APPENDIX G
BATTERY ENERGY STORAGE SYSTEM (BESS)
TECHNICAL INFORMATION AND RISK MATRIX

1.1 INTRODUCTION

The applicant proposes to install a Battery Energy Storage System (BESS) of approximately 1400 megawatt-hour (MWh) for storage of the electricity generated from Haga Haga WEF which includes batteries and associated operational, safety and control infrastructure.

The operation of the battery storage facility and integration with the WEF can be summarised as follows:

1. Electricity generated by the wind turbines is converted from direct current to alternating current.
2. The electricity (33kV) is then transferred to the battery storage facility where the plant controller will then determine whether the energy should be stored (when energy is not needed) or evacuated to the National Grid (when energy is needed);
3. If the electricity is needed, the electricity will be transferred to the onsite substation (approved as part of the original EA) where the voltage will be stepped up to 132kV and evacuated to the National Grid.

1.1.1 Site Position

The BESS will be located and developed immediately adjacent to the Substation on the remainder of the storage area footprint as illustrated in Figure 1.1 (red square including all storage facilities, substation and office space).

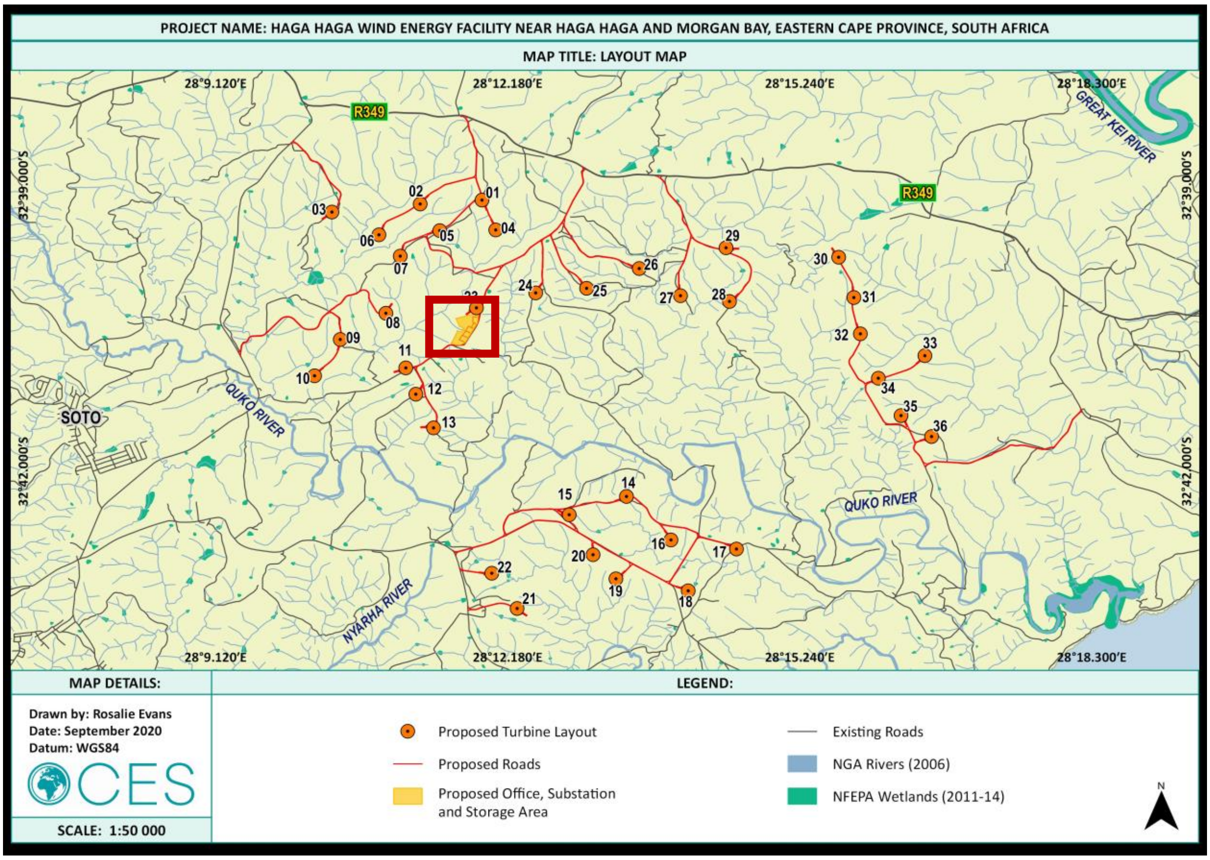

Figure 1-1: Location of proposed BESS (32°40'34.04"S, 28°11'45.01"E)

1.1.2 Description

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 can be stacked if required. Supplementary infrastructure and equipment may include power cables, transformers, power converters, buildings & offices, HV/MV switch gear, inverters and temperature control equipment that may be positioned between the battery containers.

The BESS may comprise stacked containers, with a maximum height of 8 m and will cover an area of up to 1 hectare.

Figure 1.2: Typical containerised Battery Energy Storage Facility

1.2 BATTERY COMPONENTS AND SUPPLEMENTARY INFRASTRUCTURE

Typically, BESS consist of multiple battery cells that are assembled together to form modules. Each cell contains a positive electrode, a negative electrode and an electrolyte. A module may consist of thousands of cells working in conjunction. Modules are normally packaged inside containers (similar to shipping containers) and these containers are delivered pre-assembled to the WEF site (Figure 1-3 shows the inside of one such container). There will be numerous such containers running in parallel to increase the total storage capacity of the system up to the desired/.

Supplementary infrastructure may include:

- Battery room;
- Inverters;
- Switch gear room;
- Supervisory Control and Data Acquisition (SCADA) equipment;
- Thermal management system.
- Fire Protection Unit
- MV Cabling (underground or overhead) between the BESS and the WEF substation
- Power converters
- HV/MV switch gear
- Possible firebreak around the BESS

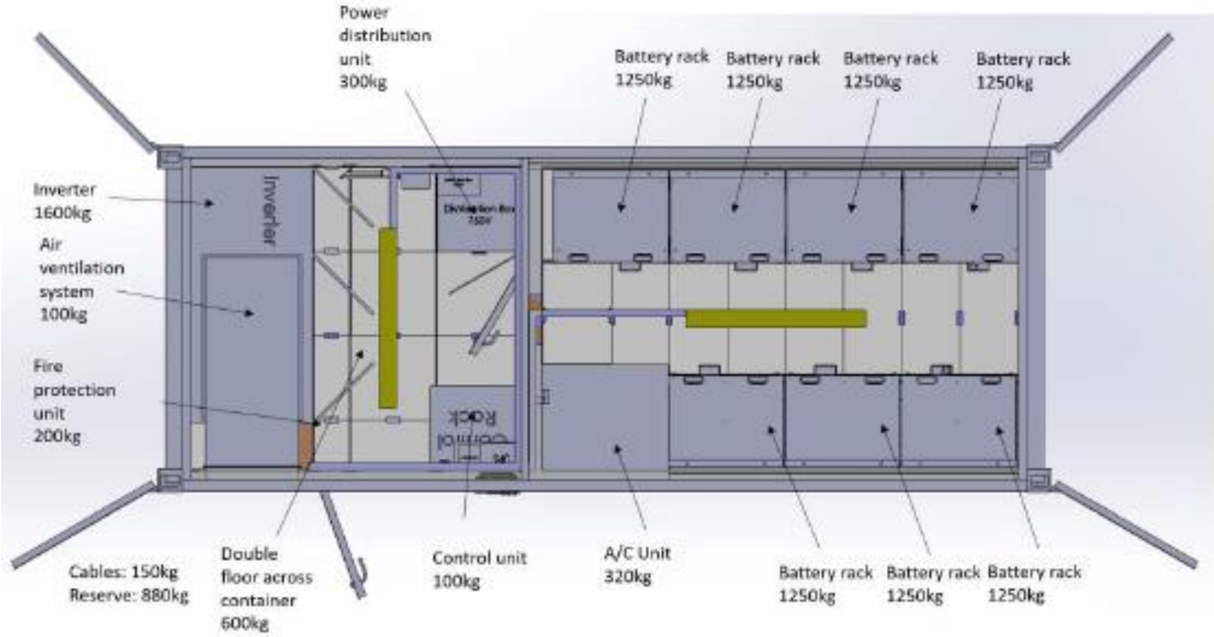

Figure 1-3: Container System Components

The containers will have approximate dimension ranges of: height 2 m - 5 m, width 1.5 m - 3 m, length 7 m - 20 m. The containers are raised slightly off the ground and are bunded to prevent possible environmental damage resulting from any equipment malfunction. The proposed development is considering the option of stacking these containers vertically to a maximum of two container layers or a height of 8m.

A summary of the details and dimensions of the planned BESS and associated infrastructure is provided in Table 1.1 below.

Table 1.1: BESS and Associated Infrastructure

INFRASTRUCTURE	FOOTPRINT, DIMENSIONS AND DETAILS
Technology	Lithium Ion, Flow or Solid State Technologies
BESS footprint	Up to 1ha in total extent, including foundation and containerised battery system
Capacity	1400MWh
Access road to BESS	The road will branch off from the BESS and will be 8m in width.
Height	Up to 8m
Fencing	Fencing around the footprint of the BESS will be installed for access restriction measures.

Figure 1-4 illustrates an example of a safe layout of a BESS facility.

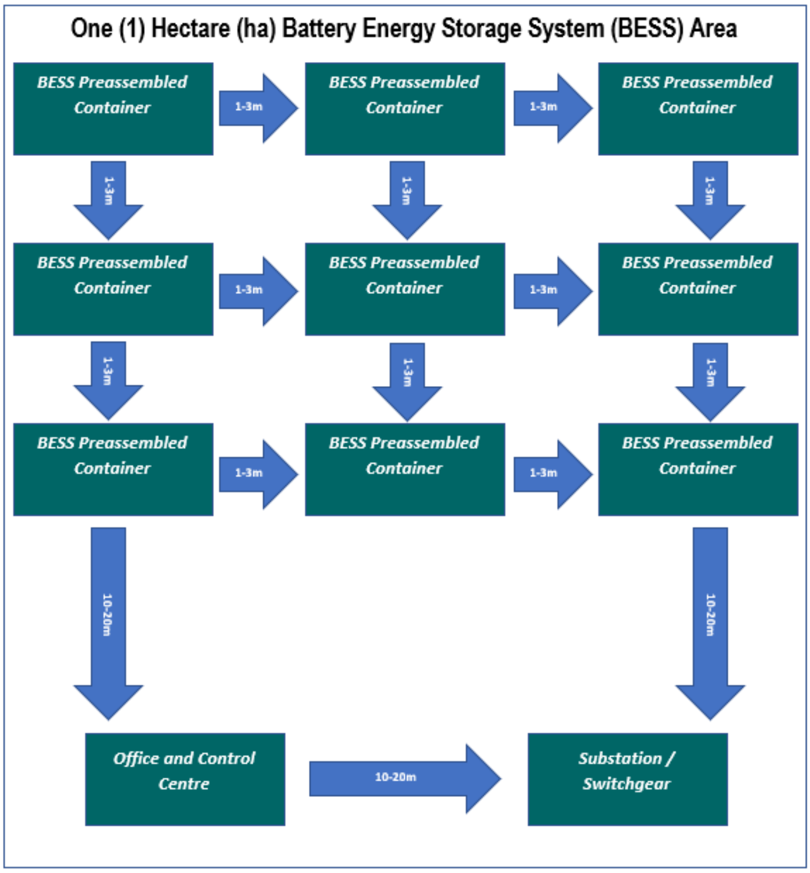

Figure 1-4: Example of the fire safety buffers applied to BESS Facilities - to be updated in accordance with industry standards at the time.

1.3 BATTERY ALTERNATIVES

Three types of battery technology are being considered for the proposed BESS, Solid State Battery, Lithium Ion and Flow Battery. The battery technologies under consideration are explained further below and compared in a table of advantages and disadvantages.

1.3.1 Solid State Battery

Solid State Battery is a technology that uses solid electrodes and a solid electrolyte, instead of a liquid of polymer gel electrolyte used in flow batteries. Solid-state battery electrolytes typically consist of Lead Acid (Pb), Nickel Cadium (NiCad), Sodium Sulphur (NaS) or Sodium Nickle Chloride / Zebra (NaNiCl). The technology consists of multiple battery cells that are strung together in series to form rack mountable modules. Typically, the racks are then installed in a specially prepared shipping container to function as an integrated battery system.

1.3.2 Flow Battery

Flow Batteries differ from conventional rechargeable batteries in that the electroactive materials are not stored within the electrode; rather, they are dissolved in electrolyte solutions. The electrolytes are stored in tanks (one at the anode side, the anolyte tank; one at the cathode side, the catholyte tank). These two tanks are separated from the regenerative cell stack. The electrolytes are pumped from the tanks into the cell stacks (i.e. reaction unit) where reversible electrochemical reactions occur during charging and discharging of the system. In “pure flow” (i.e. “true flow”) systems, electroactive materials are stored externally from the power conversion unit (i.e. cell stack) and only flow into it during operation. The most used flow battery is the Vanadium Redox Flow Battery (VRFB), which is a type of rechargeable flow battery that employs vanadium ions in different oxidative states to store chemical potential energy.

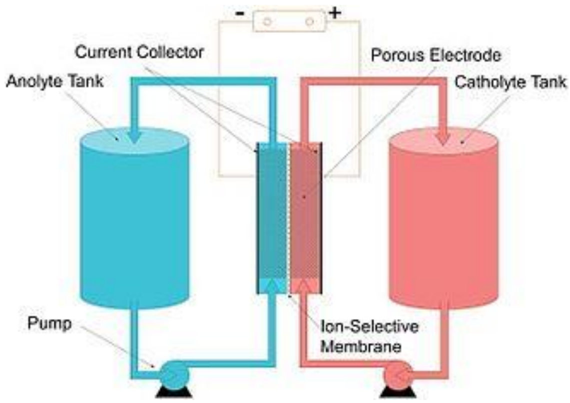

Figure 1-5: Typical flow battery

1.3.3 Lithium-Ion

Lithium ion (Li-ion) batteries are the most common stationary battery in the market today. Simply put, the batteries consist of a graphite electrode and a lithium-based electrode immersed in a liquid. When the battery is in use, charged lithium atoms ions flow from the graphite electrode to the lithium-based electrode through the liquid, and that flow of charged particles is what generates electricity. When the battery is recharged the flow is reversed, sending the lithium ions back to the graphite anode where they are stored ready for discharge.

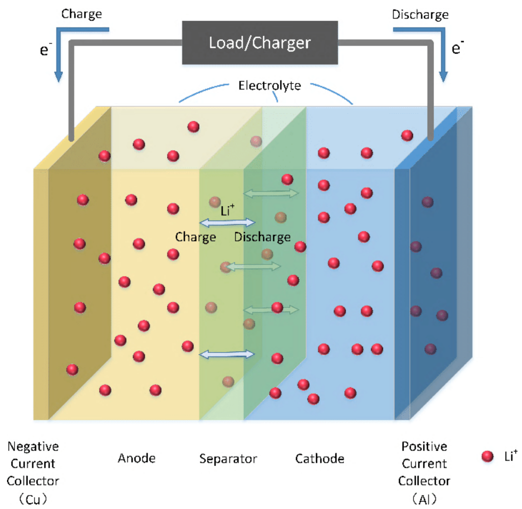

Figure 1-6: Lithium-Ion Battery

Table 1.2: Summary of technology options for the BESS[1234]

ACTIVITY ALTERNATIVE	ADVANTAGE	DISADVANTAGE
Li-Ion Batteries **(preferred alternative)**	• Lithium ion has the smallest installation footprint when compared to the technologies for the similar energy capacity. • High-energy density; Low maintenance; Low self-discharge. • Produce the highest voltage compared to other batteries by driving high electron flow.	• Volatility leading to Fire and Explosions. • Potential for issues associated with overheating (Certain Lithium chemistry's). • The Lithium element in this technology is considered hazardous / dangerous goods. • Limited number of charging cycles (They age and will need to be replace. • Lithium is a finite resource with concerns of its availability in the long term.

ACTIVITY ALTERNATIVE	ADVANTAGE	DISADVANTAGE
Flow Batteries	• Electrolyte solutions are safe, non-flammable, and non-corrosive. • The two electrolytes are compatible and easily rechargeable. • Expected to handle many more cycles than Li-ion batteries. • Are known to have the longest lifespan. • Technology is scalable for large grid infrastructure and renewable energy project.	• Maintenance cost of the tanks and pump system are high. • Overall cost is higher $/KWh than Li-ion. • Low energy density. • The volume of space that the tanks may take up.
Steady State Battery	• Marked improvement in safety at cell and battery levels: solid electrolytes are non-flammable when heated, unlike their liquid counterparts. • It permits the use of innovative, high-voltage high-capacity materials, enabling denser, lighter batteries with better shelf-life as a result of reduced self-discharge. • Simplified mechanics as well as thermal and safety management.	• Expensive compared to liquid electrolyte. • Problems with electrochemical stability in some solid electrolytes. • Sourcing of a suitable electrolyte. • Not as well researched and many examples in prototype. • Narrow temperature range and cannot tolerate varying temperature.

[1] Li-Ion Battery and Flow Battery: http://epis.com/powermarketinsights/index.php/2016/04/05/large-scale-battery-storage/

[2] Li-Ion Battery and Na-S Battery: https://ensia.com/features/battery-innovations-renewable-energy/

[3] Flow Battery: https://newatlas.com/energy/iron-aqds-flow-battery-usc/

[4] Solid State Battery: https://www.greentechmedia.com/articles/read/us-storage-companies-quietly-grow-bets-on-solid-state-batteries

Due to rapidly changing preferences and improvements to battery technology, selection of the type of battery technology will only take place during the detailed design process and after the appointment of the battery supplier. **However, at this stage the preferred technology alternative is Li–Ion Batteries.**

An updated Risk Assessment will be submitted to DEFF once the technology type and associated chemical composition has been determined. The EMPr will be amended to include these measures and will include technology specific mitigation measures.

1.4 NEMA AND BESS

The battery storage facility does not trigger any listed activities on its own due to the fact that is to be located on an area already authorised for storage related activity. Furthermore, activities relating to storage of dangerous goods, such as Activity 14 of Listing Notice 1 and Activity 10 of Listing Notice 3, will not be triggered by the proposed battery storage facility installation, due to the following:

- A battery is not deemed to be a container; and
- Electrolytes that are used within battery storage facilities: their function is deemed to be like transformers within substations: converting high voltage electricity to lower voltage electricity for further distribution. The function of the battery is not for “storage” or “storage and handling” of a dangerous good.

Battery storage does not trigger any listed activities relating to the generation of electricity as technology does not 'generate' electricity, it simply stores electricity generated by the renewable energy facility (Haga Haga WEF in this instance) and discharges the stored electricity as and when required by the grid.

1.5 BESS CONSTRUCTION

Construction risk for large scale BESS projects is generally regarded as low and is classified as a simple building task. This is because the BESS is pre-assembled and containerised, with limited construction activities required at site. Construction risks, specifically during transportation and implementation, will be managed in accordance with the Risk Management Matrix and Management Plan.

1.6 BESS MAINTENANCE

Any maintenance, service or repairs required to be carried out on the BESS will be conducted by the supplier's personal or their authorised agent. This includes any preventative maintenance that is identified to be carried out on the plant.

Any necessary maintenance equipment and spares will be kept in the Haga Haga WEF general maintenance building and/ or storage area. No hazardous or dangerous good will be stored in a container on site in volumes that may meet or exceed the thresholds specified in EIA regulations.

1.7 BESS END OF LIFE

The BESS end of life has been reached when the system's performance requirements are no longer being met, where repairs do not solve the problem and where change in the BESS does not lead to a profitable alternative business case. In this instance, the BESS system must be de-installed, disassembled, removed from the site, transported, re-used/recycled.

The BESS system must be de-energised safely before any other steps can be taken. Before the transportation of the components, relevant safety prescripts must be in effect, to ensure that the BESS system and its components are safe to transport.

When a battery module reaches its end of life or needs to be replaced for a specific technical reason, it will be returned to the Original Equipment Manufacturer for disassembly and further processing.

A decommissioning plan will be prepared before any decommissioning activities begin. The plan must and clearly define which parties are responsible for decommissioning the BESS. The plan should be a living document that is updated as technologies, experience with BESS, and relevant codes and regulations evolve over the project lifecycle. This plan must be submitted to DEFF for approval prior to the decommissioning phase.

The decommissioning of the BESS site itself must be done in accordance with the Haga Haga WEF EMPr: Decommissioning Phase mitigation measures and is subject to Rehabilitation in accordance with the Rehabilitation Management Plan.

Decommissioning and disposal of batteries must be done in accordance with South African Regulations. In the instance where batteries are disposed of without returning to the supplier, only local recycling processors that adhere to appropriate methods of disposal and recycling should be used, and under the guidance of the original equipment manufacturer.

1.8 BESS EMERGENCY RESPONSE PLAN

An Emergency Response Plan must be in place that is applicable for the full route from the ship to the site. This plan must include details of the most appropriate emergency response to fires both while the units are in transit and once they are installed and operating. The plan must be in place prior to commissioning and should include, but not limited to, aspects such as appointment of emergency controller, emergency isolation systems for electricity, provision of PPE for hazardous materials response, provision of shelter in place facilities for staff at the main office building, provision of first aid and first responder contact numbers.

The following section (as extracted from AIG: Lithium-ion Battery Energy Storage Systems: The risks and how to manage them) outlines the risks associated with BESS, the management needed to mitigate these risks and how best to incorporate these management ideals into an Emergency Response Plan.

1.8.1 Risks Associated with Lithium-ion BESS (preferred alternative)

Thermal Runaway
'Thermal runaway' – a cycle in which excessive heat keeps creating more heat – is the major risk for Li-ion battery technology. It can be caused by a battery having internal cell defects, mechanical failures/damage or overvoltage. These lead to high temperatures, gas build-up and potential explosive rupture of the battery cell, resulting in fire and/or explosion. Without disconnection, thermal runaway can also spread from one cell to the next, causing further damage.

In BESS's that utilize lead acid batteries, hydrogen evolution can result in explosive atmospheres unless proper ventilation methods are employed.

Difficulty of Fighting Battery Fires
Battery fires are often very intense and difficult to control. They can take days or even weeks to extinguish properly and may seem fully extinguished when they are not.

They can also be very dangerous to fire fighters and other first responders because, in addition to the immediate fire and electricity risks, they may be dealing with toxic fumes, exposure to hazardous materials and building decontamination issues. Different types of batteries also react differently to fire, so firefighters must be knowledgeable about how they react and how to respond. Otherwise, they may decide to contain the fire but leave it to burn itself out leading to the loss of the entire facility

Failure of control systems
Another issue can be failure of protection and control systems. For example, a Battery Management System (BMS) failure can lead to overcharging and an inability to monitor the operating environment, such as temperature or cell voltage.

Sensitivity of Li-ion batteries to mechanical damage and electrical transients
Contrary to existing conventional battery technology, Li-ion batteries are very sensitive to mechanical damage and electrical surges. This type of damage can result in internal battery short circuits which lead to internal battery heating, battery explosions and fires. The loss of an individual battery can rapidly cascade to surrounding batteries, resulting in a larger scale fire.

1.8.2 Emergency Preparedness to the Risks Associated with Lithium-ion BESS (preferred alternative)

Planning Phase (questions to be answered by the specific supplier of the lithium-ion battery modules)
- Supplier must test all modules in the BESS container prior to assembly.
- All BESS containers are be preassembled by the supplier prior to being transported to site.

Construction Phase

There are practical steps that organisations can take to minimise their risks when constructing a battery system (please note that this phase WILL NOT take place on site, this is relevant to the assembly of the BESS containers by the supplier and NOT relevant to activities on site. The BESS containers will arrive preassembled):

- Use non-combustible materials.
- Check where the battery components were made/who the manufacturer is.
- Transport the batteries very carefully as they are fragile, despite their robust appearance.
- Carry out extensive testing to detect any faults.
- Ensure an effective Battery Management System is included in the design (to be supplied to the Haga Haga WEF contractors)

These are practical steps to reduce risks on the BESS site which must be part of the emergency preparedness plan:

- Locate storage systems well away from critical buildings or equipment. Each BESS container must be situated 1-3m away from the next (depending on the industry standards at the time), unless stacked.
- Exterior protection such as a passive thermal barrier and active fire protection such as drenchers must be part of the design of the BESS.
- Battery management systems and the electrical switch gear must not be located within the preassembled containers and must be situated between 10–20m away from the closest container (depending on the industry standards at the time).
- Adequate fire doors (>FR60) must be installed as part of the preassembled containers. They must be maintained in the closed position and equipped with automatic closure mechanisms. Where insulated metal panels (IMPs) are used, these should contain a mineral wool core and be installed in accordance with the terms of their approval. Only non-combustible IMPs should be installed.
- Ensure proper management of cable/service penetrations. Cable penetrations should be adequately sealed to meet the fire resistance of the compartment (two-hour fire resistance rating). Heating, ventilation and air conditioning ducts must have fire dampers provided that automatically close on activation of the fire alarm. Establish a permit to access system to manage changes to service or cable penetrations under an audited system.

Fire Protection and Emergency Preparedness

Organisations should put automatic fire detection in place, with early warning smoke detection or very early warning highly sensitive smoke detection (using air sampling devices). The system design should include continuous remote monitoring.

As for active fire protection, testing and research is just beginning and there is no publicly available test data that proves any particular type of active fire protection can prevent or control thermal runaway. Therefore, there is no clear guidance for organisations about what kind of protection to put in place. However, inert gas and foam suppression systems seem unable to control thermal runaway, so the two main options are likely to be automatic fire sprinklers and water mist.

It is a vital requirement that the EMPr be updated and made available for public review and approval by DEFF prior to the construction phase. This update must include all safety requirements recommended and required by the supplier of the BESS systems as well as by the most up-to-date national, provincial and local legislation regarding health and safety.

Table 1-3: Risk Matrix and Recommended Management Plan

RISK MATRIX AND RECOMMENDED MANAGEMENT PLAN FOR ALL BATTERY TECHNOLOGY ALTERNATIVES							
ACTIVITIES	RISKS	CAUSE	ENVIRONMENTAL IMPACT	MITIGATION MEASURES			RISK RATING
				PROCESS	PLANT	PEOPLE	
STORAGE	• Containment breach.	• Infringement of recommended handling and storage protocols.	• Spillage of electrolyte / dangerous substances. • Contamination of environment. • Injury.	• Regular inspection of containment/ bunding. • Risk assessment to be conducted. • Appropriate supervision. • Adhere to handling and storage instructions. • Emergency Response Plan including site clean-up and rehabilitation response procedure.	• Use of suitable equipment. • Equipment properly packaged/ bunded in line with regulations. • Ensure that storage facilities meet OEM requirements.	Specialist staff trained and accredited to appropriate standard.	LOW
TRANSPORTATION	• Containment breach.	• Road accident • Cargo not secured appropriately. • Poor road and transport conditions.	• Spillage of electrolyte / dangerous substances. • Contamination of environment. • Injury.	• Regular inspection of containment/ bunding. • Risk assessment to be conducted. • Appropriate supervision. • Adhere to handling and storage instructions. • Emergency Response Plan including site clean-up and rehabilitation response procedure.	• Use accredited hazardous goods transportation companies. • The battery containers to be assembled at the manufactures factory and delivered pre-assembled to the project site. • Appropriate packaging of equipment in line with regulations.	Specialist staff trained and accredited to appropriate standard.	MEDIUM

RISK MATRIX AND RECOMMENDED MANAGEMENT PLAN FOR ALL BATTERY TECHNOLOGY ALTERNATIVES							
ACTIVITIES	RISKS	CAUSE	ENVIRONMENTAL IMPACT	MITIGATION MEASURES			RISK RATING
				PROCESS	PLANT	PEOPLE	
INSTALLATION	• Containment breach.	• Infringement of recommended handling and storage protocols. • Inadequate supervision	• Spillage of electrolyte / dangerous substances. • Contamination of environment. • Injury.	• Regular inspection of containment/ bunding. • Risk assessment to be conducted. • Appropriate supervision. • Adhere to handling and storage instructions. • Emergency Response Plan including site clean-up and rehabilitation response procedure. Limit onsite storage of equipment – transport to site once BESS ready for installation.	• Appropriate containment design to eliminate risk of contaminating soil / environment. • The battery containers to be assembled at the manufactures factory and delivered pre-assembled to the project site. • Appropriate design that supports safe handling, transportation, and installation.	Specialist staff trained and accredited to appropriate standard.	**MEDIUM**
OPERATING AND MAINTENANCE	• Fire. • Explosion. • Containment Breach.	• Hidden equipment defects. • Failure to detect wear and tear. • Equipment failure. • Inadequate O&M procedures.	• Spillage of electrolyte / dangerous substances. • Contamination of environment. • Injury. • Plant damage.	• Appropriate O&M programme in place, including regular auditing and inspections of equipment and processes. • Emergency Response Plan including site clean-up and rehabilitation response procedure.	• Appropriate containment design of BESS equipment to eliminate risk of contaminating soil / environment. • Appropriate design to reduce risk of equipment failure e.g. corrosion and ingress protection. • Equipment failure detection system.	Specialist staff trained and accredited to appropriate standard.	**MEDIUM**

RISK MATRIX AND RECOMMENDED MANAGEMENT PLAN FOR ALL BATTERY TECHNOLOGY ALTERNATIVES							
ACTIVITIES	**RISKS**	**CAUSE**	**ENVIRONMENTAL IMPACT**	**MITIGATION MEASURES**			**RISK RATING**
				PROCESS	**PLANT**	**PEOPLE**	
DECOMMISSIONING	• Containment breach.	• Infringement of recommended handling and storage protocols. • Inadequate supervision.	• Spillage of electrolyte / dangerous substances. • Contamination of environment. • Injury. • Plant damage.	• Appropriate decommissioning strategy in place. • Appropriate waste management plan in place, including all relevant waste streams identified, permits obtained and accredited waste disposal facilities identified and contracted for receiving waste. • Ensure compliance with all relevant waste management legislation.	• Recycle plant components where appropriate. • Ensure appropriate equipment used to minimise risk of contaminating soil / environment.	Specialist staff trained and accredited to appropriate standard.	**MEDIUM**