inside. This outside container serves as the positive electrode, while the liquid sodium serves as the negative electrode. The container is sealed at the top with an airtight lid. An essential part of the cell is the presence of a ceramic membrane, which selectively conducts Na^+. In commercial applications the cells are arranged in blocks for better heat conservation and are encased in a vacuum-insulated box. For operation, the entire battery must be heated to at least the melting point of sulfur at 119 °C. Sodium has a lower melting point, around 98 °C. Figure 3.2.1.1 shows the general arrangement of sodium-sulphide batteries.

FIGURE 3.2.1.1 – Schematic Diagrams of Sodium-sulphide BESS

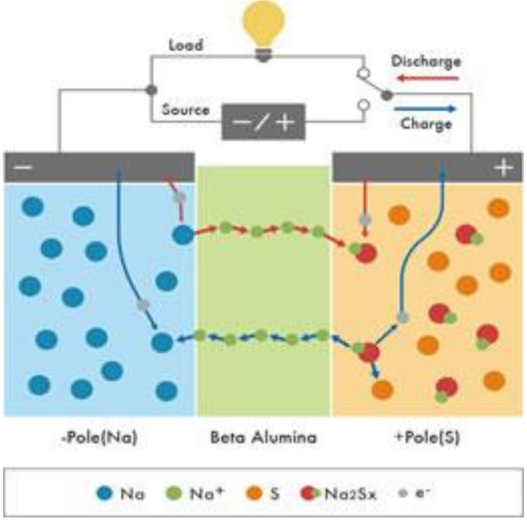


Source – NGK NAS Module – Website

3.2.2 SODIUM-SULPHIDE BATTERY CHEMISTRY

NAS batteries are rechargeable storage batteries that incorporate anodes (negative electrode) comprised of sodium (Na) and cathodes (positive electrode) comprised of sulphur (S), separated by a fine ceramic solid electrolyte. They can be repeatedly charged and discharged through sulphur-sodium chemical reactions. Pure sodium spontaneously burns in contact with air and moisture, and sulfur is combustible in air. Thus safety features are required to avoid direct contact with water and oxidizing atmospheres. Stationary NaS batteries which typically operate at 300-340 degree C are located in a thermal enclosure and hermetically sealed casing.

FIGURE 3.2.2.1 – Schematic Diagrams of Sodium-Sulphide Battery



Source – NGK Website

3.2.3 HAZARD – FIRE / DEFLAGRATION

If air or moisture enters the battery, the molten sodium can spontaneously ignite. Similarly if the battery is severely damaged such that either the molten sulphur of sodium exit the battery then either could ignite. A sodium fire cannot be extinguished with water and sand or other modern agents are required. Fire suppression systems must be part of a battery system. If sulphur vapours accumulate within the battery and are then ignited an explosion could occur.

Like all other battery systems sodium-sulphide batteries systems also have a battery management system. A battery management system ensures optimum and safe conditions for battery operation. This include a heat management system is integrated to avoid too high or too low temperatures.

3.2.4 HAZARD – HOT MOLTEN SALT

One of the main shortcomings of traditional sodium–sulfur batteries is that they require high temperatures (290- 360 deg C) to operate. This means that they must be preheated before use, and that they will consume some of their stored energy (up to 14%) to maintain this temperature when not in use. More recent developments include lower temperature (< 120deg C) sodium-sulphide batteries. Aside from saving energy, lower temperature operation mitigates safety issues such as explosions which can occur due to failure of the solid electrolyte during operation at high temperatures.

Hot surfaces are a concern. The batteries are encased for safe handling. Should the protective casing be cracked or broken molten salt may seep through. The molten salt will very quickly solidify but

There is no need for operators to be near or to work on the batteries when they are hot. Maintenance will require the batteries to be cooled down and certainly procedures will need to be in place to ensure personnel do not access hot battery parts.

During transportation, cells are shipped at ambient temperature.

3.2.5 HAZARD – TOXICITY AND CORROSIVITY

Sulphur, specifically sulphur dioxide present in the smoke from a battery fire, is an inhalation hazard that leads to irritation of the respiratory tract, bronchospasm, pulmonary congestion, oedema and can even be fatal. Other irritants will be present in any battery fire smoke, e.g. from plastic cabling, insulation material s etc.

Within the battery the molten materials are corrosive and the materials of construction and specified life time of the battery take this into account. In terms of human exposure, contact with the hit materials is more of a concern than the corrosivity of the materials.

3.2.6 HAZARD – ELECTRICAL SHOCK/ARC

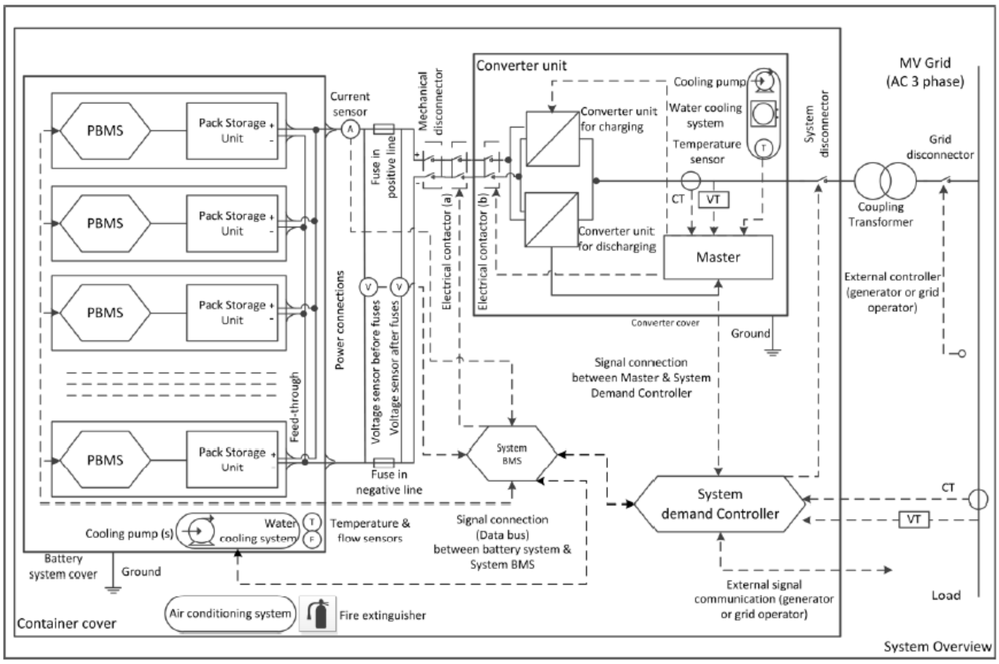
Electrical shock presents a risk to workers and emergency responders, if the energy storage system cannot be “turned off”. This is referred to as “stranded energy” and presents unique hazards. Arc flash or blast is possible for systems operating above 100 V.

During charge, sodium metal dendrites tend to form eventually leading to internal short-circuiting and immediate failure. The ceramic surface layer on the Na side turns grey after > 100 cycles. This is caused by a slower growth of micron-size sodium metal globules and the formation of such sodium metal globules gradually increases the electronic conductivity of the electrolyte and causes electronic leakage and self-discharge.

3.3 OTHER CHEMICALS OR HAZARDS

The BESS is composed not only of the batteries, but also electrical connections, switches, power converters, cooling systems etc. In this regard the hazards are similar to lithium batteries.

Figure 3.3.1 – Details of Typical BMS



Source – STALLION reports

3.3.1 COOLING SYSTEMS

Due to the need to keep the batteries within a specified temperature range most of the containerized modular system have built-in air-conditioning systems / cooling systems. Some have only fans for air cooling with filters to remove dust prior to cooling. Others, particularly those in hot environments requiring more cooling, may have refrigerant-based systems. These would have a refrigerant circuit usually containing non-flammable non-toxic refrigerant such as R134a (simple asphyxiant) etc as well as a low hazard circulating medium such as an ethylene glycol-based coolant. At high temperatures above 250 °C R134 may decompose and may generate hydrogen fluoride and other toxic gases. Ethylene glycol is really only harmful if swallowed. In the environment it breaks down quickly and at low concentrations that would typically occur from occasional small spills, it has no toxicity.

3.3.2 FIRE SUPPRESSION SYSTEMS

Although these are only effective for some fire scenarios, some of the solid-state containerized systems come fitted with “Clean agent” fire suppressant systems. These are pressurized containers of powder/gases that are released into the container to snuff a fire and do not leave a residue on the equipment. Some containers have water sprinkler systems installed to quench thermal run-away reactions. In the case of molten sodium salt systems, the fire suppressant could be sand.

In general fire fighters may respond with water cannons/hydrants, foam systems etc. Such responses may generate large amount of contaminated and hazardous water runoff. A system to contain as much of this as possible should be in place.

3.3.3 GENERAL ELECTRICAL AND ELECTRONIC EQUIPMENT

Whatever the configuration of the battery containers/ buildings there will be electrical and electronic equipment in the battery compartment, the battery building as well as outside. In some installations the main electrical equipment such as the power conversion system is in a separate compartment separated by a fire wall. In others it can be in a separate container.

Wherever there is electrical equipment there is a possibility of shorting and overheating and fire.

3.4 PAST ACCIDENTS AND INCIDENTS RELEVANT TO BESS

The following events occurred with various types of batteries, e.g., solid state, and are included for the purpose of possible ideas on how things may go wrong with equipment around the batteries themselves:

- There have been sodium-sulphur fires in Japanese installations. One such event was at the Tsukuba Plant, (Joso City, Ibaraki Prefecture) of Mitsubishi Materials Corporation where molten material (sodium-sulphide battery) leaked from a battery cell causing a short between battery cells in an adjoining block. As there was no fuse between cells the current continued to flow, with the whole battery module catching fire. Hot molten material melted the battery cell casings inside the battery overflowing to the modules below, causing the fire to spread further. Subsequently additional safety measures were adopted by the supplier: quality controls were introduced during cell production, the number of cells per module was reduced and additional fuses installed, the interconnection/wiring of the cells was changed so that in case of an internal short-circuit (e.g. due to leakage of conductive material from a cell) subsequent propagation with serious consequences (thermal runaway of complete modules, fires) is a reduced risk.

- A Tesla electric battery powered car caught fire, see image below. Initially, a metal object penetrated the battery causing damage leading to short circuiting and thermal runaway. There was an alarm and the driver warned by on-board computer to park car safely and exit. The runaway did not propagate to the other battery compartment due to separation measures installed. Fire fighters actually made the fire worse by their action to open the battery system to try and get water into it. This allowed air in and the flames to spread to the rest of the car. By way of comparison the American National Fire Protection Agency (NFPA) has stated that there are approximately 90 fires per billion kilometers driven with internal combustion engine cars as compared to the Tesla electric car with only 2 fires per billion driven kilometers.
- In August 2012, there was a fire at night at the Kahuku wind farm in Hawaii with an advanced lead-acid battery system installed indoors. The fire department were called several hours later and attempted, unsuccessfully to extinguish the fire with dry powder. The fire fighters faced thick smoke and could not enter the building for several hours because it was unclear whether the batteries were emitting toxic fumes.
- In February 2012 during commission of a solar BESS in Arizona USA a fire started. The cause is unknown, but the fire did not spread beyond the shipping container.
- On 10 August 2016 in Wisconsin USA, a fire started in the DC power control compartment of a BESS under construction. The fire department arrived and applied alcohol resistant foam to extinguish the fire. The fire did not spread to the batteries. As the system was in commissioning the fire suppression system in the PCS was not yet functional.
- On 11 November 2017 Lithium based BESS in Belgium caught fire during commissioning. Fitted fire detection and extinguishing system failed to contain the fire. The fire department were called and rapidly extinguished the fire, preventing spreading to adjacent containers.
- An explosion at utility company Arizona Public Service's (APS) solar battery facility in Surprise, Arizona. The incident on April 19, 2019, started when there were reports at around 17:00 of smoke from the building housing the BESS. A few hours later, at approximately 20:04, an explosion occurred from inside the BESS. Nine people were injured. The factual conclusions reached by the investigation into the incident were:
  - The suspected fire was actually an extensive cascading thermal runaway event, initiated by an internal cell failure within one battery cell in the BESS: cell pair 7, module 2, rack 15.
  - It is believed, to a reasonable degree of scientific certainty, that this internal failure was caused by an internal cell defect, specifically abnormal Lithium metal deposition and dendritic growth within the cell.
  - The total flooding clean agent fire suppression system installed in the BESS operated early in the incident and in accordance with its design. However, clean agent fire suppression systems are designed to extinguish incipient fires in ordinary combustibles. Such systems are not capable of preventing or stopping cascading thermal runaway in a BESS.
  - As a result, thermal runaway cascaded and propagated from cell 7-2 through every cell and module in Rack 15, via heat transfer. This propagation was facilitated by the absence of adequate thermal barrier protections between battery cells, which may have stopped or slowed the propagation of thermal runaway.
  - The uncontrolled cascading of thermal runaway from cell-to-cell and then module-to-module in Rack 15 led to the production of a large quantity of flammable gases within the BESS. Analysis and modelling from experts in this investigation confirmed that these gases were sufficient to create a flammable atmosphere within the BESS container.
  - Approximately three hours after thermal runaway began, the BESS door was opened by firefighters, agitating the remaining flammable gases, and allowing the gases to make contact with a heat source or spark. This led to the explosion.

Figure 3.4.1 – Photo of lithium battery explosion scene

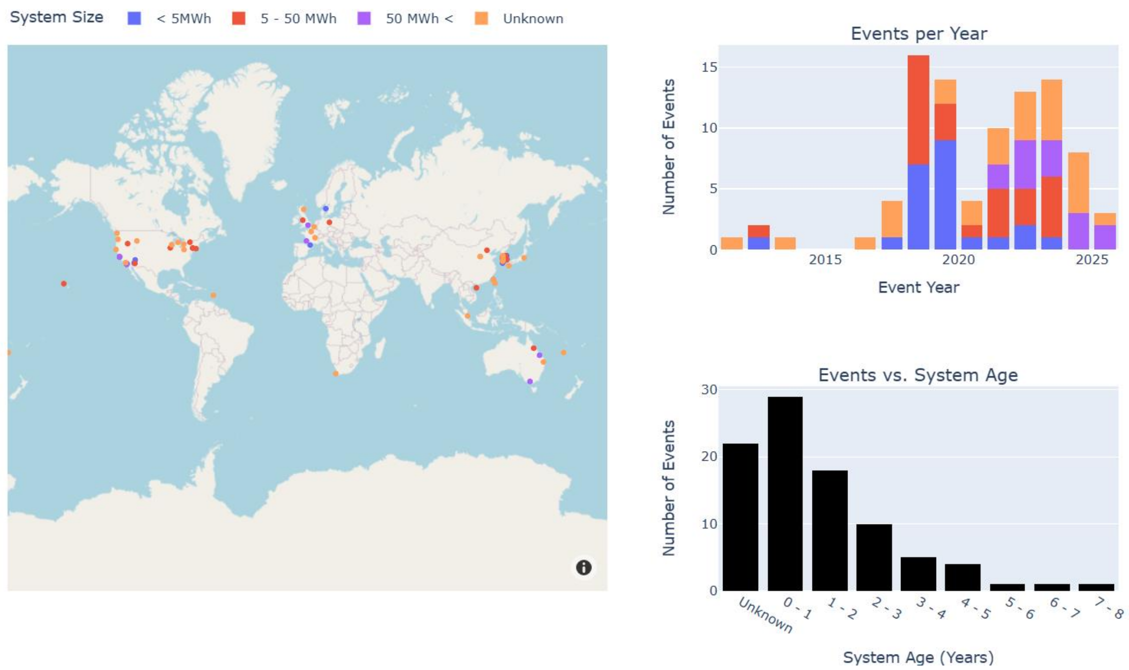
Source DNV-GL McMicken Event Analysis

- Records (By WoodMac) indicate that there are approximately 200 BESS systems in the USA and there have been 2 -3 fires in the last 5 -10 years. This is an event frequency of 0.001 - 0.003 events per unit per year. DNV-GL in their quantitative risk analysis of BESS sites found that considering all the latest (2019) safety features the theoretical event frequency should be as low as 0.00001 events/unit/year i.e., 2 orders of magnitude lower than the actual values.

- Korea has installed over 1200 energy storage systems as part of the clean energy programs. In December 2018, a lithium BESS caught fire at a cement plant in Jecheon. It was the 15th fire in 2018 in Korea. As of June 2019, there had been 23 fires at Korean facilities. The faults were reported to be with the incorrect installation of the BMS, electrical systems and not due to the batteries themselves. Assuming these BESS have on average been in place for five years then the event frequency is approximately 0.004 events per unit per year. This correlates to the high value estimated for the USA data. This data is also two orders of magnitude higher than the DNV theoretical prediction on 0.00001 events/unit/year.

- The Electric Power Research Institute (EPRI) of California USA maintains a list of Battery released accidents on its Wiki-Storage Page. The EPRI is an independent non-profit energy research, development and deployment organization that is funded by organizations around the world including the energy sector, academia, and governments. The graphs below summarize some of the incidents and the three accidents described in more detail below the table are typical of the types of accidents recorded. A full list of the incidents recorded up till June 2025 is in APPENDIX B. This list clearly shows the predominance of lithium-ion battery fires. However, it also shows that usually it is a single container that is damaged, i.e. propagation does not occur.

Table 3.4.2 – Graphs of Battery Accidents



Electric Power Research Institute (EPRI)

- There have been three incidents at the Moss Landing Power plants battery storage facility in the USA where there are 256 Tesla Mega Packs installed. The latest involved one pack which caught alight and burned out five hours later. Firefighting approach was to let the pack burn out. Near-by communities were warned to shelter-in-place and the adjacent highway shutdown due to possible toxic smoke. Only one mega pack burned out and the fire did not spread.

Figure 3.4.3 – Photo of Tesla Megapack fire scene

Source - Electric Power Research Institute

- There was a small fire at the new Terra-Gen battery storage facility on Valley Centre Road USA. A small electrical failure produced some smoke which triggered the protection systems. Those worked exactly as planned and the failure was contained to a single battery module (meaning literally a single battery which is about the size of a DVD case). The safety systems worked exactly as planned and in addition the enclosure next to the one with the problem shut down because it also detected the smoke.

- The fire broke out during testing of a 13-tonne Tesla lithium Mega Pack at the Victorian Big Battery site near Geelong, Australia. A 13-tonne lithium battery was engulfed in flames, which then spread to an adjacent battery bank. This event indicates that if the battery pack units are not suitably separated the heat from one fire can set off an adjacent unit.

Figure 3.4.4 – Photo of Tesla Megapack fire scene - Electric Power Research Institute

4. RISK ASSESSMENT

An analysis was undertaken to identify the failure events, their causes, consequences, as well as the preventative and mitigative measures in place on the proposed installation for all three phases of a typical project.

4.1 SOLID STATE LITHIUM-ION BATTERY ENERGY STORAGE SYSTEMS

TABLE 4.1.1 - CONSTRUCTION PHASE (Excluding commissioning which is part of operations)

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 1:	Human Health - chronic exposure to toxic chemical or biological agents	Causes - Construction materials such as cement, paints, solvents, welding fumes, truck fumes etc. Consequences - Employee / contractor illness.	Construction	Negative	The construction phase will be managed according to all the requirements of the Occupational Health and Safety Act 85 of 1993 specifically the Construction Regulations. SHEQ policy in place. A detailed construction Risk Assessment prior to work. SHE procedure in place. PPE to be specified. SHE appointees in place. Contractor's safety files in place and up to date. All necessary health controls/ practices to be in place, e.g., ventilation of welding and painting areas. SHE monitoring and reporting programs in place. Emergency response plan to be in place prior to beginning construction and to include aspects such as appointment of emergency controller, provision of first aid, first responder contact numbers.	Moderate	3	1	3	4	4	**44**	1	1	3	4	2	**18**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 2:	Human Health - exposure to noise	Causes - Drilling, piling, generators, air compressors. Consequences - Adverse impact on hearing of workers. Possible nuisance factor in near-by areas.	Construction	Negative	Health Risk Assessment to determine if equipment noise exceeds 85dB at workstation and 61dB at boundary of the site Employees to be provided with hearing protection if working near equipment that exceeds the noise limits.	Easy	3	1	5	5	4	**56**	2	1	5	5	2	**26**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 3:	Human Health - exposure to temperature extremes and/or humidity	Causes - Heat during the day. Cold in winter. Consequence - Heat stroke. Hypothermia.	Construction	Negative	Construction site facilities to comply with Occupational Health and Safety Act 85 of 1993 specifically the thermal, humidity, lighting and ventilation requirements of the Environmental Regulations for Workplaces. Adequate potable water for employees to be provided during all phases of the project. Bore hole, bowser and tank or small water treatment plant may be required to provide potable water for the BESS installation staff during all phases of the project.	Easy	3	2	3	1	2	**18**	2	2	3	1	1	**8**
						Significance	**N2 - Low**						**N1 - Very Low**					
Impact 4:	Human Health - exposure to psychological stress	Causes - Large projects bring many contractor workers into a small, isolated community. Consequences – Lack of sufficient accommodation, entertainment etc. Increase in alcohol abuse, violence	Construction	Negative	Refer to Social Specialist Study for this project.	Easy	2	3	3	2	2	**20**	2	3	3	2	2	**20**
						Significance	**N2 - Low**						**N2 - Low**					
Impact 5:	Human Health - exposure to ergonomic stress	Causes - Lifting heavy equipment. Awkward angles during construction. Consequences - Back and other injuries.	Construction	Negative	Training in lifting techniques. Ensure that despite the isolated location all the necessary equipment is available (and well maintained) during construction. Otherwise employees may revert to unsafe practices. Isolated location, maintenance of construction equipment to ensure safe operation is critical. Ensure this is in place prior to project beginning. First aid provision on site.	Moderate	4	1	3	2	3	**30**	4	1	3	2	2	**20**
						Significance	**N2 - Low**						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 6a:	Human and Equipment Safety - exposure to fire radiation	Causes – Involvement in an external fire. Fire involving fuels used in construction vehicles or vehicles themselves (e.g., tyre fire). Fire due to uncontrolled welding or other hot-work Consequences - Injuries due to radiation especially amongst first responders and bystanders. Fatalities unlikely from the heat radiation as not highly flammable nor massive fire.	Construction	Negative	Fuels stored on site in dedicated, demarcated and bunded areas. Suitable fire-fighting equipment on site near source of fuel, e.g., diesel tank, generators, mess, workshops etc. The company responsible for the facility at this stage is to have: 1. Emergency plan to be in place prior to commencement of construction. 2. Fuel spill containment procedures and equipment to be in place. 3. Hot-work permit and management system to be in place.	Complex	4	2	3	5	4	**56**	4	2	3	5	2	**28**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 6b:	Human and Equipment Safety - exposure to fire radiation	Causes - Solid state battery containers damaged on route e.g., dropped in port (drops do happen about 1/2000 containers) and importing possibly < 300 containers for the site. With this it is possible, although unlikely, that one will be dropped, traffic accident on-route. Involvement in an external fire e.g., at the port or on route. Data indicates	Construction	Negative	Solid state battery design includes abuse tests such as drop test, impact, rapid discharge etc. Propagation tests for systems, e.g., heat insulating materials between cells/modules. Factory acceptance test prior to prior to leaving manufacture. Batteries are usually stored at 50% charge to prolong life but may be shipped fully discharged. This level of detail should be understood so as to assess the risk during transport and storage. The company responsible for the battery installation should ensure suitably competent transport companies are appointed. The company responsible for transportation should ensure: - Compliance with National Road Traffic Act regulation 8 – dangerous goods. - Port Authorities should be alerted to the overall project and the hazardous nature of the contents of battery containers being imported. Note. If, as per one	Complex	5	2	5	5	2	**34**	5	2	5	5	1	**17**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
		installed facility events are 0.001/year. Transport of 300 units for installation assumed to take 4 weeks each so f= 0.02 - once in 45 years so likelihood is moderately low. Consequences – Injuries due to radiation especially amongst first responders and bystanders. Fatalities unlikely from the heat radiation as not highly flammable nor massive fire (refer to fire radiation in APPENDIX A below for the impact range).			of the typical suppliers (Tesla) indications, the containers are classified as IMDG Class 9 – the containers will not receive any special care in the ports and may be stored next to flammables. Port emergency response in particular need training on mitigating battery hazards. Prior to bringing any containers into the country, the company responsible for the battery installation (possibly via appointed contractors) should ensure that an Emergency response plan is in place for the full route from the ship to the site. Drivers trained in the hazards of containerized batteries. The Emergency plan must determine and address: - What gases would be released in a fire and are there inhalation hazards. - Extinguishing has two important elements, put out fire and to provide cooling. Different approaches may be needed for small fire – e.g., put out, and for large fires e.g., cool with copious quantities of water. Note inert gases and foam may put out the initial fire but fail to control thermal runaway or to cool the batteries resulting in reignition. - What initial fire extinguishing medium should be used. - Whether there are any secondary gases or residues from use of extinguishers. - If water is appropriate, determine if the system needs outside connections to sprinklers inside the container. - First responders need to know what media to use, especially if water totally unsuitable and if there are no connection points for water etc. - Must the container be left unopened or opened. - PPE to be specified including possible exposure to chemicals and fumes as well as radiate heat. - Containment of residues/water/damaged equipment. - Suitable safe making and disposal plan for after the event i.e. how do responders deal with partially charged damage units, contaminated surfaces (e.g., HF residues).													
						Significance	N3 - Moderate						N2 - Low					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 7:	Human and Equipment Safety - exposure to explosion over pressures	Causes - With solid state lithium containers, flammable gases generated by thermal run away reach explosive limits. Ignition on hot surfaces, static. Consequences - Potential fatalities amongst first responders. Damage to container, transport truck or other nearby items, e.g., other container in the port.	Construction	Negative	During transport this is only likely to happen due to possible inappropriate emergency response, e.g., opening containers when they may be the type that should be left to burn out. For simplicity one transport route would be preferable. The route needs to be assessed in terms of responding local services, rest places for drivers, refuelling if required, break down services available etc. Once an import route has been chosen, e.g., Richards Bay or Durban and along N2/N3/N11 etc, then the appointed transport company should ensure key emergency services on route could be given awareness training in battery fire/accident response. Emergency response planning and training referred to above may be important for key locations such as the mountain passes / tunnels.	N/A	5	4	5	5	3	**57**	5	4	5	5	1	**19**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 8a:	Human and Equipment Safety - exposure to acute toxic chemical and biological agents	Causes Human pathogens and diseases, sewage, food waste. Snakes, insects, wild and domesticated animals and harmful plants. Consequences - Illness and at worst without mitigation, possibly extending to fatalities. Effects can vary from discomfort to fatalities for venomous snakes or bee swarms etc	Construction	Negative	All necessary good hygiene practices to be in place, e.g., provision of toilets, eating areas, infectious disease controls. Policies and practice for dealing with known vectors of disease such as Aids, TB, COVID 19 and others. Awareness training for persons on site, safety induction to include animal hazards. First aid and emergency response to consider the necessary anti-venom, anti-histamines, topical medicines etc. Due to isolated locations some distance from town, the ability to treat with anti-venom and extreme allergic reactions on site is critical to mitigate the impacts	Complex	4	2	3	2	3	**33**	3	2	3	2	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 8b:	Human and Equipment Safety - exposure to acute toxic chemical and biological agents	Causes - Damaged solid-state batteries release fumes, leak electrolyte, are completely broken exposing hazardous chemicals. Thermal runaway and hazardous fumes released. Consequences - Impacts can vary from mild skin irritation from exposure to small leaks to serious corrosive burns or lung damage.	Construction	Negative	Appointed transport company to ensure transport in accordance with Regulation 8 of the National Road Traffic Act 93 of 1996, Dangerous Goods. Not permitted to transport prescribed goods in manner not consistent with the prescriptions, e.g., consignor and consignee responsibilities. Prescription found in SANS 10228/29 and international codes for battery transport etc. Transport in sealed packages that are kept upright, protected from movement damage etc. Also packaged to ensure no short-circuiting during transport. Transport to prevent excessive vibration considerations as battery internal may be damaged leading to thermal run-away during commissioning. Pre-assembled containers will most likely be supplied. These will be fitted with the necessary protective measures by the supplier considering marine and road transport as well as lifting, setting down etc. Route selection to consider possible incidents along the way and suitable response, e.g., satellite tracking, mobile communication, 24/7 helpline response. Standard dangerous goods requirements for Hazmat labels, Trem cards, driver trained in the hazards of the load. Likelihood similar to fire above.	Complex	4	3	3	5	3	**45**	4	3	3	5	2	**30**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 9:	Human and Equipment Safety - exposure to violent release of kinetic or potential energy	Causes - Construction moving equipment, heavy loaded, elevated loads, working at heights Consequences - Injury or possibly fatality. Damage to equipment. Delays in starting the project, financial losses	Construction	Negative	The construction phase will be managed according to all the requirements of the Occupational Health and Safety Act 85 of 1993 specifically the Construction Regulations. SHEQ policy in place. A detailed construction Risk Assessment prior to work. SHE procedure in place. PPE to be specified. SHE appointees in place. Contractors safety files in place and up to date. SHE monitoring and reporting programs in place. Standard construction site rules regarding traffic, reversing sirens, rigging controls, cordoning off excavations etc. Civil and building structures to National Building Regulations and building Standards Act 103 of 1977 SANS 10400 and other relevant codes. Other constructions such as roads, sewers etc also to relevant SANS standards. All normal procedures for working at heights, hot work permits, confined space entry, cordon off excavations etc to be in place before construction begins. Emergency response plan to be in place before construction begins.	Complex	5	1	5	5	4	**64**	5	1	5	5	1	**16**
							N4 - High						**N2 - Low**					
Impact 10:	Human and Equipment Safety - exposure to electromagnetic waves	Causes - Use of electrical machines, generators etc. Hot dry area static generation is highly likely. Lightning strike. Consequences - Electrocution. Ignition and burns. Injury and death. Damage electrical equipment.	Construction	Negative	Standard maintenance of condition of electrical equipment and safe operating instructions. Ability to shut off power to systems in use on site. If persons are decanting fuels or dealing with other highly flammable materials care should be taken regarding possible static discharge, installations to be suitably designed and maintained. Lightning strike rate in the study area is moderate. Outside work must be stopped during thunderstorms. Lighting conductors may be required for the final installation, to be confirmed during design phase.	Complex	5	2	5	5	3	**51**	5	2	5	5	1	**17**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 11:	Environment - emissions to air	Causes - Dust from construction and generally hot dry area. Consequences - Adverse impact on employee health.	Construction	Negative	Dust suppression as per normal construction practices, e.g. dampening on roads. PPE for specific construction workers, e.g. dust masks depending on conditions on site.	Easy	3	2	1	1	4	**28**	2	2	1	1	2	**12**
						Significance	**N2 - Low**						**N1 - Very Low**					
Impact 12:	Environment - emissions to water	Causes - Diesel for equipment, paints and solvents. Transformer oil spills. Sewage and kitchen/mess area wastewater. Consequences - Environmental damage, particularly to the surface and underground water in the area.	Construction	Negative	Normal construction site practices for preventing and containing fuels/paint/oil etc spills. Bunding under any temporary tanks, curbing under truck offloading areas and sealed surfaces (e.g., concrete) under truck parking area is particularly important. Spill clean-up procedures to be in place before commencing construction. Sewage and any kitchen liquids - containment and suitable treatment/disposal e.g. septic tank and soak away system.	Moderate	2	2	3	2	3	**27**	2	2	3	2	2	**18**
						Significance	**N2 - Low**						**N2 - Low**					
Impact 13:	Environment - emissions to earth	Causes - Mess area and other solid waste. Consequences - Environmental damage.	Construction	Negative	There will be packaging materials that will need to be disposed of after the entire system is connected and commissioned as well as after regular maintenance. There will need to be waste segregation (e.g., electronic equipment, chemicals) and management on the site.	Easy	2	2	3	3	3	**30**	1	2	3	3	2	**18**
						Significance	**N2 - Low**						**N2 - Low**					
Impact 14:	Environment - waste of resources e.g., water, power etc	Causes - Water usage not controlled. Battery containers damaged. Consequences - Delays.	Construction	Negative	Water usage to be monitored on site during construction. Handling protocols to be provided by battery supplier. End of Life plan needs to be in place before any battery containers enter the country as there may be damaged battery unit from day 1. Water management plan and spill containment plans to be in place.	Easy	1	1	1	2	4	**20**	1	1	1	2	2	**10**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
							N2 - Low						N1 - Very Low					
Impact 15:	Public - Aesthetics	Causes - Bright surfaces reflecting light. Tall structures in a flat area. Consequences - Irritation.	Construction	Negative	Refer to visual impact assessment.	Moderate	2	2	3	3	3	**30**	2	2	3	3	3	**30**
						Significance	**N2 - Low**						**N2 - Low**					
Impact 16:	Investors - Financial	Causes - Defective technology. Extreme project delays. Consequences - Financial loss	Construction	Negative	Design by experienced contractors using internationally recognized and proven technology. Project management with deviation monitoring.	Moderate	5	1	3	4	3	**39**	3	1	3	4	2	**22**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 17:	Employees and investors - Security	Causes - On route, potential hi-jacking of valuable but hazardous load. On site, theft of construction equipment and battery installation facilities. Civil unrest or violent strike by employees. Consequences - Theft. Injury to burglars. Damage to equipment possibly setting off thermal runaway.	Construction	Negative	Fencing around electrical infrastructure to SANS standard and Eskom Guidelines. The hazardous nature of the electrical and battery equipment should be clearly indicated – e.g., Skull and Cross Bones or other signs. Isolated location both helps and hinders security. Night lighting to be provided both indoors and outdoors where necessary.	Complex	4	1	3	2	4	**40**	3	1	3	2	3	**27**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 18:	Emergencies	Causes - Fires, explosions, toxic smoke, large spills, traffic accidents, equipment/structural collapse. Inadequate emergency response to small event leads to escalation. Consequences - Injuries turn to fatalities, small losses become extended down time.	Construction	Negative	All safety measures listed above. Emergency procedures need to be practiced prior to commencement of construction. If batteries are stored at 50% charge, thermal runaway can happen while in storage on site waiting for installation. In addition, if involved in an external fire thermal runaway can happen even with uncharged batteries. Except during shipping, ideally the units should not be stored any closer to each other than they would be in the final installation so that propagation is prevented, i.e. laydown area needs to be considered. The company in charge of the containers at each stage in the transport process needs to be very clear so that responsibility for the integrity of the load and protection of the persons involved in transfer and coordination of emergency response on-route. E.g., if purchased from Tesla where does hand over occur to the South African contractor / owner, at the factory door in USA, at the port in RSA, at the site fence. For example, who will be accountable if there's thermal runway event on a truck with a container that stops in a small town for driver refreshments	Complex	4	2	3	5	4	**56**	4	2	3	5	2	**28**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 19:	Investors - Legal	Causes Battery field is evolving quickly with new guides, codes and regulations happening at the same time as evolving technology. Consequences - Unknown hazards manifest due to using "cheaper supplier or less developed technology".	Construction	Negative	Use only internationally reputable battery suppliers who comply with all known regulations/guideline at the time of purchasing. Ensure only state of the art battery systems are used and not old technologies prone to fires/explosions etc.	Moderate	3	1	3	3	4	**40**	2	1	3	3	2	**18**
						Significance	**N3 - Moderate**						**N2 - Low**					

The above Risk Assessment shows that provided the preventative and mitigative measures are incorporated, the construction phase of the project does not present any high risks nor any fatal flaws.

TABLE 4.1.2 - OPERATIONAL PHASE (Including Commissioning)

From the details of accidents that have happened both with BESS installations and chemical plants in general, it is clear that many potential problems manifest during the commissioning phase when units are first powered up to test functionality. This phase is critical and all controls, procedures, mitigation measures etc that would be in place for full operation should be in place before commissioning commences.

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 1a:	Human Health - chronic exposure to toxic chemical or biological agents	Causes - Operation and maintenance materials spare parts, paints, solvents, welding fumes, transformers oils, lubricating oils and greases etc. Consequences - Occupational illness.	Operation	Negative	The operation and maintenance phase will be managed according to all the requirements of the Occupational Health and Safety Act 85 of 1993. SHEQ policy in place. A detailed Risk Assessment of all normal operating and maintenance activities on site to be compiled, and form the basis of operating instructions, prior to commencing commissioning. SHE procedure in place, e.g., PPE specified, management of change, integrity monitoring. SHE appointees in place. Training of staff in general hazards on site. All necessary health controls/ practices to be in place, e.g., ventilation of confined areas, occupational health monitoring if required and reporting programs in place. Emergency response plan for full operation and maintenance phase to be in place prior to beginning commissioning and to include aspects such as: - appointment of emergency controller, - emergency isolation systems for electricity, - -emergency isolation and containment systems for electrolyte, - provision of PPE for hazardous materials response, - provision of emergency facilities for staff at the main office building, - provision of first aid facilities, - first responder contact numbers etc.	Easy	2	1	3	4	5	**50**	1	1	3	4	2	**18**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 1b:	Human Health - chronic exposure to toxic chemical or biological agents	Causes - Compromised battery compartments vapours accumulate in the containers, solids/liquids on surfaces. Maintenance of battery components, corrosive and mildly toxic liquid on surfaces. Consequences - Dermatitis, skin /eye/lung irritation.	Operation	Negative	Solid state batteries sealed, individual batteries in modules which are also sealed, pre-packed in the container. Maintenance procedures will be in place should equipment need to be opened, e.g., pumps drained and decontaminated prior to repair in workshop etc. PPE will be specified for handling battery parts and other equipment on site. Training of staff in hazards of chemicals on site. Possible detectors with local alarms if regulated occupational exposure limits are exceeded etc prior to entry for inspection of battery containers. Labelling of all equipment. Confined space entry procedures if entering tanks. There needs to be careful thought given to procedures to be adopted before entering into the BESS or a container particularly after a BMS shut down where there may be flammable or toxic gases present, a fire etc. Safety Data Sheets (SDSs) to be available on site. Operating manuals to be provided including start-up, shut-down, steady state, monitoring requirements. Maintenance manuals with make safe, decontamination and repair procedures. Proposed maintenance schedules e.g., checklists for weekly, monthly, annual etc. Provided portable equipment for calibration and for testing/verification of defective equipment, e.g., volt/current meters, infrared camera	Complex	3	1	3	5	4	**48**	1	1	3	5	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 2:	Human Health - exposure to noise	Causes - Moving parts inside containers, buildings, pumps, compressors, cooling systems etc. Consequences - Adverse impact on hearing of workers. Nuisance factor at	Operation	Negative	Design to ensure continuous noise does not exceed 85dB within the facilities or at any other location on site or 61 dB at the site boundary, e.g., emergency generator, air compressor etc. Employees to be provided with hearing protection if working near equipment that exceeds the noise limits.	Easy	2	1	5	5	4	**52**	2	1	5	5	2	**26**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
		near -by residences or other activities.																
						Significance	N3 - Moderate						N2 - Low					
Impact 3:	Human Health - exposure to temperature extremes and/or humidity	Causes - Heat during the day. Batteries generate heat within enclosed building / containers. Cold in winter. Night work requires lighting. Consequences - Heat stroke. Hypothermia.	Operation	Negative	Building and container facilities to comply with Occupational Health and Safety Act 85 of 1993 specifically the thermal, humidity, lighting and ventilation requirements of the Environmental Regulations for Workplaces. Ensure containers are temperature controlled as required to remain within the optimal battery operating temperature range. Lighting to be provided inside any buildings, inside the containers, possibly linked to the door opening and outdoors where necessary. Adequate potable water to be provided during all phases of the project. Suitable lighting to be provided including emergency lighting for safe building exit in the event of power failure. PPE for operations and maintenance staff to be suitable for the weather conditions.	Easy	4	2	3	1	2	**20**	3	2	3	1	1	**9**
						Significance	N2 - Low						N1 - Very Low					
Impact 4:	Human Health - exposure to psychological stress	Causes - Isolated workstation and monotonous repetitive work. Consequences - Low performance, system productivity suffers.	Operation	Negative	Staff rotation to other activities within the site may be necessary. Performance monitoring of inspections / maintenance tasks in particular will be necessary.	Easy	2	3	3	2	2	**20**	1	3	3	2	1	**9**
						Significance	N2 - Low						N1 - Very Low					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 5:	Human Health - exposure to ergonomic stress	Causes - Lifting heavy equipment. Awkward angles during maintenance, stretching reaching to high level and bending to low level. Working at height if equipment located on top of roofs or elevated electrical equipment (e.g., pylons). Consequences - Back and other injuries.	Operation	Negative	Training in lifting techniques. Training in working at heights. If equipment is at height (see OHS Act General Safety Regulation 6), ensure suitable safe (electrically and physically) ladders / harnesses etc. are available. Working at height procedure to be in place.	Easy	5	1	3	2	3	**33**	4	1	3	2	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 6a:	Human and Equipment Safety - exposure to fire radiation	Causes – Involvement in an external fire e.g., veld fire, maintenance vehicle fire, electrical systems fire. Manufacturing defects or damage to battery leading to shorting and heating. High humidity condensation of water or ingress of water or flooding leading to shorting. Dust accumulation on electrical parts leading to overheating. Excessive electrical loads - surges Operator abuse BMS failure or software failure. Incorrect extinguishing medium, escalate the fire. Consequences - Contaminated run off. Radiation burns unlikely to be severe as no highly flammable materials on site. Damaged equipment. Fire spreads to other units or offsite if	Operation	Negative	Grass cutting and fire breaks around the BESS installations to prevent veld fires. No combustible materials to be stored in or near the batteries or electrical infrastructure. Separation of site diesel tank, transformers from BESS and vice versa. There are BESS design codes from the USA and standards of practice that can be used e.g., UL9540, NFPA 855 and DNV GL RP 43. Detailed FMEA/Hazop/Bowtie to done during design at the component level and system levels. Safety integrity level rating of equipment (failure probably) with suitable redundancy if required. Site Acceptance Testing as part of commissioning of each unit and the overall system. Abuse tests conducted by supplier. BMS should be checking individual cell voltage as well as stack, module, container, system voltages/current etc. BMS tripping the cell and possibly the stack/ building unit or module/rack/container, if variations in voltage. Diagnostics easily accessible. Diagnostics able to distinguish cell from stack or cell from module faults. Protective systems are only as good as their reliability and functionality testing is important, e.g., testing that all battery trips actually work. Fire resistant barrier between the batteries and the PCS side if in the same container, or separate containers. Suitable ingress protection level provided for electrical equipment, e.g., IP55 - 66. If air cooling into container, suitable dust filters to be provided. Smoke detectors linked to BMS & alerts in control room. Effects of battery aging to be considered. Solid state battery life starts to be impacted above 40 °C and significant impacts above 50 °C with thermal run away starting at 65-70 °C. BMS trips system at 50 °C. Temperature monitoring to be in place. Regular infrared scanning. Data needs to be stored for trend analysis. Data indicates an event frequency of 0.001 per installation and with 300 units this would mean an event once 3 years, i.e. a high probability event. Most events will be small not resulting in injuries, but this is possible if the event is not controlled.	Complex	5	1	5	5	4	**64**	5	1	5	5	1	**16**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
		grass/vegetation not controlled.			Prior to commencement of cold commissioning, emergency plan from transport and construction phase to be extended to operational phase and to include the hazards of the electrically live system. Procedure to address solid state container fires - extinguishing, ventilating, entering as appropriate or not. PPE for container firefighting include fire retardant, chemically resistant, nitrile gloves, antistatic acid resistant boots, fill face shields, BA sets. A planned fire response to prevent escalation to an explosion or an environmental event. Suitable supply of fire extinguishing medium and cooling medium Consider fire water for cooling adjacent equipment – BESS units. Can use fogging nozzles to direct smoke. Ensure procedures in place for clean up after event Lingering HF and other toxic residues in the soil and on adjacent structures. Procedures to be in place for IR scanning (or other suitable method) to determine if batteries are still smouldering / are sufficient cooled to handle as batteries may still be active some weeks after an event. Smoke or gas detector systems that are not part of the original battery container package, need to be linked to the main control panel for the entire system so that issues can be detected and responded to rapidly.													

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
						Significance	N4 - High						N2 - Low					
Impact 6b:	Human and Equipment Safety - exposure to fire radiation	Causes - Power Conversion System (PCS – DC to AC) cooling failure electrical fire. Consequences - Fire starts in PCS or another section or room and spreads to battery area.	Operation	Negative	Modern lithium container design put the PCS in another part of the container with a fire rated wall separating it from the battery. Alternately the PCS is another container altogether.	Moderate	5	2	5	5	4	**68**	5	2	5	5	1	**17**
						Significance	N4 - High						N2 - Low					
Impact 7:	Human and Equipment Safety - exposure to explosion over pressures	Cause 1 - Transformer shorting / overheating / explosion. Cause 2 - Flammable gases generated by thermal run away reach explosive limits. Ignition on hot surfaces, static. Lithium Cobalt Oxide generates O2 during decomposition – escalation. Consequences - Potential fatalities amongst first responders. Damage to container or other nearby items, e.g., other container.	Operation	Negative	Electrical equipment will be specified to suit application. Emergency response plan and employee training referred to above is to be in place. This is only really likely to happen due to possible inappropriate emergency response, e.g., opening containers when they may be the type that should be left to burn out. Modern state of the art containers have ventilation systems for vapours. Undertake a hazardous area classification of the inside of the container to confirm the rating of electrical equipment, due to possible leaks of electrolyte or generation of flammable gases under thermal run away. Emergency response plan and employee training referred to above is critical. Suitable training of selected emergency responders who may be called out to the facilities is critical. NOTE. Refer to Appendix A for an initial approximation of worst-case possible explosion impact zones.	Moderate	5	1	5	5	2	**32**	5	1	5	5	1	**16**
						Significance	N3 - Moderate						N2 - Low					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 8a:	Human and Equipment Safety - exposure to acute toxic chemical and biological agents	Causes Human pathogens and diseases, sewage, food waste. Snakes, insects, wild and domesticated animals and harmful plants. Consequences - Illness and at worst without mitigation, possibly extending to fatalities. Effects can vary from discomfort to fatalities for venomous snakes or bee swarms etc	Operation	Negative	All necessary good hygiene practices to be in place, e.g., provision of toilets, eating areas, infectious disease controls. Policies and practice for dealing with known vectors of disease such as Aids, TB, COVID 19 and others. Awareness training for persons on site, safety induction to include animal hazards. First aid and emergency response to consider the necessary anti-venom, anti-histamines, topical medicines etc. Due to isolated locations some distance from town, the ability to treat with anti-venom and extreme allergic reactions on site is critical to mitigate the impacts	Moderate	4	1	3	2	3	**30**	3	1	2	2	2	**16**
						Significance	**N2 - Low**						**N2 - Low**					
Impact 8b:	Human and Equipment Safety - exposure to acute toxic chemical and biological agents	Causes - Damaged batteries components, leak electrolyte, are completely broken exposing hazardous chemicals. Hazardous fumes released on thermal run away see fire above. Consequences - Impacts can vary from mild skin irritation from exposure to small leaks to serious corrosive burns for large exposure.	Operation	Negative	Acid resistant PPE (e.g., overalls, gloves, eyeglasses) to be specified for all operations in electrolyte areas. PPE to be increased (e.g., full-face shield, aprons, chemical suits) for operations that involve opening equipment and potential exposure, e.g., sampling, maintenance. All operators/maintenance staff trained in the hazards of chemicals on site. Batteries contained, modules contained and all inside a container that acts as bund. Refer to fire above as all the protective measures apply to prevent toxic smoke. Refer to fire above as all the measures apply to mitigate toxic smoke. 24/7 helpline response. Standard dangerous goods requirements for Hazmat labels. All operators/maintenance staff trained in the hazards.	Moderate	4	3	3	5	3	**45**	3	3	3	5	2	**28**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
		In the case of toxic fumes, serious lung damage.			NOTE Refer to Appendix A for an initial approximation of worst case possible noxious smoke impact zones.													
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 9:	Human and Equipment Safety - exposure to violent release of kinetic or potential energy	Causes - Moving equipment, pumps, heavy equipment at elevation, nip points, working at heights. Traffic accidents. Earthquake / tremor. Consequences - Injury. Fatality in unlikely worst case, e.g., traffic accidents or fall from heights. Damage to equipment, spills, environment pollution	Operation	Negative	Apart from pumps, no major moving parts during operation. Maintenance equipment to be serviced and personnel suitably trained in the use thereof. Normally just small vehicles on site, bakkies, grass cutting, cherry-pickers etc. Possibly large cranes if large equipment or elevated structure removed/replaced. Traffic signs, rules etc in place on site. All normal working at heights, hot work permits, confined space entry, cordon off unsafe areas/works etc to be in place. Emergency response plan. Civil design to take seismic activity into account.	Moderate	5	1	5	5	3	**48**	5	1	5	5	1	**16**
							N3 - Moderate						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 10:	Human and Equipment Safety - exposure to electromagnetic waves	Causes - Use of electrical machines, generators etc. Hot dry area static generation is highly likely. Lightning strike. Consequences - Electrocution. Ignition and burns. Injury and death. Damage electrical equipment.	Operation	Negative	Codes and guidelines for electrical insulation. Suitable PPE to be specified. Low voltage equipment (e.g., batteries) separated from high voltage (e.g., transmission to grid). Ensure trained personnel and refer to guideline – IEE 1657 – 2018. Ensure compliance with Eskom Operating Regulations for high voltage systems including access control, permit to work, safe work procedures, live work, abnormal and emergency situations, keeping records. Electromagnetic fields, impact on other equipment e.g., testing devices, mobile phones – malfunction, permanent damage. Software also need to be kept as update to date as reasonably practicable. Consider suitably located Emergency stop buttons for the facility and the other equipment on site. PPE to consider static accumulation for entering the facility, and particularly the battery containers especially after a high temperature shut down where there could possibly be flammable materials. The procedures for responding to alarm and auto shut down on containers, needs to consider that there may be a dangerous environment inside and how to protect personnel who may enter to respond. Lightning strike rate in proposed development area is moderate. All outside work must be stopped during thunder storms. Lighting conductors may be required for the installation, to be confirmed during design	Complex	5	2	5	5	3	**51**	5	2	5	5	1	**17**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 11:	Environment - emissions to air	Not expected on a normal basis. Refrigerant may be an asphyxiant if accidentally released indoors it can	Operation	Negative	Especially after any warning alarms have gone off, but possibly even normally the container could be treated as entering a confined space and similar procedures could be in place, e.g., do not enter alone, gas testing prior to entering, ensure adequate ventilation	Easy	3	1	1	1	3	**18**	3	1	1	1	1	**6**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
		accumulate and displace oxygen.																
						Significance	N2 - Low						N1 - Very Low					
Impact 12:	Environment - emissions to water	Causes - Cooling water blow-down. Laboratory waste (if included in the design). Maintenance waste, e.g., oils. Spills from batteries, coolant system, diesel trucks, transformers. Parked vehicles – oil drips. Fire water runoff control. Kitchen waste and sewage. Refrigerant release. Consequences - Pollution if not contained. Excessive disposal costs if emissions not limited.	Operation	Negative	Bunding under any outdoors tanks, curbing under truck offloading areas and sealed surfaces (e.g., concrete) under truck parking area is particularly important. Sewage and any kitchen liquids - containment and suitable treatment/disposal e.g. septic tank and soak away. Procedures for dealing with damaged/leaking equipment as well as clean-up of spills. Normal site practices for preventing and containing diesel/paint etc spills. Waste management plan to be in place e.g., liquid waste treatment or suitable removal and disposal will be provided. Spill clean-up procedures to be in place before bringing container on site, including spill kits – non-combustible materials, hazmat disposal. The National Environment Management Act (NEMA) has a list of substances with Reportable spill Quantities, ensure compliance with this.	Moderate	2	2	3	2	3	**27**	2	2	3	2	2	**18**
						Significance	N2 - Low						N2 - Low					
Impact 13:	Environment - emissions to earth	Causes - Mess area and other solid waste. Disposal of solid-state batteries. Consequences - Environmental damage.	Operation	Negative	Implement waste segregation (e.g., electronic equipment, chemicals, domestic) and management on the site.	Easy	2	2	3	3	3	**30**	2	2	3	3	1	**10**
						Significance	N2 - Low						N1 - Very Low					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 14:	Environment - waste of resources e.g., water, power etc	Causes - Similar to construction phase. Disposal of batteries or components. Disposal of containers. Water usage not controlled. Consequences - Delays. Excessive costs and disposal of large volumes of hazardous waste.	Operation	Negative	Water usage to be monitored on site. Handling protocols to be provided by supplier of batteries. Water management plan and spill containment plans to be in place. Investigate end of Life plan for solid state batteries - reuse / recovery / reconditioning. Similarly, for decommissioned containers – reuse / recovery / repurpose	Easy	1	1	1	2	4	**20**	1	1	1	2	2	**10**
							N2 - Low						**N1 - Very Low**					
Impact 15:	Public - Aesthetics	Causes - Bright surfaces reflecting light. Tall structures in a flat area. Consequences - Irritation.	Operation	Negative	Refer to Visual Impact Assessment which is to include the BESS installation once design details are available	Easy	1	2	4	4	2	**22**	1	2	4	4	2	**22**
						Significance	**N2 - Low**						**N2 - Low**					
Impact 16:	Investors - Financial	Causes - Defective technology. Extreme project delays. Consequences - Financial loss	Operation	Negative	Design by experienced contractors using internationally recognized and proven technology. Project management with deviation monitoring.	Easy	5	1	3	4	3	**39**	3	1	3	4	2	**22**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 17a:	Employees and investors - Security	Causes - On route, potential hi-jacking of valuable but hazardous load. On site, theft of construction equipment and battery installation facilities. Civil unrest or violent strike by employees. Consequences - Theft. Injury to burglars. Damage to equipment possibly setting off thermal runaway.	Operation	Negative	Fencing around electrical infrastructure to SANS standard and Eskom Guidelines. Consider motion detection lights and CCTV. The hazardous nature of the electrical and battery equipment should be clearly indicated – e.g., Skull and Cross Bones or other signs. Isolated location both helps and hinders security. Night lighting to be provided both indoors and outdoors where necessary.	Moderate	3	1	3	2	4	**36**	3	1	3	2	2	**18**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 17b:	Employees and investors - Security	Causes - Cyber security attacks aimed at the National Electricity Grid. Consequences - Ransom of the National Electricity Grid.	Operation	Negative	Cyber security needs monitoring. Remote access to system needs to be negotiated and controlled. Password controls, levels of authority etc. Protection of the National Electricity Grid from Cyber-attacks accessing through the BESS. Cyber emergency procedures – should be in place prior to commissioning.	Complex	4	4	3	1	4	**48**	4	4	3	1	2	**24**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 18:	Emergencies	Causes - Fires, explosions, toxic smoke, large spills, traffic accidents, equipment/structural collapse. Inadequate emergency response to small event leads	Operation	Negative	All safety measures listed above. Emergency procedures need to be practiced prior to commencement of operations. Escape doors should swing open outwards and not into the container. Doors should be able to be hooked open when persons are inside the container, i.e. they should not be automatically self-closing. More than one exit from buildings. Storage of spare batteries (e.g., in stores on site or	Complex	4	2	3	4	3	**39**	4	2	3	4	2	**26**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
		to escalation. Consequences - Injuries turn to fatalities, small losses become extended down time.			elsewhere) also needs to consider possible thermal run away.													
						Significance	N3 - Moderate						N2 - Low					
Impact 19:	Investors - Legal	Causes Battery field is evolving quickly with new guides, codes and regulations happening at the same time as evolving technology. Consequences - Unknown hazards manifest due to using “cheaper supplier or less developed technology”.	Operation	Negative	Use only internationally reputable battery suppliers who comply with all known regulations/guideline at the time of purchasing. Ensure only state of the art battery systems are used and not old technologies prone to fires/explosions etc.	Moderate	3	1	3	3	4	**40**	3	1	3	3	2	**20**
						Significance	N3 - Moderate						N2 - Low					

The above Risk Assessment shows that, provided the preventative and mitigative measures are incorporated, the operational phase of the project does not present any high risks nor any fatal flaws.

TABLE 4.1.3 - DECOMMISSIONING PHASE

Battery components may have a limited lifespan; there are damaged equipment etc. There could already be "waste" on the first day of commissioning and plans should be in place to deal with this. Ideally an End-of-Life plan needs to be in place before the first container / equipment is brought on site.

All decommissioning activities must comply with the relevant regulations at the time. Decommissioning will ultimately need to be informed by the regulatory requirements at the time, which may be different to present requirements. The impact rating are not possible to determine now given the uncertainties in mitigations applicable at that time; hence they have been left as neutral.

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 1:	Human Health - chronic exposure to toxic chemical or biological agents	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**As for Construction and Operation**						**As for Construction and Operation**					
Impact 2:	Human Health - exposure to noise	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**As for Construction and Operation**						**As for Construction and Operation**					
Impact 3:	Human Health - exposure to temperature extremes and/or humidity	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**As for Construction and Operation**						**As for Construction and Operation**					
Impact 4:	Human Health - exposure to psychological stress	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
						Significance	As for Construction and Operation						As for Construction and Operation					
Impact 5:	Human Health - exposure to ergonomic stress	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	As for Construction and Operation						As for Construction and Operation					
Impact 6:	Human and Equipment Safety - exposure to fire radiation	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	As for Construction and Operation						As for Construction and Operation					
Impact 7:	Human and Equipment Safety - exposure to explosion over pressures	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	As for Construction and Operation						As for Construction and Operation					
Impact 8:	Human and Equipment Safety - exposure to acute toxic chemical and biological agents	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	As for Construction and Operation						As for Construction and Operation					
Impact 9:	Human and Equipment Safety - exposure to violent release of kinetic or potential energy	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
							#N/A						**#N/A**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 10:	Human and Equipment Safety - exposure to electromagnetic waves	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**As for Construction and Operation**						**As for Construction and Operation**					
Impact 11:	Environment - emissions to air	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**As for Construction and Operation**						**As for Construction and Operation**					
Impact 12:	Environment - emissions to water	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**As for Construction and Operation**						**As for Construction and Operation**					
Impact 13:	Environment - emissions to earth	Causes - Batteries / equipment reached end of life and may leak. Consequences - Environment damage from heavy metal ions.	De-commission	Negative	End of Life shutdown procedure including a Risk Assessment of the specific activities involved. Where possible re-purpose the solid-state batteries / containers and equipment with associated environmental impact considered. Disposal according to local regulations and other directives such as the European Batteries Directive. End of life, which is affected by temperature and time, cycles etc, should be predefined and the monitoring should be in place to determine if it has been reached.	Complex	4	3	3	5	4	**60**	4	3	3	5	2	**30**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 14:	Environment - waste of resources e.g., water, power etc	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**As for Construction and Operation**						**As for Construction and Operation**					
Impact 15:	Public - Aesthetics	Similar to the construction and	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
		operational phases - no new hazards.																
						Significance	As for Construction and Operation						As for Construction and Operation					
Impact 16:	Investors - Financial	Similar to the construction n and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	As for Construction and Operation						As for Construction and Operation					
Impact 17:	Employees and investors - Security	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	As for Construction and Operation						As for Construction and Operation					
Impact 18:	Emergencies	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	As for Construction and Operation						As for Construction and Operation					
Impact 19:	Investors - Legal	Disposal of hazardous “waste” is rife with difficulties and numerous regulations that need to be complied with.	De-commission	Negative	Applicants should seek the opinion from a waste consultant on how to correctly dispose of hazardous waste.	Complex	3	1	3	3	4	**40**	3	1	3	3	3	**30**
						Significance	N3 - Moderate						N2 - Low					

The above Risk Assessment shows that, provided the preventative and mitigative measures are incorporated, the de-commissioning phase of the project does not present any high risks nor any fatal flaws.

4.2 SODIUM SULPHIDE BATTERY ENERGY STORAGE SYSTEMS

TABLE 4.2.1 - CONSTRUCTION PHASE (Excluding commissioning which is part of operations)

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
Impact 1:	Human Health - chronic exposure to toxic chemical or biological agents	Causes - Construction materials such as cement, paints, solvents, welding fumes, truck fumes etc. Consequences - Employee / contractor illness.	Construction	Negative	The construction phase will be managed according to all the requirements of the Occupational Health and Safety Act 85 of 1993 specifically the Construction Regulations. SHEQ policy in place. A detailed construction risk assessment prior to work. SHE procedure in place. PPE to be specified. SHE appointees in place. Contractors safety files in place and up to date. All necessary health controls/ practices to be in place, e.g. ventilation of welding and painting areas. SHE monitoring and reporting programs in place. Emergency response plan to be in place prior to beginning construction and to include aspects such as appointment of emergency controller, provision of first aid, first responder contact numbers.	Moderate	3	1	3	4	4	**44**	1	1	3	4	2	**18**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 2:	Human Health - exposure to noise	Causes - Drilling, piling, generators, air compressors. Consequences - Adverse impact on hearing of workers. Possible nuisance factor in near-by areas.	Construction	Negative	The construction phase will be the noisy phase of the project. No extreme construction envisaged, normal road, industrial building type construction similar to what would take place in an industrial area. Health risk assessment to determine if equipment continuous noise exceeds 85dB at workstation and 61dB at boundary of the site Employees to be provided with hearing protection if working near equipment that exceeds the noise limits. Due to rural nature of site, construction is unlikely to continue at after sunset.	Easy	3	1	5	5	4	**56**	2	1	5	5	2	**26**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact 3:	Human Health - exposure to temperature extremes and/or humidity	Causes - Heat during the day. Cold in winter. Consequence - Heat stroke. Hypothermia.	Construction	Negative	Construction site facilities to comply with Occupational Health and Safety Act 85 of 1993 specifically the thermal, humidity, lighting and ventilation requirements of the Environmental Regulations for Workplaces. Adequate potable water to be provided during all phases of the project. Bore hole, bowser and tank or small water treatment plant may be required to provide potable water for the plants during all phases of the project.	Easy	3	2	3	1	2	**18**	2	2	3	1	1	**8**
						Significance	**N2 - Low**						**N1 - Very Low**					
Impact 4:	Human Health - exposure to psychological stress	Causes - Large projects bring many contractor workers into a small, isolated community. Consequences – Lack of sufficient accommodation, entertainment etc. Increase in alcohol abuse, violence	Construction	Negative	Depending on size of contract and scope, project may need to provide regular/periodic transport to town and nearby cities. Local community involvement and as far as possible preferably use of local persons as contract workers on the project.	Easy	2	3	3	2	2	**20**	1	3	3	2	1	**9**
						Significance	**N2 - Low**						**N1 - Very Low**					
Impact 5:	Human Health - exposure to ergonomic stress	Causes - Lifting heavy equipment. Awkward angles during construction. Consequences - Back and other injuries..	Construction	Negative	Training in lifting techniques. Ensure that despite the isolated location all the necessary equipment is available (and well maintained) during construction. Otherwise employees may revert to unsafe practices. Isolated location, maintenance of construction equipment to ensure safe operation is critical. Ensure this is in place prior to project beginning. Development of local service providers. First aid provision on site.	Moderate	4	1	3	2	3	**30**	4	1	3	2	2	**20**
						Significance	**N2 - Low**						**N2 - Low**					

Impact 6a:	Human and Equipment Safety - exposure to fire radiation	Causes – Involvement in an external fire. Fire involving fuels used in construction vehicles or vehicles themselves (e.g., tyre fire). Fire due to uncontrolled welding or other hot-work Consequences - Injuries due to radiation especially amongst first responders and bystanders. Fatalities unlikely from the heat radiation as not highly flammable nor massive fire.	Construction	Negative	Fuels stored on site in dedicated, demarcated and bunded areas. Suitable fire-fighting equipment on site near source of fuel, e.g., diesel tank, generators, mess, workshops etc. The company responsible for the facility at this stage is to have: 1. Emergency plan to be in place prior to commencement of construction. 2. Fuel spill containment procedures and equipment to be in place. 3. Hot-work permit and management system to be in place.	Complex	4	2	3	5	4	**56**	4	2	3	5	2	**28**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 6b:	Human and Equipment Safety - exposure to fire radiation	Causes - Solid state battery containers damaged on route e.g., dropped in port (drops do happen about 1/2000 containers) and importing possibly < 300 containers for the site. With this it is possible, although unlikely, that one will be dropped, traffic accident on-route. Involvement in an external fire e.g., at the port or on route. Data indicates installed facility events are 0.001/year. Transport of 300 units	Construction	Negative	Solid state battery design includes abuse tests such as drop test, impact, rapid discharge etc. Propagation tests for systems, e.g., heat insulating materials between cells/modules. Factory acceptance test prior to prior to leaving manufacture. Batteries are usually stored at 50% charge to prolong life but may be shipped fully discharged. This level of detail should be understood so as to assess the risk during transport and storage. The company responsible for the battery installation should ensure suitably competent transport companies are appointed. The company responsible for transportation should ensure: - Compliance with National Road Traffic Act regulation 8 – dangerous goods. - Port Authorities should be alerted to the overall project and the hazardous nature of the contents of battery containers being imported. Note. If, as per one of the typical suppliers (NPK) indications, the containers are classified as IMDG Class 9 – the containers will not receive any special care in the ports and may be stored next to flammables. Port	Complex	5	2	5	5	2	**34**	5	2	5	5	1	**17**

		for the installation assumed to take 4 weeks each so f= 0.02 - once in 45 years so likelihood is moderately low. Consequences – sodium spontaneous ignition in air, possibly aggravated by fire water. Injuries due to radiation especially amongst first responders and bystanders. Fatalities unlikely from the heat radiation as not massive fire (refer fire radiation in APPENDIX A below for the impact range).			emergency response in particular need training on mitigating battery hazards. Prior to bringing any containers into the country, the company responsible for the battery installation (possibly via appointed contractors) should ensure that an Emergency response plan is in place for the full route from the ship to the site. Drivers trained in the hazards of containerized batteries. The Emergency plan must determine and address: - What gases would be released in a fire and are there inhalation hazards. - Extinguishing has two important elements, put out fire and to provide cooling for adjacent equipment. Different approaches may be needed. Note that water cannot be used on s sodium fire and also on electrical fires. - What initial fire extinguishing medium should be used. - Whether there are any secondary gases or residues from use of extinguishers. - First responders need to know what media to use, especially if water totally unsuitable. - Must the container be left unopened or opened. - PPE to be specified including possible exposure to chemicals and fumes as well as radiate heat. - Containment of residues/water/damaged equipment. - Suitable safe making and disposal plan for after the event i.e. how do responders deal with partially charged damage units, contaminated surfaces (e.g., sulphur residues).													
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 7:	Human and Equipment Safety - exposure to explosion over pressures	No credible causes	Construction	Negative	No causes, hence no actions.	N/A	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					

Impact 8:	Human and Equipment Safety - exposure to acute toxic chemical and biological agents	Causes Human pathogens and diseases, sewage, food waste. Snakes, insects, wild and domesticated animals and harmful plants. Consequences - Illness and at worst without mitigation, possibly extending to fatalities. Effects can vary from discomfort to fatalities for venomous snakes or bee swarms etc	Construction	Negative	All necessary good hygiene practices to be in place, e.g. provision of toilets, eating areas, infectious disease controls. Policies and practice for dealing with known vectors of disease such as Aids, TB, COVID 19 and others. Prior to construction determine the dangerous species in the area and what responses are needed to bites/exposure/attacks. Awareness training for persons on site, safety induction to include animal hazards. First aid and emergency response to consider the necessary anti-venom, anti-histamines, topical medicines etc. Due to isolated locations some distance from town, the ability to treat with anti-venom and extreme allergic reactions on site is critical to mitigate the impacts	Complex	4	2	3	2	3	**33**	3	2	3	2	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 9:	Human and Equipment Safety - exposure to violent release of kinetic or potential energy	Causes - Construction moving equipment, heavy loaded, elevated loads, working at heights Consequences - Injury or possibly fatality. Damage to equipment. Delays in starting the project, financial losses	Construction	Negative	The construction phase will be managed according to all the requirements of the Occupational Health and Safety Act 85 of 1993 specifically the Construction Regulations. SHEQ policy in place. A detailed construction risk assessment prior to work. SHE procedure in place. PPE to be specified. SHE appointees in place. Contractors safety files in place and up to date. SHE monitoring and reporting programs in place. Standard construction site rules regarding traffic, reversing sirens, rigging controls, cordoning off excavations etc. Civil and building structures to National Building Regulations and building Standards Act 103 of 1977 SANS 10400 and other relevant codes. Other constructions such as roads, sewers etc also to relevant SANS standards. All normal procedures for working at heights, hot work permits, confined space entry, cordon off excavations etc to be in place before construction begins. Emergency response plan to be in place before construction begins.	Complex	5	1	5	5	4	**64**	5	1	5	5	1	**16**

							N4 - High						N2 - Low					
Impact 10:	Human and Equipment Safety - exposure to electromagnetic waves	Causes - Use of electrical machines, generators etc. Hot dry area static generation is highly likely. Lightning strike. Consequences - Electrocution. Ignition and burns. Injury and death. Damage electrical equipment.	Construction	Negative	Standard maintenance of condition of electrical equipment and safe operating instructions. Ability to shut off power to systems in use on site. If persons are decanting fuels or dealing with other highly flammable materials care should be taken regarding possible static discharge, installations to be suitably designed and maintained. Lightning strike rate in the study area is moderate. Outside work must be stopped during thunder storms. Lighting conductors may be required for the final installation, to be confirmed during design phase.	Complex	5	2	5	5	3	**51**	5	2	5	5	1	**17**
						Significance	N3 - Moderate						N2 - Low					
Impact 11:	Environment - emissions to air	Causes - Dust from construction and generally hot dry area. Consequences - Adverse impact on employee health.	Construction	Negative	May need to use dampening on roads etc. as per normal construction practices. May need PPE (dust masks) for specific construction workers.	Easy	3	2	1	1	4	**28**	2	2	1	1	2	**12**
						Significance	N2 - Low						N1 - Very Low					
Impact 12:	Environment - emissions to water	Causes - Diesel for equipment, paints and solvents. Transformer oil spills. Sewage and kitchen/mess area waste water. Consequences - Environmental damage, particularly to the surface and underground water in the area.	Construction	Negative	Normal construction site practices for preventing and containing fuels/paint/oil etc spills. Bunding under any temporary tanks, curbing under truck offloading areas and sealed surfaces (e.g. concrete) under truck parking area is particularly important. Spill clean-up procedures to be in place before commencing construction. Sewage and any kitchen liquids - containment and suitable treatment/disposal	Moderate	2	2	3	2	3	**27**	2	2	3	2	2	**18**
						Significance	N2 - Low						N2 - Low					

Impact 13:	Environment - emissions to earth	Causes - Mess area and other solid waste. Consequences - Environmental damage.	Construction	Negative	There will be packaging materials that will need to be disposed of after the entire system is connected and commissioned as well as after regular maintenance. There will need to be waste segregation (e.g. electronic equipment, chemicals) and management on the site.	Easy	2	2	3	3	3	**30**	1	2	3	3	2	**18**
						Significance	**N2 - Low**						**N2 - Low**					
Impact 14:	Environment - waste of resources e.g. water, power etc	Causes - Water usage not controlled. Battery equipment damaged. Consequences - Delays.	Construction	Negative	Water usage to be monitored on site during construction. Handling protocols to be provided by battery supplier. Water management plan and spill containment plans to be in place.	Easy	1	1	1	2	4	**20**	1	1	1	2	2	**10**
							N2 - Low						**N1 - Very Low**					
Impact 15:	Public - Aesthetics	Causes - Bright surfaces reflecting light. Tall structures in a flat area. Consequences - Irritation.	Construction	Negative	Limited height for electrical infrastructure. Visual impact assessment to include BESS installation when design details become available. Battery containers single storey as physical space is not a constraint that would require stacking of containers. Containers likely to be painted white, not left as reflective steel.	Moderate	3	2	3	4	4	**48**	1	2	3	4	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 16:	Investors - Financial	Causes - Defective technology. Extreme project delays. Consequences - Financial loss	Construction	Negative	Design by experienced contractors using internationally recognized and proven technology. Project management with deviation monitoring. Project insurance for construction phase.	Moderate	5	1	3	4	3	**39**	3	1	3	4	2	**22**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 17:	Employees and investors - Security	Causes - On route, potential hi-jacking of valuable but hazardous load. On site, theft of construction equipment and battery installation facilities. Civil unrest or violent strike by employees. Consequences - Theft.	Construction	Negative	Fencing around electrical infrastructure to SANS standard and Eskom Guidelines. The hazardous nature of the electrical and battery equipment should be clearly indicated – e.g. Skull and Cross Bones or other signs. Isolated location both helps and hinders security. Night lighting to be provided both indoors and outdoors where necessary.	Complex	4	1	3	2	4	**40**	3	1	3	2	3	**27**

		Injury to burglars. Damage to equipment possibly setting off thermal runaway.																
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 18:	Emergencies	Causes - Fires, explosions, toxic smoke, large spills, traffic accidents, equipment/structural collapse. Inadequate emergency response to small event leads to escalation. Consequences - Injuries turn to fatalities, small losses become extended down time.	Construction	Negative	All safety measures listed above. Small events not handled correctly and escalate into larger events. Emergency procedures need to be practiced prior to commencement of construction.	Complex	4	2	3	4	3	**39**	4	2	3	4	2	**26**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 19:	Investors - Legal	Causes Battery field is evolving quickly with new guides, codes and regulations happening at the same time as evolving technology. Consequences - Unknown hazards manifest due to using "cheaper supplier or less developed technology".	Construction	Negative	Use only internationally reputable battery suppliers who comply with all known regulations/guideline at the time of purchasing. Ensure only latest state of the art battery system are used.	Moderate	3	1	3	3	4	**40**	3	1	3	3	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**					

The above Risk Assessment shows that provided the preventative and mitigative measures are incorporated, the construction phase of the project does not present any high risks nor any fatal flaws.

TABLE 4.2.2 - OPERATIONAL PHASE (Including Commissioning)

From the details of accidents that have happened both with BESS installations and chemical plants in general, it is clear that many potential problems manifest during the commissioning phase when units are first powered up to test functionality. This phase is critical and all controls, procedures, mitigation measures etc that would be in place for full operation should be in place before commissioning commences.

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
Impact 1a:	Human Health - chronic exposure to toxic chemical or biological agents	Causes - Operation and maintenance materials spare parts, paints, solvents, welding fumes, transformers oils, lubricating oils and greases etc. Consequences - Occupational illness.	Operation	Negative	The operation and maintenance phase will be managed according to all the requirements of the Occupational Health and Safety Act 85 of 1993. SHEQ policy in place. A detailed risk assessment of all normal operating and maintenance activities on site to be compiled, and form the basis of operating instructions, prior to commencing commissioning. SHE procedure in place, e.g. PPE specified, management of change, integrity monitoring. SHE appointees in place. Training of staff in general hazards on site. All necessary health controls/ practices to be in place, e.g. ventilation of confined areas, occupational health monitoring if required and reporting programs in place. Emergency response plan for full operation and maintenance phase to be in place prior to beginning commissioning and to include aspects such as: - appointment of emergency controller, - emergency isolation systems for electricity, - -emergency isolation and containment systems for molten electrolyte, - provision of PPE for hazardous materials response, - provision of emergency facilities for staff at the main office building, - provision of first aid facilities, - first responder contact numbers etc.	Easy	2	1	3	4	5	**50**	1	1	3	4	2	**18**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact 1b:	Human Health - chronic exposure to toxic chemical or biological agents	Causes - Compromised battery compartments vapours accumulate in the containers, solids/liquids on surfaces. Maintenance of battery components, corrosive and mildly toxic liquid on surfaces. Consequences - Dermatitis, skin /eye/lung irritation.	Operation	Negative	Molten salt Batteries facilities normally containerized. Maintenance procedures will be in place should equipment need to be opened, e.g. cooling down the entire container prior to entry, decontaminated prior to repair in workshop etc. PPE will be specified for handling battery parts and other equipment on site. Training of staff in hazards of chemicals on site. Labelling of all equipment. Confined space entry procedures if entering cooled battery containers? Safety Data Sheets (SDSs) to be available on site. Operating manuals to be provided including start-up, shut-down, steady state, monitoring requirements. Maintenance manuals with make safe, decontamination and repair procedures. Proposed maintenance schedules daily, weekly, monthly, annual etc. Provided portable equipment for calibration and for testing/verification of defective equipment, e.g. volt/current meters, infrared camera	Complex	2	1	3	5	4	**44**	1	1	3	5	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 2:	Human Health - exposure to noise	Causes - Moving parts inside containers, buildings, pumps, compressors, cooling systems etc. Consequences - Adverse impact on hearing of workers. Nuisance factor at near -by residences or other activities.	Operation	Negative	Design to ensure continuous noise does not exceed 85dB in the plant or at any other location on site or 61 dB at the site boundary, e.g. emergency generator, air compressor etc. Employees to be provided with hearing protection if working near equipment that exceeds the noise limits.	Easy	2	1	5	5	4	**52**	2	1	5	5	2	**26**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact 3:	Human Health - exposure to temperature extremes and/or humidity	Causes - Heat during the day. Batteries generate heat within enclosed building / containers. Cold in winter. Night work requires lighting. Consequences - Heat stroke. Hypothermia.	Operation	Negative	Building and container facilities to comply with Occupational Health and Safety Act 85 of 1993 specifically the thermal, humidity, lighting and ventilation requirements of the Environmental Regulations for Workplaces. PPE for operations and maintenance staff to be suitable for the weather conditions. Lighting to be provided inside the building, inside the containers, possibly linked to the door opening and outdoors where necessary. Suitable lighting to be provided including emergency lighting for safe building exit in the event of power failure. Adequate potable water to be provided during all phases of the project.	Easy	4	2	3	1	2	**20**	3	2	3	1	1	**9**
						Significance	**N2 - Low**						**N1 - Very Low**					
Impact 4:	Human Health - exposure to psychological stress	Causes - Isolated work station and monotonous repetitive work. Consequences - Low performance, system productivity suffers.	Operation	Negative	Staff rotation to other activities within the site may be necessary. Performance monitoring of inspections / maintenance tasks in particular will be necessary.	Easy	2	3	3	2	2	**20**	1	3	3	2	1	**9**
						Significance	**N2 - Low**						**N1 - Very Low**					
Impact 5:	Human Health - exposure to ergonomic stress	Causes - Lifting heavy equipment. Awkward angles during maintenance, stretching reaching to high level and bending to low level. Working ta height if equipment located on top of electrolyte tanks, roofs or elevated electrical equipment (e.g. pylons). Consequences - Back and other injuries.	Operation	Negative	Training in lifting techniques. Training in working at heights. If equipment is at height, ensure suitable safe (electrically and physically) ladders / harnesses etc. are available. Working at height procedure to be in place.	Easy	5	1	3	2	3	**33**	4	1	3	2	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact 6a:	Human and Equipment Safety - exposure to fire radiation	Causes – Involvement in an external fire e.g. veld fire, maintenance vehicle fire, electrical systems fire. Manufacturing defects or damage to battery leading to shorting and heating. High humidity condensation of water or ingress of water or flooding leading to shorting. Dust accumulation on electrical parts leading to overheating. Operator abuse. BMS failure or software failure. Molten salt leaks onto combustible material (e.g. cables, supports) starts fire, or sodium spontaneously ignites. Moten sulphur can also burn. Incorrect extinguishing medium, escalate the fire. Consequences - Contaminated run off. Radiation burns injuries but unlikely to be severe. No affected bystanders. Damaged equipment. Fire spreads to other units or offsite if	Operation	Negative	Grass cutting and fire breaks around the BESS installations to prevent veld fires. No combustible materials to be stored in or near the batteries or electrical infrastructure. Separation of site diesel tank, transformers from BESS and vice versa. Fire resistant barrier between the batteries and the PCS side if in the same container, or separate containers. Design codes from USA and standards of practice UL9540, NFPA 855 and DNV GL RP 43. Detailed FMEA/Hazop/Bowtie to done during design at the component level and system levels. Safety integrity level rating of equipment (failure probably) with suitable redundancy if required. Site Acceptance Testing as part of commissioning of each unit and the overall system. BMS should be checking individual cell voltage as well as stack, module, container, system voltages/current etc. BMS tripping the cell and possibly the stack/ building unit or module/rack/container, if variations in voltage. Diagnostics easily accessible. Diagnostics able to distinguish cell from stack or cell from module faults. Suitable ingress protection level provided for electrical equipment, e.g. IP55 - 66. If air cooling into containers (not with hot molten metal which will likely need to stay hot) / building, suitable dust filters to be provided if needed. Smoke detectors may be needed linked to BMS and alerts in the main control room. Effects of battery deterioration to be considered.. Data needs to be stored for trend analysis. Protective systems are only as good as their reliability and functionality testing is important, e.g. testing that all battery plant trips actually work. Refer to construction phase above and apply. Emergency plan from transport and construction phase to be extended to operational phase and to include the hazards of the electrically live system. Procedure to address suitable extinguishing media, ventilating, entering container as appropriate or not. PPE for fire-fighting may need to include fire retardant, chemically resistant, nitrile gloves, antistatic acid resistant boots, fill face shields, BA sets. A planned fire response to prevent escalation	Complex	5	1	5	5	3	**48**	5	1	5	5	1	**16**

		grass/vegetation not controlled.			to an environmental event is critical. Suitable fire extinguishing medium, and cooling mediums and adequate supply of both is critical. Consider fire water for cooling adjacent equipment – BESS units, noting however that water is not compatible with sodium and neither with electricity. Can use fogging nozzles to direct smoke. Clean up after event Lingering toxic residues in the soil and on adjacent structures.														
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 6b:	Human and Equipment Safety - exposure to fire radiation	Causes - Power Conversion System (PCS – DC to AC) cooling failure electrical fire. Consequences - Fire starts in PCS or another section or room and spreads to battery area.	Operation	Negative	Modern container design put the PCS in another part of the container with a fire rated wall separating it from the battery. Alternately the PCS is another container altogether. Failure of cooling on PCS or fires on other electrical equipment such as cooling system pump motors etc, and failure to trip the entire system and raise the alert.	Moderate	5	2	5	5	3	**51**	5	2	5	5	1	**17**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 7:	Human and Equipment Safety - exposure to explosion over pressures	Transformer shorting / overheating / explosion. Consequences - Potential fatalities, e.g. amongst first responders. Damage to nearby equipment.	Operation	Negative	Electrical equipment will be specified to suit application. Emergency response plan and employee training referred to above is critical.	Moderate	5	1	5	5	2	**32**	5	1	5	5	1	**16**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact 8a:	Human and Equipment Safety - exposure to acute toxic chemical and biological agents	Causes Human pathogens and diseases, sewage, food waste. Snakes, insects, wild and domesticated animals and harmful plants. Consequences - Illness and at worst without mitigation, possibly extending to fatalities. Effects can vary from discomfort to fatalities for venomous snakes or bee swarms etc	Operation	Negative	All necessary good hygiene practices to be in place, e.g. provision of toilets, eating areas, infectious disease controls. Policies and practice for dealing with known vectors of disease such as Aids, TB, COVID 19 and others. Awareness training for persons on site, safety induction to include animal hazards. First aid and emergency response to consider the necessary anti-venom, anti-histamines, topical medicines etc. Due to isolated locations some distance from town, the ability to treat with anti-venom and extreme allergic reactions on site is critical to mitigate the impacts	Moderate	4	1	3	2	3	**30**	3	1	2	2	2	**16**
						Significance	**N2 - Low**						**N2 - Low**					
Impact 8b:	Human and Equipment Safety - exposure to acute toxic chemical and biological agents	Causes - Damaged batteries components, leaked solids, completely broken exposing hazardous chemicals. Consequences - Impacts can vary from mild skin irritation from exposure to small leaks to serious corrosive or heat burns for large exposure.	Operation	Negative	Corrosion resistant PPE (e.g. overalls, heat gloves, eye glasses) to be specified for all operations in battery areas. PPE to be increased (e.g. full-face shield, aprons, chemical suits) for operations that involve opening equipment and potential exposure, e.g. sampling, maintenance. All operators/maintenance staff trained in the hazards of hot surfaces, hot metals, corrosive chemicals and of all other chemicals on site. Molten metal contained within ceramic and stainless steel casing as well as overall outer container which acts as final bund. Material will solidify soon after leak. 24/7 helpline response. Standard dangerous goods requirements for Hazmat labels. All operators/maintenance staff trained in the hazards.	Moderate	4	3	3	5	3	**45**	3	3	3	5	2	**28**
						Significance	**N3 - Moderate**						**N2 - Low**					

Impact 9:	Human and Equipment Safety - exposure to violent release of kinetic or potential energy	Causes - Moving equipment, heavy equipment at elevation, nip points, working at heights. Traffic accidents. Extremely hot surfaces on the molten salt batteries. Hot molten salt if in contact with internals. Consequences - Injury. Fatality in unlikely worst case, e.g. traffic accidents or fall from heights or exposed directly to molten salt. Damage to equipment, spills, environment pollution.	Operation	Negative	NOTE handling of hot batteries to be forbidden, cooling down times/temperatures to be specified in procedures. Suitable PPE (heat resistant) to be specified. No major moving parts during operation. Maintenance equipment to be serviced and personnel suitably trained in the use thereof. Normally just small vehicles on site, bakkies, grass cutting, cherry-pickers etc. Possibly large cranes if large equipment or elevated structure removed/replaced. Traffic signs, rules etc in place on site. All normal working at heights, hot work permits, confined space entry, cordon off unsafe areas/works etc to be in place. Emergency response plan.	Moderate	5	1	5	5	3	**48**	5	1	5	5	1	**16**
							N3 - Moderate						**N2 - Low**					

Impact 10:	Human and Equipment Safety - exposure to electromagnetic waves	Causes - Use of electrical machines, generators etc. Hot dry area static generation is highly likely. Lightning strike. Consequences - Electrocution. Ignition and burns. Injury and death. Damage electrical equipment.	Operation	Negative	Codes and guidelines for electrical insulation. PPE to suit. Low voltage equipment (e.g. batteries) separated from high voltage (e.g. transmission to grid). Trained personnel – IEE 1657 – 2018. Eskom Operating Regulations for high voltage systems including access control, permit to work, safe work procedures, live work, abnormal and emergency situations, keeping records. Electromagnetic fields, impact on other equipment e.g. testing devices, mobile phones – malfunction, permanent damage. Software also needs maintenance, patches, updates. Consider suitably located Emergency stop buttons for the plant and the other equipment on site. PPE to consider static accumulation for entering the plant, and particularly the battery containers especially after a high temperature shut down where there could possibly be flammable materials. The procedures for responding to alarm and auto shut down on containers, needs to consider that there may be a dangerous environment inside and how to protect personnel who may enter to respond. Lightning strike rate in proposed development area is moderate. All outside work must be stopped during thunder storms. Lighting conductors may be required for the installation, to be confirmed during design	Complex	5	2	5	5	3	**51**	5	2	5	5	1	**17**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 11:	Environment - emissions to air	Not expected on a normal basis. Refrigerant may be an asphyxiant if accidentally released indoors it can accumulate and displace oxygen.	Operation	Negative	Especially after any warning alarms have gone off, but possibly even normally the container / refrigeration room could be treated as entering a confined space and similar procedures could be in place, e.g. do not enter alone, gas testing prior to entering, ensure adequate ventilation.	Easy	3	1	1	1	3	**18**	3	1	1	1	1	**6**
						Significance	**N2 - Low**						**N1 - Very Low**					

Impact 12:	Environment - emissions to water	Causes - Cooling water blow-down. Laboratory waste (if included in the design). Maintenance waste, e.g. oils. Spills from batteries, coolant system, diesel trucks, transformers. Parked vehicles – oil drips. Fire water runoff control. Kitchen waste and sewage. Refrigerant release. Consequences - Pollution if not contained. Excessive disposal costs if emissions not limited.	Operation	Negative	Molten metal solidifies rapidly upon release and can be easily collected. Container acts as bund. Bunding under any outdoors tanks (e.g. diesel), curbing under truck offloading areas and sealed surfaces (e.g. concrete) under truck parking area is particularly important. Sewage and any kitchen liquids - containment and suitable treatment/disposal. Procedures for dealing with damaged/leaking equipment as well as clean-up of spills. Normal site practices for preventing and containing diesel/paint etc spills. Waste management plan to be in place e.g. liquid waste treatment or suitable removal and disposal will be provided. Ensure proposed locations of the BESS facilities are a suitable distance from the closest water course. In the event of a major fire where water is used (unlikely in remote location) it should allow time for mitigation (secondary containment) to be taken.	Moderate	3	2	3	2	3	**30**	3	2	3	2	2	**20**
						Significance	**N2 - Low**						**N2 - Low**					
Impact 13:	Environment - emissions to earth	Causes - Mess area and other solid waste. Disposal of battery components. Consequences - Environmental damage.	Operation	Negative	There will be packaging materials that will need to be disposed of after regular maintenance. There will need to be waste segregation (e.g. electronic equipment, chemicals) and management on the site.	Easy	2	2	3	3	3	**30**	2	2	3	3	1	**10**
						Significance	**N2 - Low**						**N1 - Very Low**					
Impact 14:	Environment - waste of resources e.g. water, power etc	Causes - Similar to construction phase. Disposal of batteries or components. Disposal of containers. Water usage not controlled.	Operation	Negative	Water usage to be monitored on site. Water management plan and spill containment plans to be in place. Investigate End of Life plan for electrolyte/electrodes/battery casings - reuse / recovery / reconditioning. Molten metal electrodes/electrolyte has an expected long lie (	Easy	2	1	1	2	4	**24**	2	1	1	2	2	**12**

		Consequences - Delays. Excessive costs and disposal of large volumes of hazardous waste.			>20years) Similarly, for decommissioned containers / equipment – reuse / recovery / repurpose														
							N2 - Low						**N1 - Very Low**						
Impact 15:	Public - Aesthetics	Causes - Bright surfaces reflecting light. Tall structures in a flat area. Consequences - Irritation.	Construction	Negative	Limited height for electrical infrastructure. Sheeting likely to be painted, not left as reflective steel. Confirm height limitations for electrical infrastructure, in terms of visual aspects. Visual impact assessment to include BESS installation when design details become available. Containers single storey as physical space is not a constraint that would require stacking of containers. Containers likely to be painted white, not left as reflective steel.	Moderate	3	2	3	4	4	**48**	1	2	3	4	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**						
Impact 16:	Investors - Financial	Causes - Defective technology. Extreme project delays. Consequences - Financial loss	Operation	Negative	Design by experienced contractors using internationally recognized and proven technology. Project management with deviation monitoring. Project insurance for construction phase. Project insurance.	Easy	5	1	3	4	3	**39**	3	1	3	4	2	**22**
						Significance	**N3 - Moderate**						**N2 - Low**						
Impact 17a:	Employees and investors - Security	Causes - On route, potential hi-jacking of valuable but hazardous load. On site, theft of construction equipment and battery installation facilities. Civil unrest or violent strike by employees. Consequences - Theft. Injury to burglars.	Operation	Negative	Fencing around electrical infrastructure to SANS standard and Eskom Guidelines. Consider motion detection lights and CCTV. The hazardous nature of the electrical and battery equipment should be clearly indicated – e.g. Skull and Cross Bones or other signs. Isolated location both helps and hinders security. Night lighting to be provided both indoors and outdoors where necessary.	Moderate	3	1	3	2	4	**36**	3	1	3	2	2	**18**

		Damage to equipment possibly setting off thermal runaway.																	
						Significance	N3 - Moderate						N2 - Low						
Impact 17b:	Employees and investors - Security	Causes - Cyber security attacks aimed at the National Electricity Grid. Consequences - Ransom of the National Electricity Grid.	Operation	Negative	Cyber security needs monitoring. Remote access to system needs to be negotiated and controlled. Password controls, levels of authority etc. Protection of the National Electricity Grid from Cyber-attacks accessing through the BESS. Cyber emergency procedures – should be in place prior to commissioning.	Complex	4	4	3	1	4	**48**	4	4	3	1	2	**24**
						Significance	N3 - Moderate						N2 - Low						
Impact 18:	Emergencies	Causes - Fires, explosions, toxic smoke, large spills, traffic accidents, equipment/structural collapse. Inadequate emergency response to small event leads to escalation. Consequences - Injuries turn to fatalities, small losses become extended down time.	Operation	Negative	All safety measures listed above. Small events not handled correctly and escalate into larger events. Emergency procedures need to be practiced prior to commencement of operations. Escape door open outwards, doors hooked open when persons inside. More than one exit from buildings.	Complex	4	2	3	4	3	**39**	4	2	3	4	2	**26**
						Significance	N3 - Moderate						N2 - Low						

Impact 19:	Investors - Legal	Causes Battery field is evolving quickly with new guides, codes and regulations happening at the same time as evolving technology. Consequences - Unknown hazards manifest due to using “cheaper supplier or less developed technology”.	Operation	Negative	Use only internationally reputable battery suppliers who comply with all known regulations/guideline at the time of purchasing. Ensure only latest state of the art battery system are used.	Moderate	3	1	3	3	4	**40**	3	1	3	3	2	**20**
						Significance	**N3 - Moderate**						**N2 - Low**					

The above Risk Assessment shows that, provided the preventative and mitigative measures are incorporated, the operational phase of the project does not present any high risks nor any fatal flaws.

TABLE 4.2.3 - DECOMMISSIONING PHASE

Battery components may have a limited lifespan, there are damaged equipment, waste electrolyte etc. There could already be "waste" on the first day of commissioning and plans should be in place to deal with this. Ideally an End-of-Life plan needs to be in place before the first electrolyte / container / equipment is brought on site.

All decommissioning activities must comply with the relevant regulations at the time. Decommissioning will ultimately need to be informed by the regulatory requirements at the time, which may be different to present requirements. The impact rating are not possible to determine now given the uncertainties in mitigations applicable at that time; hence they have been left as neutral.

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 1:	Human Health - chronic exposure to toxic chemical or biological agents	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 2:	Human Health - exposure to noise	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 3:	Human Health - exposure to temperature extremes and/or humidity	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 4:	Human Health - exposure to psychological stress	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 5:	Human Health - exposure to ergonomic stress	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 6:	Human and Equipment Safety - exposure to fire radiation	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 7:	Human and Equipment Safety - exposure to explosion over pressures	Similar to the construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 8:	Human and Equipment Safety - exposure to acute toxic chemical and biological agents	Similar to the Construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 9:	Human and Equipment Safety - exposure to violent release of kinetic or potential energy	Similar to the Construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
							#N/A						**#N/A**					

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
Impact 10:	Human and Equipment Safety - exposure to electromagnetic waves	Similar to the Construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 11:	Environment - emissions to air	Similar to the Construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 12:	Environment - emissions to water	Similar to the Construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 13:	Environment - emissions to earth	Causes - Batteries / electrolyte / equipment reached end of life. Consequences - Environment damage from heavy metal ions.	Construction	Negative	End of Life shutdown procedure including a Risk Assessment of the specific activities involved. Where possible re-purpose the batteries / containers and equipment with associated Environmental impact considered. Disposal according to local regulations and other directives such as the European Batteries Directive. End of life, which is affected by temperature and time, cycles etc, should be predefined and the monitoring should be in place to determine if it has been reached.	Complex	4	3	3	5	4	**60**	4	3	3	5	2	**30**
						Significance	**N3 - Moderate**						**N2 - Low**					
Impact 14:	Environment - waste of resources e.g., water, power etc	Similar to the Construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	**#N/A**						**#N/A**					
Impact 15:	Public - Aesthetics	Similar to the Construction and	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**

Impact number	Receptor	Description	Stage	Character	Preventative and Mitigative Measures	Ease of Mitigation	(M+	E+	R+	D)x	P=	S	(M+	E+	R+	D)x	P=	S
							Raw Risk						Residual Risk					
		operational phases - no new hazards.																
						Significance	#N/A						#N/A					
Impact 16:	Investors - Financial	Similar to the Construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	#N/A						#N/A					
Impact 17:	Employees and investors - Security	Similar to the Construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	#N/A						#N/A					
Impact 18:	Emergencies	Similar to the Construction and operational phases - no new hazards.	De-commission	Negative	As per construction and operational phases.	Easy	1	1	1	1	1	**4**	1	1	1	1	1	**4**
						Significance	#N/A						#N/A					
Impact 19:	Investors - Legal	Disposal of hazardous “waste” is rife with difficulties and numerous regulations that need to be complied with.	De-commission	Negative	Applicants should seek the opinion from a waste consultant on how to correctly dispose of hazardous waste.	Complex	3	1	3	3	4	**40**	3	1	3	3	3	**30**
						Significance	N3 - Moderate						N2 - Low					

The above Risk Assessment shows that, provided the preventative and mitigative measures are incorporated, the de-commissioning phase of the project does not present any high risks nor any fatal flaws.

5. CONCLUSIONS AND RECOMMENDATIONS

The tables in Section 4 contain all the recommended preventative and mitigative measures necessary to ensure risks are not unacceptably high.

Below are a few extracted items that are possibly of highest risks and therefore a priority.

5.1 CONCLUSIONS

GENERAL

- This Risk Assessment has found that with suitable preventative and mitigative measures in place, none of the identified potential risks are excessively high, i.e., from a Safety, Health and Environment (SHE) perspective no fatal flaws were found with either type of technology for the BESS installation at the proposed Bethel Solar PV near Bandilierkop.

- At a large facility, without installation of the state-of-the art battery technology that includes protective features, there can be significant risks to employees and first responders. The latest battery designs include many preventative and mitigative measures to reduce these risks to tolerable levels. (Refer to tables in section 4 under preventative and mitigative measures). State-of-the-art technology should be used, i.e., not old technology, such as liquid phase lithium ion batteries, that may have been prone to fire and explosion risks.

- The design should be subject to a full Hazard and Operability Study (HAZOP) prior to commencement of procurement. A HAZOP is a detailed technical systematic study that looks at the intricacies of the design, the control system, the emergency system etc. and how these may fail under abnormal operating conditions. Additional safeguards may be suggested by the team doing the study.

- For most projects, from an acute health and safety point of view, the No-Go option will usually be a preferred option since there are no immediate health and safety risks associated with not doing a project, i.e. no one can get hurt if something does not exist. However, some projects aim to reduce adverse effects elsewhere and can be viewed at offsetting either current or future risks. In this case, renewable energy projects should help to mitigate possible adverse impacts of climate change, create jobs and contribute to sustainable energy, i.e. the project risks are offset against future social risk reduction

LITHIUM SOLID STATE CONTAINERIZED BATTERIES

- With lithium solid-state batteries, the most significant hazard with battery units is the possibility of thermal runaway and the generation of toxic and flammable gases. There have been numerous such incidents around the world with lithium-ion batteries at all scales and modern technology providers include many preventative and mitigative features in their designs, e.g. solid state electrolytes being one of these improvements. This type of event also generates heat which may possibly propagate the thermal runaway event to neighbouring batteries if suitable state of the art technology is not employed.

- The flammable gases generated may ignite leading to a fire which accelerates the runaway process and may spread the fire to other parts of the BESS or other equipment located near-by.

- If the flammable gases accumulate within the container before they ignite, they may eventually ignite with explosive force. This type of event is unusual with solid state batteries, but has happened with an older technology container installed at McMicken in the USA in 2019.

- Due to a variety of causes, thermal runaway could happen at any point during transport to the facility, during construction or operation / maintenance at the facility or during decommissioning and safe making for disposal.

- Due to the containerized approach as well as the usual good practice of separation between containers, which should be applied on this project, and therefore the likely restriction of events to one container at a time, the main risks are close to the containers i.e., to transport drivers, employees at the facilities and first responders to incidents.

- In terms of a worst conceivable case container fires, the significant impact zone is likely to be limited to within 10m of the container and mild impacts to 20m. Based on the current proposed layouts, radiation impacts at the closest isolated farmhouses are not expected.

- In terms of a worst conceivable case explosion, the major impact zone is likely to be limited to with 10m of the container, noticeable damage within 25m and minor impacts such as debris within 50m. Based on the current proposed layouts, explosion impacts at the closest isolated farmhouses are not expected.

- In terms of a worst reasonably conceivable toxic smoke scenario, provided the units are placed suitably far apart to prevent propagation from one unit to another and large external fires are prevented, the amount of material burning should be limited to one container at any one time. In this case, beyond the immediate vicinity of the fire, the concentrations of harmful gases within the smoke should be low.

- For the Bethel Solar PV, the BESS location is over 500m from any occupied farmhouse and in this context the location is therefore considered suitable in terms of toxic gas risks.

SODIUM-SULPHIDE SOLID STATE CONTAINERIZED BATTERIES

- With sodium-sulphide solid-state batteries, the most significant hazard with battery units is the presence of sodium and the possibility of some failure (mechanical or electrical) leading to a sodium and sulphur fire. In addition to an intense localized fire there could be generation of toxic gases. There have been a few such incidents in the early days of these batteries. Modern technology providers include many preventative and mitigative features in their designs. This type of event also generates heat which may possibly thermal instability neighbouring batteries propagate if suitable state of the art technology is not employed.

- The fire, explosion and toxic smoke events are not expected to be significantly worse than those estimated for the lithium batteries and similar on site separation distances should be applied, e.g. to occupied buildings, electrical infrastructure etc.

- For the Bethel Solar PV, the BESS location is over 500m from any occupied farmhouse and in this context the location is therefore considered suitable in terms of fire, explosion and toxic gas risks to the public outside the site.

- Suitable Battery Management System (BMS), safety procedures, operating instructions, maintenance procedures, trips, alarms and interlocks should be in place. (Refer to tables in section 4 under preventative and mitigative measures).

TECHNOLOGY AND LOCATION OF BESS FACILITIES

- Overall, from a SHE RA points of view, there is no specific preference for a type of technology.

- From a SHE risk assessment point of view, where there is a choice of location that is further from public roads, water courses, isolated farmhouses or other occupied facilities, this would be preferred. The current chosen location is suitably far from the above with a very low risk of any significant impacts.

CUMULATIVE IMPACTS

- Unless another BESS is installed within 500m of the BESS location proposed for this project, cumulative impacts of other developments in the greater area do not affect the safety and health of employees, contractors of members of the public within the BESS impact zone. The same can be said for the BESS electrical infrastructure and grid connection.

5.2 RECOMMENDATIONS

The following recommendations have been made:

- There are numerous different battery technologies, but using one consistent battery technology system for the BESS installations associated with all the developments in the Bandelierkop Area would allow for ease of training, maintenance, emergency response and could significantly reduce risks.

- Where reasonably practicable, state-of-the-art battery technology should be used with all the necessary protective features e.g., draining of cells during shutdown and standby-mode, full BMS with deviation monitoring and trips, leak detection systems.

- There are no fatal flaws associated with the proposed Bethel battery installation for either technology type.

- The tables in Section 4 of this report contains technical and systems suggestions for managing and reducing risks. Ensure the items listed in these tables under preventative and mitigative measures are included in the design.

- The overall design should be subject to a full Hazop prior to finalization of the design.

- Prior to bringing any solid-state battery containers into the country, the contractor should ensure that:
    - An Emergency Response Plan is in place that would be applicable for the full route from the ship to the site. This plan would include details of the most appropriate emergency response to fires both while the units are in transit and once they are installed and operating.
    - An End-of-Life plan is in place for the handling, repurposing or disposal of dysfunctional, severely damaged batteries, modules and containers.

- The site layout and spacing between solid-state containers should be such that it mitigates the risk of a fire or explosion event spreading from one container to another. The battery supplier should be able to provide guidance as well as technical proof that the proposed container to container separation distances are adequate.

- Suitable separation must also be ensured between the BESS containers and other onsite facilities such as transformers, any high voltage overhead powerlines etc. In this regard there are National Fire Protection Agency (NFPA - USA) and Eskom guidelines. Suitable separation must also be ensured between the BESS containers and other onsite facilities such as transformers, any high voltage overhead powerlines etc. In this regard there are National Fire Protection Agency (NFPA - USA) and Eskom guidelines.

- Separation from offices (O&M) areas should be at least 25m to avoid direct damage from possible explosions and fires and possibly be 50m to avoid minor impacts explosion debris.

- Under certain weather conditions, the noxious smoke from a fire in a lithium battery container or a sodium-sulphide battery container could travel some distance from the unit. The smoke will most likely be acrid and could cause irritation, coughing, distress etc. Close to the source of the smoke, the concentration of toxic gases may be high enough to cause irreversible harmful effects. Location of the facilities needs to ensure a suitable separation distance from public facilities/residences etc. The current proposed BESS location is over 500m from isolated farmhouses / other occupied facilities and is therefore suitable. The risks of significant impacts is very low.

- Where there is a choice of alternative locations for the BESS, those that are further from water courses would be preferred. The buffer distance between water bodies and the facilities containing chemicals should be set in consultation with a water specialist and is therefore not specified in this SHE RA. It should be noted that the location is well over 100m from the closest stream and will likely be suitable.

- Finally, it is suggested once the technology has been chosen and more details of the actual design are available, the necessary updated Risk Assessments should be in place.

6 REFERENCES

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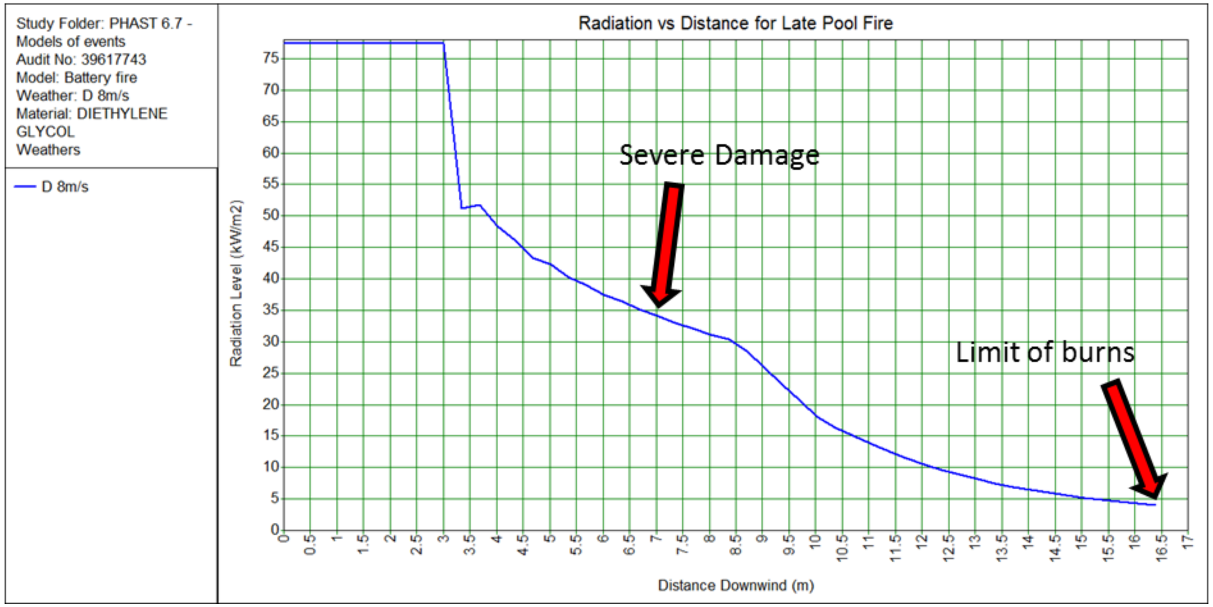
APPENDIX A

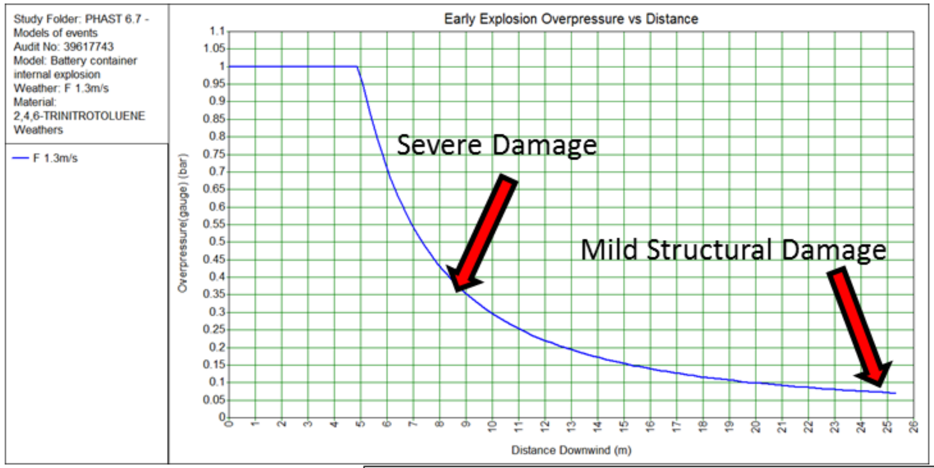
Preliminary Approximations of Absolute WORST-CASE Consequence and Risk Modelling
(Modelling done using DNV-GL software PHAST RISK 6.7)

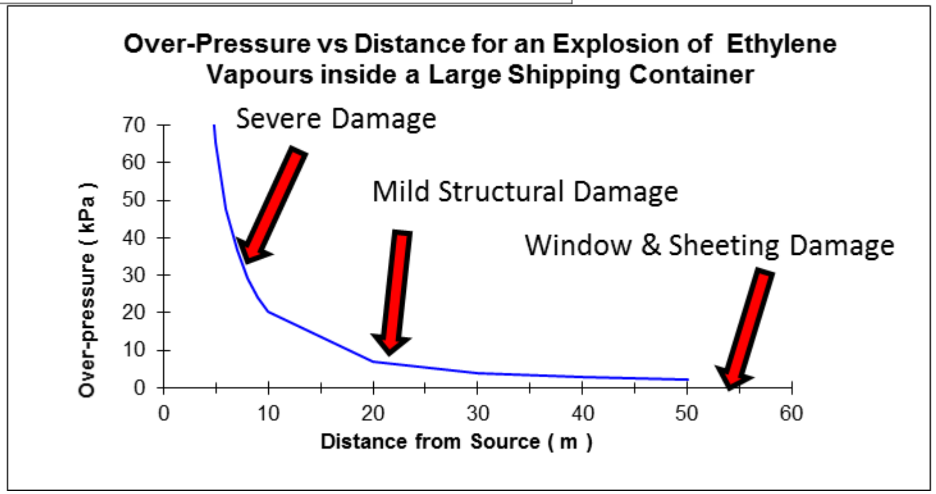
PLEASE NOTE – the modelling, especially the noxious smoke modelling, is an approximation.

Approximation of WORST-CASE Radiation Levels from an Entire Container on Fire

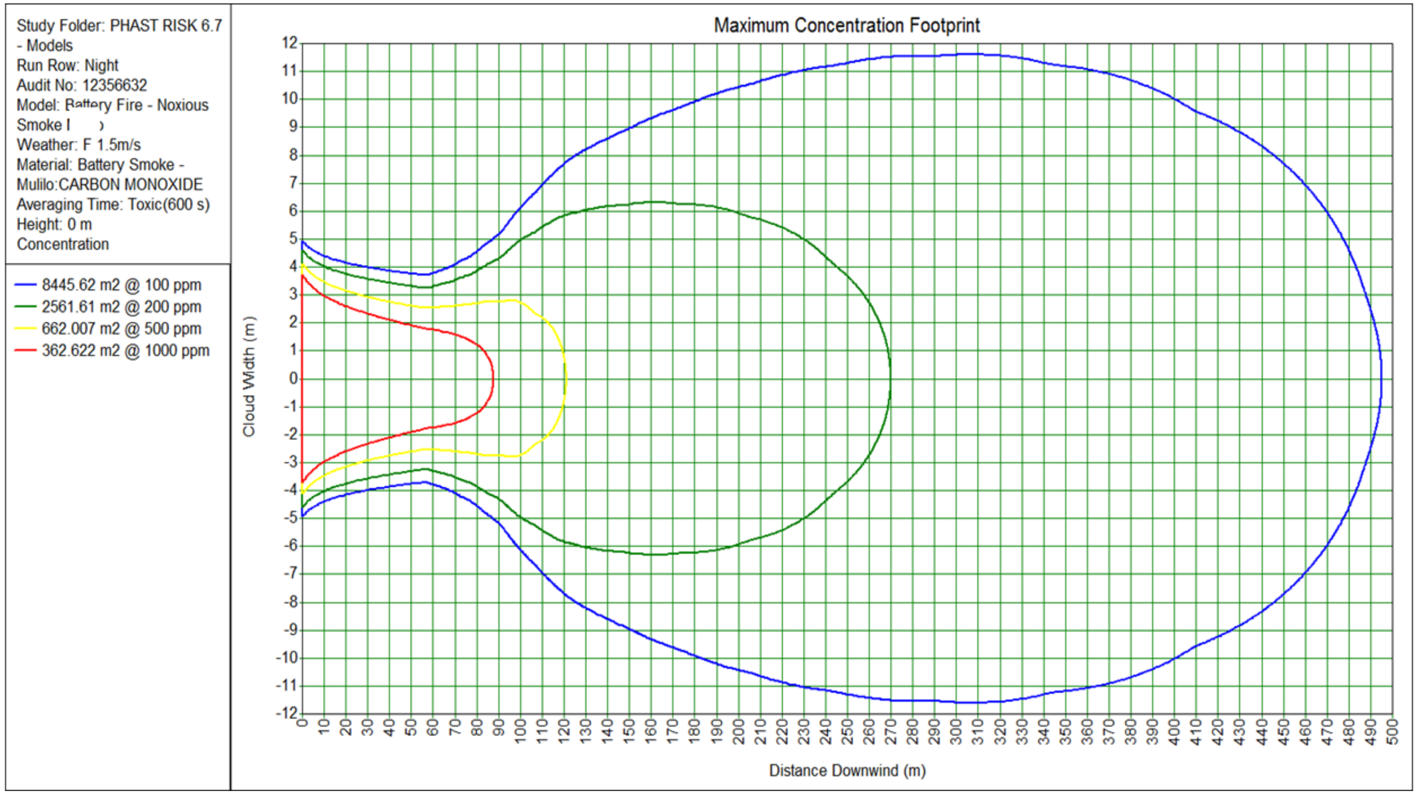


Approximation of WORST-CASE Explosion Over pressures from an Entire Container Explosion





Approximation of Maximum Concentration of Carbon Monoxide in Noxious Smoke Cloud from Lithium Container Fire
200ppm is the Nuisance Level, 500ppm is potentially harmful



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APPENDIX B

Full list of Battery incidents recorded on EPRI Wiki Storage page.

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
		MWh	MW					Type	(yr)			
2011/09/21	Japan, Ibaraki Prefecture		2	NGK [NaS]			Industrial			Fire		A sodium-sulphur BESS fire occurred at Mitsubishi Material Corp's Tsukuba plant. The report states, â€œA localized high temperature occurred due to a clearance malfunction in a single battery cell, causing that one battery cell to rupture. This caused a short circuit to occur inside the modular battery, causing multiple battery cells to rupture, and the entire modular battery caught fire.â€ The conclusion of the investigation committee was that either a manufacturing flaw or initial defect caused the fire.
2012/08/01	US, HI, Kahuku	10	15	Xtreme [PbA]		Wind Integration	Island	Prefab	1.5	Fire		The BESS, co-located with a 30 MW wind farm, caught fire.
2012/11/26	US, AZ, Flagstaff	1.5	0.5		Electrovaya	Solar integration			1.5			
2013/07/03	US, WA, Port Angeles					Energy Shifting	Mall			Fire		The hybrid solar + wind + storage system caught fire inside Landing Mall.
2016/08/10	US, WI, Franklin						Factory		0.0	Fire	Assembly, Installation	S&C Electric was assembling a BESS at its facility. The batteries were not operating nor connected to a power source/load when the partially assembled lithium ion system caught fire, starting in one of the DC power and control compartments of a battery rack and then propagating. Fire suppression and containment systems were not yet functional, but propagation was limited to one container

Event Date	Location	Capacity	Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
											with water cooling. The fire extinguished in a few hours.
2017/03/07	China, Shanxi						Container				BESS containers caught fire. The same site experienced another failure and fire 8 months later.
2017/08/02	South Korea, North Jeolla, Gochang	1.46			Wind Integration	Waterfront	Container	0.0		Installation	
2017/11/11	Belgium, Drogenbos	6		Engie	Frequency Regulation	Research Park	Container				
2017/12/21	China, Shanxi						Container				BESS containers caught fire. The same site experienced a failure and fire 8 months prior.
2018/05/02	South Korea, North Gyeongsang, Gyeongsan	8.6			Frequency Regulation	Mountains	Container	1.8		Maintenance	BMS system Error.
2018/06/02	South Korea, South Jeolla, Yeongam	14	Samsung SDI		Wind Integration	Mountains	Prefab	2.4		Maintenance	BMS System Error
2018/06/15	South Korea, North	18.965	Samsung SDI		Solar Integration	Waterfront	Prefab	0.5		Charged, inactive	Due to poor construction (such as condensation or water leakage)

Event Date	Location	Capacity	Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
2018/07/12	Jeolla, Gunsan South Korea, South Jeolla, Haenam	2.99	LG Chem		Solar Integration	Waterfront	Prefab	0.6		Charged, inactive	Due to poor construction (such as condensation or water leakage)
2018/07/21	South Korea, South Gyeongsang, Geochang	9.7	Samsung SDI		Wind Integration	Mountains	Prefab	1.6		Charged, inactive	BMS System Error
2018/07/28	South Korea, Sejong	18	Samsung SDI		Demand Charge Mgmt	Factory	Prefab	0.0		Installation	Occurred in the process of supplying electricity for the commissioning of ESS, presumption of operator negligence,
2018/09/01	South Korea, Chungcheongbuk-do, Yeongdong	5.989	LG Chem		Solar Integration	Mountains	Prefab	0.7		Charged, inactive	poor construction (deterioration of insulation due to poor construction such as condensation or water leakage)
2018/09/07	South Korea, Chungcheongnam, Taean	6	Samsung SDI		Solar Integration	Waterfront	Prefab	0.0		Installation	Negligence of the operator & construction defects during construction,
2018/09/14	South Korea, Jeju	0.18	Revo Co., Ltd. (KEPCO) product use		Solar Integration		Concrete	4.0		Charging	Not tested before use, Battery burnout due to poor BMS
2018/10/18	South Korea, Gyeonggi, Yongin	17.7	Samsung SDI		Frequency Regulation	Factory	Container	2.6		Maintenance	Occurred during performance test, Occurred only 6 days after the Close Safety Diagnosis was carried out, presumed to be a fire caused by PCS breakage,

Event Date	Location	Capacity	Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
2018/11/12	South Korea, North Gyeongsang, Yeongju	3.66	LG Chem		Solar Integration	Mountains	Prefab	0.8		Charged, inactive	Occurred even after passing Close Safety Diagnosis.
2018/11/12	South Korea, South Chungcheong, Cheonan	1.22	LG Chem		Solar Integration	Mountains	Prefab	0.9		Charged, inactive	
2018/11/21	South Korea, Gyeongsangbuk-do, Mungyeong	4.16	LG Chem		Solar Integration	Mountains	Prefab	0.9		Charged, inactive	
2018/11/22	South Korea, South Gyeongsang, Geochang	1.331	LG Chem		Solar Integration	Mountains	Prefab	0.6		Charged, inactive	
2018/12/17	South Korea, North Chungcheong, Jecheon	9.316	LG Chem		Demand Charge Mgmt	Mountains	Prefab	1.0		Charged, inactive	
2018/12/22	South Korea, Gangwon, Samcheok	2.662			Solar Integration	Mountains	Concrete	1.0		Charged, inactive	
2019/01/14	South Korea,	3.289	LG Chem	LG CNS	Demand Charge Mgmt	Factory	Concrete	0.8		Charged, inactive	

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
	South Gyeongsangnam, Yangsan											
2019/01/14	South Korea, South Jeolla, Wando	5.22		INCELL		Solar Integration	Mountains	Assembly Room	1.2		Charging	
2019/01/15	South Korea, North Jeolla, Jangsu	2.496				Solar Integration	Mountains	Container	0.8		Charged, inactive	
2019/01/21	South Korea, Ulsan	46.757				Demand Charge Mgmt	Factory	Concrete	0.6		Charged, inactive	
2019/04/11	US, OR, Tualatin			Powin Energy		Manufacturing/Testing			0.0	Fire	Testing	A fire broke out during a new product test of six large lithium ion batteries at a warehouse.
2019/04/19	US, AZ, Surprise	2	2	LG Chem [NMC]	AES/Fluence	Volt Reg., PQ, Solar int.	Substation	Prefab	2.1	Explosion		Cell defect. The cause was found to be an internal cell defect, which initiated a cascading thermal runaway event. Alarms and the clean agent fire suppression system activated but was not capable of preventing or stopping cascading thermal runaway in a BESS. Three hours after thermal runaway was initiated, firefighters opened a door to the battery container, agitating accumulated flammable gases and allowing the gases to contact a heat source or spark. Minutes later, an explosion occurred, injuring several firefighters.
2019/05/04	South Korea, North Gyeongsa	3.66		LG Chem		Solar Integration	Mountains	Prefab	2.3		Charged, inactive	A fire occurred during operation after LG Chem's self-inspection and reinforcement measures such as software upgrades.

Event Date	Location	Capacity	Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
	ng, Chilgok										
2019/05/26	South Korea, North Jeolla, Jangsu	1.027			Solar Integration	Mountains	Prefab	1.0		Charged, discharging	Wasn't reported to the fire department
2019/08/30	South Korea, Yesan	1.5			Solar Integration	Mountains	Prefab	1.7	Fire	Charged, inactive	The battery charging rate was increased from 70 % to 95 %, and a fire occurred 2 days later.
2019/09/16	France, Vitry-sur-Seine					Datacentre	Cabinet			Maintenance	A small explosion occurred.
2019/09/24	South Korea, Pyeongchang	21			Wind Integration	Mountains	Prefab	2.7		Charged, inactive	Battery thermal runaway occurred after battery abuse from repeated overcharging and discharging, as confirmed in the EMS log record.
2019/09/29	South Korea, Gunwi	1.5			Solar Integration	Mountains	Prefab	1.8	Fire	Discharging	Smoke of an unknown cause occurred in batteries (Rack#3, Module#9) and battery internal fire occurred as a result of BMS investigation.
2019/10/21	South Korea, Hadong	1.3			Solar Integration	Mountains	Prefab	1.3	Fire	Charged, inactive	A sudden deterioration in insulation performance first occurred on BSC#1, followed by a gradual deterioration on the other side (BSC#2), resulting in a fire .

Event Date	Location	Capacity	Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
2019/10/27	South Korea, Gimhae	2.2			Solar Integration		Prefab	1.5		Charged, inactive	In the EMS log record, the voltage deviation of each battery inside the battery rack continuously increases, resulting in thermal runaway.
2020/03/17	Australia, Brisbane							6.7	Explosion		A battery on the fifth floor of a Griffith University building caught fire. An explosion occurred, injuring one firefighter. The fire was extinguished in 2 hours.
2020/05/27	South Korea, Haenam				Solar Integration	Field	Prefab	2.2	Fire		Overcharge. The BESS at a solar + storage facility caught fire. The South Korean government had implemented an upper limit of SOC of 90% for outdoor installations at the beginning of the year, but it was confirmed that the company had continued to operate with an upper limit of SOC of 95% as before. The cause is suspected to be battery deterioration due to overcharging or BMS error.
2020/09/15	UK, Liverpool	10 20		Orsted	Frequency Regulation		Container	1.5	Explosion		The cause is suspected to be thermal runaway, which led to the ignition of flammable gases produced by the cells. An explosion occurred before emergency responders were notified. The fire department arrived and contained the fire, which was limited to one out of the three containers, and confirmed end of incident two days later.

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
2020/12/01	France, Ariege, Perles-et-Castelet	0.5	0.5	Narada [LFP]		Hybrid Supercapacitor plus Storage System	Substation	Container	0.0	Fire	Commissioning, testing	Electrical and insulation failure. The substation has 500 kWh of batteries and 1 MW - 10s of supercapacitors. The supercapacitors were not involved in the cause of failure, which happened during acceptance testing. The investigation found that rack #2 suddenly discharged into rack #3, and the current passed through only modules #1 to #7 of rack #3. The insulation resistance of rack #2 fell below the safety threshold and neared short circuit for rack #3. The investigation report provides a hypothesis of two faults resulting in failure: an electrical connection failed and came into contact with the metal frame, and an insulation fault between the busbar connecting a module to the BPU box, which may have caused an electric arc upstream of the fuse. The container was destroyed.
2021/03/11	Gogyeong-myeon, Gyeongsangbuk-do, South Korea	4		LG Energy Solution		Solar Integration						
2021/03/11	South Korea, YoungCheon City	8.4				Solar Integration				$770k est.		
2021/04/06	South Korea, Hongseong			LG Energy Solution		Solar Integration			3.0			
2021/04/07	Australia, Bohle Plains	8	4	Tesla	Tesla	VPP		Integrated	1.3		Commissioning	A fire broke out during commissioning of Tesla Powerpacks.

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure products	System Age	Extent of Damage	State during Accident	Description
2021/04/16	China, Beijing	25		Gotion High-Tech [LFP]		Solar Integration	Commercial	Container	2.0	Explosion	Construction, Commissioning	The report details several possible causes, but is inconclusive. Possible causes included cell defects, sand/dust accumulation, overcharging, and other possibilities. A fire broke out at a BESS located on the roof of a shopping mall. An explosion occurred, killing two firefighters and injuring a third.
2021/04/19	US, MI, Standish					Demand Charge Mgmt	Substation	Container		Fire		Sparks were seen coming out of a BESS container. A fire broke out, and was limited to one container.
2021/07/13	France, New Caledonia, Bouloupari s					Solar Integration	Rural					Two BESS containers were destroyed in a fire at a solar + storage facility.
2021/07/18	Germany, Neuhardenberg	5	5	[LFP]		Solar Integration and Frequency Regulation	Indoor/Hangar	Container	5.0			A BESS caught fire at a solar + storage facility. Images show the BESS being indoors.
2021/07/19	US, IL, LaSalle	36	36	Sinexcel [LFP]	Energport	Solar and Wind Integration, Frequency Regulation	Rural	Container	1.6			One container at a BESS plant caught fire. The fire was extinguished later the same day.
2021/07/30	Australia, Victoria, Moorabool	450	300	Tesla [NMC]	Tesla	Grid Stability	Rural	Integrated products	0.0	Fire	Construction, Commissioning	The probable root cause was identified as a leak in the internal coolant system of the Tesla Megapack. The thermal event started in one Megapack and propagated to another. Two adjacent megapacks were damaged by thermal radiation from the fire. This event occurred during commissioning, when the Megapack was switched to off-line service

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
												mode. The resulting shutdown of telemetry systems, battery cooling system, and battery protection system led to a loss of visibility on the Megapack's condition, alarming, and other prevention/mitigation functionalities.
2021/09/04	US, CA, Moss Landing	1200	300	LG Energy Solution	Fluence	Solar Integration	Power Plant		0.8	Scorched racks, melted wires		
2022/01/12	South Korea, Nam-gu, Ulsan	50	10	SK Innovation		Peak Load Reduction	Urban	3-story Building	2.0	Fully burnt	Operational	
2022/01/17	South Korea, Gunwi-gun, Gyeongsangbuk-do	1.5	0.45	LG Energy Solution		Solar integration	Rural		3.0	Fully burnt. Explosion	Operation. Fully charged	
2022/02/13	US, CA, Moss Landing	400	100	LG Energy Solution		Solar Integration	Power Plant	Building	1.0	Burnt racks	Operational	
2022/03/30	Taiwan, Taichung City, Longjing District	1	1			Solar Integration	Power Plant	Container	2.0	Fire	Operational	
2022/04/05	US, CA, Valley Center	560	140	LG Energy Solution	Terra-Gen		Rural	Container	0.2	Damage to single rack	Operational	
2022/04/18	US, AZ, Chandler	40	10	LG Chem [NMC]	AES/Fluence		Substation	Building	3.0		Operational	

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
2022/05/02	South Korea, Jangseong-gun					Solar Integration		Container				The battery in a solar plus storage system caught fire.
2022/08/03	US, CA, Rio Dell			Lead Acid	Narada	Solar Integration / Backup	Rural	Container	4.0	Explosion. Nearby building damage	Operational	
2022/09/06	South Korea, Incheon		103			Energy Shifting	Factory	Building			Operational	
2022/09/06	USA, Wyoming, Yellowstone National Park					Solar Integration	Indoor			Exterior of building was undamaged.		Smoke was seen coming from a building housing a solar plus storage system. West Thumb Geyser Basin was closed for 6 days following the incident.
2022/09/20	US, CA, Moss Landing	730	182.5	Tesla	Tesla	Energy Shifting, Ancillary Services	Substation	Container	0.5		Operational	Fire in one Megapack unit at PG&E Elkhorn battery facility
2022/10/20	China, Hainan	50	25	Ruipu	Beijing Baoguang Zhizhong Energy Technology Co.	Solar Integration		Container	0.0	One of the ten battery containers destroyed	Commissioning	
2022/12/08	South Korea, Jeollanam-do, Damyang-gun, Mujeong-	9.1	2.5	Samsung SDI		Solar Integration	Rural	Building	5.5	System destroyed	Operational	

Event Date	Location	Capacity	Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
	myeon, Deokgok-ri										
2022/12/27	South Korea, Jeollanam-do, Yeongam-gun, Geumjeong-myeon	251		Daemyung Energy	Solar Integration	Rural	Building	1.8	At least one of 24 BESS buildings destroyed	Operational	
2023/01/30	US, PA, Millvale		SimpliPhi Power (LFP)		Solar Integration	Urban	Basement		System destroyed with severe damage to basement	Operational	Relatively small battery system in the basement of a commercial building. Batteries were tied to rooftop solar and used to power a kitchen on the main floor.
2023/03/28	France, Saint-Trivier-sur-Moignans					Indoor, Datacentre					Data centre burned down. Data centre had a solar + storage system, and lithium ion battery is suspected to be the cause of fire.
2023/04/26	Sweden, Gothenburg, Vastra Frolunda	0.875				Indoor	Container	0.0	Explosion	Pre-commissioning	Investigation concludes that the most likely cause was a leak into the battery cell during pressure testing of the cooling system, which caused a short circuit and thermal runaway. The container was on wheels and was moved from indoors to outdoors when smoke was seen. A cutting extinguisher was used to cool the battery, but several minutes later an explosion occurred. The nearby community was directed to stay indoors and an adjacent building was evacuated during firefighting activities. Fire propagation to the adjacent

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
												building was limited by water from jet pipes and water cannons. The fire was extinguished, but the batteries began smoking again the next day. The battery container was submerged by crane in water in a larger container.
2023/05/31	US, NY, East Hampton	40	5	LG Chem	Haugland Energy Group	Resiliency, Utility Peak Reduction	Substation	Building	4.8		Operational	A 'smouldering battery' was reported, closing down roads and stopping train service for about an hour until the fire was contained. NextEra reported that an internal sprinkler system contained the fire.
2023/06/26	US, NY, Warwick	36	8	Powin Energy	Convergent Energy and Power	Energy Shifting, Backup	Substation	Integrated products	0.1	Multiple racks destroyed	Operational	This event is one half of a larger simultaneous failure across 2 discrete sites in Warwick, NY. Both sites deployed the new "Centipede" model from Powin and both failures seemed to have occurred within 24 hours of each other. The failure appeared to occur during a large storm that affected both sites in Warwick
2023/06/27	US, NY, Warwick	17.9	4	Powin Energy	Convergent Energy and Power	Energy Shifting, Backup	Substation	Integrated products	0.1	It is unclear if this site experienced a fire, but the system "was experiencing problem	Operational	This event is one half of a larger simultaneous failure across 2 discrete sites in Warwick, NY. Both sites deployed the new "Centipede" model from Powin and both failures seemed to have occurred within 24 hours of each other. The failure appeared to occur during a large storm that affected both sites in Warwick.

Event Date	Location	Capacity	Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
									s" and fire alarms were triggered. The batteries were later removed from the site to be disposed of.		
2023/07/04	Taiwan, Taichung City, Longjing District		LFP				Shipping container		At least one container was damaged. Burn extent was reported to be 30 sq. m.		Fire was reported in an outdoor storage facility. At least one container with batteries was on fire. The damage area was reported by to ~30 sq. m.
2023/07/27	US, NY, Chaumont	15 5	General Electric	Convergent Energy and Power	Solar Integration	Rural	Container	0.4		Operational	Fire was reported in an outdoor storage facility co-located with solar PV. A shelter-in-place order was issued for the surrounding community within 1 mile of the facility.
2023/08/19	China, Xiangzhou District, Zuhai City					Warehouse	Cabinet				Fire fighters used water to extinguish the fire. Later, the battery cabinet suddenly caught fire again. Staff protected by fire fighters used a forklift to transfer each battery cabinet to an outdoor open area for cooling.

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
2023/08/22	France, Saucats, Barban	98	105		Nidec Industrial Solutions		Rural	Container	0.0	Single container damaged	Pre-commissioning	Fire broke out at an outdoor storage facility. A water curtain was used to prevent propagation. No injuries were reported. Local residents raised concerns about smoke affected nearby cropland and forests.
2023/09/18	US, CA, Valley Center	560	140	LG Energy Solution	Terra-Gen		Rural	Container	1.6	Damage to single container	Operational	Fire in one of the containers. This is the 2nd event that this system has experienced, the [https://storagewiki.epri.com/index.php/Failure_Event_-_US,_CA,_Valley_Center_-_5_Apr_2022 first event was on April 5, 2022]
2023/09/26	Australia, Queensland, Bouldercombe	100	50	Tesla	Tesla		Substation	Integrated products	0.1	Single container on fire, possible damage to surrounding containers	Operational	
2023/09/29	France, Martinique, Saint-Esprit					Solar Integration	Farm	Container		Explosion	Operational	The explosion blew out windows from nearby residential homes and led to an evacuation. Water was used to reduce toxic air emissions and the fire was suppressed with powder and foam within 3 hours.
2023/10/02	USA, ID, Melba	8	2	Powin Energy	Powin Energy	Distribution Resource	Substation	Integrated products	0.0	Several stacks appeared to be burnt	Pre-commissioning	Battery fire at the substation was reported, leading to road closures. The fire was contained and allowed to burn out over 3 days, and air quality testing was conducted by the county. The substation remained operational through the fire.
2023/12/28	Taiwan, Lanyu		1.1				Power Plant	Container			Operational	A battery cabinet outside the Lanyu Power Plant caught fire. The cause is suspected to be a short circuit that occurred during a grid connection test. The plant's operation was

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
												not affected, and the fire was controlled and suppressed after a day.
2024/05/15	USA, CA, San Diego	250	250	LG Chem	LS Power, NEC Energy Solutions	Energy shifting		Indoor	3.7			The Gateway Energy Storage Facility was involved in a fire, and water was pumped into the building's fire suppression system to extinguish it. A 600-foot safety barrier was maintained for over 22 hours due to air monitors showing high levels of hydrogen. A drone and unmanned robot were been used to monitor the fire, measure air quality and take temperature readings, and firefighters opened the building once heat was no longer detected. A shelter in place order and an evacuation warning were sent out as a precaution. The fire was declared extinguished the next day, but reignited several times until the fire department left the scene nearly 17 days later.
2024/03/27	Japan, Kagoshima, Isa					Solar Integration						The BESS of a solar+storage plant caught fire. The BESS was co-located with the 1200 kW Takayanagi Solar Power Plant, Unit 6. Firefighters checked the temperature and opened the door to the building, and an explosion occurred when they tried to use the smoke exhaust system. Four firefighters were injured. The fire was extinguished the next day.
2024/07/17	US, CA, Santa Ana					Industrial						A BESS fire occurred in an industrial area, leading to a 1 hour evacuation in the area due to smoke.

Event Date	Location	Capacity		Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
2024/09/05	US, CA, Escondido	120	30		AES Energy Storage		Substation	Container	7.6		Under maintenance	One of 24 containers caught fire. Businesses adjacent to the substation or within approximately 0.25 mi were evacuated. A shelter-in-place order was issued for locations farther east. Classes were cancelled at some nearby schools. The fire started at noon on September 5, and was extinguished by 1 AM on September 6. Air quality and water runoff reports were made publicly available after the incident, and found that all readings taken were well below acceptable exposure limits and considered expected readings during a routine structure fire.
2024/09/10	Singapore					UPS	Data centre			Significant disruption to servers. Minor structural damage. No injuries.		An explosion and fire occurred in a lithium ion BESS at a data centre owned by Digital Realty. The BESS was located in the battery rooms on the third floor. Four water jets and the sprinkler system were used to contain the fire, and an unmanned firefighting robot was used to cool the batteries. The fire was declared to be under control after 2 days.
2024/10/25	South Africa, Table Mountain					Backup energy resource	Indoor			Building damage.		A lithium ion battery system intended as back up energy for cable car operation caught fire. The system was inside a parking garage and was contained within 4 hours.

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2025/01/16	US, CA, Moss Landing	1200	300	LG Energy Solution	Fluence	Solar Integration	Power Plant	Building	4.1	80% of batteries were burnt.		A fire broke out in Vistra's 300 MW / 1200 MWh Phase I BESS plant. Firefighters are using a "monitor and contain" approach and allowing the fire to burn itself out. The police issued evacuation orders and closed two nearby roads and a highway, and the local school district closed all schools for one day. The US EPA, the Monterey Bay Air Resources District, and Vistra monitored air quality in and around the fire perimeter and across Monterey County, and found that levels of Hydrogen Fluoride (HF) remained below acute Reference Exposure Level thresholds. Moss Landing Marine Laboratories found elevated levels of nickel, cobalt, and manganese in soil samples at concentrations roughly 100 to 1,000 times higher than normal. The Moss Landing site is home to two separately owned BESS systems: PG&E's Elkhorn system, and Vistra's Moss Landing systems (Phase I, II, and III). The Phase I Vistra system experienced an incident in 2021 and came back online in 2022.
2024/09/12	Canada, ON, Brantford				Aypa Power	Peak Shaving	Commercial	Container	3.0	One container burned.		A single 40 ft container BESS caught fire. The container was located on the property of a bakery, and the fire did not disrupt the bakery's operations. Firewater runoff from the site impacted a retention pond and a nearby creek. The Ministry of Environment stated that â€œthe gate at the outfall of the pond was immediately closed, containing the majority of the firewater to the pond. Impacts to the creek are minimal and are not expected to cause adverse effects.â€

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												Cleanup of the pond and disposal of the firewater was to be conducted in accordance with the Environmental Protection Act.
2024/04/29	US, CA, Kearny Mesa	80	20	LFP	Fluence		Substation	Integrated products	2.1			A safety incident occurred at the Kearny South Energy Storage Facility. The 20 MW / 80 MWh Kearny system consists of the Kearny North Energy Storage Facility and Kearny South Energy Storage Facility; both located at the same substation.
2025/02/19	England, Essex, Tilbury	600	300			Frequency Regulation, Capacity Market, Balancing Mechanism, Wholesale Power Markets	Substation	Container	0.0	A single container out of "multiple"	Construction	A fire occurred in a single BESS container and was extinguished 1 day later. The Thurrock site was still under construction at the time. Firefighters relied on thermal imaging cameras and drones to monitor temperatures and manage the fire, and a water curtain was used to prevent propagation.
2025/03/28	England, Gloucestershire, Cirencester	51	10	Li ion	Gridserve	Solar shifting	Solar + storage	Container	2.5	Two containers were affected.		A fire occurred in two BESS containers at Cirencester Hybrid Solar Farm. The solar + storage facility is DC coupled, with 23 MW solar and 10 MW of BESS. Two containers were affected by the fire, and propagation to a third container was prevented. The event lasted 7 hours.
2025/05/22	US, OR, Hillsboro					Data centre	Data centre					A fire occurred in the battery room of a data centre. The fire was extinguished after 5 hours.
2025/06/16	South Korea, Gyeongsa					Industrial	Indoor			Building and system		A BESS fire occurred at a steel plant. The fire was extinguished after 30 hours and

Event Date	Location	Capacity	Battery Modules	Integrator	Application	Installation	En-closure	System Age	Extent of Damage	State during Accident	Description
	ngbuk-do, Songdong -ri								destroye d.		monitored for reignition. The building where the BESS was located burned down.