SHEET 1

CONSOLIDATED RISK ASSESSMENT FOR ALL TECHNOLOGIES

Lifecycle Activities	Risks	Cause	Consequences / Environmental Impact	Mitigation Measures / Controls			Re-assessed Risks
				Process	Plant	People	
Storage	1) Damage to equipment or containment breach.	1) Not adhering to recommended handling and storage instructions. 2) No supervision during activities.	1) Spillage of electrolyte / dangerous substances. 2) Contamination of environment / soil / flora. 3) People injured.	1) Inspection of packaging for damage. 2) Risk assessment to be conducted. 3) Proper supervision. 4) Adhere to OEM handling and storage instructions. 5) Agreement / contract with HazMat company for first response, site cleanup and rehabilitation.	1) Use of Equipment suitable for activity. 2) Equipment properly packaged in line with regulations. {[1] Section 3.21.4 b)} 3) Ensure that storage facilities meet OEM requirements.	People trained and competent for activity / task.	No incidents.
Transportation	1) Damage to equipment or containment breach.	1) Road accident caused by driver or 3rd party. 2) Cargo not properly secured. 3) Bad road conditions.	1) Spillage of electrolyte / dangerous substances. 2) Contamination of environment / soil / flora. 3) People injured.	1) Inspection of packaging for damage. 2) Risk assessment to be conducted. 3) Route planning and obtaining all relevant permits from the local authorities. 4) Adhere to OEM handling and transportation instructions. 5) Agreement / contract with HazMat company for first response, site cleanup and rehabilitation. 6) All MSDS available for the BESS. {[1] Section 3.16.1 c) 4); 3.16.10 b)}	1) Making use of accredited hazardous goods transportation companies. 2) Equipment properly packaged in line with regulations to facilitate safe handling, transportSation and placement. {[1] Section 3.19.14.1 h); 3.21.4 a)}	1) People trained and competent for activity / task.	No incidents.
Installation	1) Damage to equipment or containment breach.	1) Not adhering to recommended handling and storage instructions. 2) No supervision during activities.	1) Spillage of electrolyte / dangerous substances. 2) Contamination of environment / soil / flora. 3) People injured.	1) Inspection of packaging for damage. 2) Risk assessment to be conducted. 3) Effective scheduling to limit onsite storage of equipment - site to be ready to readily accept BESS. 4) Adhere to OEM handling and transportation instructions. 5) Agreement / contract with HazMat company for first response, site cleanup and rehabilitation. 6) All MSDS available for the BESS. {[1] Section 3.16.1 c) 4); 3.16.10 b)}	1) Civil design ensures that spillages (of any nature) does not contaminate soil / environment. 2) Equipment designed to facilitate safe handling, transportation and placement. {[1] Section 3.19.14.1 h)}	1) OEM accredited staff to be used for installation, testing and commissioning.	1) BESS equipment safely installed in line with OEM standards. 2) No incidents.
Operating & Maintenance	1) Fire 2) Explosion 3) Equipment augmentation.	1) Latent defects. 2) Wear and tear not detected during maintenance inspections. 3) O&M not according to OEM instructions. 4) Shortcircuits, thermal runaway, equipment failure or malfunctioning. 4) Augmentation needed to maintain plant contractual performance.	1) Spillage of electrolyte / dangerous substances. 2) Contamination of environment / soil / flora. 3) People injured. 4) Damage to plant.	1) OEM operating and maintenance documentation available. {[1] Section 3.22.4} 2) Operating and Maintenance programme in place. {[1] Section 3.22.7} 3) Auditing of all operating and maintenance functions. 4) Waste management programme in place.	1) Enclosure corrosion protection and ingress protection suitable for the expected enviornmental conditions. {[1] Section 3.19.14.1} 2) Primary and secondary containment of hazardous substances within the BESS equipment. {[1] Section 3.16.9} 3) Civil design shall prevent any discharge of hazardous substances into the soil. 4) Hazard detection and effective safety controls implemented. {[1] Section 3.16.2; 3.16.3; 3.16.8} 5) Staff and first responders suitably equipped to effectively deal with on site incidents. 6) Plant designed for safe O&M by staff. {[1] Section 3.16.4 - 3.16.7; 3.16.11}	1) Staff trained and accredited to operate and maintain plant. {[1] Section 3.16.10; 3.23} 2) First responders trained in effectively handling plant fires and explosions. {[1] Section 3.16.10; 3.23}	1) No incidents. 2) Limited environmental impacts due to incidents.
Retire/ Decommissioning	1) Damage to equipment or containment breach.	1) Not adhering to recommended handling and decommissioning instructions. 2) No supervision during activities.	1) Spillage of electrolyte / dangerous substances. 2) Contamination of environment / soil / flora. 3) People injured. 4) Damage to plant.	1) Decommissioning strategy in place. 2) Environmental management plan in place. 3) Waste management plan in place. 4) Waste streams identified and documented. 5) Waste permits in place. 6) Accredtied waste facilities to be contracted for accepting / recycling the waste. 7) An EIA for the decommissioning of the BESS plant will be required and could trigger the need for a waste management license.	1) Plant recyclable components identified. 2) Use of suitable equipement to minimise or eliminate any spillages during decommissioning.	1) Making use of accredited staff.	1) No incidents. 2) No environmental impacts.

SHEET 2
FLOW BATTERY TECHNOLOGY

This is applicable to activities happening in South Africa

No.	Risk Status	Risk Title	Risk Description (something occurs.....)	Cause	Impact (leading to.....)	Existing controls (controlled by.....)	RCE per control	Control Owner	Task on Controls	Task on control Due Date	Task on control Percentage complete	Task on control owner	Cons. rating	Likelihood rating	Risk Rating	Risk Rating comment	Risk Owners	Potential Exposure	Risk Treatment tasks	Risk Treatment task Owner	Percentage Completion	Due date	Risk Treatment Plan Feedback	Target Risk Rating	Target Risk Rating Due Date	Risk Movement Comments	Type of technology
1		**PreCom: Road Transportation**	1. Accident whilst being transported	1. Accident caused by driver or 3rd party. 2. Poor road conditions.	1. Spillage of electrolyte / dangerous substances. 2. Contamination of environment / soil / flora.	1. Transport company accredited to transport dangerous goods on public roads. 2. Proper securing of cargo.	Mostly Effective	Contractor	1. Check that transportation company is accredited. 2. Ensure that cargo is checked.			1. Eskom 2. Contractor / Transportation company	3	C	II										
2		**PreCom: Storage**	1. Accident whilst being stored on site / warehouse.	1. Not adhering to storage instructions.	1. Spillage of electrolyte / dangerous substances. 2. Contamination of environment / soil / flora.	1. Store according to OEM instructions. 2. Storing in line with Environmental Management Programme. 3. Electrolyte and active materials are encapsulated by protective covering.	Mostly Effective	Contractor	Ensure compliance with OEM instructions and EMP.				2	B	IV				1. Environmental officer on site. 2. Eskom will conduct frequent site visits and audits.	Contractor and Environmental Dept						
3		**PreCom: Handling**	1. Accident whilst being handled (off-loaded or installed) on site / warehouse.	1. Not adhering to handling instructions. 2. Not taking care whilst handling equipment.	1. Spillage of electrolyte / dangerous substances. 2. Contamination of environment / soil / flora.	1. Handle according to OEM instructions. 2. Handling in line with Environmental Management Programme. 3. Use of correct equipment for off-loading by accredited operators. 4. Installation by accredited staff. 5. Electrolyte and active materials are encapsulated by protective covering.	Mostly Effective	Contractor	Ensure compliance with OEM instructions and EMP.				2	C	III				1. Environmental officer on site. 2. Eskom will conduct frequent site visits and audits.	Contractor and Environmental Dept						
4		**PreCom: Storage**	1. Accident whilst being stored on site / warehouse.	1. Not adhering to storage instructions.	1. Spillage of electrolyte / dangerous substances. 2. Contamination of environment / soil / flora.	1. Store according to OEM instructions. 2. Storing in line with Environmental Management Programme.	Mostly Effective	Contractor	Ensure compliance with OEM instructions and EMP.				3	B	III				1. Environmental officer on site. 2. Eskom will conduct frequent site visits and audits.	Contractor and Environmental Dept						
5		**PreCom: Handling**	1. Accident whilst being handled (off-loaded or installed) on site / warehouse.	1. Not adhering to handling instructions. 2. Not taking care whilst handling equipment.	1. Spillage of electrolyte / dangerous substances. 2. Contamination of environment / soil / flora.	1. Handle according to OEM instructions. 2. Handling in line with Environmental Management Programme. 3. Use of correct equipment for off-loading by accredited operators. 4. Installation by accredited staff.	Mostly Effective	Contractor	Ensure compliance with OEM instructions and EMP.				3	C	II				1. Environmental officer on site. 2. Eskom will conduct frequent site visits and audits.	Contractor and Environmental Dept						
6		**Construction: Land Clearing**	1. Actual vegetation clearing for the placement the plant and access roads.	Required for construction activities and placement of plant.	1. Destruction of indigenous and protected vegetation. 2. Temporary land clearing for construction material / equipment. 3. Impact on surrounding communities.	1. Activities in line with Environmental Management Programme.	Mostly Effective	Contractor	Ensure compliance with EMP.				2	E	II				1. Environmental officer on site. 2. Eskom will conduct frequent site visits and audits.	Contractor and Environmental Dept						
7		**Construction: Non-potable Water Usage**	1. Non-compliance to Water Use License or not permitted.	Not adhering to EMP requirements.	1. Legal contravention 2. Financial penalties	1. Activities in line with Environmental Management Programme.	Mostly Effective	Contractor	Ensure compliance with EMP.				3	A	IV											
8		**Construction: Potable Water Usage**	1. Abuse of potable water supplies.	Not adhering to EMP requirements.	1. Legal contravention 2. Financial penalties	1. Activities in line with Environmental Management Programme.	Mostly Effective	Contractor	Ensure compliance with EMP.				3	A	IV											
9		**Construction: Waste Generation**	1. Waste generation due to construction activities. 2. Different waste types will be generated.	Construction activities.	1. Incorrect / Illegal handling and disposal of different types of waste. 2. Spillage of electrolyte / dangerous substances. 3. Contamination of environment / soil / flora or injury to fauna. 4. Impact on surrounding communities.	1. Activities in line with Environmental Management Programme and Waste Management Plan.	Mostly Effective	Contractor	Ensure compliance with EMP and WMP.				4	C	II											
10		**O&M: Equipment replacements**	Augmentation of plant will lead to waste generation of electronics and dangerous substances that need to recycled or disposed of.	1. Augmentation of plant to meet operational performance requirements. 2. Equipment / component failures.	1. Incorrect / Illegal handling and disposal of different types of waste. 2. Spillage of electrolyte / dangerous substances. 3. Contamination of environment / soil / flora or injury to fauna.	1. Activities in line with Waste Management Controls in the Environmental Management Programme.	Mostly Effective	Contractor & Eskom	Ensure compliance with EMP.				2	E	II											
11		**O&M: Short circuit**	Short circuit condition in the plant.	1. Failing of insulation. 2. Failure during switching.	1. Safety and fire risk. 2. Explosion could lead to spread of debris over a large area. 3. Emission of toxic gasses. 4. Equipment damage. 5. Interruption of customer power supply.	1. Short circuit detection and protection devices. 2. Fire detection and suppression systems installed	Mostly Effective	Contractor	Ensure that protective devices and safety systems are working as expected.				2	B	IV											
16	Active	**Spillage of the electrolyte liquid**	Spillage of the electrolyte which is composed of highly acidic (or alkaline) material causes health and environmental effects.	1.Mishandling and personnel fault. 2.Improper decommisioning and disposal of the membranes/stacks.	1.Health risk 2.Equipment damage 3.Interruption of customer power supply 4.Environmental pollution - soil pollution	1. An effective handling and instructions manual are aquired from the manufacturer and is directly followed, monitored and efficiently managed. 2.During decommissioning, users can dispose of the membranes using the same processes used to handle highly corrosive substances.	Mostly Effective	Peter Langley and Ryan Gilbert	research conducted on the Vanadium redox flow battery	2021	none	none	3	D	II	Measurable environental harm-medium term recovery. High potential for complaints from stakeholders and community. Environmental detectives issued by authorities.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2. Procurement document should state that the manufacturer hadhas managed the risk.	Peter Langley and Ryan Gilbert	0%	Aligned with project procurement				Vanadium redox flow battery
17	Active	**Fouling Membrane**	Membrane foul, wherein the vanadium ions become irreversibly trapped in the membrane and increase resistive losses in the cell, ultimately failing in its functioning.	1.The higher voltage and highly oxidative V5+ electrolyte puts more chemical stress on the materials used in the cell electrodes, membranes, and fluid handling components.	1.Leading to battery repairs 2.Interruption of customer power supply 3.High financial cost for the membrane	Low cost membranes are being developed to enable cheaper replacements.	Mostly Effective	Peter Langley and Ryan Gilbert	research conducted on the Vanadium redox flow battery	2021	none	none	1	C	III	Net position between reverse and expenditure. Between R1m and R10m. Insignificant and no apparent disruption.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer hadhas managed the risk. 3.New and cheaper technologies should be provided as alternatives from the manufacturer when they are made available.	Peter Langley and Ryan Gilbert	0%	Aligned with project procurement				Vanadium redox flow battery
18	Active	**Failure of the Vanadium Redox Flow Battery system**	Failure of the Vanadium Redox Flow Battery system which is due to its low reliability leading to an interruption of the power supply.	1.Low reliability of the system and equipment such as (eg. pumps and power electronics) which have little to no experience with failure modes and effects in the substation environment.	1.Equipment damage/battery damage 2.Interruption of customer power supply 3.High financial cost for the replacement of every equipment that could possibly fail.	Extended field experience will be required to validate the reliability of the newer system designs.	Mostly Effective	Peter Langley and Ryan Gilbert	research conducted on the Vanadium redox flow battery	2021	none	none	2	C	III	Event that abe management can readily manage internally. No press reporting or external interest. Disciplinary action may be taken.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer hadhas managed the risk. 3.Procurement document should have a test and result status.	Peter Langley and Ryan Gilbert	0%	Aligned with project procurement				Vanadium redox flow battery
19	Active	**Battery capacity loss and electrolyte imbalance**	Battery capacity loss and electrolyte imbalance and parasitic side reactions as a result of poor design of the Fe-Cr Redox Flow Batteries.	1.Inefficient and inadequate designs of the Fe-Cr Redox flow batteries (Redox Flow Batteries).	1.Equipment damage/battery damage 2.Interruption of customer power supply	Current developers of Fe-Cr Redox Flow Batteries appear to have addressed the side reaction and implemented effective rebalancing sub-systems with minimal system efficiency loss.	Mostly Effective	Peter Langley and Ryan Gilbert	none	none	none	none	1	B	IV	Entirely an internal issue. Attention is confined to site.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer hadhas managed the risk. 3.Procurement document should have a test and result status.	Peter Langley and Ryan Gilbert	0%	Aligned with project procurement				Iron-chromium flow battery
20	Active	**Self-discharge of the battery**	Self-discharge of the cells due to bromine crossover to the anode side from the cathode side of the battery leads to lowering of the battery life span.	1.Crossover of bromine from cathode to anode in the cell.	1.Equipment damage/battery damage 2.Interruption of customer power supply	Stopping electrolyte circulation during stand periods, limiting the degree of crossover to bromine that is in the cell when circulation ceases.	Mostly Effective	Peter Langley and Ryan Gilbert	none	none	none	none	1	C	III	Entirely an internal issue. Attention is confined to site.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer hadhas managed the risk. 3.Procurement document should have a test and result status.	Peter Langley and Ryan Gilbert	0%	Aligned with project procurement				Zinc-bromine flow battery
21	Active	**Spillage of the electrolytes within the battery**	Environmental and health effects as a result of a spill of the battery contents, electrolytes, etc.	1.Toxic spillage of the contents of the battery could result in a detrimental effect on the environment and people in the region of the spill. 2.Improper decommisioning and disposal of the chemical composition leading to a spillage of the chemicals, causing harm to the environment and the health of the users.	1.Health risk 2.Equipment damage 3.Interruption of customer power supply 4.Environmental pollution	1.Proper handling and monitoring systems are employed as a preventative measure. 2.Proper recovery of Zinc should be effectively conducted when the unit is decomissioned	Mostly Effective	Peter Langley and Ryan Gilbert	none	none	none	none	2	B	IV	Short-term transient environmental or community impact and some clean-up cost.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer hadhas managed the risk. 3.Procurement document should have a decomission mandate.	Peter Langley and Ryan Gilbert	0%	Aligned with project procurement				Zinc-bromine flow battery
22		**EoL: Decommissioning**	Incorrect / illegal disposal of components or electrolyte.	Not adhering to the EMP and WMP.	1. Incorrect / Illegal handling and disposal of different types of waste. 2. Spillage of electrolyte / dangerous substances. 3. Contamination of environment / soil / flora or injury to fauna. 4. Impact on surrounding communities.	1. Activities in line with Environmental Management Programme and Waste Management Plan.	Mostly Effective	Contractor					4	C	II											

Contamination of surrounding environment

Electrolyte spillage leading to environmental contamination.

Incorrect handling, accident, system failure

Financial loss due to penalties, fines, cleanup costs or COUE

1. Primary and secondary containment on plant to prevent contamination of surrounding environment.
2. Tertiary containment in foundation - bund walls.
3. Applicable accreditation of staff to contain any spillages.
4. Contractor to have waste clean-up agreement with accredited service providers.

SHEET 3
SOLID STATE BATTERY TECHNOLOGIES

This is applicable to activities happening in South Africa

PreCom: Means all activities before Commissioning, e.g. Shipping, Transportation, Installation, Construction, Testing

No.	Risk Status	Risk Title	Risk Description (something occurs.....)	Cause	Impact (leading to.....)	Existing controls (controlled by.....)	RCE per control	Control Owner	Task on Controls	Task on control Due Date	Task on control Percentage complete	Task on control owner	Cons. rating	Likelihood rating	Risk Rating	Risk Rating comment	Risk Owners	Potential Exposure	Risk Treatment tasks	Risk Treatment task Owner	Percentage Completion	Due date	Risk Treatment Plan Feedback	Target Risk Rating	Target Risk Rating Due Date	Risk Movement Comments	Type of technology
1		**PreCom: Road Transportation**	1. Accident whilst being transported	1. Accident caused by driver or 3rd party. 2. Poor road conditions.	1. Spillage of electrolyte / dangerous substances. 2. Contamination of environment / soil / flora.	1. Transport company accredited to transport dangerous goods on public roads. 2. Proper securing of cargo. 3. Route planning and necessary approvals and permits.	Mostly Effective	Contractor	1. Check that transportation company is accredited. 2. Ensure that cargo is checked. 3. Method statement for handling and transportation of dangerous goods and substances. To be submitted to Eskom.			1. Eskom 2. Contractor / Transportation company	3	C	II										
2		**PreCom & O&M: Storage**	1. Accident whilst being stored on site / warehouse.	1. Not adhering to storage instructions.	1. Spillage of electrolyte / dangerous substances. 2. Contamination of environment / soil / flora.	1. Store according to OEM instructions. 2. Storing in line with Environmental Management Programme. 3. Electrolyte and active materials are encapsulated by protective covering.	Mostly Effective	Contractor					2	B	IV				1. Environmental officer on site. 2. Eskom will conduct frequent site visits and audits.	Contractor and Environmental Dept						
3		**PreCom & O&M: Handling**	1. Accident whilst being handled (off-loaded or installed) on site / warehouse.	1. Not adhering to handling instructions. 2. Not taking care whilst handling equipment.	1. Spillage of electrolyte / dangerous substances. 2. Contamination of environment / soil / flora.	1. Handle according to OEM instructions. 2. Handling in line with Environmental Management Programme. 3. Use of correct equipment for off-loading by accredited operators. 4. Installation by accredited staff. 5. Electrolyte and active materials are encapsulated by protective covering.	Mostly Effective	Contractor	Ensure compliance with OEM instructions and EMP.				2	C	III				1. Environmental officer on site. 2. Eskom will conduct frequent site visits and audits.	Contractor and Environmental Dept						
6		**Construction: Land Clearing**	1. Actual vegetation clearing for the placement the plant and access roads.	Required for construction activities and placement of plant.	1. Destruction of indigenous and protected vegetation. 2. Temporary land clearing for construction material / equipment. 3. Impact on surrounding communities.	1. Activities in line with Environmental Management Programme.	Mostly Effective	Contractor	Ensure compliance with EMP.				2	E	II				1. Environmental officer on site. 2. Eskom will conduct frequent site visits and audits.	Contractor and Environmental Dept						
7		**Construction: Non-potable Water Usage**	1. Non-compliance to Water Use License or not permitted.	Not adhering to EMP requirements.	1. Legal contravention 2. Financial penalties.	1. Activities in line with Environmental Management Programme.	Mostly Effective	Contractor	Ensure compliance with EMP.				3	A	IV											
8		**Construction: Potable Water Usage**	1. Abuse of potable water supplies.	Not adhering to EMP requirements.	1. Legal contravention 2. Financial penalties.	1. Activities in line with Environmental Management Programme.	Mostly Effective	Contractor	Ensure compliance with EMP.				3	A	IV											
9		**Construction: Waste Generation**	1. Waste generation due to construction activities. 2. Different waste types will be generated.	Construction activities.	1. Incorrect / Illegal handling and disposal of different types of waste. 2. Spillage of electrolyte / dangerous substances. 3. Contamination of environment / soil / flora or injury to fauna. 4. Impact on surrounding communities.	1. Activities in line with Environmental Management Programme and Waste Management Plan.	Mostly Effective	Contractor	Ensure compliance with EMP and WMP.				4	C	II											
10		**O&M: Equipment replacements**	Augmentation of plant will lead to waste generation of electronics and dangerous substances that need to recycled or disposed of.	1. Augmentation of plant to meet operational performance requirements. 2. Equipment / component failures.	1. Incorrect / Illegal handling and disposal of different types of waste. 2. Spillage of electrolyte / dangerous substances. 3. Contamination of environment / soil / flora or injury to fauna.	1. Activities in line with Waste Management Controls in the Environmental Management Programme.	Mostly Effective	Contractor & Eskom	Ensure compliance with EMP.				2	E	II											
11		**O&M: Short circuit**	Short circuit condition in the plant.	1. Failing of insulation. 2. Failure during switching.	1. Safety and fire risk. 2. Explosion could lead to spread of debris over a large area. 3. Emission of toxic gasses. 4. Equipment damage. 5. Interruption of customer power supply.	1. Short circuit detection and protection devices. 2. Fire detection and suppression systems installed	Mostly Effective	Contractor	Ensure that protective devices and safety systems are working as expected.				2	B	IV											
				1. Poor manufacturing and design		1. Procurement management systems are in place to allow us to specify user requirements and control measures. 2.Suppliers have existing control management systems with a facility to send alarms in any case of emergency faults.																			
12	Active	**O&M: Battery overcharging**	1. Overcharging caused by battery management system design deficiency/failure leading to battery fire.	2. Inadequate charging control systems. 3. Incorrect settings applied.	1. Safety and fire risk. 2. Explosion could lead to spread of debris over a large area. 3. Emission of toxic gasses. 4. Equipment damage. 5. Interruption of customer power supply.	3. Battery Management Systems employed to ensure proper charging and effective cooling of systems. 4. Cell level temperature monitoring. 5. Cell level protective devices which disconnect faulty cells / modules. 6. Fire detection and suppression systems installed.	Mostly Effective	Peter Langley and Ryan Gilbert	research conducted on the lithium-ion battery	2020	none	none	3	C	II	Serious event that can be readily managed but management effort is still required to minimise impact locally. Adverse local media reporting. Disciplinary likely.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2. Procurement document should state that the manufacturer has/has managed the risk. 3. Technical specification requires that international best practices are implemented and test certificates / reports be presented to proof compliance with safety requirements. 4. First responders to be trained and suitably equipped to deal with [illegible] on customer premises.	Peter Langley and Ryan Gilbert	0%	Aligned with project procurement				Lithium ion solid state
13	Active	**O&M: Overheating cell and thermal runaway**	1. Excessive charging and discharging, high current, or imbalances between cells can cause overheating in a cell and result in thermal runaway as neighboring cells also overheat, which essentially leads to a system failure.	1.Improper and inefficient monitoring and sensoring equipement or tools that control the input and outputs for these large systems. 2. Cooling system not operating effectively to keep cells within safe operating temperature range. 3. Malfunctioning of protective devices. 4. Internal short-circuit.	1. Safety and fire risk. 2. Explosion could lead to spread of debris over a large area. 3. Emission of toxic gasses. 4. Equipment damage. 5. Interruption of customer power supply.	1.Procurement management systems are in place to allow us to specify user requirements and control measures. 2.Suppliers have existing control management systems with a facility to send alarms in any case of emergency faults. 3. Battery Management Systems employed to ensure proper charging and effective cooling of systems. 4. Cell level temperature monitoring. 5. Cell level protective devices which disconnect faulty cells / modules. 6. Fire detection and suppression systems installed.	Mostly Effective	Peter Langley and Ryan Gilbert	research conducted on the lithium-ion battery	2020	none	none	1	C	III	Entirely an internal issue. Attention is confined to site.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2. Procurement document should state that the manufacturer has/has managed the risk. 3.Manufacturers should make all the products testing and results availble to all customers for full awareness on the specific risk procedure.	Peter Langley and Ryan Gilbert	0%	Aligned with project procurement				Lithium ion solid state
14	Active	**O&M: High temperature combustion of the cell**	Extreme high temperatures lead to leaks, smoke, gas venting, and/or combustion of the cell pack.	2. Improper and inefficient temperature control. 2. Malfunctioning of monitoring and sensing equipement or tools are designed for these large systems.	1. Safety and fire risk. 2. Explosion could lead to spread of debris over a large area. 3. Emission of toxic gasses. 4. Equipment damage. 5. Interruption of customer power supply.	1. Improved monitoring and sensoring systems have been introduced which are inherently safer than the previously employed systems. 2. Secondary containment. 3. Tertiary containment control - civil up to 110%.	Mostly Effective	Peter Langley and Ryan Gilbert	research conducted on the lithium-ion battery	2020	none	none	4	C	II	Section 24 injury: Multiple Sect. 24 injured, Irreversible disablement or impalement due to serious incident.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2. Procurement document should state that the manufacturer has/has managed the risk. 3.Manufacturers should make all the products testing and results availble to all customers for full awareness on the specific risk procedure.	Peter Langley and Ryan Gilbert	0%	Aligned with project procurement				Lithium ion solid state
22		**EoL: Decommissioning**	Incorrect / Illegal disposal of components or electrolyte.	Not adhering to the EMP and WMP.	1. Incorrect / Illegal handling and disposal of different types of waste. 2. Spillage of electrolyte / dangerous substances. 3. Contamination of environment / soil / flora or injury to fauna. 4. Impact on surrounding communities.	1. Activities in line with Environmental Management Programme and Waste Management Plan. 2. Review of EMP and WMP for Decommissioning.	Mostly Effective	Contractor					4	C	II											

Fire department

SHEET 4
CHEMICAL COMPOSITION AND RELATED SANS10234 STATUS PER TECHNOLOGY

Main source:USTDA Report

Type	Chemistry		Maturity	Electrolyte & Active Materials	Individual chemicals	SANS10234:2008 Listed	SANS10234:2008 Environmental hazard	Toxicity & Environmental Impact	Environ affected	Controls (refer to sheet #)	Decommissioning & Disposal
Flow	Vanadium Redox (VRB)		Mature		Vanadium pentoxide	023-001-00-8, Vanadium pentoxide	H 411 - Toxic to aquatic life with long lasting effects	H372 - Causes damage to organs H335 - May cause respiratory irritation Vanadium is a nontoxic chemical; however, the electrolyte is caustic and poses corrosive and environmental hazards similar to lead-acid batteries. Another barrier to the wide deployment of flow battery systems is the issue of bringing large quantities of potentially dangerous liquid electrolytes to locations that could expose the public to these chemicals in the vent of a spill.	Water Skin Inhalation	PPE Sheet 2. Flow Battery Technology	Vanadium is a nontoxic chemical; however, the electrolyte is caustic and poses corrosive and environmental hazards.
					Vanadium trichloride	No	None			Sheet 2. Flow Battery Technology	
					Vanadium oxide sulphate	No	None			Sheet 2. Flow Battery Technology	
					Vanadium(III) sulphate	No	None			Sheet 2. Flow Battery Technology	
					Hydrochloric acid	017-002-01-X Hydrochloric acid, concentration 10 % < 25 %, by mass 017-002-01-X Hydrochloric acid, concentration > 25 %, by mass 006-006-00-X Hydrocyanic acid , see Hydrogen cyanide	None	H315 - Causes skin irritation H319 - Causes serious eye irritation H335 - May cause respiratory irritation H314 - Causes severe skin burns and eye damage H318 - Causes serious eye damage	Skin Inhalation	PPE Sheet 2. Flow Battery Technology	
					Sulfuric acid	Yes 016-020-00-8 Sulfuric acid, with > 5 % 15 % acid, by mass 016-020-00-8 Sulfuric acid, with > 51 % acid, by mass 016-020-00-8 Sulfuric acid, with >15 % 51 % acid, by mass	None. Only precautionary statement codes	**Sulphuric acid** is highly corrosive and when **overcharged** the battery generates **hydrogen** which presents an **explosion risk**. Freshwater fish: 96 Hr LC50 Brachydanio rerio >500 mg/L [static]; Fish: LC50 - Ganbusia affinis - 42mg/L -96h; Invertebrates: EC50 - Daphnia magna - 29 mg/L - 24h	Air Fire Water	Sheet 2. Flow Battery Technology	
					Zinc Bromide Solution (Synonym - Zinc Dibromide Solution)	No	None	Potential bromine toxicity. Zn-Br poses additional environmental and safety concerns relating to the use of bromine and the potential for release or exposure. Bromine creates a harsh and corrosive environment that requires more robust mechanical systems and materials. Bromine is a highly toxic material through inhalation and absorption; as a result, the possibility of a hazardous environmental event or personnel exposure must be addressed through adequate design features and operational practices. Based on the hazards of bromine, some companies may consider shipping systems without electrolyte and then loading it at a location near, or at, its point of installation. Solutions containing zinc bromide are considered Marine Pollutants and Environmentally Hazardous. Prevent entry into waterways, sewers, basements or confined areas. Do not flush into surface water or sanitation sewer system. Prevent further leakage or spillage if safe to do so. Prevent product from entering drains as far as possible. (EPA DATA SHEET) Avoid contact with skin, eyes and clothing. Wear personal protective equipment. Do not eat, drink or smoke when using this product. Do not take internally. Wash thoroughly after handling. (EPA DATA SHEET)	Inhalation Skin Water	exhaust ventilation PPE Designated areas Sheet 2. Flow Battery Technology	Bromine is a toxic material and should be recovered in the event of a spill or if the unit is decommissioned. Zinc-bromine is corrosive and should be handled appropriately. Zinc is considered a transition-metal contaminant in some locales and thus should be properly recovered when the unit is decommissioned.Handle in accordance with good industrial hygiene and safety practice. Use only in area provided with appropriate exhaust ventilation. Do not breathe vapors or spray mist. Ensure adequate ventilation. Avoid contact with skin, eyes and clothing. Wear personal protective equipment. Do not eat, drink or smoke when using this product. Do not take internally. Wash thoroughly after handling. (EPA DATA SHEET)
					Zinc Chloride	No	None			Sheet 2. Flow Battery Technology	

Flow Batteries	Zinc Bromine (ZBr)		Demo	The cell electrodes are generally composed of carbon plastic and are designed to be bipolar. The two electrolytes (anolyte and catholyte) will have the same zinc and bromine ion concentrations at any given time during the charge/discharge cycle and differ only in the concentration of elemental bromine.	Bromine	No	None	Bromine creates a harsh and corrosive environment that requires more robust mechanical systems and materials. Bromine is a highly toxic material through inhalation and absorption; as a result, the possibility of a hazardous environmental event or personnel exposure must be addressed through adequate design features and operational practices. Based on the hazards of bromine, some companies may consider shipping systems without electrolyte and then loading it at a location near, or at, its point of installation.	Inhalation Skin Water	exhaust ventilation PPE Designated areas Sheet 2. Flow Battery Technology	Bromine is a toxic material and should be recovered in the event of a spill or if the unit is decommissioned. Zinc-bromine is corrosive and should be handled appropriately. Zinc is considered a transition-metal contaminant in some locales and thus should be properly recovered when the unit is decommissioned.Handle in accordance with good industrial hygiene and safety practice. Use only in area provided with appropriate exhaust ventilation. Do not breathe vapors or spray mist. Ensure adequate ventilation. Avoid contact with skin, eyes and clothing. Wear personal protective equipment. Do not eat, drink or smoke when using this product. Do not take internally. Wash thoroughly after handling. (EPA DATA SHEET)
					Lead bromide	No	None	Bromine creates a harsh and corrosive environment that requires more robust mechanical systems and materials. Bromine is a highly toxic material through inhalation and absorption; as a result, the possibility of a hazardous environmental event or personnel exposure must be addressed through adequate design features and operational practices. Based on the hazards of bromine, some companies may consider shipping systems without electrolyte and then loading it at a location near, or at, its point of installation.	Inhalation Skin Water	exhaust ventilation PPE Designated areas Sheet 2. Flow Battery Technology	Bromine is a toxic material and should be recovered in the event of a spill or if the unit is decommissioned. Zinc-bromine is corrosive and should be handled appropriately. Zinc is considered a transition-metal contaminant in some locales and thus should be properly recovered when the unit is decommissioned.Handle in accordance with good industrial hygiene and safety practice. Use only in area provided with appropriate exhaust ventilation. Do not breathe vapors or spray mist. Ensure adequate ventilation. Avoid contact with skin, eyes and clothing. Wear personal protective equipment. Do not eat, drink or smoke when using this product. Do not take internally. Wash thoroughly after handling. (EPA DATA SHEET)
	Iron-Chromium (FeCr)		Demo	Iron-chromium flow batteries were pioneered and studied extensively by NASA in the 1970's - 1980's and by Mitsui in Japan. The iron-chromium flow battery is a redox flow battery (RFB). Energy is stored by employing the Fe2+ - Fe3+ and Cr2+ - Cr3+ redox couples. The active chemical species are fully dissolved in the aqueous electrolyte at all times. Like other true RFBs, the power and energy ratings of the iron-chromium system are independent of each other, and each may be optimized separately for each application. All the other benefits and distinctions of true RFBs compared to other energy storage systems are realized by iron-chromium RFBs. Flow batteries are classed as 'true' when all of their chemical active species are fully dissolved, at all times. Examples include vanadium-vanadium and iron-chromium systems.	Iron solution	No	None	The active materials in Zn-Fe are fairly benign.		Sheet 2. Flow Battery Technology	
					Chromium solution	No	None	Hexavalent chromium, Cr(VI), is produced industrially when Cr(III) is heated in the presence of mineral bases and atmospheric oxygen (for instance, during metal finishing processes). It is the form of chromium that has proven to be of the greatest occupational and environmental health concern. Chromium plays a key role in the biological life but above critical level it is toxic (Balamurugan et al., 2004; Han et al., 2004;) mutagenic (Gili et al., 2002; Puzon et al., 2002; Wise et al., 2005), carcinogenic (Codd et al., 2003; Reddy et al., 2003; Sato et al., 2003) and teratogenic (Asmatullah et al., 1998). Due to chromium accumulation reduction in plant production along with toxicity in the nutritional contents are also observed (Pandey and Sharma, 2003; Klumpp et al., 2002). Some plants show tolerance against chromium, but some have acquired the ability to accumulate chromium (Tripathi and Chandra, 1991). The root and shoot growth rate and leaf chlorosis could be elicited in hyacinth (Eichornia crassipes) by exposure to chromium and copper for several weeks (Hafeez and Ramzan, 2002). In Triticum aestivum, hexavalent chromium showed adverse effect on the growth parameters and also caused accumulation of chromium in the plants (Faisal et al., 2005). The hexavalent chromium salt has more adverse effect on germination and growth of Helianthus annuus (Faisal and Hasnain, 2005) and Vigna radiata (Hsu and Chou, 1992). The effect of chromium on the cortical cells of meristematic zone was observed in Pisum sativum L. (Gabara et al., 1992). Chromium toxicity on the seed germination and growth of Phaseolus vulgaris was markedly increased with an increase in its concentration (Zeid, 2001).	Air Inhalation Skin contact Ingestion Transportation Storage Water Soil/ sediment Fauna	Sheet 2. Flow Battery Technology	
	Zinc-Iron Redox (ZnFe)		Demo	Zinc Iron Redox flow batteries are closed loop batteries, with the battery operating at ambient temperatures. Closed loop refers to the unit in question being devoid of hazardous gases as it is depressurised and there is no potential for waste by products.	Zinc solution	No	None	Limited Environmental impact, avoid watercourses. Considered hazardous with a low environmental risk.	Water	Sheet 2. Flow Battery Technology	
					Iron solution	No	None			Sheet 2. Flow Battery Technology	
					Iron chloride	No	None			Sheet 2. Flow Battery Technology	
					Zinc chloride	No	None			Sheet 2. Flow Battery Technology	

				The **polysulfide bromide battery** (PSB), (sometimes *polysulphide bromide*), is a type of regenerative fuel cell involving a reversible electrochemical reaction between two salt-solution electrolytes: sodium bromide and sodium polysulfide. It is an example and type of redox (reduction–oxidation) flow battery.	Sodium chloride	No	None	Normal table salt		Sheet 2. Flow Battery Technology	
	Polysulfide Bromide				Sodium bromide	No	None			Sheet 2. Flow Battery Technology	
					Sodium polysulfide	No	None			Sheet 2. Flow Battery Technology	
					Nickel	No	None			Sheet 2. Flow Battery Technology	
					Carbon	No	None			Sheet 2. Flow Battery Technology	
	Lead Acid (Pb) and Advanced Lead Acid / Lead Carbon		Mature	Diluted Sulphuric Acid, Lead and Lead Dioxide	Diluted Sulphuric Acid	Yes 016-020-00-8 Sulfuric acid, with > 5 % 15 % acid, by mass 016-020-00-8 Sulfuric acid, with > 51 % acid, by mass 016-020-00-8 Sulfuric acid, with >15 % 51 % acid, by mass	None. Only precautionary statement codes	environmental consideration. **Sulphuric acid** is highly corrosive and when **overcharged** the battery generates **hydrogen** which presents an **explosion risk**. Freshwater fish: 96 Hr LC50 Brachydanio rerio >500 mg/L [static]; Fish: LC50 - Ganbusia affinis - 42mg/L -96h; Invertebrates: EC50 - Daphnia magna - 29 mg/L - 24h These batteries are used in all cars and therefore are used extensively, albeit at a small scale in South Africa. There is also a very **strong recycling system** in South Africa for lead-acid batteries, however, this is again at a smaller scale and generally situated within larger metropolitan areas.	Air Fire Water Skin	PPE Sheet 2: Solid State Battery technology Risk Assessment	Some lead compounds are extremely toxic. Long-term exposure to even tiny amounts of these compounds can cause brain and kidney damage, hearing impairment, and learning problems in children. Lead–acid battery recycling is effectively practiced in most parts of the world.
					Lead	No	None			Sheet 2: Solid State Battery technology Risk Assessment	will pose a health risk to operators over long periods of time. Although lead can be **recycled**, vast quantities are transported to landfill sites. Electrolyte is caustic and poses corrosive and environmental hazards.
					Lead dioxide	No	None			Sheet 2: Solid State Battery technology Risk Assessment	
					Nickel hydroxide	No	None		Skin Inhalation Ingestion Water Fauna Fire	PPE Sheet 2: Solid State Battery technology Risk Assessment	
						048-004-00-1 Cadmium cyanide	Yes. H400 Acute aquat 1 H410 Very toxic to aquatic life with long lasting effects precautionary statement codes	Because cadmium is a heavy metal, it can cause substantial pollution when discarded in a landfill or incinerated. H300-Fatal if swallowed H330- Fatal if inhaled H373- May cause damage to organs	Skin Inhalation Ingestion Water Fauna	PPE Sheet 2: Solid State Battery technology Risk Assessment	
						048-004-00-1 Cadmium dicyanide	Yes. H400 Acute aquat 1 H410 Very toxic to aquatic life with long lasting effects precautionary statement codes	H350-May cause cancer H300-Fatal if swallowed H310-Fatal in contact with skin H330- Fatal if inhaled	Skin Inhalation Ingestion Water Fauna	PPE Sheet 2: Solid State Battery technology Risk Assessment	
						048-003-00-6 Cadmium diformate	Yes. H400 Acute aquat 1 H410 Very toxic to aquatic life with long lasting effects precautionary statement codes	H301-Toxic if swallowed H331-Toxic if inhaled H372-Causes damage to organs	Skin Inhalation Ingestion Water Fauna	PPE Sheet 2: Solid State Battery technology Risk Assessment	
						048-005-00-7 Cadmium fluorosilica, see Cadmiumhexafluorosilicate	None			Sheet 2: Solid State Battery technology Risk Assessment	

S	Nickel Cadmium (NiCd)		Mature	Potassium Hydroxide, using nickel oxide hydroxide and metallic cadmium as electrodes.	Cadmium	048-003-00-6 Cadmium formate	Yes. H400 Acute aquat 1 H410 Very toxic to aquatic life with long lasting effects precautionary statement codes	H350-May cause cancer H301-Toxic if swallowed H331-Toxic if inhaled H373- May cause damage to organs	Skin Inhalation Ingestion Water Fauna	PPE Sheet 2: Solid State Battery technology Risk Assessment	NiCd batteries contain cadmium, which is a toxic heavy metal and therefore requires special care during battery disposal. In the United States, part of the battery price is a fee for its proper disposal at the end of its service lifetime. In the European Union, used industrial NiCd batteries must be collected by their producers to be recycled in dedicated facilities. Because cadmium is a heavy metal, it can cause substantial pollution when discarded in a landfill or incinerated.
						048-005-00-7 Cadmium hexafluorosilicate	Yes. H400 Acute aquat 1 H410 Very toxic to aquatic life with long lasting effects precautionary statement codes	H350-May cause cancer H300-Fatal if swallowed H331-Toxic if inhaled H373- May cause damage to organs	Skin Inhalation Ingestion Water Fauna	PPE Sheet 2: Solid State Battery technology Risk Assessment	
						048-007-00-8 Cadmium iodide	Yes. H400 Acute aquat 1 H410 Very toxic to aquatic life with long lasting effects precautionary statement codes	H350-May cause cancer H301-Toxic if swallowed H331-Toxic if inhaled H373-May cause damage to organs	Skin Inhalation Ingestion Water Fauna	PPE Sheet 2: Solid State Battery technology Risk Assessment	
						048-003-00-6 Cadmium formate, see Cadmium diformate	None. Only precautionary statement codes			Sheet 2: Solid State Battery technology Risk Assessment	
					Potassium Hydroxide	019-002-00-8 Potassium hydroxide solution, concentration 0,5 % < 2 %, by mass	None. Only precautionary statement codes	H315 - Causes skin irritation H319 - Causes serious eye irritation	Skin	PPE Sheet 2: Solid State Battery technology Risk Assessment	
						019-002-00-8 Potassium hydroxide solution, concentration 2 % < 25 %, by mass	None. Only precautionary statement codes	H314 - Causes severe skin burns and eye damage H318 - Causes serious eye damage	Skin	PPE Sheet 2: Solid State Battery technology Risk Assessment	
						019-002-00-8 Potassium hydroxide solution, concentration 25 %, by mass	None. Only precautionary statement codes	H302 - Harmful if swallowed H314 - Causes severe skin burns and eye damage H318 - Causes serious eye damage	Skin Ingestion	PPE Sheet 2: Solid State Battery technology Risk Assessment	
					Graphite	No	None				
					Lithium Cobalt Oxide	No	None	003-001-00-4 Lithium: H260 - In contact with water releases flammable gases that may ignite spontaneously H314 - Causes severe skin burns and eye damage Safety - thermal runaway. OVERHEATING AND RUNAWAY One of the greatest challenges facing lithium-ion is safety. The energy density of the cells and the combustibility of the organic-based electrolyte make these batteries a fire hazard. Excessive charging, discharging, high current, or imbalances between cells can cause overheating in a cell and result in thermal runaway as neighboring cells also overheat. Extreme high temperatures lead to leaks, smoke, gas venting, and/or combustion of the cell pack. Manufacturers of large systems have employed sophisticated battery management systems to monitor cell performance and limit operation to safe and acceptable performance ranges. Misuse of these products, such as deliberate destruction, may release diethyl carbonate, ethylene carbonate, and organic solvents contained within the batteries.	Skin Water Air Fire Explosion		

Solid State	Lithium Ion (Li-ion)	Lithium cobalt oxide (LCO)		Li-ion cell electrolytes are typically fluorine-based lithium salts in an organic solvent. Cathode materials can generally be grouped into two categories, namely iron phosphate and mixed metal (combinations of cobalt and manganese oxide). Anode material is generally graphite/carbon or titanate. Safety - thermal runaway. OVERHEATING AND RUNAWAY One of the greatest challenges facing lithium-ion is safety. The energy density of the cells and the combustibility of the organic-based electrolyte make these batteries a fire hazard. Excessive charging, discharging, high current, or imbalances between cells can cause overheating in a cell and result in thermal runaway as neighboring cells also overheat. Extreme high temperatures lead to leaks, smoke, gas venting, and/or combustion of the cell pack. Manufacturers of large systems have employed sophisticated battery management systems to monitor cell performance and limit operation to safe and acceptable performance ranges. Misuse of these products, such as deliberate destruction, may release diethyl carbonate, ethylene carbonate, and organic solvents contained within the batteries.	Lithium salt e.g. Lithium sulfate or Lithium Nitrate	Yes, as 003-001-00-4 Lithium	None	003-001-00-4 Lithium: H260 - In contact with water releases flammable gases that may ignite spontaneously H314 - Causes severe skin burns and eye damage Safety - thermal runaway. OVERHEATING AND RUNAWAY One of the greatest challenges facing lithium-ion is safety. The energy density of the cells and the combustibility of the organic-based electrolyte make these batteries a fire hazard. Excessive charging, discharging, high current, or imbalances between cells can cause overheating in a cell and result in thermal runaway as neighboring cells also overheat. Extreme high temperatures lead to leaks, smoke, gas venting, and /or combustion of the cell pack. Manufacturers of large systems have employed sophisticated battery management systems to monitor cell performance and limit operation to safe and acceptable performance ranges. Misuse of these products, such as deliberate destruction, may release diethyl carbonate, ethylene carbonate, and organic solvents contained within the batteries	Skin Water Air Fire Explosion	battery management systems to monitor cell performance and limit Sheet 2: Solid State Battery technology Risk Assessment	These products are solid articles consisting of sealed cylindrical and coin batteries. The following information is for the chemicals contained inside the batteries. As manufactured, exposure to individual components is not expected. If these products are cut or otherwise manipulated in such a way that will release the chemicals contained inside, exposure to these components is possible. If involved in a fire, the chemicals contained in the battery may decompose and produce toxic gases (e.g. carbon, phosphorous, sulfur, and metal oxides and metal compounds). During a fire involving this product care should be taken to avoid inhalation of fumes. Water applied to ruptured batteries involved in fire may generate flammable hydrogen gas. Modularized and packaged systems offer ease of system removal from site for disposal at end of life. Site contamination is unlikely, and site restoration would include infrastructure removal and revegetation. The materials used in Li-ion batteries are typically considered non-hazardous waste. The metals in the system can be recycled, but they do not represent a high salvage value. Misuse of these products, such as deliberate destruction, may release diethyl carbonate, ethylene carbonate, and organic solvents contained within the batteries
					Polyvinylidene difluoride	No	None				
					Diethyl carbonate	No	None				
					Ethylene carbonate	No	None				
					Lithium hexaflurophosphate	Yes, as 003-001-00-4 Lithium	None	H260 - In contact with water releases flammable gases that may ignite spontaneously H314 - Causes severe skin burns and eye damage	Skin Water Air Fire Explosion		
		Lithium manganese oxide (LMO)	Commercial		Manganese Dioxide	No	None				
					Lithium	003-001-00-4 Lithium	None	003-001-00-4 Lithium: H260 - In contact with water releases flammable gases that may ignite spontaneously H314 - Causes severe skin burns and eye damage	Skin Water Air Fire Explosion		
					Propylene Carbonate	No	None				
					1,2-Dimethoxyethane	No	None				
		Lithium nickel cobalt aluminum oxide (NCA)	Commercial		Graphite	No	None				
					Carbon	No	None				
					Aluminum	No	None				
					Copper	No	None				
					Polyvinylidene fluoride	No	None				
					Lithium iron phosphate	No	None				

		Lithium iron phosphate (LFP)	Commercial		Graphite	No	None					
					Aluminum	No	None					
					Copper	No	None					
					Ethylene carbonate	No	None					
					Dimethyl carbonate	607-013-00-6 Dimethyl carbonate	None					
					Ethyl methyl carbonate	No	None					
					Lithium hexaflurophosphate	Yes, as 003-001-00-4 Lithium	None	H260 - In contact with water releases flammable gases that may ignite spontaneously H314 - Causes severe skin burns and eye damage	Water Fire Explosion Skin			
		Lithium nickel cobalt manganese (NMC)	Pre-Commercial		Manganese	No	None					
					Graphite	No	None					
					Polyvinylidene fluoride	No	None					
					Cobalt	No	None					
					Nickel	No	None					
					Copper	No	None					
					Aluminum	No	None					
	Sodium Sulphur (NaS)		Mature	The active materials in a NaS battery are molten sulfur as the positive electrode and molten sodium as the negative. The electrodes are separated by a solid ceramic, sodium alumina, which also serves as the electrolyte.	Sulfur	016-013-00-X Sulfur dichloride	Yes. H400 Acute aquat 1	H314 -Causes severe skin burns and eye damage H335 - May cause respiratory irritation NaS batteries use hazardous materials, including metallic sodium, which is combustible if exposed to water.	Skin Inhalation Water Fauna Fire Explosion	PPE Sheet 2: Solid State Battery technology Risk Assessment Fuses, insulation, fire barriers, and fire suppression systems battery management system Airtight, double-walled stainless-steel enclosures that contain the series-parallel arrays of NaS cells. Completely sealed and allows no emissions during operation. Each cell is hermetically sealed and surrounded with sand both to anchor	The sodium, sulfur, beta-alumina ceramic electrolyte, and sulfur polysulfide components of the battery are disposed of by routine industrial processes or recycled at the end of the NaS battery life. More than 99 wt.% of the battery materials can be recycled. Only sodium must be handled as a hazard material.
						016-013-00-X Sulfur dichloride, concentration 5 % < 10 %, by mass	Yes. H401 -	H315 - Causes skin irritation H335 - May cause respiratory irritation	Skin Inhalation	Sheet 2: Solid State Battery technology Risk Assessment	
						016-012-00-4 Sulfur monochloride	Yes. H400 Acute aquat 1	H301 -Toxic if swallowed H332 -Harmful if inhaled H314 -Causes severe skin burns and eye damage	Skin Inhalation Ingestion	Sheet 2: Solid State Battery technology Risk Assessment	
						016-014-00-5 Sulfur tetrachloride	Yes. H400 Acute aquat 2	H314 - Causes severe skin burns and eye damage	Skin	Sheet 2: Solid State Battery technology Risk Assessment	
					Sodium	011-001-00-0 Sodium	None	H260 - In contact with water releases flammable gases that may ignite spontaneously H314 - Causes severe skin burns and eye damage	Water Fire Explosion Skin	Sheet 2: Solid State Battery technology Risk Assessment Monitor/Control - SOC - Thermal management - Fault detection - Over/under voltage - Over/under temperature - Over current	Sodium must be handled as a hazard material
					Sodium	011-001-00-0 Sodium	None	H260 - In contact with water releases flammable gases that may ignite spontaneously H314 - Causes severe skin burns and eye damage	Water Fire Explosion Skin	Cells are hermetically sealed and packaged into modules of about 20 kWh each . Sheet 2: Solid State Battery technology Risk Assessment	

	Sodium Nickel Chloride (NaNiCl)		Commercial	Sodium-nickel-chloride batteries contain a molten sodium negative electrode and a nickel chloride salt in sodium tetrachloroaluminate (NaAlCl4) as the positive electrode.	Nickel chloride	None	None			Sheet 2: Solid State Battery technology Risk Assessment	Certain manyfacturers are SIO14001 EMS and ISO9001 QMS certified
					Sodium tetrachloroaluminate / Sodium Aluminium Chloride	None	None			Sheet 2: Solid State Battery technology Risk Assessment	
					Nickel metallic	None	None			Sheet 2: Solid State Battery technology Risk Assessment	
					Sodium fluoride	None	None			Sheet 2: Solid State Battery technology Risk Assessment	
					Nickel sulphide	None	None			Sheet 2: Solid State Battery technology Risk Assessment	
					Sodium iodide	None	None	In the USA it is a listed hazardos substance. GHS Classification in accordance with 29 CFR 1910 (OSHA HCS) Skin irritation (Category 2), H315 Eye irritation (Category 2A), H319 Acute aquatic toxicity (Category 1), H400 Chronic aquatic toxicity (Category 1), H410		Sheet 2: Solid State Battery technology Risk Assessment	

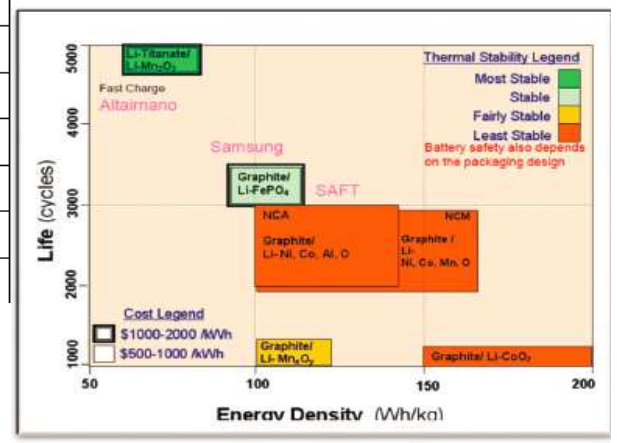
BESS Risks	Cause	Consequence / Environmental Impact	Mitigating measures		
			Process	People	Plant
A) Electrolyte spillage	1) Leak in the fluid flow path. 2) Spillage during installation or O&M. 3) Thermal runaway leading to equipment failure.	1) Electrolyte spillage onto the soil. 2) Injury to personnel. 3) Environmental Damage.	Secondary containment		
B) Overcharging C) Undercharging	Malfunctioning of the monitoring and control system.	Fire and / or explosion.	Fire detection and suppresion, Secondary monitoring and control, isolation of faulty circuit, containment of fire, no spreading		
D) Short circuit	Insulation failure or internal equipment malfunctioning.	Fire and / or explosion.	Fire detection and suppresion, Secondary monitoring and control, isolation of faulty circuit, containment of fire, no spreading		

Table 3-1: US and SA Energy Storage Equipment, Systems, and Service Providers

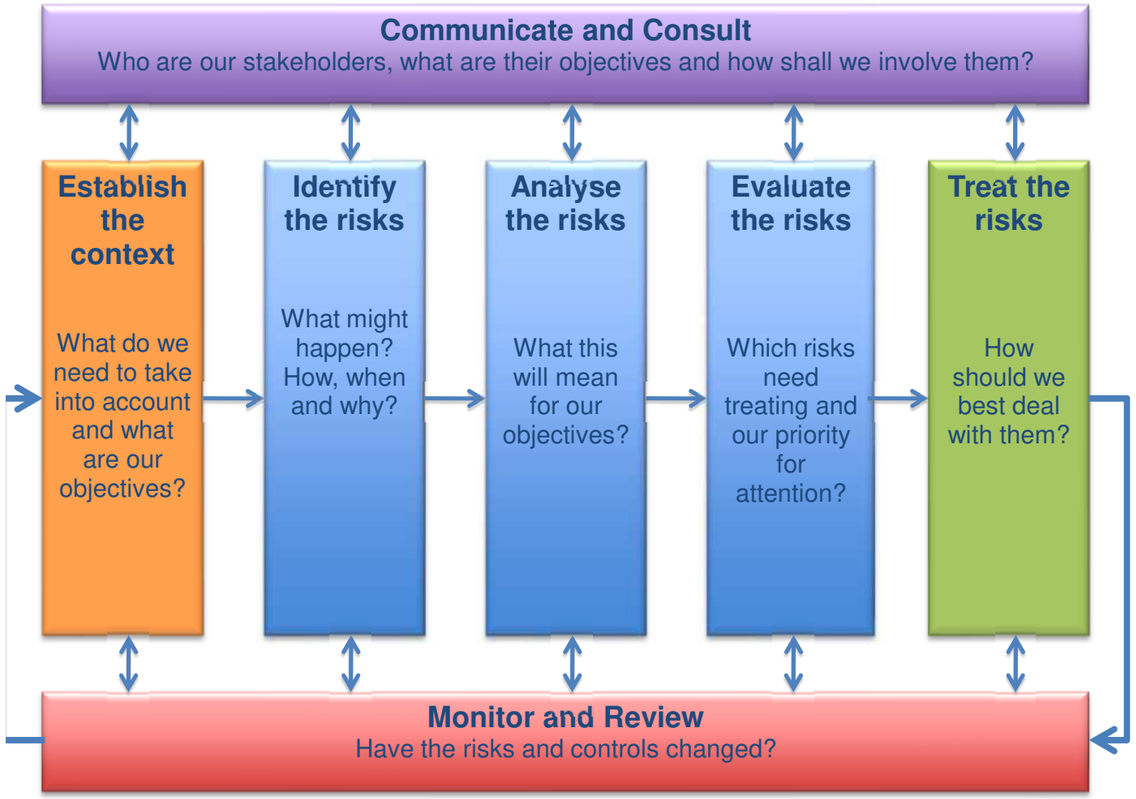
Company	Service	Technology	Location
1Energy	Software / Control	Power Controls Systems	Seattle, WA
Adara power	ESS / Integrator	Lithium Ion	Milpitas, CA
AES	ESS / Integrator	Lithium Ion	Arlington, VA
Alevo	ESS / Service Provider	Lithium Ion	Concord, NC
Ambri	Storage	Molten Metal Battery	Cambridge, MA
Aquion	Storage	Aqueous Hybrid Ion	Pittsburgh, PA
ARES	ESS	Rail based – gravity	Sata Clara, CA
Axion Power	storage / ESS	Advanced Lead Acid	New Castle, PA
Bushveld	Manf. / Service Provider	Vanadium Flow Battery	Johannesburg, SA
Dresser-Rand	Equipment	Compressed Air Energy Storage	Houston, TX
Dynapower	PCC / Integrator	Power Conversion	South Burlington, VT
Ecoult	Storage / ESS	Advanced Lead Acid	Lyon Station, PA
ElectronVault	ESS / Integrator	Lithium Ion	Woodside, CA
EnSync	ESS / PCC	Zinc-Bromine Flow Battery	Menomonee Falls, WI
Eos Energy Storage	ESS	Zn-air Battery	Edison, NJ
Fluidic Energy	ESS / Integrator	Zn-air Battery	Scottsdale, AZ
Freedom Won	ESS	Lithium Ion	Ruimsig, SA
GreenSmith Energy	Software / Control	Power Controls Systems	Rockville, MD
Imergy	ESS / Integrator	Vanadium Flow Battery	Fremont, CA
Ingeteam	Equipment / PCC	Power Control Systems	Milwaukee, WI
Johnson Controls	Storage / ESS	Lithium Ion	Milwaukee, WI
LG Chem	Storage / ESS	Lithium Ion	Troy, MI
LightSail	ESS	ICAES	Berkley, CA
Lockheed Martin	ESS / integrator	Li-ion and Flow battery	Bethesda, MD
Maxwell Technologies	Storage	Ultracapacitor	San Diego, CA
NEC	ESS	Lithium Ion	Westborough, MA
Powertech System Integrator	System Integrator	ESS	Pretoria, SA
PowerStormESS	ESS	Li-ion and generator	Los Angeles, CA
Powin Power	ESS / Integrator	Lithium Ion	Tualatin, OR
Primus Power	ESS	Zinc-Bromine Flow Battery	Hayward, CA
PV Hardware	ESS / Integrator	Vanadium Flow Battery	San Francisco, CA
Redflow	ESS	Zinc-Bromine Flow Battery	Austin, TX
S&C Electric	PCC / Integrator	Power Controls Systems	Chicago, IL
Simpliphi	ESS	Lithium Ion	Ojai, CA
Tesla	ESS	Lithium Ion	Palo Alto, CA
UET	ESS / Integrator	Vanadium Flow Battery	Mukilteo, WA
Vionx	ESS / Integrator	Vanadium Flow Battery	Woburn, MA
ViZn	ESS / Integrator	Zinc-Iron Flow Battery	Austin, TX
WattJoule	ESS	Vanadium Flow Battery	Devens, MA

General Technical Comparison of severa

	Commercial		
Cathode Type and Abbreviation	Lithium-Manganese (LMO)	Lithium-Nickel Cobalt Aluminum (NCA)	Li P
Chemistry	$LiMn_2O_4$	$LiNiCoAlO_2$	
Voltage (V vs Li/Li+)	3.8	3.6	
Specific capacity (mAh/g)	100–120	180–200	
Volumetric energy density: practical (and theoretical) (Wh/L)	280	250 (730)	
Gravimetric energy density: practical (and theoretical) (Wh/kg)	110 (280)	210 (280)	
Cycle life	500–1,000	500	2



Performance of various Li-ion chemistries [0337]

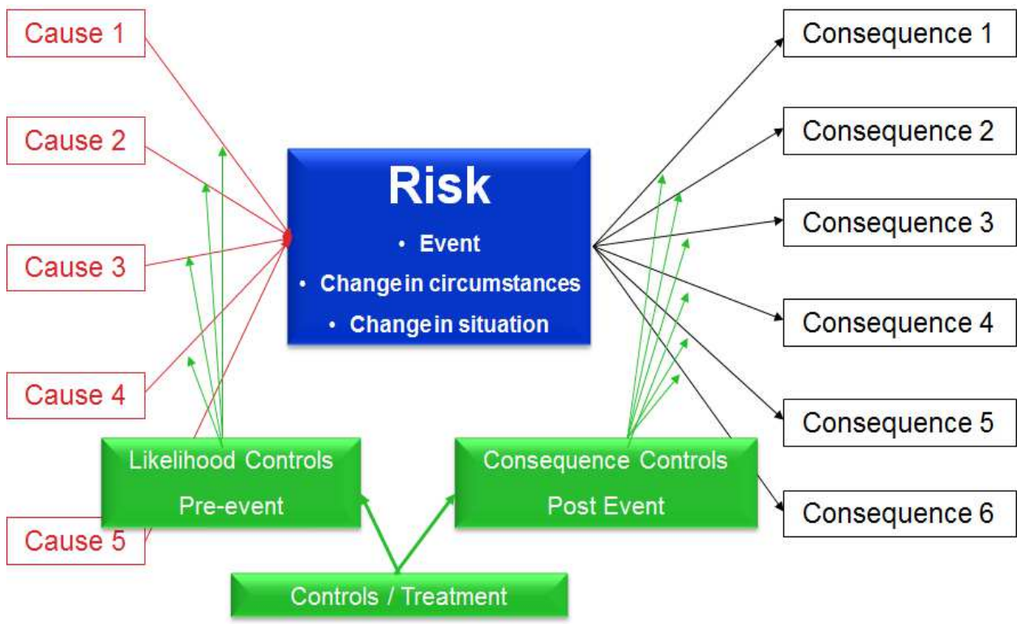


Risk = Effect of uncertainty on objectives

Risk description: Some (uncertain) event happens, leading to..., caused by..., controlled by...

Risks should be in your domain, i.e. you should have the accountability and authority to deal with the risk

Event - Occurrence or change of a particular set of circumstances



	Financial Sustainability	Operations	Sustainable Asset Creation	Environmental & Climate Change Sustainability	Legal & Compliance	Reputation	Health and Safety	Information Management
6	**Net position between Revenue and operational expenditure (EBITDA = Revenue - Opex - PC) > R38n** **Impact:** Catastrophic impact (financial and business operations) that threatens the existence of Eskom	**GWh lost:** >50000GWh (Unable to meet demand by equivalent of a PS unit for a period of 3 months) **National load shedding** < six months. **National blackout:** Enormous impact on country from image, economic, point of view.	**Project Cost:** > 20% **Schedule deviate:** > 35% delay **Quality:** Catastrophic - Major non-conformance that would result in a chain reaction that has huge negative impact on the plant. Project outcomes effectively unusable.	Community: * Irreversible long term environmental harm * Community outrage due to environmental harm in the area- potential large-scale class action (legal). e.g. greenhouse gas emissions, continued use of coal) Regulation and Legal: * Public inquiry by Government agency * Environmental licence revoked * Significant legal sanctions against Eskom * Stringent carbon budgets and taxes imposed Physical changes to the Climate: * Major generation and transmission infrastructure damage due to severe climate events * Inadequate water supply for power generation	**Legal and Compliance:** * Major litigation or prosecution with damages including costs in excess of R100m * Custodial sentence for Chief Executive. * Custodial sentence for multiple company Executives. * Closure of operations by authorities across multiple sites / regions. * Inability to meet suspensive conditions in multiple loan agreement	**Reputation:** * Sustained adverse international / national press reporting over several weeks * Prolonged loss of shareholder/ client confidence and community support * Critical event that the organisation would be forced to undergo significant change	**Fatalities:** Multiple Fatalities	**Cyber-resiliency** - Malicious damage to computer networks or systems resulting in widespread prolonged national supply interruptions and the ongoing inability to safely operate or restore supply to the country **Data confidentiality** - Disclosure of sensitive and/or confidential data and information could lead to ongoing community unrest, sabotage of operations, damage to Eskom's credit rating and reputation(nationally and abroad) plus result in litigation **Critical System/Data Availability** - Major loss of or unavailability of mission critical systems and/or data throughout Eskom could severely impact Eskom's revenue, profitability, license to operate, credit rating and reputation **Information/data governed as a corporate asset** - Failure to fulfil Eskom's fiduciary duties pertaining to the treatment of data/information as a corporate asset, could result in investigations, liability and harm to Eskom's reputation
5	**Net position between Revenue and operational expenditure** Between R18n and R38n **Impact:** Severe financial loss and / or impairment impacting financial health and business operations	**GWh lost:** 500 – 5000GWh (Unable to meet demand by equivalent of PS Unit for a period of 1 month) **Regional blackout:** Lasting <60hrs **National load shedding:** Stage 2. Loss of critical supply to critical customer for an extended period (deep level mines, smelters etc.)	**Project cost deviate:** > 15% and ≤ 20% **Schedule deviate:** > 25% and ≤ 35% delay **Quality:** Severe – Major non-conformance that would results in a few chain reactions, negatively impacting project outcome.	Community: * Prolonged environmental impact * High-profile community concerns raised – requiring significant rectification measures Regulation and Legal: * Government agency inquiry * Environmental licences revoked and directives issued * Significant financial penalties due to non -compliance with carbon emission limits Physical Changes to the Climate: * Significant impact on infrastructure - long lead times for repairs * Eskom's water allowance reduced due to inadequate supply of water	**Legal and Compliance:** * Major litigation or prosecution with damages including costs between R50m and R100m. * Custodial sentence for a company Executive. * Closure of operations by authorities at single sites / region. * Inability to meet sus pensive conditions in any loan agreement	Reputation: * Significant event that would require ongoing management and brings the organisation into the national / international spotlight * Sustained adverse national press reporting over several days * Sustained impact on the reputation of Eskom / Rotek / Rushcon * Loss of Government trust * Executive management restructure	**Fatality:** Single fatality	Cyber-resiliency - Malicious damage to computer networks or systems resulting in prolonged regional supply interruptions and the inability to safely operate or restore supply to the region Data confidentiality - The disclosure of confidential / sensitive data to unauthorised employees could result in labour unrest in specific regions Critical System/Data Availability - Major loss of or unavailability of mission critical systems and/or data throughout an Eskom region could severely impact on a region's revenue and profitability Information/data governed as a corporate asset - Governance structures to be aligned across divisions in all regions ensuring protection and enhancement of data Data integrity - Incorrect decisions based on corrupt regional data, resulting in regional inefficiencies
4	**Net position between Revenue and operational expenditure** Between R100m and R1Bn **Impact:** Significant financial loss and / or impairment impacting financial health and business operations	**GWh lost:** 100 – 500GWh (Unable to meet demand by equivalent of PS Unit for a period of 1 month) **Regional blackout:** Lasting <8hrs **National load shedding:** Stage 1. Loss of supply to major Centre or customer for >12 hrs.	**Project cost deviate:** > 10% and ≤ 15% **Schedule deviate:** > 15% and ≤ 25% delay **Quality:** Substantial - Major non-conformance resulting in scrapping of product. Product that is not fit for the purpose.	**Community:** * Measurable environmental harm – medium term recovery * High potential for complaints from stakeholders and community **Regulation and Legal:** * Environmental directives issued by authorities * Carbon budgets imposed with grace period for compliance (5 years) **Physical changes to the Climate:** Significant climate events - plant unavailability or impact on coal supply (e.g. flooding) or unavailability of water	**Legal and Compliance:** * Litigation or prosecution with damages including costs between R10m and R50m. * Major breach of regulation with punitive fine. * Significant litigation involving many weeks of senior management time. * Legal / Regulatory directives issued by authorities with < 6 month compliance notice period	**Reputation:** * Major event that causes adverse national media reporting – over several days * Minister raises concerns	**Section 24 injury** Multiple Sect. 24 injured, irreversible disability or impairment cases due to single incident	**Cyber-resiliency** Malicious attempts to damage or disrupt computer networks or systems, could disrupt core operations in other divisions **Data confidentiality** Confidential / sensitive data in a division could be leaked to unauthorised employees within a division **Information/data governed as a corporate asset** Divisional structures to be aligned across divisions ensuring protection and enhancement of data **Data integrity** Incorrect decisions based on corrupt data from divisional sources, resulting in inefficiencies **Data availability** Interdependency of data across divisions compromised
3	**Net position between Revenue and operational expenditure** Between R50m and R100m **Impact:** Moderate financial loss and / or impairment impacting financial health and business operations	**GWh lost:** 10 – 100GWh (based on 1 month of up to 100 MW partial load loss) **Local loss of supply:** Affecting >10,000 customers (>50MW) for >12hrs.	**Project cost deviate:** > 5% and ≤ 10% **Schedule deviate:** > 10% and ≤ 15% delay **Quality:** Significant - Standard requirements not met and rework needed. Significant elements of scope or functionality are affected.	**Community:** Medium term recovery, immaterial effect on environment / community **Regulation and Legal:** * Required to inform Government agency, (e.g.: noise, dust) * Carbon emission limits imposed but not linked to penalties **Physical changes to the Climate:** Minor climate events that result in partial unavailability of plant (few hours as opposed to months - e.g. flash floods)	**Legal and Compliance:** * Litigation or prosecution with damages including costs less than R10m. * Breach of regulation with investigation or report to authority with prosecution and/or moderate fine possible * Legal / Regulatory directives issued by authorities with > 6 month compliance notice period	Reputation: * Serious event that can be readily managed but management effort is still required to minimise impact locally * Adverse local media reporting * Disciplinary action likely	**Lost time injury:** Multiple Lost time injured and/or extensive injuries or irreversible disability or impairment to one person (Sect. 24)	**Cyber-resiliency** - Malicious attempts to damage or disrupt computer networks or systems, could disrupt core operations performed by BUs/departments within a division **Data confidentiality** - Confidential / sensitive data in a division could be leaked to unauthorised employees within a division **Information/data governed as a corporate asset** - BU structures to be aligned across different BUs ensuring protection and enhancement of data **Data integrity** - Incorrect decisions based on corrupt data from BU sources, resulting in inefficiencies **Data availability** - Interdependency of data across BUs compromised
2	**Net position between Revenue and operational expenditure** Between R10m and R50m **Impact:** Minor financial loss and / or impairment impacting financial health and business operations	**GWh lost:** 1 – 10GWh (based on 1 month of 10 MW partial load loss) **Local loss of supply:** Loss of supply to large customer or affecting >10,000 customers for <4hrs. Loss of large load Centre for <2 hours (typically between 0.1 and1 system minutes)	**Project cost deviate:** > 2% and ≤ 5% **Schedule deviate:** > 5% and ≤ 10% delay **Quality:** Moderate - Requirements not met but requires concession. Failure to include certain elements promised to stakeholders.	**Community:** Short term transient environmental or community impact- some clean-up costs **Regulation and Legal:** Carbon emission limits imposed but not linked to penalties **Physical changes to the Climate:** Climate events have minor impact on infrastructure performance	**Legal and Compliance:** Minor legal issues, non-compliances and breaches of regulation.	**Reputation:** * Event that site management can readily manage internally * No press reporting or external interest * Disciplinary action may be taken	**Medical Treatment:** Medical treatment cases or single lost time injury	**Cyber-resiliency** - Malicious attempts to damage or disrupt computer networks or systems that could disrupt core operations performed by departments/BU **Data confidentiality** - Confidential / sensitive data in a BU could be leaked to unauthorised employees within a BU **Information/data governed as a corporate asset** - BU structures to be aligned across different departments ensuring protection and enhancement of data **Data integrity** - Incorrect decisions based on corrupt data from departmental sources, resulting in inefficiencies **Data availability** - Interdependency of data across departments compromised
1	**Net position between Revenue and operational expenditure** Between R1m and R10m **Impact:** Insignificant – no apparent disruption	**GWh lost:** <1 GWh (based on 1 month of 1 MW partial load loss) **Local loss of supply:** Loss of supply to some customers (normal interruption) effects 3,000 customers for <4hrs. <0.1 System minute incident	**Project cost deviate:** ≤ 2% **Schedule deviate:** ≤ 5% delay **Quality:** Minor - Slight deviation from specified requirements. Has no overall impact on usability / standards.	**Community:** Negligible impact on the environment, little to no ecological effect and no measurable impact on human health **Physical changes to the Climate:** Minor climate events that do not impact on infrastructure performance	**Legal and Compliance:** Very minor breaches.	**Reputation:** * Entirely an internal issue * Attention is confined to site	**First Aid:** First aid treatment or minor injuries requiring no treatment	**Cyber-resiliency** - Malicious attempts to damage or disrupt computer networks or systems that could disrupt core operations performed by specific departments **Data confidentiality** - Confidential / sensitive data in a department could be leaked to unauthorised employees within a department **Information/data governed as a corporate asset** - Departmental structures to be aligned across systems and data bases ensuring protection and enhancement of data **Data integrity** - Incorrect decisions based on corrupt data from departmental sources, resulting in departmental inefficiencies **Data availability** - Interdependency of data across department specific systems compromised

Current Purpose	The purpose of financial sustainability is to move the organisation towards a state where its rate of return on assets is equal to the cost of capital and to ensure that Eskom remains a going concern is able to meet its short-term liquidity requirements as well as service long-term debt and financial commitments.	Operations aims to deliver effective and efficient operations of all current assets of the value chain throughout their lifespan. This includes successful implementation of Generation Sustainability strategy (including the 80:10:10 plan) and improving current performance levels with Transmission, Distribution and Customer Services.	Effective execution of capital projects and real estate management enabled by a project management centre of excellence in support of relaibility and security of power generation and supply to foster economic growth and social prosperity	Environmental and Climate Change sustainability aims to address the linkages between environmental management and operational sustainability. This includes environmental impact assessments, air quality, land and biodiversity, water and waste/ash management. Environmental compliance is critical to ensuring that Eskom maintains its licence to operate, keeps the lights on and meets its "zero harm" mandate.	The purpose of Legal and Compliance is to ensure that Eskom conducts its business within its "licence to operate" by ensuring good governance and compliance with current policy, regulatory and legal frameworks; and to influence the policy, regulatory and legal frameworks required for achieving Eskom's strategic objectives.	Building a solid reputation aims to improve Eskom's overarching current reputation and positions the organisation as a key driver for economic growth. Eskom is pursuing a number of specific actions to safeguard and improve its reputation. This is to protect existing customer bases (and ensure our sustainability) and to ensure stakeholder alignment.	Eskom is committed to ensuring occupational and health and safety across all line divisions and functions. The company's safety principle is that no operating condition or urgency of service justifies exposing anyone to injury or safety or environmental risks arising out of Eskom's business. It follows that occupational health and safety of Eskom employees, contractors and the public at large, is of critical importance to Eskom.	Group IT is committed to lead the Eskom business in Digital Transformation and in doing so applying the established ICT principles to new digitised sources of business data/information and operating technology systems/applications in order to ensure Eskom's alignment to Cobit (as per King IV on Corporate Governance) and other applicable regulations and acts. Furthermore, in light of the King IV separation of technology and information (data) as a corporate asset, Group IT will advise the Eskom business on the necessary business governance structures and enterprise information management roles needed at different levels of the organisation to protect and enhance Eskom data/information as a corporate asset.

Category	Criteria
E	• Could occur within “days to weeks”, or • Impact is imminent, or • ≥ 90% probability
D	• Could occur within “weeks to months”, or • Balance of probability will occur, or • ≥ 70% and < 90% probability
C	• Could occur within “months to years”, or • May occur shortly but a distinct probability it won’t, or • ≥ 20% and < 70% probability
B	• Could occur in “years to decades”, or • May occur but not anticipated, or • ≥ 5% and < 20% probability
A	• More than a “100 year event” • Exceptionally unlikely, even in the long term future • < 5% probability

Consequences	A	B	C	D	E
6	I	I	I	I	I
5	II	II	II	I	I
4	III	III	II	I	I
3	IV	III	II	II	I
2	IV	IV	III	II	II
1	IV	IV	III	III	III
	Likelihood				

CR	L
1	A
2	B
3	C
4	D
5	E
6	

CR	L	CRL	RR
1	A	1A	IV
1	B	1B	IV
1	C	1C	III
1	D	1D	III
1	E	1E	III
2	A	2A	IV
2	B	2B	IV
2	C	2C	III
2	D	2D	II
2	E	2E	II
3	A	3A	IV
3	B	3B	III
3	C	3C	II
3	D	3D	II
3	E	3E	I
4	A	4A	III
4	B	4B	III
4	C	4C	II
4	D	4D	I
4	E	4E	I
5	A	5A	II
5	B	5B	II
5	C	5C	II
5	D	5D	I
5	E	5E	I
6	A	6A	I
6	B	6B	I
6	C	6C	I
6	D	6D	I
6	E	6E	I

RCE	Guide
Fully effective	Nothing more to be done except review and monitor the existing controls. Controls are well designed for the risk, are largely preventative and address the root causes and Management believes that they are effective and reliable at all times. Reactive controls only support preventative controls.
Mostly effective	Most controls are designed correctly and are in place and effective. Some more work to be done to improve operating effectiveness or Management has doubts about operational effectiveness and reliability of the controls.
Mostly Ineffective	While the design of controls may be largely correct in that they treat most of the root causes of the risk, they are not currently operationally very effective. There may be an over-reliance on reactive controls, or Some of the controls do not seem correctly designed in that they do not treat root causes.
None	Virtually no credible control. Management has no confidence that any degree of control is being achieved due to poor control design and/or very limited operational effectiveness.

Priority	Suggested timing of treatment
I	Short term. Normally within 1 month.
II	Medium term. Normally within 3 months.
III	Normally within 1 year
IV	Ongoing control as part of a management system.

Potential Exposure (PE) will be estimated for each risk. This will represent the total plausible maximum impact on Eskom arising from a risk without regard to controls. It will be expressed in terms of a consequence rating as given on the Consequence Criteria Table 2. The purposes of this measure are:

· Assisting / alerting Eskom's Enterprise Resilience Department to ensure effective disaster response strategies.
· Assisting Audit & Forensic Department to align their audit plans to ensure that significant risks are always included. Risks with high consequences as a result of not taking any existing controls into account will focus their attention on the existing controls to determine their effectiveness and adequacy.

Risk Status	Risk Title	Risk Description (something occurs……)	Cause	Impact (leading to……)
Active	**Battery overcharging**	**Overcharging caused by battery management system design defficiency/failure leading to battery fire.**	**1. Poor manufacturing and design 2. Inadequate charging control systems**	**1. Safety and fire risk 2. Equipment damage 3. Interuption of customer power supply**
Active	**Overheating cell and thermal run away**	**Excessive charging and discharging, high current, or imbalances between cells can cause overheating in a cell and result in thermal runaway as neighboring cells also overheat, which essentially leads to a system failure.**	**1.Improper and inefficient monitoring and sensoring equipement or tools that control the input and outputs for these large systems.**	**1.Equipment damage/battery damage 2.Interuption of customer power supply**
Active	**High temperature combustion of the cell**	**Extreme high temperatures lead to leaks, smoke, gas venting, and/or combustion of the cell pack.**	**1.Improper and inefficient temperature control, monitoring and sensoring equipement or tools are designed for these large systems.**	**1. Safety and fire risk 2. Equipment damage/battery damage 3. Interuption of customer power supply**
Active	**Shortened battery life cycle**	**Physical change when mangenese is disolved in the electrolyte leading to a shortened life cycle of the battery due to .**	**1.Cycling depth of discharge of the battery capacity is not completely depleted which results in a shortened life cycle.**	**1. Equipment damage/battery damage 2. Interuption of customer power supply 3.Unplanned replacement costs as a result of a shortened life span**
Active	**Spillage of the electrolite liquid**	**Spillage of the toxic ion exchange membrane, which is composed of highly acidic (or alkaline) material causes health and enviromental effects.**	**1.Mishandling and personnel fault. 2.Improper decommisioning and disposal of the membranes.**	**1.Health risk 2.Equipment damage 3.Interuption of customer power supply 4.Enviroment potential polution**
Active	**Fouling Membrane**	**Membrane foul, wherein the vanadium ions become irreversibly trapped in the membrane and increase resistive losses in the cell, ultimately failing in its functioning.**	**1.The higher voltage and highly oxidative V5+ electrolyte puts more chemical stress on the materials used in the cell electrodes, membranes, and fluid handling components.**	**1.Leading to battery repairs 2.Interuption of customer power supply 3.High financial cost for the membrane**
Active	**Failure of the Vanadium Redox Flow Battery system**	**Failure of the Vanadium Redox Flow Battery system which is due to its low reliability leading to an interuption of the power supply.**	**1.Low reliability of the system and equipment such as (eg. pumps and power electronics) which have little to no experience with failure modes and effects in the substation enviroment.**	**1.Equipment damage/battery damage 2.Interuption of customer power supply 3.High financial cost for the replacement of every equipment that could possibly fail.**
Active	**battery capacity loss and electrolyte imbalance**	**Battery capacity loss and electrolyte imbalance and parasitic side reactions as a result of poor design of the Fe-Cr Redox Flow Batteries.**	**1.Inefficient and inaddeqaute designs of the Fe-Cr Redox flow batteries (Redox Flow Batteries).**	**1.Equipment damage/battery damage 2.Interuption of customer power supply**
Active	**Self-discharge of the battery**	**Self-discharge of the cells due to bromine crossover to the anode side from the cathode side of the battery leads to lowering of the battery life span.**	**1.Crossover of bromine from cathode to anode in the cell.**	**1.Equipment damage/battery damage 2.Interuption of customer power supply**
Active	**Toxic spill of the electrolytes within the battery**	**Enviormental and health effects as a result of a toxic spill of the battery contents, electrolytes, ect.**	**1.Toxic spillage of the contents of the battery could result in a detremental effect on the enviroment and people in the region of the spill. 2.Improper decommisioning and disposal of the chemical composition leading to a spillage of the chemicals, causing harm to the enviroment and the health of the users.**	**1.Health risk 2.Equipment damage 3.Interuption of customer power supply 4.Enviroment potential polution**
	Contamination of surrounding environment	Electrolyte spillage leading to environmental contamination.	Incorrect handling, accident, system failure	Financial loss due to penalties, fines, cleanup costs or COUE

Existing controls (controlled by……)	RCE per control	Control Owner	Task on Controls	Task on control Due Date	Task on control Percentage complete	Task on control owner	Cons. rating	Likelihood rating
1.Procurement management systems are in place to allow us to specify user requirements and control measures. 2.Suppliers have existing control management systems with a facility to send alarms in any case of emergency.	1.Mostly effective 2.None	Peter Langley and Ryan Gilbert	research conducted on the lithium-ion battery	2020	none	none	3	C
Sophisticated battery management systems to monitor cell performance and limit operation to safe and acceptable performance ranges are employed by the monitoring team.	1.Mostly effective	Peter Langley and Ryan Gilbert	research conducted on the lithium-ion battery	2020	none	none	1	C
Improved monitoring and sensoring systems have been introduced which are inherently safer than the previously employed systems.	1.Mostly effective	Peter Langley and Ryan Gilbert	research conducted on the lithium-ion battery	2020	none	none	4	C
An effective cycling schedule is in place and monitored for efficient functioning and increased life span of the battery.	1.Mostly effective	Peter Langley and Ryan Gilbert	research conducted on the lithium-ion battery	2020	none	none	2	B
1.An effective handling and instructions manual are aquired from the manufacturer and is directly followed, monitored and efficiently managed. 2.During decommissioning, users can dispose of the membranes using the same processes used to handle highly corrosive substances.	1.Mostly effective. 2.Mostly effective.	Peter Langley and Ryan Gilbert	research conducted on the Vanadium redux flow battery	2021	none	none	3	D
Low cost membranes are being developed to enable cheaper replacements.	1.Mostly effective	Peter Langley and Ryan Gilbert	research conducted on the Vanadium redux flow battery	2021	none	none	1	C
Extended field experience will be required to validate the reliability of the newer system designs.	1.Mostly effective	Peter Langley and Ryan Gilbert	research conducted on the Vanadium redux flow battery	2021	none	none	2	C
Current developers of Fe-Cr Redox Flow Batteries appear to have addressed the side reaction and implemented effective rebalancing sub-systems with minimal system efficiency loss.	1.Mostly effective	Peter Langley and Ryan Gilbert	none	none	none	none	1	B
Stopping electrolyte circulation during stand periods, limiting the degree of crossover to bromine that is in the cell when circulation ceases.	1.Mostly effective	Peter Langley and Ryan Gilbert	none	none	none	none	1	C
1.Proper handling and monitoring systems are employed as a preventative measure. 2.Proper recovery of Zinc should be effectively conducted when the unit is decomisioned .	1.Mostly effective 2.Mostly effective	Peter Langley and Ryan Gilbert	none	none	none	none	2	B
1. Primary and secondary containment on plant to prevent contamination of surrounding environment. 2. Tertiary containment in foundation - bund walls. 3. Applicable accreditation of staff to contain any spillages. 4. Contractor to have waste clean-up agreement with accredited service providers.								

Risk Rating	Risk Rating comment	Risk Owners	Potential Exposure	Risk Treatment tasks	Risk Treatment task Owner	Percentage Completion	Due date
II	Serious event that can be readily managed but management effort is still required to minimise impact locally. Adverse local media reporting. Disciplinary likely.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2. Procurement document should state that the manufacturer had/has managed the risk.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement
III	Entirely an internal issue. Attention is confined to site.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2. Procurement document should state that the manufacturer had/has managed the risk. 3.Manufacturers should make all the products testing and results availible to all customers for full awareness on the specific risk procedure.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement
II	Section 24 injury: Multiple Sect. 24 injured, Irreversible disablement or impalement due to serious incident.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2. Procurement document should state that the manufacturer had/has managed the risk. 3.Manufacturers should make all the products testing and results availible to all customers for full awareness on the specific risk procedure.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement
IV	Event that the site management can readily manage internaly. No press reporting or external interest. Disciplinary action may be taken	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2. Procurement document should state that the manufacturer had/has managed the risk.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement
II	Measurable enviromental harm-medium term recovery. High potential for complaints from stakeholders and community. Enviromental detectives issued by authorities.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2. Procurement document should state that the manufacturer had/has managed the risk.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement
III	Net position between revenue and expenditure. Between R1m and R10m. Insignificant and no apparent disruption.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer had/has managed the risk. 3.New and cheaper technologies should be provided as alternatives from the manufacturer when they are made availible.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement
III	Event that site management can readily manage internally. No press reporting or external interest. Disciplinary action may be taken.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer had/has managed the risk. 3.Procurement document should have a test and result status.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement
IV	Entirely an internal issue. Attention is confined to site.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer had/has managed the risk. 3.Procurement document should have a test and result status.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement
III	Entirely an internal issue. Attention is confined to site.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer had/has managed the risk. 3.Procurement document should have a test and result status.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement
IV	Short-term transient enviromental or community impact and some clean up cost.	Gabi Mkhantswa		1.Specification on procurement request that suppliers must be ISO 9001:2015. 2.Procurement document should state that the manufacturer had/has managed the risk. 3.Procurement document should have a decomision mandate.	Peter Langley and Ryan Gilbert	0%	Alligned with project procurement

Risk Treatment Plan Feedback	Target Risk Rating	Target Risk Rating Due Date	Risk Movement Comments	Type of technology
				Lithium ion solid state
				Lithium ion solid state
				Lithium ion solid state
				Lithium ion solid state
				Vanadium redox flow battery
				Vanadium redox flow battery
				Vanadium redox flow battery
				Iron-chromium flow battery
				Zinc-bromine flow battery
				Zinc-bromine flow battery