APPENDIX L PRELIMINARY HAZARDS ANALYSIS

Preliminary Hazard Analysis of

Hills of Gold Wind Farm

For Environmental Resources Management Australia Pty Ltd

6 August 2021

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Contents

List of Figures

List of Tables

Notation

Abbreviation	Description
AGL	Above Ground Level
APZ	Asset Protection Zone
Arriscar	Arriscar Pty Limited
AS	Australian Standard
BESS	Battery Energy Storage System
BMS	Battery Management System
DPIE	NSW Department of Planning, Industry and Environment
EIS	Environmental Impact Statement
EMF	Electro-Magnetic Field
FM	Factory Mutual
g	Peak ground acceleration expressed in fractions of g (the standard acceleration due to Earth's gravity, equivalent to g-force) as either a decimal or percentage; in m/s^2 (1 g = 9.81 m/s^2)
HIPAP	Hazardous Industry Planning Advisory Paper
HVAC	Heating, Ventilation and Air-Conditioning
IEC	International Electrotechnical Commission
kV	kilo-volt
LFP	Lithium Iron Phosphate (cathode)
LIB	Lithium Ion Battery
LTO	Lithium Oxide (cathode)
m	metres
MW	Mega Watt
MWh	Mega Watt hour
NFPA	National Fire Protection Association
NMC	Nickel-Manganese-Cobalt (cathode)
O&M	Operations and Maintenance
PHA	Preliminary Hazard Assessment
pmpy	Per million per year
SSD	State Significant Development
UL	Underwriters Laboratories

1 INTRODUCTION

1.1 Background

The Hills of Gold Wind Farm project includes construction and operation of a wind farm (68 wind turbine generators), battery energy storage system (BESS), transmission line and associated infrastructure near Hanging Rock, NSW.

An Environmental Impact Statement (EIS) [1] has been prepared by Environmental Resources Management Australia Pty Ltd (ERM) to accompany a development application for State Significant Development in accordance with the Environmental Planning and Assessment Act 1979 (EP&A Act). These documents were submitted to NSW Department of Planning, Industry and Environment (DPIE) in November 2020. Following submission of the EIS, NSW DPIE requested further information relating to hazards as per the scope described below.

1.2 Objectives and Scope

1. Include the findings from EIS Appendix K [2] (including and not limited to Table 3-2) in the relevant sections of the Preliminary Hazard Analysis (PHA) report.
2. Undertake fire/explosion consequence analysis (PHAST modelling) to confirm the BESS can fit within the area identified in the EIS [1] (inclusive of required buffers to the O&M / Substation and buffer to each BESS compartment), with reference to relevant standards as per DPIE advice (as applicable).
3. Undertake fire/explosion and toxic gas/smoke consequence analysis (PHAST modelling) to confirm emergency services can access the BESS in the event of an incident (i.e. including restrictions / risks that may be posed by the O&M / Substation locations).
4. Estimate the likelihood of a tower collapse or blade throw (blade or fragments) incident impacting upon the BESS, O&M and Substation locations (including considering of blade orientation based on wind patterns).
5. Evaluate the potential for an ice throw incident to pose a risk to members of the public.
6. Draft PHA report. The PHA will be largely qualitative and will utilise the information already included the EIS [1] (see Task 1 above). Quantification of risk will only be undertaken for the specific matters raised by DPIE (i.e., principally Tasks 2-4 above). Compliance with risk criteria in HIPAP No. 4 [3] is expected to be largely demonstrated on basis of consequence analysis (i.e., risk criteria will be met if consequences do not extend to relevant receptors).
7. Respond to items A1 to A4 and B1 to B5 in the Hazards queries e-mail forwarded by the NSW DPIE in the updated PHA, originally provided in EIS Appendix L [4]. See Appendix B for details.

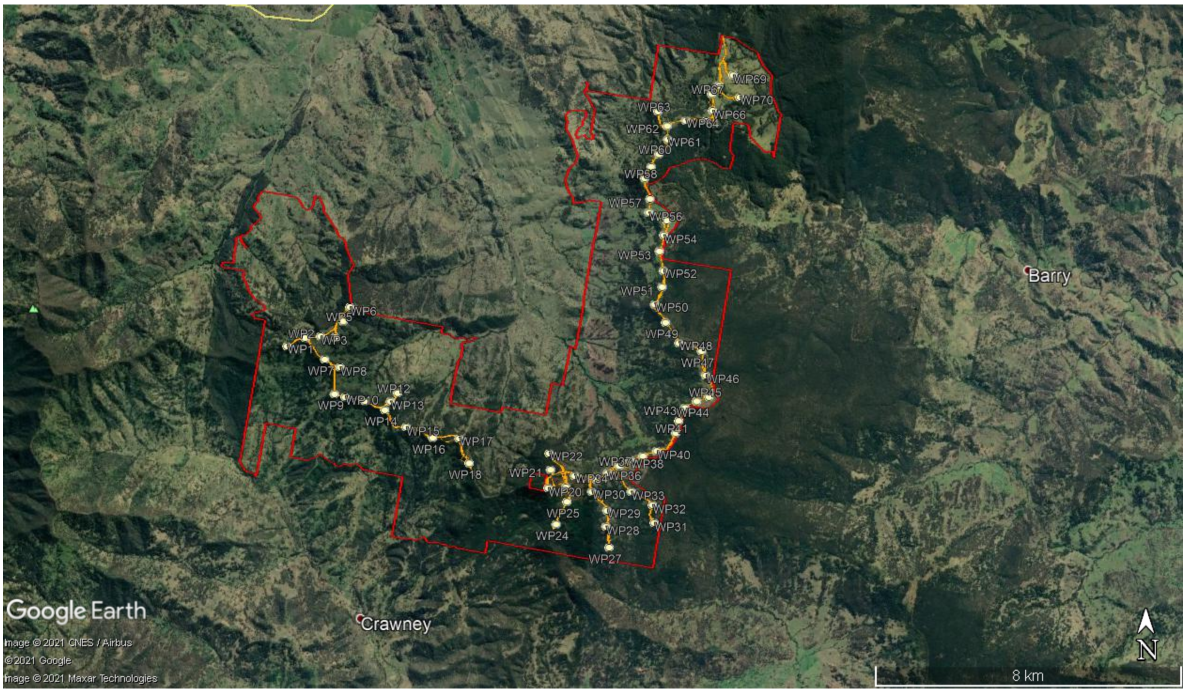
2 SITE LOCATION AND SURROUNDING USES

2.1 Location

The Project Area is located within the New England region, approximately 5 km south of Hanging Rock and 8 km south-east of Nundle (refer to Figure 1 and Figure 2). The Project Area is located over three LGAs, being the Tamworth Regional LGA, Upper Hunter Shire LGA, and the Liverpool Plains LGA. The nearest major township is Tamworth, located approximately 60 km northwest.

Figure 1 Location of Hills of Gold Wind Farm

Figure 2 Overview Layout of Hills of Gold Wind Farm



2.2 Surrounding Land Uses

The principal land uses at Nundle and Hanging Rock are agriculture, timber, and tourism. Directly east of Nundle is Hanging Rock State Forest, which includes land zoned as forestry (RU3 – Forestry). Nundle is the closest locality to the Project Area with residential and commercial land use zonings. The surrounding land is predominately zoned for agricultural purposes (RU1 – Primary Production).

Ben Halls Gap Nature Reserve and Ben Halls Gap State Forest are in the eastern side of the Project Area and Crawney Pass National Park are on the western side.

The land surrounding the Project Area is steep and partially cleared and is predominately used for grazing.

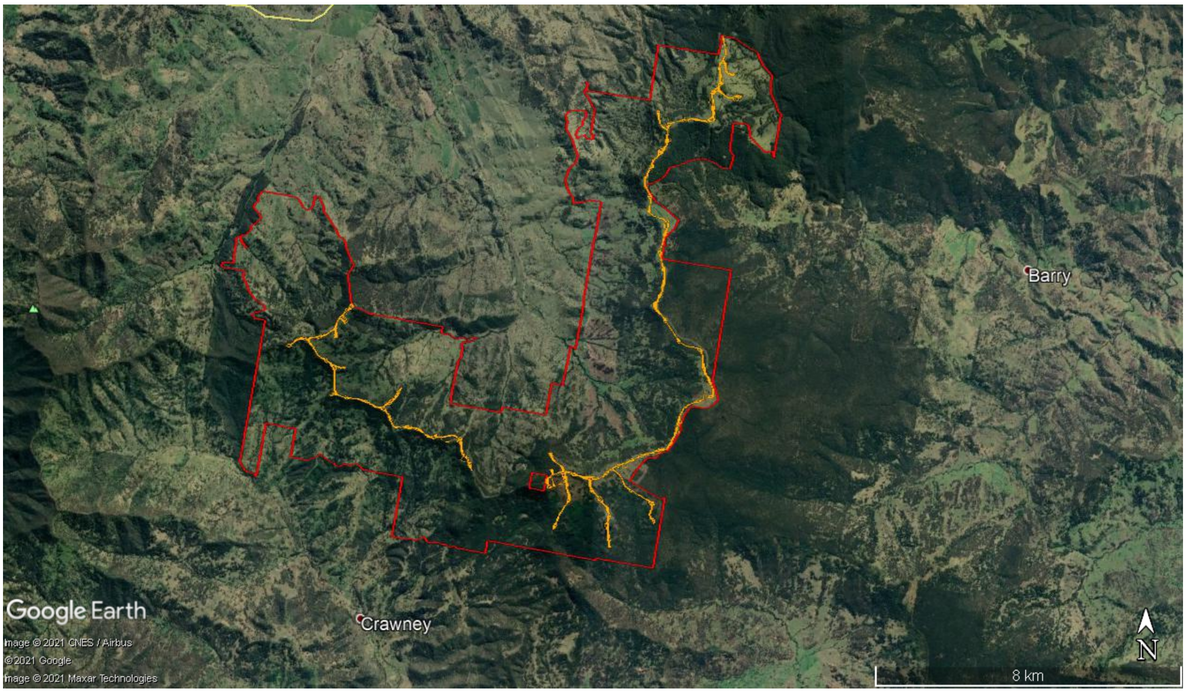
2.3 Access

Site access is via Morrisons Gap Road, located to the northeast of the Project Area. This Tamworth Regional Council road is unsealed for approximately 3 km prior to the Project Area. Access via the Head of Peel Road is for emergency access only.

The construction and maintenance of the Project will require construction of private access roads within the Project Area. The roads will provide ongoing access to the WTGs and other Project infrastructure including the transmission line. Where practicable, the internal road network will be aligned on the route of existing farm or other access roads. The internal roads will be up to 5.5 m wide (with approximately 1.5 m shoulders on either side), with localised widening where required to support transportation of the WTG components (refer to Figure 3).

Included within the internal road network proposed for both construction and ongoing use is the 'Transverse Track', which provides internal road access between WTG 18 to WTG 40 to overcome topography challenges for road construction between WTG 19 and WTG 20.

Figure 3 Winds of Gold Wind Farm Road Access



2.4 Residential Dwellings

For this report, the same nomenclature is adopted as used in the EIS [1] regarding dwellings. Dwellings whose owners are hosting Project infrastructure or have entered into an agreement in relation to the Project are referred to as 'associated dwellings' with all other dwellings in proximity to the Project Area are referred to as 'non-associated dwellings'.

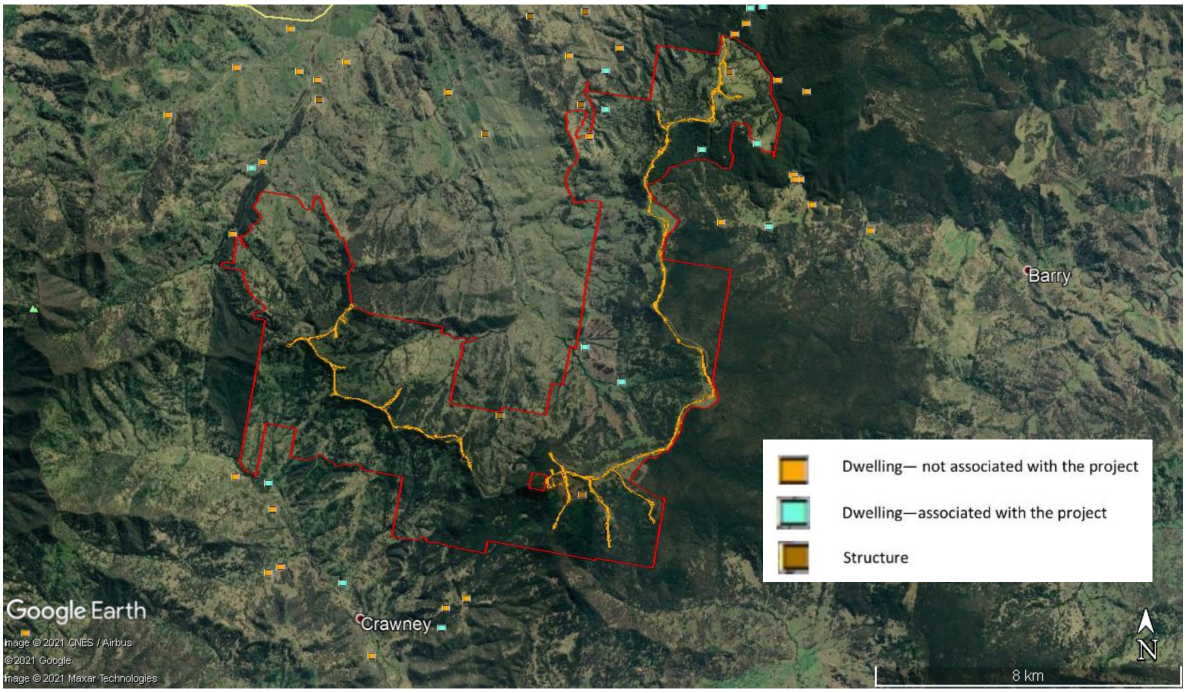
There are:

- five (5) associated dwellings located within the Project Area;
- seven (7) associated dwellings and seven (7) non associated dwellings within 2 km of a turbine; and
- seven (7) associated dwellings and 23 non associated dwellings between 2 km and 4 km of a turbine.

The closest residence is associated dwelling AD_5, which is approximately 765 m from WTG No. 65.

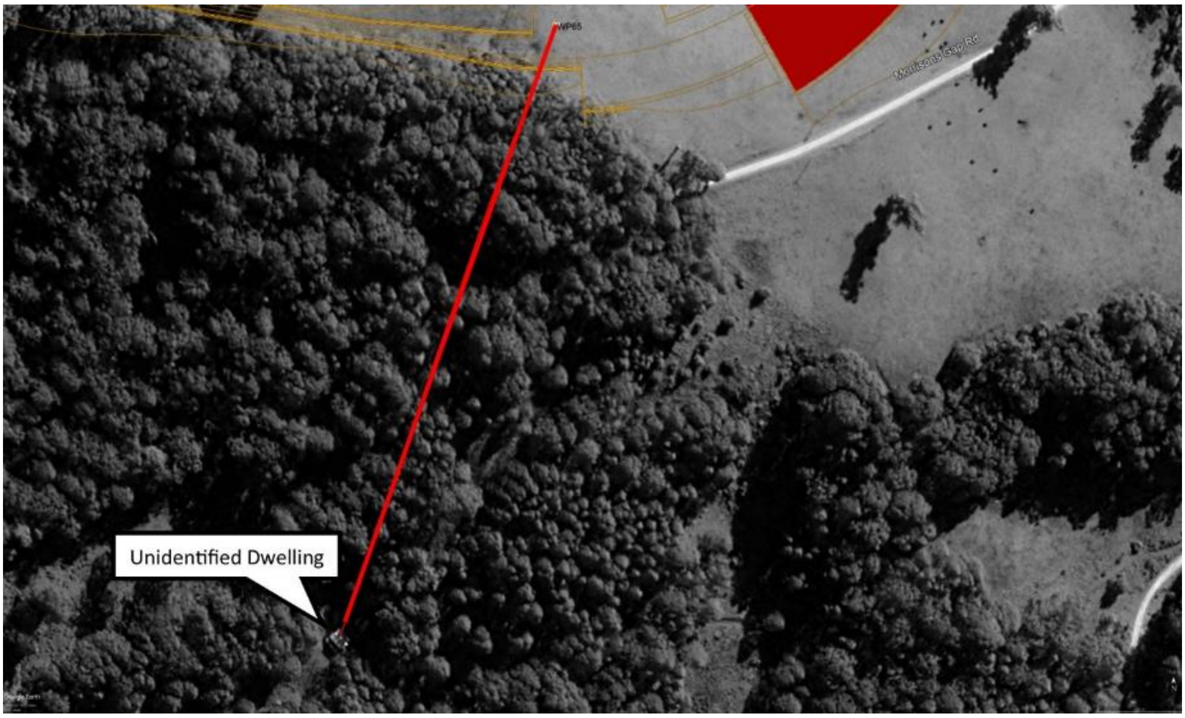
There are also several other non-residential structures located nearby (refer to Figure 4).

Figure 4 Location of Dwellings & Structures Around Proposed Hills of Gold Wind Farm



It is also noted from the Hills of Gold Preservation Inc Objection [5] that there appears to be a building that has not been accounted for in the EIS [1]: Lot 210 DP 819485, which is only 350 meters from the turbine WP65 and 525 meters from the turbine WP64. The coordinates of this building are 31°32'48.08"S, 151°10'36.29"E (refer to Figure 5). This building has been identified to be a storage shed and is not a development approved dwelling [6].

Figure 5 Building near Wind Turbine WP65



The authors also identified what appears to be a non-residential structure, which was not accounted for in the EIS [1], which is approximately 350 m from turbine WP70, at coordinates 31°32'19.46"S, 151°11'0.91"E. The purpose and occupancy of the structure has been identified as a cattle yard with farm equipment and supplies storage [7] (refer to Figure 6).

Figure 6 Structure Near Wind Turbine WP70

2.5 Meteorology

2.5.1 Temperature and Humidity

Temperature and relative humidity have been measured within the Project Area at varying heights above ground level (AGL). The Mast Nundle M4 system has the most complete temperature and relative humidity data, with measurements recorded at 10-minute intervals at 3 m and 104.5 m AGL.

The data for 12 April 2020 to 11 April 2021 at 3 m and 104.5 m AGL is presented in Figure 7 and Figure 10, respectively.

Figure 7 10-Minute Average Temperature and Relative Humidity at 3 m AGL (M4)

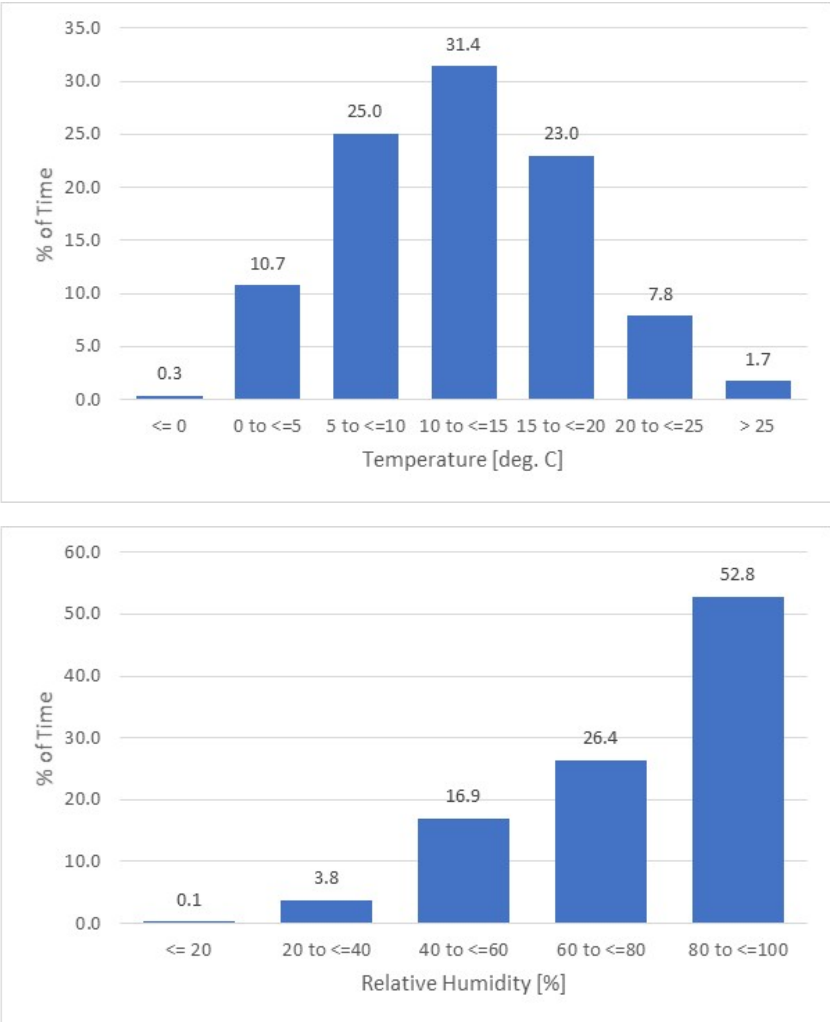
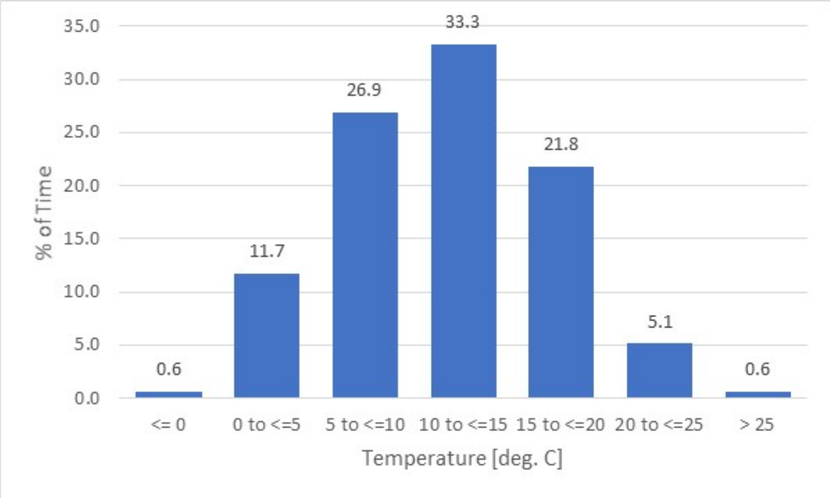
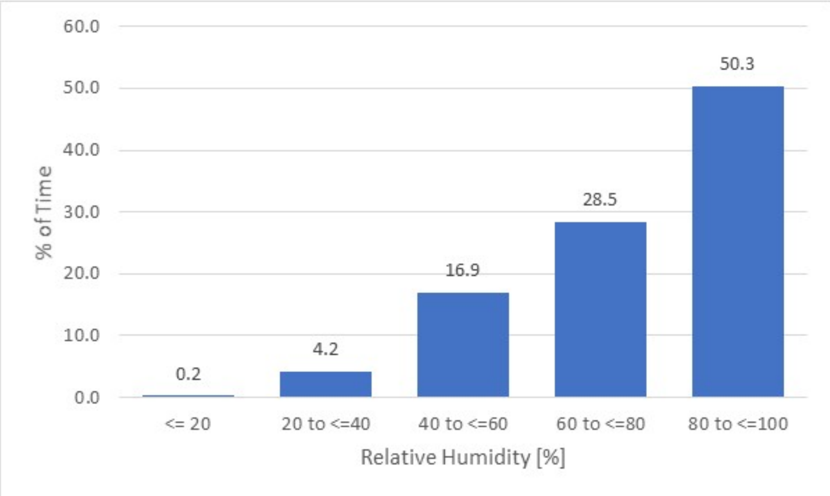


Figure 8 10-Minute Average Temperature and Relative Humidity at 104.5 m AGL (M4)





2.5.2 Icing Conditions

The most important meteorological parameters for icing are the humidity in the air (liquid water content, mean volume droplet size and cloud base height), air temperature and wind speed.

Meteorological icing is the period during which the meteorological conditions for ice accretion are favourable (active ice formation) and instrumental icing is the period during which ice is present/visible at a structure and/or a meteorological instrument [8]. These periods have been used by the IEA [9] to categorise the relative Ice Class for a site (refer to Table 1).

Instrumental icing commonly refers to stationary (non-rotating) objects. For a rotating turbine rotor, high flow velocity and blade vibrations result typically in shorter incubation and recovery times than for stationary instruments [8]. Rotor icing is defined as the period during which the wind turbine rotor accumulates ice. Ice is accreted continuously on a wind turbine rotor until the meteorological conditions for icing are not present anymore (end of the meteorological icing). Ice will remain on the wind turbine for a certain time – the recovery time – until ice erodes, sublimates, melts or sheds away from the rotor (end of the rotor icing) [8].

Table 1 IEA Icing Classes for Meteorological and Instrumental Icing [9]

Icing Class	Meteorological Icing (% of year)	Instrumental Icing (% of year)
5	> 10	> 20
4	5 – 10	10 – 30
3	3 – 5	6 – 15
2	0.5 – 3	1 – 9
1	0 – 0.5	0 – 1.5

The determination of the meteorological icing duration is based on the measurement of atmospheric conditions such as air temperature, wind speed, liquid water content of the air and the droplet size distribution [8]. Cloud base height and relative humidity may also be used, but relative humidity is not the primary mechanism of meteorological icing [8]. As the optimal data is not available from the measurement systems within the Project area, the following boundary conditions for the determination of meteorological icing have been considered [8]:

- Above 100% relative humidity (saturation) and temperature below +3°C a very high probability for meteorological icing exists, with the highest probabilities for meteorological icing observed between +2°C and -5°C and extremely low probabilities for meteorological icing observed below -10°C.

A combination of air temperature below 3°C and high relative humidity as criteria for meteorological icing may overestimate the frequency of icing [8].

Table 2 Analysis of Potential for Meteorological Icing Conditions (M4)

	104.5 m AGL
Max Duration Avg Temp. >= -10 to < 3 Deg C and RH >= 100% (hours)	32.5
Total Duration Avg Temp. >= -10 to < 3 Deg C and RH >= 100% (hours p.a.)	259.8
% of year Avg Temp. >= -10 to < 3 Deg C and RH >= 100%	<3.0

Based on the data presented in Table 2, the proposed turbine locations may be categorised as IEA Icing Class 2 (refer to Table 1) based on the potential for meteorological icing.

For instrumental icing, direct ice measurement is typically undertaken by observing ice with a camera, measuring the ice mass, etc. As this data is not available from the measurement systems within the Project Area, the following boundary conditions for the determination of instrumental icing have been considered [8]:

- the measured temperature at the reference height is lower than 3˚C.
- the measured relative humidity at the reference height is higher than 95%.

This approach is very conservative and may lead to an over-estimation of the instrumental icing duration [8].

Table 3 Analysis of Potential for Instrumental Icing Conditions (M4)

	104.5 m AGL
Max Duration Avg Temp. < 3 Deg C and RH > 95% (hours per event)	56.0
Total Duration Avg Temp. < 3 Deg C and RH > 95% (hours p.a.)	339.3
% of year Avg Temp. < 3 Deg C and RH > 95%	3.9

Based on the data presented in Table 3, the proposed turbine locations may be categorised as IEA Icing Class 2 (refer to Table 1) based on the potential for instrumental icing.

The analysis of the potential for both meteorological and instrumental icing indicates that the Project Area may be categorised as IEA Icing Class 2 (refer to Table 1). This analysis is based on an approach that is very conservative and may lead to an over-estimation of the icing duration; however, the potential for ice formation does appear to be credible for the wind turbines in the Project Area.

The different forms of atmospheric icing include [10]:

- **Rime** – This type of icing is caused by the instantaneous freezing of supercooled water droplets (liquid water at temperatures below 0°C) upon contact with a structure. This type of ice most often forms in a homogeneous, cloudy environment and will accumulate on the structure's surface exposed to the wind.

  Soft rime has a density ranging from 200 to 600 kg/m^3, has a white colour, and has low to medium adhesion to structures. Conversely, hard rime has a density ranging from 600 to 900 kg/m^3, has an opaque colour, and has strong adhesion to structures.

- **Glaze** – This type of ice is also known as clear ice and is caused by different types of supercooled precipitation that freezes upon contact with a cold structure.

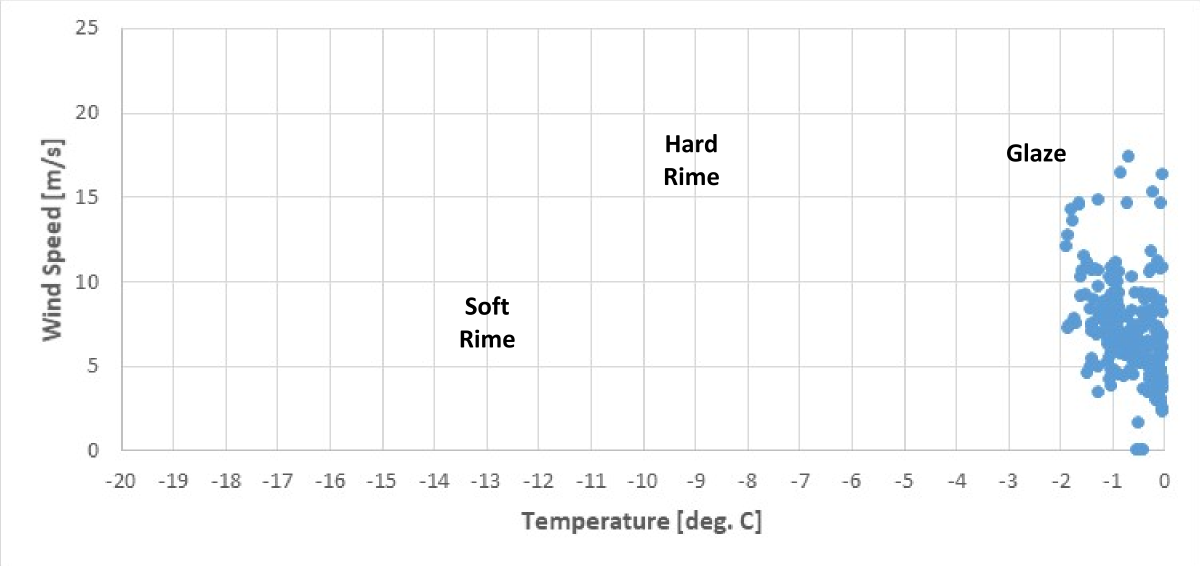
  This type of ice has a density of approximately 900 kg/m^3. It is generally produced at temperatures ranging from 0°C to -6°C, combined with freezing rain. On roads, a thin and transparent layer of glaze is often referred to as black ice.

- **Wet Snow** – When temperatures fluctuate between 0 °C and 3°C, snow crystals with a high water content can adhere and bond to structures. When the temperature drops, accumulated wet snow freezes to form ice that has a density varying between 300 and 600 kg/m^3. Visually, it resembles rime.

- **Hoar Frost** - At very low temperatures, the likelihood of ice formation diminishes, as the water droplets no longer exist in a supercooled state. However, another phenomenon may occur, namely the solid condensation of water vapor in the air. This type of ice, known as hoar frost, is produced when relative air humidity is high (above 90%) and winds are low. Its density and bond strength are low, which limits the mechanical loads imparted on structures. As a result, hoar frost is also less dangerous in terms of ice shed.

Figure 9 shows typical ice type as a function of air temperature and wind speed [10]. The plotted data is for the Mast Nundle M4 system at 104.5 m AGL for 12 April 2020 to 11 April 2021. This data suggests that glaze ice is more likely to occur than rime ice for the wind turbines in the Project Area.

Figure 9 Average Wind Speed vs Minimum Temperature at 104.5 m AGL when RH >=95% (M4)



2.5.3 Rainfall

The nearest weather station to Nundle is Quirindi Post Office, which is 42.7km away. This has been assumed to be representative of rainfall at the Project Area.

Table 4 Rainfall Data for Quirindi Post Office

Rainfall mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly for all years	80.1	64.9	54.4	40.8	44.0	51.1	47.7	44.2	46.3	59.8	65.0	80.2
Highest Monthly	277.8	334.5	292.5	183.0	157.2	234.5	187.2	137.2	155.9	167.7	220.0	244.1
Highest Daily for all years	94.0 *16 Jan 1898*	104.6 *13 Feb 1898*	136.7 *03 Mar 1921*	74.4 *04 Apr 1950*	85.9 *29 May 1889*	89.2 *02 Jun 1993*	77.0 *21 Jul 1998*	53.6 *23 Aug 1893*	58.4 *17 Sep 1932*	97.0 *14 Oct 2000*	67.8 *25 Nov 1911*	99.6 *11 Dec 2002*

2.5.4 Flooding

The Project Area sits on an elevated ridgeline which has an orientation with good exposure to prevailing wind directions.

The wind turbines are proposed to be positioned along the ridgeline, forming a “J” shape which spans approximately 24 km in length.

The Project Area is located along the Liverpool Range which forms part of the Great Dividing Range. The ridgeline runs generally north-south, bordered to the east by Ben Halls Gap Nature Reserve, and then wrapping west towards Crawney Pass National Park. The undulating landform falls toward the centre of the Project Area converging at the Peel River and Nundle Creek along the Nundle Valley floor. The topography surrounding the Project Area is variable and ranging from: steep/sloping in sections around Crawney Pass National Park and Hanging Rock Lookout; sloping in areas along creek lines; and undulating on the foothills of the surrounding ranges.

The steep ridgeline declines to the north undulating foothills with creeks and tributaries carving through the landscape, converging at the Peel River and Nundle Creek along Nundle Valley floor.

The elevation across the site ranges from 776 m to 1418 m Australian Height Datum (AHD). This elevation range highlights the significantly variable topography across the site. The ridgeline slopes dramatically downhill, generally forming a valley towards the Peel River. Topography of the Project Area is presented in the EIS [1] Figure 16-1.

As the project is largely installed at the top of the ridgeline, the probability of flooding is remote.

Access to the Project Area via Barry Road and Morrisons Gap Road.

2.5.5 Prevailing Winds

Measurement systems within the Project Area have recorded the wind direction and wind speed at varying heights AGL. Two of these systems are particularly relevant to the hazard analysis:

- Mast Nundle M2 (WMT2). This system is located at the proposed location of the BESS. Wind direction and wind speed measurements are recorded at 10-minute intervals at 40 and 85 m AGL. The data for 4 April 2020 to 3 April 2021 at 85 m AGL was used to generate the wind rose shown in Figure 10. The prevailing winds at this location are from the N, NNW and ESE.
- WindCube v2 LiDAR. This system is located at the northern end of the Project Area. Wind direction and wind speed measurements are recorded at 10-minute intervals at 40, 50, 60, 70, 82, 84, 90, 110, 130, 150, 175 and 200 m AGL. The data for 12 April 2020 to 11 April 2021 at 150 m AGL was used to generate the wind rose shown in Figure 11. The prevailing winds at this location are from the NW, WNW, E and ESE.

Figure 10 Wind Rose for Average Wind Speed at 85 m AGL (M2)

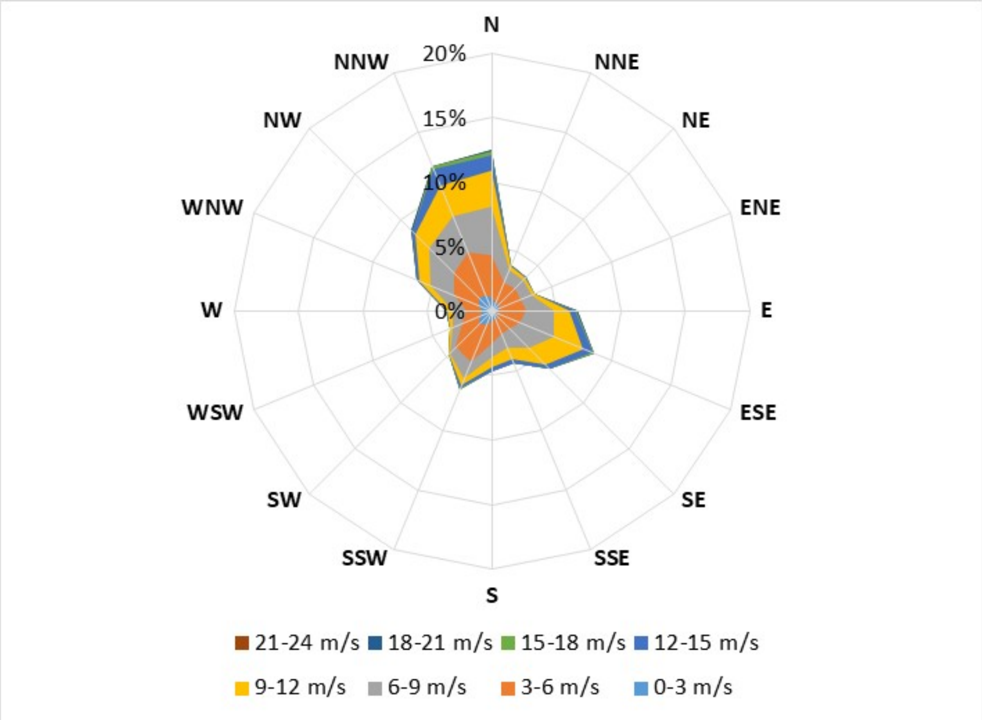
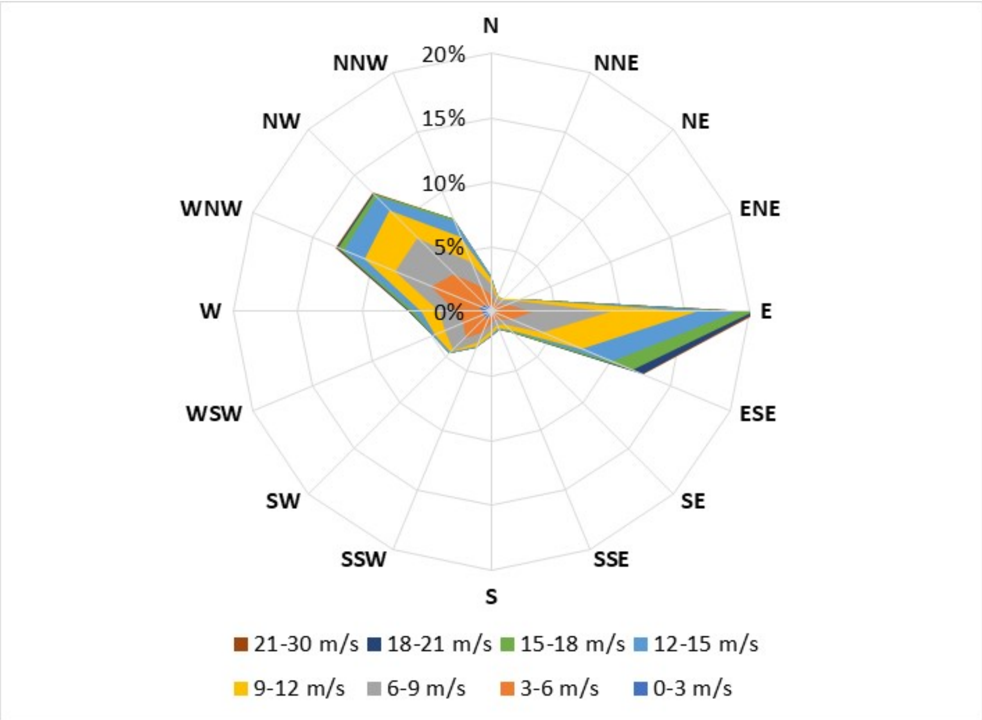


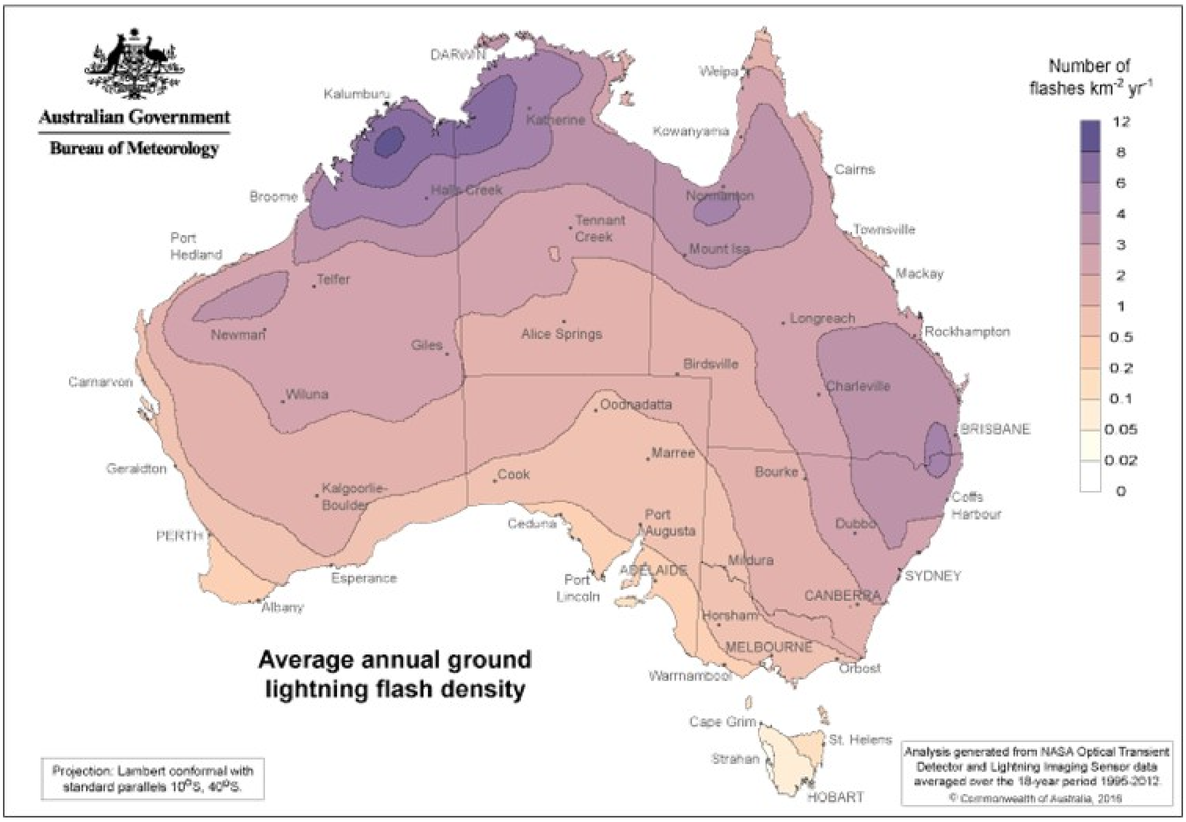
Figure 11 Wind Rose for Average Wind Speed at 150 m AGL (LiDAR)



2.5.6 Thunderstorm Activity

The Bureau of Meteorology has mapped the lightning ground flash density (Ng) across Australia using data over an 18-year period (1995-2012) (refer to Figure 12). The lightning ground flash density (Ng) at the Project Area is 3 to 4 flashes per km per year.

Figure 12 Average Annual Ground Lightning Flash Density [11]



2.5.7 Seismic Activity

The site is in an area of relatively low seismic activity with a peak ground acceleration of 0.01-0.02 g [12]. Peak ground acceleration is related to the expected severity of earthquake ground motion.

Seismic activity in the area is considered low. The Munich Reinsurance World map of Natural Hazards [13] categorises the area as Zone 1, i.e., Modified Mercalli Scale VI with an exceedance probability of 10 % in 50 years (equivalent to a return period of 475 years) for medium subsoil conditions. Overall, this exposure would be considered low.

3 DESCRIPTION OF FACILITIES

The Project involves the construction, operation and commissioning of a wind farm with 68 wind turbine generators (WTG), together with associated and ancillary infrastructure. The proposed wind farm will have an approximate energy generating capacity of 420 megawatts (MW) and includes a 100MW/400MWh battery energy storage system (providing 4 hours of storage for 100MW).

The key components of the Project are:

- 68 WTGs (refer to Section 3.1);
- decommissioning of three current monitoring masts and installation of up to 10 additional monitoring masts for power testing. Five of the new monitoring masts will be located close to a WTG location with a maximum height of approximately 150 m AGL, equivalent to the hub height of the installed WTGs. An additional five masts proposed will be placed on the same location as a WTG prior to its installation and removed shortly before WTG installation. The exact number and location will be defined at the detailed design stage;
- a central 330 kV electrical substation, including transformers, insulators, switchyard and other ancillary equipment;
- an operations and maintenance facility;
- a battery energy storage system (BESS) of 100MW/400 MWh (4 hours of storage for 100MW);
- aboveground and underground 33 kV electrical reticulation and fibre optic cabling connecting the WTGs to the onsite substation (designed to follow site access tracks where practicable) (connection lines);
- a 330 kV single circuit twin conductor overhead transmission line (transmission line). The transmission line will connect the onsite substation to the existing 330 kV TransGrid Liddell to Tamworth overhead transmission line network, located approximately 18.8 km west of the substation, or approximately 13.5 km from the WTG Project Area;
- a switching station to connect the transmission line to the existing TransGrid Liddell to Tamworth 330 kV transmission line and enable the Project to connect to the gird. The switching station will also be located approximately 18.8 km west of the substation, or approximately 13.5 km from the WTG Project Area;
- an internal private access road network (combined total length of approximately 48 km) connecting the WTGs and other Project infrastructure to the public road network; and
- upgrades to local roads and crossings required for the delivery, installation and maintenance of WTG components and associated materials and structures.

3.1 Wind Farm

The WTGs have a generating capacity of approximately 6 MW and include:

- three blades mounted to a rotor hub on a tubular steel tower;
- a gearbox and generator assembly housed in a nacelle; and
- adjacent hardstands for use as crane pads and assembly and laydown areas.

Various wind turbine models are being considered and the final model has not been selected at this stage. The dimensions and operating parameters vary for the models being considered; therefore, conservative values have been assumed for the hazard analysis (e.g. blade throw analysis) as listed in the table below. These are consistent with the values adopted in the EIS [1].

Table 5 Wind Turbine Generators

Dimension or Operating Parameter	Range	Data Selected for Hazard Analysis
Rotor Diameter	155 to 170 m	170 m
Blade Length	77.5 to 85 m	83.5 m (Assuming 3 m rotor diameter)
Tower / Hub Height	115 to 151 m	145 m (Based on tip height and rotor diameter)
Tip Height	192.5 to 230 m	230 m AGL
Start up wind speed	3 m/s	3 m/s
Shut down wind speed	25 to 27 m/s	27 m/s
Rotational speed	8.83 to 12.1 rpm	12.1 rpm (Nominal) and 24.2 rpm (Emergency)

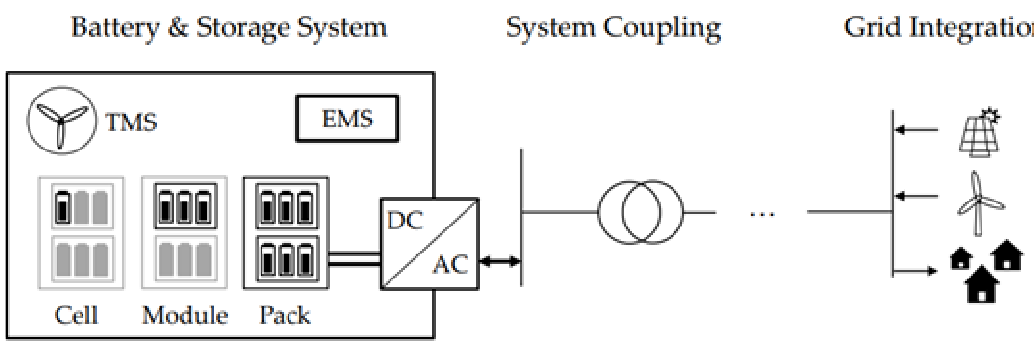
3.2 Battery Energy Storage System (BESS)

A Battery Energy Storage System (BESS) is an advanced technology developed for storing the electricity generated by solar or wind power by using specially developed batteries.

The BESS includes battery cells, assembled into modules and packs, and stored in cabinets inside buildings or containers (ISO containers) in the open. The DC electricity from the packs are fed through energy converters (inverters) to convert to AC, voltage boosted through power transformers and fed to the power grid.

A schematic of an example BESS is shown in Figure 13 [14].

Figure 13 Schematic of Example Battery Energy Storage System



3.2.1 Lithium-Ion Battery

The most common BESS consists of an array of lithium-ion batteries (LIB). There are different LIBs, but they all use the technology of transferring lithium ion between an anode and cathode. The anode is mainly carbon, due to its cost effectiveness and higher energy density. The differences are in the cathodes.

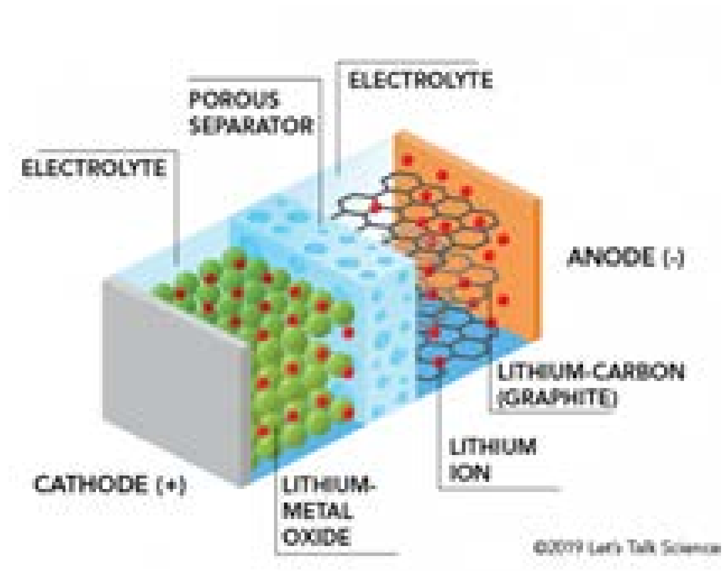
The cathode accepts lithium ions during discharge and releases them during the charge cycle. The cathode consists of metal oxides such as Nickel-Manganese -Cobalt oxide (NMC), Lithium-Iron Phosphate (LFP) and Lithium Oxide (LTO) [14], [15].

The electrolyte is typically composed of an organic solvent and a lithium-based salt, commonly Lithium Fluorophosphate (LiPF6). In between the anode and cathode is a polymer membrane separator.

Because of the mixture of a range of chemicals, a decomposition reaction from overheating of the cell can result in the evolution of flammable and toxic gases. Ignition of these gases can result in a battery fire or explosion in the confined volume.

A typical example cell is shown in Figure 14 [16].

Figure 14 Typical Example Lithium-Ion Cell



3.2.2 Battery Storage

Multiple cells are typically assembled into a module by connecting them in series and parallel arrangements. The modules are stacked and interconnected in a battery rack. The racks are stored in a cabinet for small installations and containerised storage for large installations. Depending on the capacity of BESS, a number of containers can be stored.

The wind farm BESS can consist of a number of storage containers. A facility operating in South Australia with a capacity similar to the proposed development is shown in Figure 15 [17].

Figure 15 Typical BESS and Wind Farm

The cross section of an example BESS container is shown in Figure 16 [15]. The container itself is an ISO shipping container, 20’ or 40’ long.

Figure 16 Typical BESS Container

The container is typically modified for the following purposes:

- Cable penetrations.
- Fire protection system/s.
- HVAC installation.
- Strengthening of the walls for blast protection, where required.

The batteries are stacked and connected to the Battery Management System (BMS). The BMS is typically designed with a range of safeguards, such as:

- Prevention of overcharging and current surges.
- Maintaining voltage levels.
- System trip in the event of electrical shorts or overheating.
- A HVAC system maintaining the container temperature within safe operating limits.

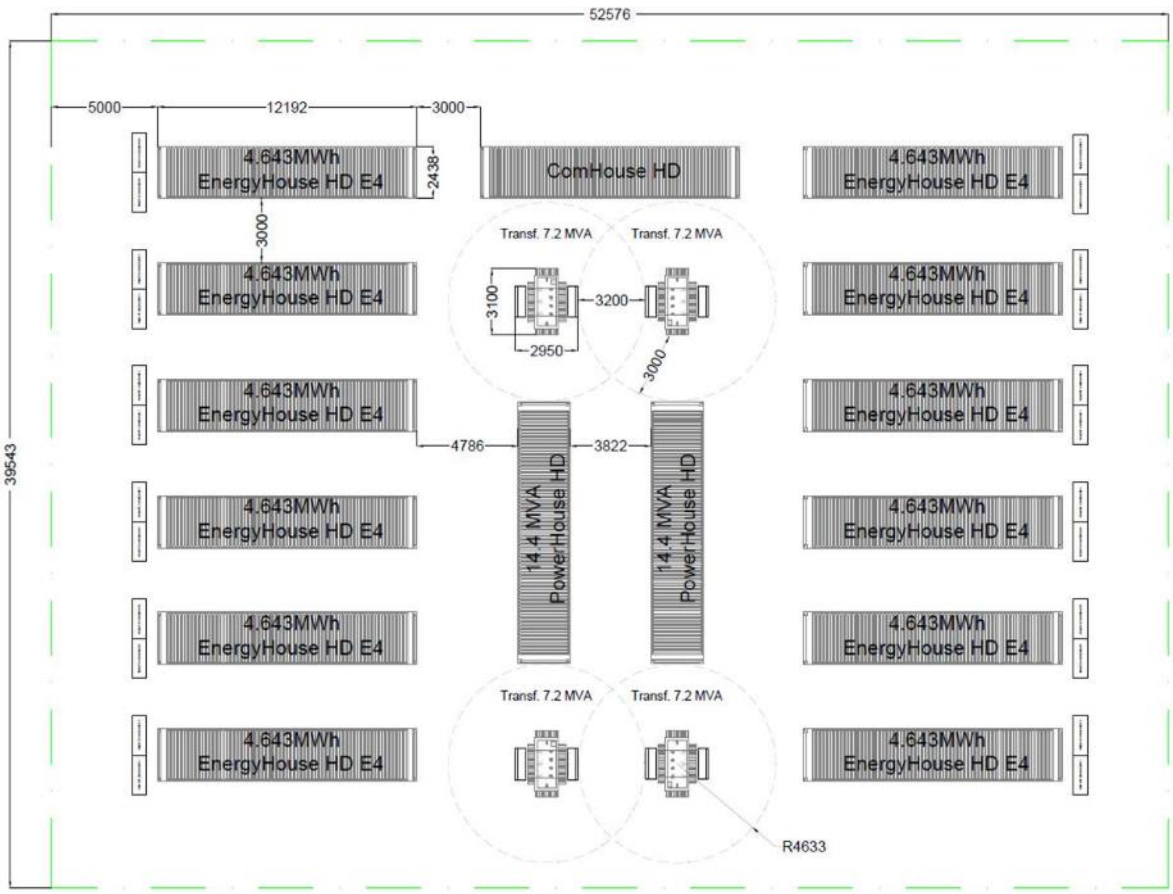
Each BESS container will be equipped with gas (<4% of LFL for hydrogen and <25% of LFL for all toxic and flammable gases) and fire (smoke / flame) detectors and a gaseous fire suppression and water deluge system. The gas detectors are installed as follows:

- Each gas detector is installed in at least two different locations.
- An alarm is sent to a control room with someone permanently present.
- Both visual and audible alarms are provided on the container.
- Hydrogen and methane detectors are located on the ceiling.
- CO detectors are located at potential exposure height (c. 1.5 m).

3.2.3 BESS Arrangement Considered for Study

The detailed design of the BESS is unavailable at this time. A configuration similar to the following is assumed for the PHA [18].

Figure 17 Example BESS Block (25MW/55MWh)



The proposed development will have a capacity of 100 MW providing energy for 4 hours (400 MWh). It will have 8 x 12.5MW/55MWh Blocks, with each block having 10 BESS ‘Energy House’ containers (1.25MW/4.643MWh per BESS container, each with a nominal 1214V DC output).

Note: The 12.5MW/55MWh layout is slightly different to the example 25 MW/55MWh layout shown in Figure 17 – The 12.5MW/55MWh layout excludes two of the 7.2MVA transformers and one of the 14.4MVA Power Houses (i.e. it only includes 10 Battery containers, 1 inverter container and 1 comms container in each block).

It is assumed that each BESS container will have its own Battery Management System (BMS) and HVAC system and that the BESS will be monitored by a SCADA system with remote monitoring facility.

It is assumed there will be two power transformers feeding the grid at 330 kV, which will be located in the substation (refer to Section 3.3).

3.2.4 HVAC System

Maintaining the temperature within limits is critical to the safety of the operations and this is typically achieved by dedicated HVAC system for each container and controlled by the BMS.

It is assumed that the BMS can shut down the BESS if the temperature limits are exceeded.

3.3 Substation

It is proposed that a new 33 kV/330 kV substation compound will be constructed onsite with approximate dimensions of 70 m by 160 m. The primary purpose of the substation will be the reception, transformation and transmission of electrical power and energy. The electrical substation will house transformers, switch gear, and ancillary equipment for the transformation and distribution of energy.

The transformers and radiators in the electrical substation will be located on foundations and will be surrounded by concrete bunds and/or collection sumps designed with sufficient capacity to retain 110% of the oil contained within each transformer [1].

It assumed that fire detection and protection in this area will be to Australian Standards.

3.4 Permanent Operations and Maintenance (O&M) Facility

A permanent site operations and maintenance facility (O&M), approximately 120 m by 220 m will be constructed to provide for all operations and maintenance activities associated with the Project.

Car parking facilities will also be provided for employee and service vehicles.

During operations, up to approximately 31 permanent staff will occupy these premises. Whilst most activity is anticipated to occur during business hours, access to the Project Area will be required on a 24-hour basis, seven days a week.

Normal facility working hours are stated to be 7am to 6pm, 6 days per week [19].

It is assumed this facility will meet the Building Code of Australia.

3.5 Fire Protection System

The following fire protection is reported in the EIS [1]:

- Page 47 *"The major components of the BESS will be batteries, inverters, transformers, heating ventilation air conditioning and fire protection."*
- Page 273 *"Maintenance staff will be trained in the basic first response firefighting techniques."*
- Page 273 *"Firefighting equipment will be provided and maintained capable of controlling and suppressing small initial outbreaks of fire. As a minimum, these will be located on the outside of the switching station, substation, BESS and O&M buildings."*
- Page 274 "*activation of water spray/foam systems and any other response/protection measures".*
- Page 274 *"Water supply will be designed to provide filling points for fire tanker units near the windfarm entrance. A storage of 50,000 litres is recommended, based on refilling six tanker units (4,000 litres) twice each although the required capacity will be confirmed in consultation with RFS."*
- Appendix L SEPP 33 Screening Assessment [4] Page 16:
    - *"Ensuring that there are external fire protection systems for the BESS where relevant."* and
    - "*Ensuring that the BESS system is relevant to the appropriate standards (Global and local)."*

It is assumed that the fire protection system will meet the requirements of NFPA 855 [20] (or equivalent - See Appendix A for details).

4 HAZARD IDENTIFICATION

The hazard identification process has utilised the information presented in Appendix L of the EIS [4], and in addition, included additional hazards associated with the wind turbine system and BESS.

4.1 Wind Turbine Hazards

The hazards associated with the wind turbines include:

- Blade installation coming loose, and blade throw during operation causing damage to receptor infrastructure and serious harm to exposed people.
- Tower or nacelle collapse.
- Ice formation on the blades during winter months and subsequent melting of ice resulting in ice throw damage to receptors and serious harm to exposed people.
- Working at height hazards for maintenance and inspection work on the turbines.
- Turbine fires.

4.2 BESS Hazards

Lithium ion batteries are classified as a Class 9 dangerous good (UN No. 3480). The main hazards are [21]:

- Overheating with toxic gas generation and emission to atmosphere and potential exposure to toxic gases such as Carbon Monoxide (CO), Hydrogen Chloride (HCl), Hydrogen Fluoride (HF).
- Overheating with flammable gas generation within the container (CO, Hydrogen, hydrocarbons such as Benzene, Ethylene), ignition and explosion within the container, and potential for escalation to adjacent containers.
- Fire in Lithium-ion battery, escalating into the packs in the container, with potential for escalation to adjacent containers.

4.3 Electrical Hazards

- Power converter fire and explosion.
- High voltage transformer fire/ explosion, and potential for escalation.
- Electrical fire in sub-station (arcing etc.).
- Contact with electricity.

4.4 Other Hazards

Other hazards identified in the EIS include:

- Vehicle interaction with infrastructure.
- Electromagnetic radiation from high voltage sources.
- Natural hazards (earth tremor, adverse weather, bush fires).
- Dangerous goods storage and handling.

4.5 Hazard Register

A hazard identification register has been compiled, outlining the consequences of the identified hazards and the safeguards provided in the design towards prevention and mitigation. This register provided in Table 6.

Table 6 Hazard Identification and Safeguards Summary

No.	Hazard Scenario	Causes	Consequence	Identified / Recommended Safeguards
I	**Wind Turbine Hazards**			
1.	Blade throw – turbine blade detaches from the rotor and flung like a projectile	- Incorrect installation - Corrosion - Vibration - Environmental forces	- Damage to receptor structure - Fatality if strikes people - Impact can occur at distances up to c. 1.2 km (refer to Section 5.1.1.1)	• Installation QA • Corrosion resistant material • Vibration monitoring • Inspection and maintenance
2.	Ice throw	- Ice formation during still conditions at low ambient temperatures, thawing as temperature rises	- Fatality if strikes people - Impact can occur at distances up to c. 475 m (refer to Section 5.1.3)	• Separation distance to occupied buildings and people • Risk management plan for accessing potential ice throw area during icing conditions
3	Fire	- Overheating - Friction	- Serious harm if fire occurs during maintenance	• Regular lubrication • Inspection of electrical component integrity
3	Occupational hazards	- Fall from height during turbine inspection and maintenance - Confined space hazards	- Injury/ potential fatality	• Fall protection. • Confined space entry training • Competency training • Permit to work and isolation system • Job safety analysis
II	**BESS Hazards**			
4	Battery Fire	- Electrical failures – overcharging/ over discharging - Internal short-circuit - Damaged battery - Battery overheating - Frequent charging and discharging of the battery capacity and degradation of	- Thermal runaway from exothermic reaction - Escalation to other battery packs and modules - Thermal radiation and escalation to adjacent battery container	• Battery inspection and testing during installation • HVAC system to maintain temperatures within operating limits • Adequate spacing between battery packs for HVAC air circulation for heat dissipation • Regular inspection and maintenance regime for the battery assemblies • Installation as per AS/NZS 5139:2019

No.	Hazard Scenario	Causes	Consequence	Identified / Recommended Safeguards
		battery resulting in overheating [22]	- Toxic gas generation (CO, HF, benzene and other flammable gases - Part of the off gases may combust depending on generation rate and oxygen availability, but combustion gases are still toxic (HF, HCl)	• Fire detection and suppression system to prevent the outbreak of fires between battery modules and between containers • Ensuring that there are external fire protection systems for the BESS where relevant
5	Battery Explosion	- Battery overheating and off gases generation that are flammable. - Ignition of off gases within enclose resulting in confined explosion	- Significant damage to the container - Explosion may be followed by fire - Escalation to adjacent containers	• HVAC system for temperature control • Battery Management System (Temperature monitoring and high temperature trip, levelizes charges across battery modules and cells, etc.) • Off gas monitoring and alarm through a CO detector at the ventilation exhaust recommended
III	**Vehicle Interaction**			
6	Vehicle collision with site infrastructure	- Vehicle movements in vicinity of personnel, - Vehicle impact to infrastructure	- Personal injury - Damage to equipment	• Construction management plan that includes standard traffic rules and signage. • Traffic management plan that includes implementation of site speed limits, ensuring driver competency, fencing / bollards and positioning of batteries to minimise vehicle interaction. • Transport of dangerous goods will comply with the requirements of the Australian Code for the Transport of Dangerous Goods by Road and Rail (the ADG Code). • Install bollards/protective barriers around key battery areas and infrastructure.
IV	**Electromagnetic Radiation**			
7	EMF	- EMF generated from BESS, High Voltage Power lines, Grid infrastructure)	- Exposure to EMF and personal injury	• All designs will be in accordance with the Guidelines for limiting exposure to Time varying Electric, Magnetic and Electromagnetic Fields (ICNIRP, 1998; ICNIRP, 2010b) and

No.	Hazard Scenario	Causes	Consequence	Identified / Recommended Safeguards
				relevant codes and industry best practice standards in Australia. • All relevant procedures in relation to a high voltage installation will be adhered to throughout the life of the Project. • The security system for the site, including safety fencing and closure of gates, will be maintained throughout the construction and operation, to provide safe exposure distances to the public. • Restricted access to site and access only to trained personnel. • Refer to Section 13.3 of the EIS for the EMF assessment.
V	**Natural hazards**			
8	Earthquake	- Earthquake	- Personal injury, Wind Farm shut down	• Project infrastructure will be built to relevant construction codes.
9	Lightning	- Lightning	- Personal injury, Wind Farm shut down	• Project infrastructure to be constructed in accordance with electrical standards.
10	Bushfires	- Bushfires	- Personal injury, Wind Farm shut down, - Possible fire	• A Bushfire Emergency Management and Operations Plan will be prepared in consultation with the RFS. This plan will include but is not limited to the following aspects: - Management of activities with a risk of fire ignition. - Management of fuel loads onsite. - Storage and maintenance of firefighting equipment, including siting and provision of adequate water supplies. • Respond to the requirements of the '*Planning for Bush Fire Projection 2018*' regulation, including: - Implementing APZ setbacks to mitigate external fire hazards, as well as mitigation of propagation of external fires to outside the Project boundary.
11	External fire (adjacent to site)	- Fire or explosion from adjacent land users	- Asset damage, Wind Farm shut down, Personal injury	

No.	Hazard Scenario	Causes	Consequence	Identified / Recommended Safeguards
				- Implementing increased APZs for the BESS system, substation and switching station, and positioning outside of the flame throw distance, as detailed in the bushfire assessment (refer Appendix J). - Providing adequate egress/access to site, including multiple entrances and exits to site. - Emergency evacuation measures - ensuring that site staff and contractors are aware of evacuation measures and emergency procedures. • Operational procedures relating to mitigation and suppression of bush fire relevant to the operation of the Project. • Installation as per AS/NZS 5139:2019. • Ensuring that there are on site fire protection systems to protect exposures. • Design buildings and structures to appropriate codes and standards. • Manage fuel for vehicles and machinery on site to appropriate standards. • Refer to Section 13.4 and Appendix J of the EIS for the bushfire assessment.
VI	**Flammable and Combustible Materials Storage and Handling**			
12	Loss of containment of chemicals, including dangerous goods	- Damaged to chemical containers, spill during transport - Decanting of chemicals	- Environmental impairment - Personal injury	• Construction Environmental Management Plan and Operation Environmental Management Plan including spill containment and management. • Store chemical in line with appropriate Australian standards. • Implement a regular inspection and maintenance schedule for chemical storage areas. • Develop Safe Work Method Statement detailing methods for handling chemicals.

No.	Hazard Scenario	Causes	Consequence	Identified / Recommended Safeguards
				• Provide spill kits to be used for accidental spill cleanup. • Safety Data Sheets (SDS's) available on site and referred to in handing processes. • Provide correct PPE to all staff (as per SDS).
VII	**Electrical Hazards**			
13	Power converter fire/ explosion	- internal failure of a power capacitor - Overvoltage and cables overheated - Overcurrent and cables overheated - Arc fault	- Localised fire damage. - Plant shutdown - Injury if personnel present in the vicinity	• Equipment certified and installed to relevant standards • Inverters tested for compliance with Australian Standard AS 4777.1-2015 • Voltage rating to match maximum open circuit voltage • Overcurrent trip if maximum current exceeded • Quality checks of installation before commissioning
14	Inverter failure	- Reverse polarity of cables, human error	- Electric shock and serious injury/ fatality	• Certified electrician • Quality checks of installation before commissioning
15	Power Transformer Fire	- Coolant leak and ignition - Overheating - Earth leakage	- Localised fire - Injury to personnel in the vicinity - Potential for escalation	• Designed to AS 2374.8:2000 – Power Transformers – Application Guide • Fire protection provided • Separation distance/ fire isolation of transformers
16	Transformer explosion	- Gases generation inside transformer enclosure (hydrogen)	- Overheating of transformer and explosion from overpressure	• Dissolved gas testing (DGA) and nitrogen detection • Relief valve on transformer to vent off gases • High temperature trip
17	Contact with electricity	- Contact with live electrical sources; - Cranes impacting overhead lines; - Hitting underground services; - Overhead services damaged during natural hazards; and	- Personal injury / fatality	• Implement Isolation procedures. • Install fit for purpose electrical systems. • Ensure that installation is carried out by suitably qualified electrical personnel. • Adherence to AS 3000. • Follow underground utility identification protocols, including Dial Before You Dig.

No.	Hazard Scenario	Causes	Consequence	Identified / Recommended Safeguards
		- Security issues with trespassers in contact with electrical lines.		• Contractor management, including: - Sign on/off registers. - Ensuring familiarity with site WHS procedures. - Appropriate permit to work procedures. - Crane height limitations where works are undertaken in the vicinity of overhead power lines – overhead work height limits.
VIII	**Site Security**			
18	Security breach	- Persons seeking theft of property/battery components	- Theft of equipment Personal injury	• Installation of fencing around facility and battery facility separately. • CCTV where practical on critical infrastructure/battery units. • Alarms/locks on battery doors. • Inspections to monitor for potential security concerns.
IX	**Construction Related Hazards**			
19	Construction risks	- General miscellaneous construction risks	- Personal injury / fatality	• Implement a Workplace Health and Safety (WHS) plan. • Conduct a detailed Safety in Design processes during project execution.
20	Transport and delivery (manual handling)	- Personnel injury though manual handling of equipment during operations	- Personal injury	• Adhere to requirement of a WHS plan and the ADG code. • Ensure batteries have specific equipment handling advice where appropriate for staff.

Only the hazards that could potentially result in an impact at an occupied area (e.g. O&M building, associated dwellings) and/or on-site infrastructure (e.g. BESS and Substation), and those hazards that may impact on emergency service providers, are analysed in detail in Section 5.

5 RISK ANALYSIS

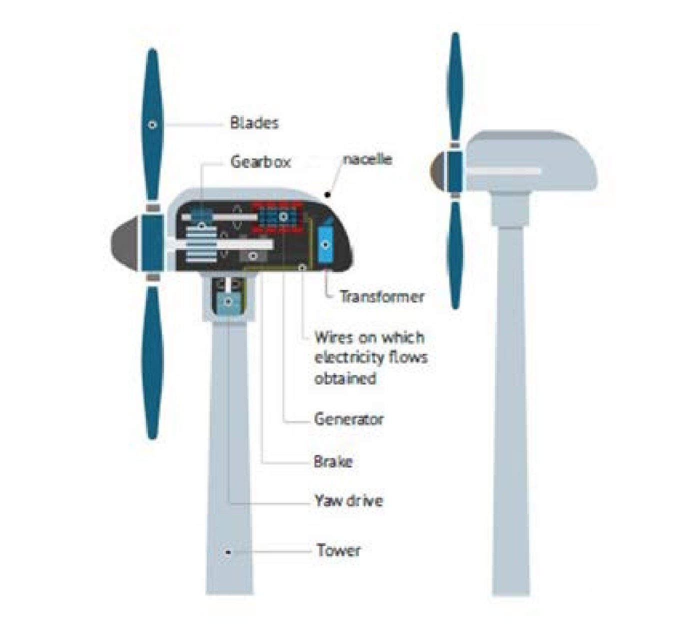
5.1 Wind Turbine Hazards

5.1.1 Blade Throw, Tower Collapse or Nacelle Collapse

The main wind turbine subassemblies and components are shown in Figure 18. There are three main points of failure that can result in an impact hazard:

- Detachment of a blade.
- Collapse of the supporting tower.
- Collapse of the nacelle (i.e. detachment from the tower).

Figure 18 Wind Turbine Components



Key Assumptions:

- The dimensions and operating parameters for the WTGs are as reported in Table 5.
- The direction of rotation for the blades on the WTGs is anti-clockwise.
- The effects of the wind and air resistance (drag) are not included in the blade throw analysis. This is conservative as drag significantly reduces the maximum potential range of a projectile.
- Blade failure results in a full blade fragment rather than a smaller partial blade fragment (refer to Section 5.1.1.2).

Additional assumptions are included in the following sub-sections.

5.1.1.1 Estimation of Hazard Range and Impact Area

Blade Throw

The lateral throw distance is the driving factor for the maximum extent of the potential risk contours. Neglecting aerodynamics, the maximum range of a projectile may be estimated using following formula [23]:

$$D = \frac{v_T^2 s_{\theta_T} c_{\theta_T} \pm v_T^2 \sqrt{s_{\theta_T}^2 c_{\theta_T}^2 + 2\frac{g}{v_T^2}\left(h - Rc_{\theta_T}\right) c_{\theta_T}^2}}{g}$$

Where: D = Lateral distance (m)

v_T = Initial velocity (m/s)

Θ_T = Initial angle (refer to Figure 19)

$c_{\Theta T}$ = $\sin\Theta_T$

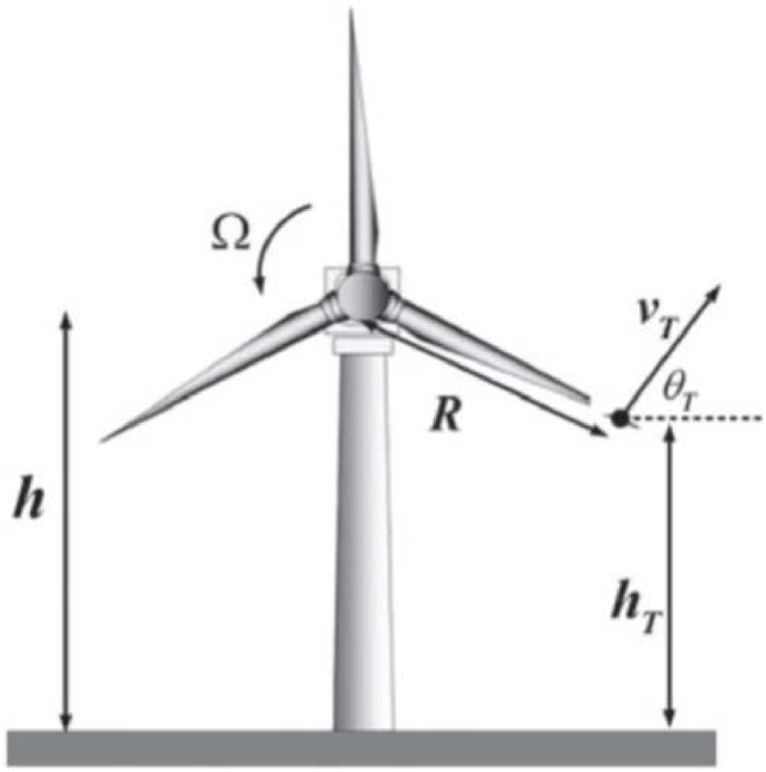
$c_{\Theta T}$ = $\cos\Theta$

g = acceleration due to gravity (m/s^2)

h = Hub height (m)

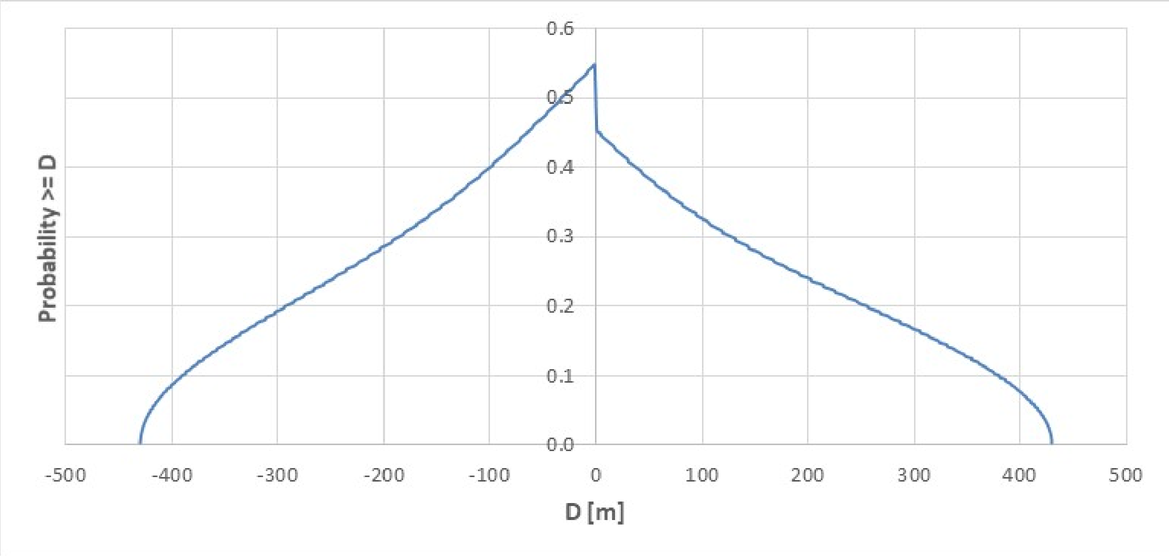
R = Radial distance (m)

Figure 19 Blade Throw Diagram [23]



Using the formula above, and assuming an equal probability of failure at any angle of rotation (i.e. omega divided into one-degree increments), the probability vs. distance distribution for an entire blade fragment (at nominal rpm speed) is shown in Figure 20. A fragment is slightly more likely to impact on one side of turbine than the other and there is a < 10% chance of a blade throw at greater than approximately 380 to 390 m (Note: This increases to approximately 1145 to 1165 m at the higher 'emergency' rpm speed). With inclusion of drag, these maximum distances would be lower.

Figure 20 Example Distance Distribution for Blade Throw at Nominal RPM



The length and width of the potential impact area is assumed to be equivalent to twice the fragment length (i.e. up to 2 x 83.5 m for a full blade – refer to Table 5).

The direction of blade throw is assumed to be perpendicular to the wind direction with the probability of each wind direction factored into the risk calculations (refer to Section 2.5.5 and Section 5.1.1.3).

Tower Collapse

In the event of a collapse at the base of the tower, a person or object may be impacted if located within a distance equal to the tip height of the WTG (i.e. up to 230 m – refer to Table 5). A break in the lower or upper half is assumed to occur at the centre of the corresponding half, which reduces the maximum impact distance.

The width of the potential impact area is assumed to be equivalent to the rotor diameter (i.e. up to 170 m – refer to Table 5).

The direction of collapse is assumed to be in the same direction as the wind with the probability of each wind direction factored into the risk calculations (refer to Section 2.5.5 and Section 5.1.1.3).

Nacelle Collapse

In the event of a nacelle collapse, a person or object may be impacted if located within a distance equal to half the rotor diameter (i.e. up to 85 m – refer to Table 5). This assumes the nacelle collapses at the base of the tower.

The width of the potential impact area is assumed to be equivalent to half the rotor diameter (i.e. up to 85 m for the proposed WTGs – refer to Table 5).

5.1.1.2 Likelihood of Blade Throw, Tower Collapse or Nacelle Collapse

The frequency (per turbine per year) of blade throw, tower collapse or nacelle collapse reported in various sources is summarised in Table 7. The frequency data from the *Handboek Windturbines* (2019) [24] was assumed to apply for the risk analysis as it is the most recent complete data set.

Table 7 Frequency (per turbine per year) of Blade Throw, Tower Collapse or Nacelle Collapse

Failure Case	Braam & Rademakers (2002) [25]	Handboek Risicozonering Windturbines (2002) [26]	Data cited cited in RR968 (2013) [27]							Handboek Risicozonering Windturbines (2014) [28]	Handleiding Omgevingsveiligheid (2019) [29]	Handboek Windturbines (2019) [24]
			Data cited by Larwood (2005)						HSE			
			Solar Energy Research Institute (1979)	Alameda County (2000-2003)	Denmark (1993 to 2004) and Germany (1996 to 2004)	Manufacturers (1989)						
						Netherlands	Denmark	USA				
Tower collapse												
- Break at base	3.2E-04	3.2E-04	-	6.9E-04	-	-	-	-	1.3E-04	1.3E-04	-	1.5E-05
- Break in lower half	-	-	-	-	-	-	-	-	-	-	-	3.5E-05
- Break in upper half	-	-	-	-	-	-	-	-	-	-	-	8.0E-06
Loss of an entire blade	8.4E-04	8.4E-04	-	5.4E-03	3.4E-03	-	-	-	8.4E-04	8.4E-04	8.4E-04	6.2E-04
- Nominal operating rpm	4.2E-04	4.2E-04	-	-	-	-	-	-	-	8.4E-04	8.4E-04	6.2E-04
- Mechanical braking (1.25 x nominal rpm)	4.2E-04	4.2E-04	-	-	-	-	-	-	-	-	-	-
- Emergency (2.0 x nom. rpm)	5.0E-06	5.0E-06	-	-	-	-	-	-	-	5.0E-06	5.0E-06	5.0E-06
Loss of a blade tip	2.6E-04	-	-	-	-	-	-	-	-	-	-	-
Nacelle collapse	1.3E-04	1.3E-04	1.2E-02	-	1.5E-02	2.0E-02	5.0E-03	3.0E-03	3.2E-04	4.0E-05	-	1.8E-05

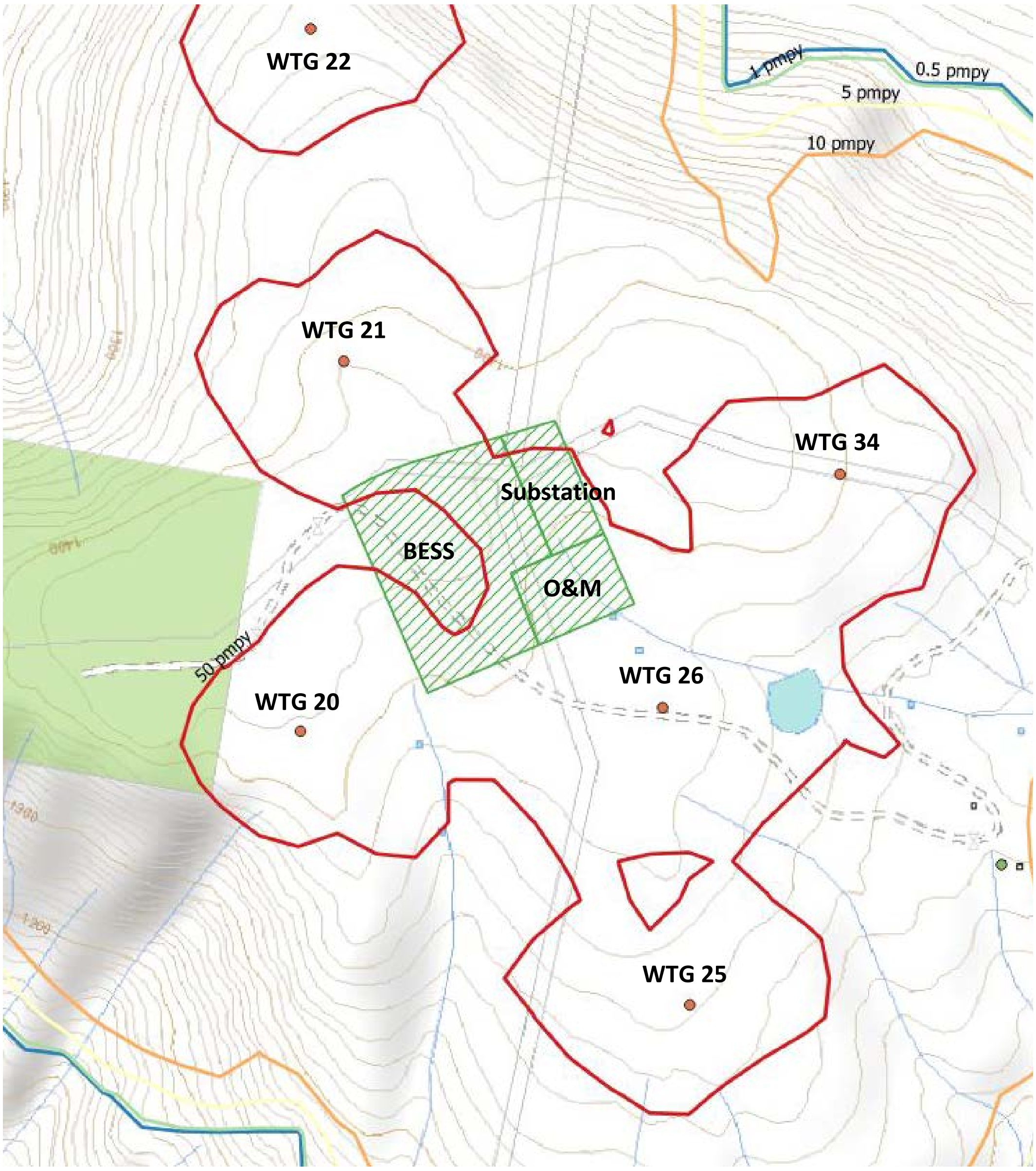
Notes: Nominal operating rpm is regular operation during power production, from the lowest wind speed that the turbine turns on (typically 3–5 m/s) to the highest wind speed that the turbine turns off (typically 22–27 m/s). Braking refers to the condition when the turbine is shutting down, for any reason except an overspeed condition, and emergency refers to a rotor overspeed condition.

Mechanical braking no longer occurs in modern wind turbines. This type of braking used a separate segment of the blade near the tip which could be independently rotated to slow the blade. Modern turbines do not have a separate blade tip and are assembled as a single piece. Therefore, the blade tip scenario is excluded from more recently reported failure rate data and blade breakage during mechanical braking is excluded from the risk analysis.

5.1.1.3 Location-Specific Impact Risk due to Blade Throw, Tower Collapse or Nacelle Collapse

The location-specific risk results presented in Figure 21 and Figure 22 indicate the cumulative risk of potential impact by a thrown blade or a tower or nacelle collapse. Any impact by a blade, tower or nacelle would be fatal; therefore, the risk results presented in Figure 21 and Figure 22 also show the cumulative location-specific individual fatality risk contours.

Figure 21 Cumulative Risk of Impact due to Blade Throw, Tower Collapse or Nacelle Collapse for WTG No. 20, 21, 22, 25, 26 and 34



The maximum cumulative risk of impact due to blade throw, tower collapse or nacelle collapse for WTG No. 20, 21, 22, 25, 26 and 34 is approximately 71.6 pmpy at the centre of the O&M building and approximately 52.2 pmpy at the centre of the BESS.

The contribution to the cumulative risk at the centre of the O&M building and BESS from each turbine is shown in Table 8. The risk values shown are location-specific risk of impact and do not account for the occupancy of personnel.

Table 8 Risk Contribution to Centre of O&M Building and BESS

WTG No.	Risk at Centre of O&M Building		Risk at Centre of BESS	
	Risk [pmpy]	%	Risk [pmpy]	%
20	19.5	27.2	20.2	38.7
21	8.3	11.6	10.4	19.9
22	0.01	0.01	0.01	0.02
25	0.01	0.01	0.01	0.02
26	22.9	32.0	11.0	21.1
34	20.9	29.2	10.6	20.3
Total =	71.6	100.0	52.2	100.0

The BESS (and substation) are not normally occupied areas and normal working hours for the O&M are 7am to 6pm, 6 days per week (i.e. not normally 24 hours – refer to Section 3.4). Therefore, the risk to individual personnel is lower than reported in Table 8 when occupancy is considered.

The DPIE risk criteria for land use safety planning in HIPAP No. 4 do not apply to the O&M building and the BESS (or substation) since these facilities are within the boundary of the proposed development (Note: The DPIE risk criteria also do not apply public roads). However, to comply with Section 2.4.2.1 of HIPAP No. 4, “Individual fatality risk levels for industrial sites at levels of 50 in a million per year (50 x 10-6 per year) should, as a target, be contained within the boundaries of the site where applicable”. Therefore, the risk was estimated at some alternative potential locations for the O&M building (refer to Table 9).

Table 9 Risk of Impact at Alternative O&M Building Locations

Alternative O&M Building Location	Risk of Impact [pmpy] at Centre of Area
Batching / laydown area between turbines 37 and 38	88
Batching / laydown area between turbines 44 and 45	102
Compound between turbines 55 and 56	34

The risk of impact at two of the alternative potential locations for the O&M building is higher than at the O&M building location near the BESS. Whilst there are fewer turbines near these locations, the centre of the relocated O&M building would be closer to a turbine (viz. c. 140 m for turbine 37 and c. 110 m for turbine 45), which results in a higher cumulative risk.

The risk of impact at the centre of the compound located between turbines 55 and 56 (viz. 34 pmpy) is lower than at the O&M building location near the BESS (viz. 71.6 pmpy). If the centre of the O&M building was to be located equidistant between turbines 55 and 56 (i.e. c. 250 m from each), then the risk of impact would be further reduced to c. 15 pmpy.

Figure 22 Cumulative Risk of Impact due to Blade Throw, Tower Collapse or Nacelle Collapse for WTG No. 60, 61, 62, 64, 65 and 66

The maximum cumulative risk of impact due to blade throw, tower collapse or nacelle collapse for WTG No. 60, 61, 62, 64, 65 and 66 is approximately 0.06 pmpy at the closest residence (AD_5). This is lower than the DPIE risk criterion of 1 pmpy, which applies for residential uses.

5.1.2 Turbine Fire

A fire in the nacelle may occur due to a lightning strike, electrical malfunction, mechanical malfunction, or maintenance. These fires are relatively infrequent, with reported fire frequencies of approximately 1.7×10^{-4} fires per turbine per year [30] to 5.8×10^{-4} fires per turbine per year [31]. Some example fires are described in the European Confederation of Fire Protection Associations (CFPA) *Wind Turbines Fire Protection Guidelines* [32] and Appendix J of the EIS [30].

A fire in the nacelle may be difficult to extinguish due to its height AGL and can lead to a secondary fire on the ground (due to falling burning components, such as parts of the blade). Bush fire risks due to a turbine fire are addressed separately in the *Bushfire Risk Assessment* (Appendix J of the EIS [30]).

The falling burning components pose a potential hazard to people and a potential escalation hazard (e.g. if this burning debris were to fall into the BESS area).

5.1.3 Ice Throw

The maximum distance for ice throw for an operating wind turbine can be estimated with the following empirical formula [33]:

$$dt = 1.5 * (D + H)$$

Where: dt = Maximum throwing distance (m)

D = Rotor diameter (m)

H = Hub height (m)

This formula is widely accepted as being conservative (i.e. Ice throw will remain within this zone) [10] and is typically used as the maximum ice throw distance for screening purposes. Measurements of collected ice particles confirm the conservatism of this formula, for example:

- Bredesen reports that ice pieces have been found at 68% of the maximum throw distance [34].
- An analysis of 1000 collected ice particles for wind farms located in the Jura Mountains (Switzerland) indicated that all landed within 1.4 x tip height, with only 3% located further than the tip height [35].
- An analysis of 530 collected ice particles from three wind farms in Sweden indicated that 75% landed at 20 to 90 m, with almost all particles located within 1 x tip height [36].

The maximum falling distance for a non-operating (i.e. stationary) wind turbine can be established with the following empirical formula [33]:

$$df = (H+D/2) * V/15$$

Where: df = Maximum falling distance (m)

D = Rotor diameter (m)

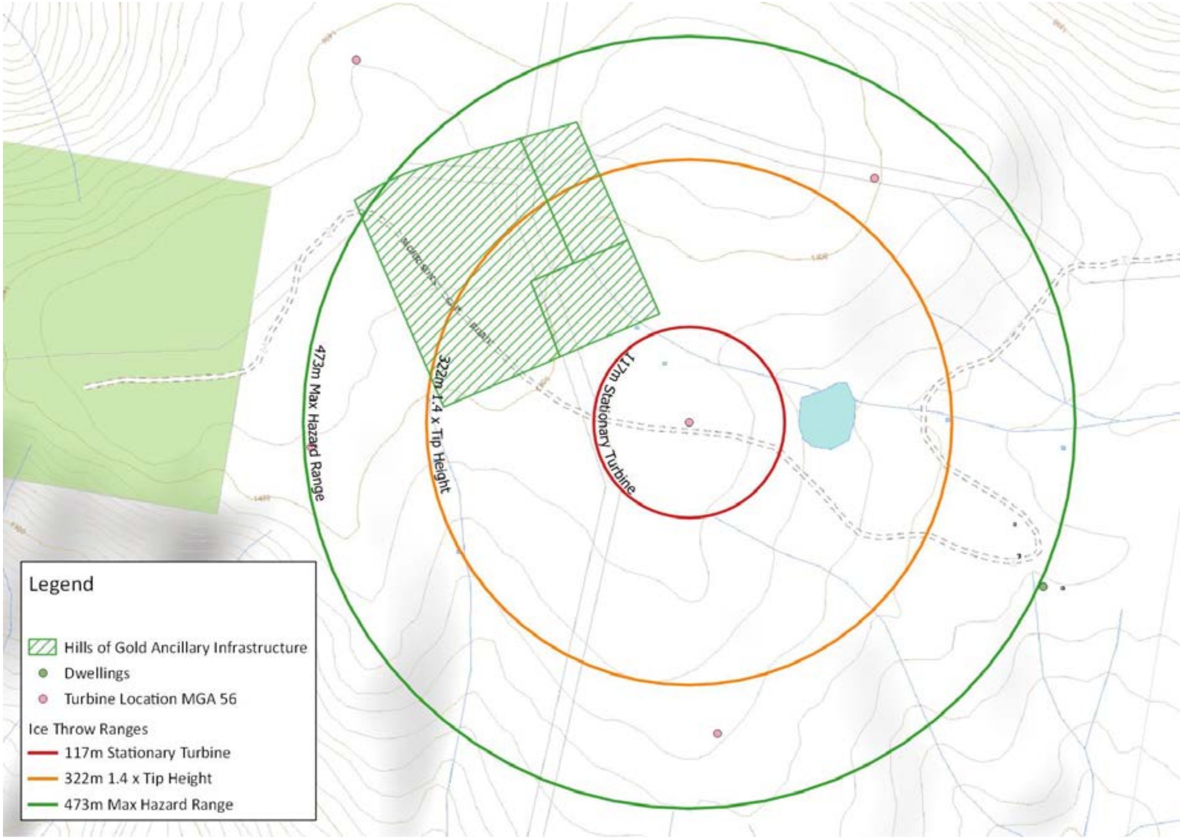
H = Hub height (m)

V = Wind speeds at the hub height (m/s). For the Mast Nundle M2 (WMT2) measurement system, the average wind speed at the hub height is approximately 7.6 m/s.

Table 10 Estimation of Ice Throw Hazard Range

Combined Height of Blade and Tower [m AGL]	Rotor Diameter, D [m]	Hub Height, H [m]	Max. Ice Throw Distance, dt [m]	68% of Max. Ice Throw Distance [m]	1.4 x Tip Height [m]	Ice Drop from Stopped Turbine, df [m] @7.6 m/s WS
230	170	145	473	321	322	117

Figure 23 Example Ice Throw Hazard Ranges for WTG No. 25



The maximum ice throw hazard range (473 m) is significantly less than the distance to the closest residence (viz. c. 765 m to AD_5). However, ice throw may pose a hazard for personnel at the O&M building, BESS and substation. It may also pose a potential hazard when driving along roads or accessing the WTGs during icing conditions.

The three proposed alternative locations for the O&M building (refer to Section 5.1.1.3) are closer (viz. c. 140 m for turbine 37, c. 110 m for turbine 45 and c. 177 m for turbine 56) than the distance from turbine 26 to the centre of the O&M building near the BESS (viz. 192 m). However, if the centre of the O&M building were to be located towards the eastern end of the compound between turbines 55 and 56 (or better still equidistant c. 250 m from each turbine), then the risk of impact from ice throw would be lower than for the centre of the O&M building near the BESS.

5.2 BESS Hazards

5.2.1 Battery Fires

The causes of battery fires are outlined in Table 6. This section described fire modelling of a battery storage fire and its consequences.

There is no established methodology for quantitatively assessing fire hazards. Earlier studies were based on the total quantity of electrolyte in the container and treated the fire like other batteries. This had led to unrealistic separation distances [37].

Experiments on a Tesla Battery Pack conducted by Exponent Inc. [37] found the following:

- The propagation of fire within the container is slow when the source of fire was inside the container.
- The smoke is associated with thick white fumes vented through the container vent, with flames of up to 4m in height.
- At the centre of fire, temperatures up to 1100°C were experienced, but outside temperature of container was not significantly higher than the ambient.
- The walls of the container did not fail for a fire that lasted 90 minutes. Many panels were unaffected and could be reused.

The study concluded that separation distances between containers was not required except for access to the end door(s). NFPA has acknowledged that changes to codes may be necessary based on this finding.

Some of the earlier studies on BESS fire assessment [38] have postulated a fire temperature of the panel as 500°C and calculated thermal radiation from a planar surface (battery panel dimensions) to a receiving plane. The distances were quite short, 3m to 4.7 kW/m^2, and 1m to 23 kW/m^2. This approach does not reflect the nature of the battery fires described in the experiment [37].

A battery container fire behaves quite differently whether the container is naturally ventilated or forced ventilated. In more detailed study sponsored by the NFPA in the USA, Hutchison [15] described a battery container fire development with forced ventilation as follows:

(a) Local heating and generation of off gases containing significant flammables.

(b) Ignition of flammables resulting in jet fire of high intensity, but does not last long.

(c) The fire further heats the battery racks and generates more off gases and jet fire.

(d) Thus, the fire is a cyclical phenomenon, alternating between a jet fire and developing fire in target racks.

(e) Not only the decomposing electrolyte, but the battery materials, cables and insulation materials containing plastics also get involved in the fire, as the fire spreads.

(f) Without fire protection, the fire spreads to the whole of the container, whose wall may collapse due to excessive pressure inside, if the ventilation system cannot remove the smoke layer effectively.

(g) In a fully developed fire, the radiating rectangular surface of the container wall can radiate what to the surrounds by heating an adjacent container and generating off gases from the battery rack on the heat receiving container.

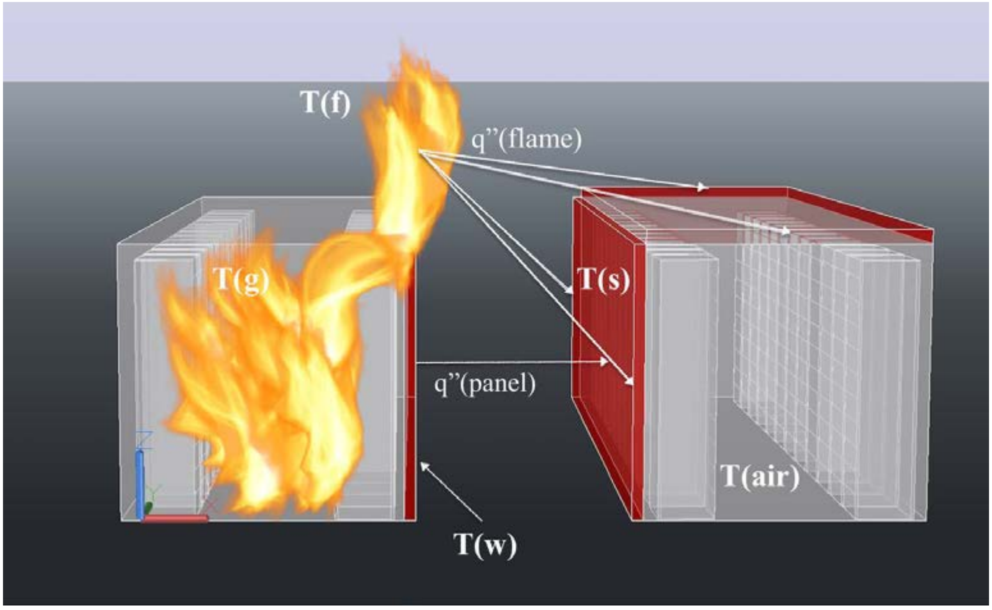
(h) The fully developed fire may be modelled as a surface fire of the whole side wall of the container, radiating with a surface temperature of 500ºC, and high emissivity, similar to a plastic material fire.

(i) With fire protection, the container would remain intact and while the fire gradually abates, the generated gases and combustion products are vented through the ventilation exhaust duct on the roof.

(j) The vent itself can catch fire and the torch fire of ignited flammable gases can radiate high intensity thermal radiation to the surroundings, an additional source of thermal radiation that helps to heat up adjacent container and impact on personnel in the vicinity.

The fire growth is schematically shown in Figure 24, reproduced from [15].

Figure 24 BESS Container Fire Radiation Modelling Schematic



While Figure 24 shows the fully developed fire, it is necessary to take into account the fire protection aspects into account as an integral part of fire modelling, which makes the modelling more complex, but more representative of the fire.

Since the BESS fire modelling is still in the developmental stages, with limited field data and some planned experimental data [37], this study has not quantitatively modelled BESS fires. Instead, based on the available data, it can be concluded that, provided adequate fire protection is provided, including cooling adjacent containers, fire escalation to adjacent containers can be prevented with the proposed separation distance.

Further, it may be concluded that the thermal radiation effects of BESS fires would be confined within the site and there would be no offsite effect. The separation distance between containers also enables approach of the fire by firefighting personnel.

5.2.2 Toxic Gas Exposure

When a battery pack gets overheated, it produces off gases that are flammable and toxic. Typical composition of off gas for NMC battery is listed in Table 11 [21].

Table 11 Off Gas Composition from BESS Overheating

Chemical	Name	% in off gas
CO_2	Carbon Dioxide	25.7
CO	Carbon Monoxide	38.1
CH_4	Methane	9.4
C_2H_6	Ethane	10.5
C_2H_4	Ethylene	4.4
HCl	Hydrogen Chloride	0.8
HF	Hydrogen Fluoride	0.3
HCN	Hydrogen Cyanide	0
C_6H_6	Benzene	5.2
C_7H_8	Toluene	4.1
C_2H_5OH	Ethanol	0.7
CH_3OH	Methanol	0.8
	Total	100
	Molecular weight	36.51

The total flammable gas content is 73.2%. Toxic gas concentration is 39.2% (CO, HCl and HF).

The off gas generation rate is calculated as follows (normalised to 25°C), and using the molecular weight in Table 11:

- Off gas generation rate = [3 L/Ah x 2 Ah/s x (1/000) m^3/s] / [24.44 m3/kg mol] x 36.51 kg/ kmol = 0.0107 kg/s.
- Emission temperature = 75°C.

Gas dispersion calculation were conducted for a generation rate of 0.0107 kg/s emitted through the roof vent, at a height of 3m above ground level, using the gas composition in [21].

The DNV software package PHAST 8.4 was used for dispersion.

Toxic exposures were tracked at the following concentrations for HCl, HF, CO and CO_2. The definitions of ERPG are reproduced from Ref. [39].

- ERPG 2: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.

  Evacuation required as soon as possible. Emergency services to approach with breathing apparatus, as the fire could escalate.

- ERPG 3: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

  Immediate evacuation required. Emergency services to approach with breathing apparatus

The ERPG concentrations are listed in Table 12 [40].

Table 12 ERPG Concentrations for Toxic Components

No.	Component	Symbol	ERPG2, ppm	ERPG3, ppm
1	Hydrogen Chloride	HCl	20	150
2	Hydrogen Fluoride	HF	20	50
3	Carbon Monoxide	CO	350	500

5.2.2.1 Injury Concentrations

The dispersion modelling results are shown in Figure 25, Figure 26 and Figure 27 for HCl, HF and CO, respectively. The injury concentration is taken as the ERPG-3 level, at which a person may experience life-threatening effects if exposed for more than 1 hour.

Figure 25 Dispersion Profile (Side View) for HCl to ERPG-3

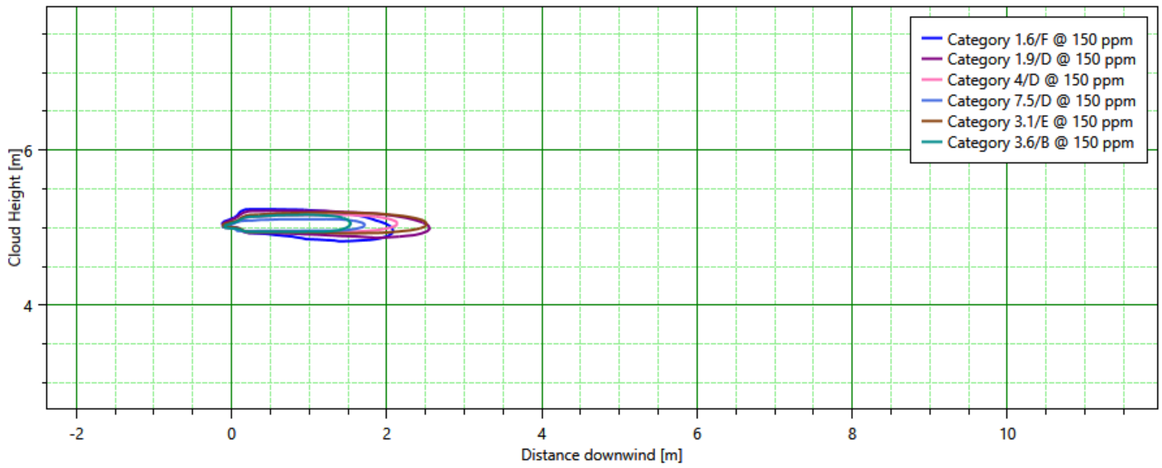


Figure 26 Dispersion Profile (Side View) for HF to ERPG-3

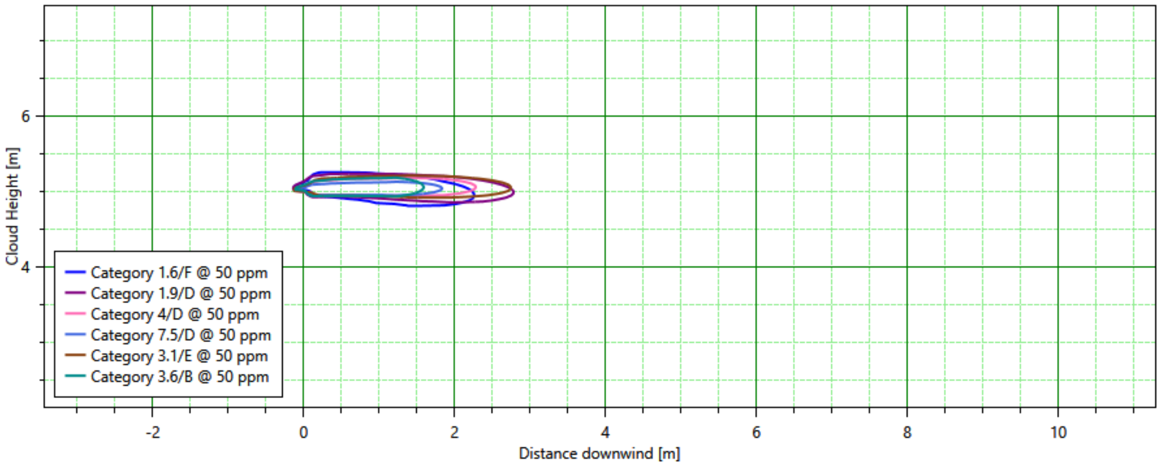
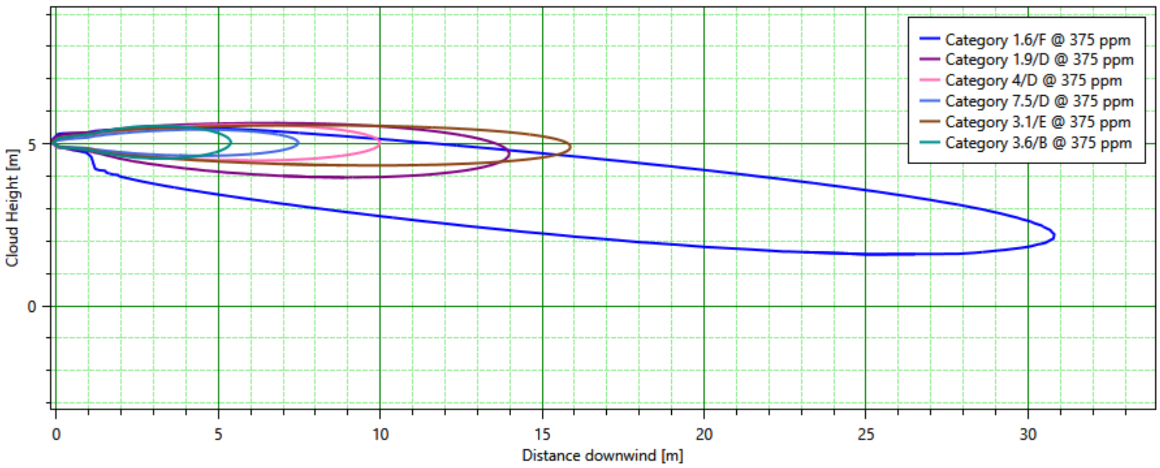


Figure 27 Dispersion Profile (Side View) for CO to ERPG-3



Findings from the dispersion modelling are summarised below:

- For HCl and HF dispersions, the toxic substance stays in the dispersing plume, released 5m above ground level and does not result in injury producing concentrations at ground level.
- For CO dispersion, the maximum distance to a concentration that can produce 0.1% lethal effect is 21-36m from the container vent and this stays within the site boundary. The 0.1% lethality concentration is less than the ERPG3 concentration of 500 ppm, which can occur up to 31m. The distance of 36m from a container is within the site boundary. The concentration, however, does not reach ground levels.
- There is no toxic injury impact to personnel or public from CO, HCl and HF in the emission of off gases.
- Entry into the container for firefighting will require self-contained breathing apparatus to be worn by the fire fighters.

5.2.2.2 Irritation/ Discomfort Concentrations

The toxic concentrations at which a person exposed may experience irritation and discomfort, but not injury effects, are taken as the ERPG-2 levels.

The dispersion modelling results for ERPG-2 levels are shown in Figure 28, Figure 29 and Figure 30 for HCl, HF and CO, respectively.

Figure 28 Dispersion Profile (Side View) for HCl to ERPG-2

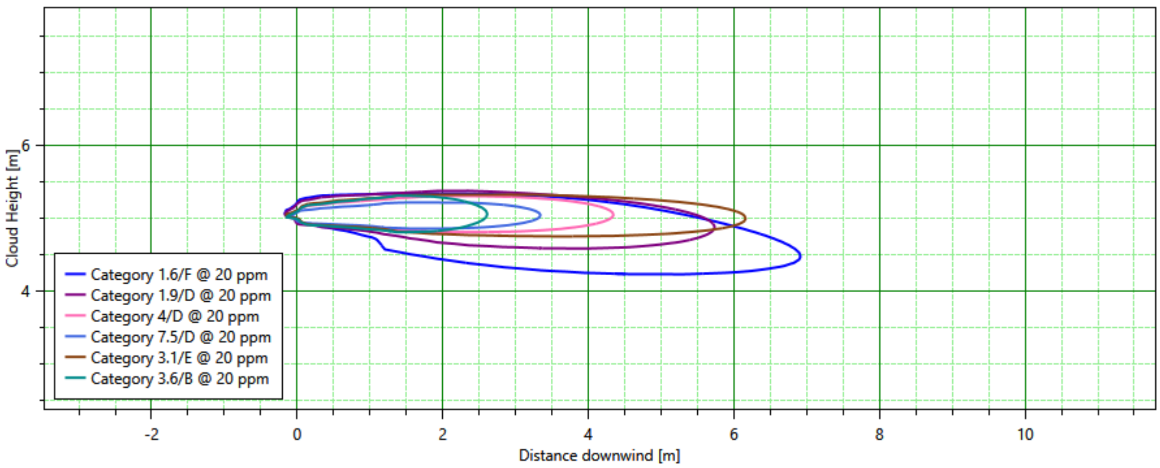


Figure 29 Dispersion Profile (Side View) for HF to ERPG-2

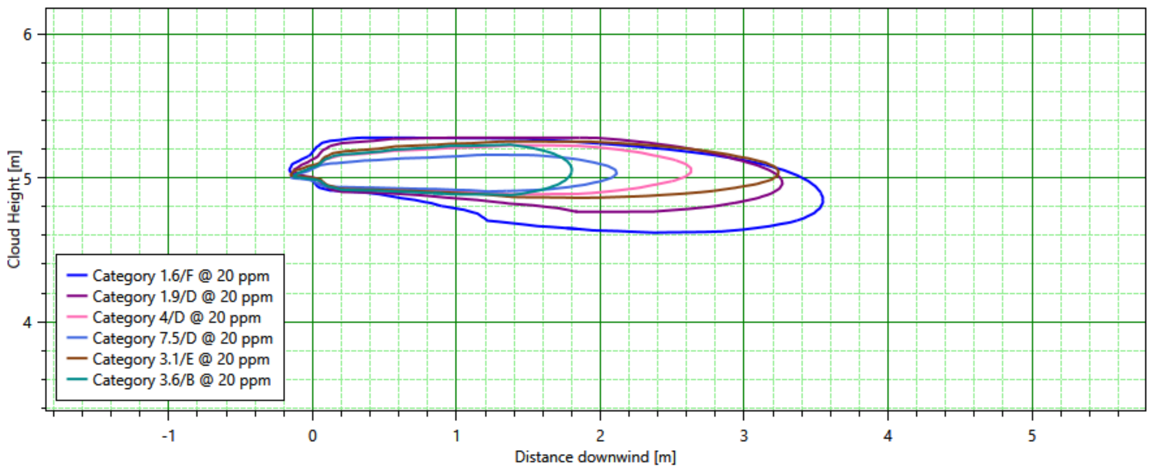
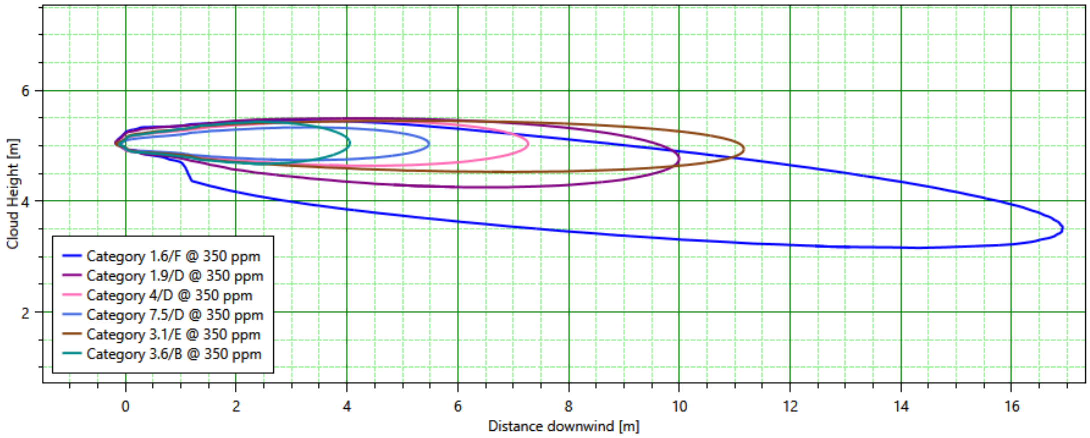


Figure 30 Dispersion Profile (Side View) for CO to ERPG-2



Findings from the dispersion modelling are summarised below:

- Toxic concentrations to ERPG-2 level do not reach ground level.
- Toxic concentrations to ERPG-2 level cover a range of 3-17m and are confined entirely within the site boundary.
- A frequency assessment was not carried out as there is no offsite consequence.

5.2.3 Battery Storage Container Explosion

When a battery pack gets overheated, it produces off gases that are flammable and toxic.

The off gas composition in Table 11 does not show hydrogen. According to Ref. [21], hydrogen evolves as part of the off gases, and gets consumed in the process by the time the gas reaches the sensors and hence H_2 was not reported. A maximum of 30% hydrogen could be present. The DNV study [21] assumed 30% in the off gas and normalised the composition of the measured gas to arrive at the gas composition as it is evolved from the battery pack.

The gas composition adjusted for hydrogen is shown in Table 13.

Table 13 Calculated Off Gas Contents Incorporating Assumed Hydrogen Content of 30%

Chemical	Name	% in off gas
CO_2	Carbon Dioxide	20
CO	Carbon Monoxide	30
CH_4	Methane	8
C_2H_6	Ethane	8
C_2H_4	Ethylene	4
H2	Hydrogen	30
	Total	100
	Molecular weight	22.61

The off gas generation rate is calculated as follows (normalised to 25°C):

- Overheating is assumed to evolve off gases until ignition occurs, after which the gas themselves would be combusted in the flame [41].
- 1.5 racks are assumed to be involved in the overheating, with 18 modules to a rack [41].
- The capacity of a module is 115-175 Ah (Ampere-hours) [21]. An average of 150 Ah/module was taken.
  - Thus, the capacity emitting off gases = [1.5 racks x 18 module/ rack x 150 Ah/module] /1800 s = 2 Ah/s.
- Volume of off gases = 3 L/Ah [21].
- Thus, off gas generation rate = [3 L/Ah x 2 Ah/s x (1/000) m^3/s] / [24.44 m3/kg mol] x 22.51 kg/ kmol = 6.61E-03 kg/s.

5.2.3.1 Flammable Concentration in Container

The lower flammability limit (LFL) of the gas mixture in the container is calculated using the Le Chatelier principle as follows:

Table 14 Calculation of Lower Flammability Limit of Off Gas Mixture

Gas	LFL,%	UFL,%	% in off gas
CO_2	-	-	20
CO	12	75	30
CH_4	4.4	16.4	8
C_2H_6	3	12.4	8
C_2H_4	2.75	28.6	4
H2	4	75	30
Molecular weight			22.61
Molecular weight (flammables alone)			17.3

$$LFL_{mixture} = \frac{\sum y_i}{\sum \frac{y_i}{LFL_i}}$$

Where yi = mole fraction of component 'I' and $LFL_{i\,i}$s the lower flammability limit (volume fraction) of component 'I'.

Therefore, LFL = 0.8/[1/(0.12/0.3+0.08/0.044+0.08/0.03+0.3/0.04)] = 0.0502, or (flammables alone)

On mass basis, LFL mixture = 0.0303 kg/m^3

Container volume = 12.2m x 2.62m x 2.44m = 77.93 m^3.

Free volume in container (i.e. volume not occupied by battery modules) = 25% (19.48 m^3).

Flammables concentration in container is calculated as follows:

$$V\,dc/dt = v.\,c_0 - v.\,c + w$$

Where V = free volume in container; c = concentration in container kg/m^3; v = HVAC flow rate m^3/s; w = flammable off gas generation rate; and t = time; c_0 = concentration in incoming air = 0.

v can also be expressed as an air change rate per hour (ACH) = v/V x 3600

Solving, c =(w/v) [1- exp(-v.t/V)].

Steady state concentration in the container = w/v.

A sensitivity analysis for various ACH values gave the results shown in Table 15.

Table 15 Flammable Gas Concentrations in Container for Various ACH

No.	ACH	v, m^3/s	C (steady state) = w/v kg/m^3	LFL mixture kg/m^3	Flammable mixture in container?	Time to reach LFL, min
V_{free} = 19.48 m^3;	w =	6.61E-03 kg/s				
1	6	0.032	2.04E-01	3.03E-02	Yes	2.17
2	12	0.065	1.02E-01	3.03E-02	Yes	2.47
3	20	0.108	6.11E-02	3.03E-02	Yes	3.15
4	30	0.162	3.11E-02	3.03E-02	Yes	12.45
5	32	0.173	2.92E-02	3.03E-02	No	Not Reached

If the ACH is < 32, the off gas mixture in the container can be still flammable and an ignition may result in an explosion.

For ACH 32 and higher, an explosion can be averted.

If HVAC fails, any off gas would quickly accumulate and result in an explosion if ignited.

It is desirable to have a CO detector on the ventilation exhaust duct (CO is present whether the gas is ignited or not), and shutdown the BESS charging / discharging if CO is detected. HVAC should be kept on, and alarm if HVAC flow stops. These aspects are covered in the recommendations.

5.2.3.2 Explosion Consequence

If ignition if off gases occurs, at the time of ignition, the total amount of flammable gas present in the container is taken as the stoichiometric mixture (worst case explosion scenario).

The flammable gas concentration in the container at the time of ignition is taken as 0.084 kg/m^3 (the geometric mean of LFL and UFL), and the flammable gas content is 1.64 kg.

The flammable gas concentrations are taken as listed in Table 13.

The explosion overpressures generated by ignition of the gas cloud are calculated using the TNT explosion model in PHAST 8.4.

The explosion overpressures generated are summarised in Table 16.

Table 16 BESS Explosion Results (30% hydrogen in off gas)

Explosion overpressure, kPa	Distance from Container, m	Consequences	Offsite Impact?
7	13.7	Damage to battery pack Injury to personnel on site	No
14	8.3	Damage to battery pack Injury to personnel on site	No
21	Not Reached	Major damage to storage Potential for damage to adjacent container	No
35	Not Reached	Escalation to adjacent BESS container and damage to battery package in adjacent container, propagating to other containers	No

It was found that there would be no offsite impact from a battery storage container explosion. Hence this incident was not carried forward for frequency assessment.

Since an explosion overpressure of 0.21 bar is not reached, there is no explosion-based design distances between containers.

The off gas composition containing 30% hydrogen is an assumption in Ref. [21], but actual measurements have shown much less hydrogen content.

NFPA 855 [20] (Clause 4.4.3.3) specifies a distance of 10 ft (3.05m) between containers and fire rating of the containers, provided the BESS container has a 2-hour fire resistance, or there is a freestanding 1 hour fire barrier extending 5 ft above and 5 ft beyond the physical BESS container. The NFPA requirement is recommended in this study.

If a high LFL alarm is raised, then personnel entry into a BESS container is not advisable due to the potential for an explosion.

5.3 Electrical Hazards

5.3.1 Transformer Fire

The BESS produces 1214V DC. This needs to be converted into ultimate grid voltage of 330 kV AC through a series of power transformers.

There are several configurations possible and the optimum configuration will be finalised during detailed design. For sake of the PHA, the following configuration is selected:

BESS (1214 V DC) -> Inverter -> Kiosk Transformers (0.69/33 kV) -> Power transformer (33 to 330 kV)

The main power transformer has a capacity of 225MVA - 33/330 kV. The transformer oil volume in circulation is assumed to be 800 Litres [42]. The oil tank of capacity 12,000 L is located on top of the transformer, which is in a bunded area.

5.3.2 Impairment Criteria

The levels of heat radiation selected to examine the heat effects were 4.7, 12.5, 23, 30, and 37.5 kW/m², as given in HIPAP No.4 [3].

The general effects of these levels of heat radiation are summarised in Table 17. These heat flux radiation effects are widely accepted by industry and is appropriate for this analysis.

Table 17 Heat Radiation Effects

Heat Radiation (kW/m²)	Effect
4.7	Maximum heat radiation level to which fire-fighting personnel may be exposed.
12.5	Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure. 30% chance of fatality for long exposure. High chance of injury.
23	Unprotected steel will reach thermal stress temperatures to cause failure. Pressure vessels need to be relieved or failure will occur. 100% chance of fatality for long exposure and 10% chance of fatality for instantaneous exposure.
37.5	100% chance of fatality for instantaneous exposure.

5.3.3 Material Modelled

The transformer oil is a mineral oil, comprising of hydro-treated light naphthenic and paraffinic distillates. On this basis, dodecane (C12) was selected as a representative single component material for the consequence modelling.

PHAST 8.4 models both the luminous and smoky part of the flame for calculating thermal radiation impact distances.

5.3.4 Pool Fire Results

The results in the following table represent the maximum ground level impact distance measured from the centre of the bund in a downwind orientation. The flame height represents the length of the flame from the pool surface to the tip of the flame.

Substation layout design details are not available at the stage of the EIS; however, the main power transformers will be protected by firewalls in accordance with Australian Standards.

The heat radiation hazard zones are determined using PHAST 8.4. The bund fire was modelled as a circular pool with an equivalent area to that of the area of the rectangular bund (equivalent 8m diameter).

Table 18 Transformer Bund Pool Fire Heat Radiation Impact Distances

Stability Class /Wind Speed	Maximum Surface Emissive Power (kW/m^2)	Pool Diameter (m)	Flame Height (m)	Wind Tilt (deg)	Distance to heat radiation kW/m^2 (m)			
					4.7	12.6	23	35
D 1.9	86.4	8	11.8	30.6	22.5	15.3	11.1	7.8
D 4	86.4	8	11.8	34.9	23.4	16.6	13.0	8.8
D 7.5	86.4	8	11.8	58.9	23.5	17.8	14.5	9.4

*pool fire diameter based on the equivalent diameter of the bund.

The thermal radiation impacts from transformer fires are confined within the site boundary with no potentially injurious offsite effects. The separation distances between transformers and to protected works on site is specified in AS-2067 (2016).

From fire hydrants available, the fire can be fought with fire water and foam.

It is necessary that that all bund penetrations, including conduits, are sealed with a suitable fire-resistant packing or sealant.

6 STANDARDS APPLICABLE TO BESS

Several Australian and International standards exist or are in development for battery energy storage systems. The relevance of each standard to the Winds of Gold Wind Farm BESS is discussed below.

6.1 NFPA 855: Standard for the Installation of Stationary Energy Storage Systems

The purpose of this standard [20] is to provide the minimum requirements for mitigating the hazards associated with stationary energy storage systems.

6.2 AS/NZS 5139: Electrical Installations - Safety of Battery Systems for use with Power Conversion Equipment

This standard [43] only applies if "each individual BESS is no more than 200 kWh". Current advice is that each individual BESS unit will be 4.643 MWh. Therefore AS/NZS 5139 is not applicable.

6.3 IEC 62897: ED1 Stationary Energy Storage Systems with Lithium Batteries - Safety Requirements

This standard is still under development, and therefore not applicable.

6.4 IEC 62933 Series

This standard [44] is currently under development, with the following sections published:

- IEC 62933-1:2018, Electrical energy storage (ESS) systems – Part 1: Vocabulary

  Defines terms applicable to electrical energy storage (EES) systems including terms necessary for the definition of unit parameters, test methods, planning, installation, safety and environmental issues.

  This terminology document is applicable to grid-connected systems able to extract electrical energy from an electric power system, store it internally, and inject electrical power to an electric power system. The step for charging and discharging an EES system may comprise an energy conversion.

- IEC 62933-2-1:2017, Electrical energy storage (ESS) systems – Part 2-1: Unit parameters and testing methods – General specification

  Focuses on unit parameters and testing methods of EES systems. The energy storage devices and technologies are outside the scope of this document. This document deals with EES system performance defining:

  - unit parameters,
  - testing methods.

- IEC TS 62933-3-1:2018, Electrical energy storage (ESS) systems – Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification

  Is applicable to EES systems designed for grid-connected indoor or outdoor installation and operation. This document considers:

  - necessary functions and capabilities of EES systems

- test items and performance assessment methods for EES systems
- requirements for monitoring and acquisition of EES system operating parameters
- exchange of system information and control capabilities required.

- IEC TS 62933-4-1:2017, Electrical energy storage (ESS) systems – Part 4-1: Guidance on environmental issues – General specification

  Describes environmental issues associated with electrical energy storage systems (EES systems), and presents guidelines to address the environmental impacts to and from EES systems including the impacts to humans due to chronic exposure associated with the mentioned environmental impacts.

- IEC TS 62933-5-1:2017, Electrical energy storage (ESS) systems – Part 5-2: Safety requirements for grid integrated ESS systems – electrochemical based systems

  Specifies safety considerations (e.g. hazards identification, risk assessment, risk mitigation) applicable to EES systems integrated with the electrical grid.

  This document provides criteria to foster the safe application and use of electric energy storage systems of any type or size intended for grid-integrated applications.

- IEC 62933-5-2:2020, Electrical energy storage (ESS) systems – Part 5-2: Safety requirements for grid integrated ESS systems – electrochemical based systems

  Primarily describes safety aspects for people and, where appropriate, safety matters related to the surroundings and living beings for grid-connected energy storage systems where an electrochemical storage subsystem is used.

6.5 UL 9540: Energy Storage System (ESS) Requirements

These requirements [45] cover energy storage systems that are intended to receive and store energy in some form so that the energy storage system can provide electrical energy to loads or to the local/area electric power system (EPS) when needed. The types of energy storage covered under this standard include electrochemical, chemical, mechanical, and thermal. This standard is covered/referred to by NFPA 855.

6.6 UL 9540A: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

This standard [46] is a test method for BESS fires, and is covered/referred to by NFPA 855.

6.7 FM Global Property Loss Prevention Data Sheet 5-33: Electrical Energy Storage Systems

This data sheet [47] describes loss prevention recommendations for the design, operation, protection, inspection, maintenance, and testing of electrical energy storage systems (ESS) that use lithium-ion batteries.

6.8 FM Global's Development of Sprinkler Protection Guidance for Lithium Ion Based Energy Storage Systems

This guidance document [48] is only relevant for commercial occupancies and is not applicable for the Hills of Gold Wind Farm.

6.9 IEEE Std 2030.2.1-2019: Guide for Design, Operation, and Maintenance of Battery Energy Storage Systems, both Stationary and Mobile, and Applications Integrated with Electric Power Systems

IEEE Std 2030.2.1 [49] provides guidance in understanding and defining the general structure of a battery energy storage system, its basic technical characteristics and general applications in an electric system, and how to design the battery system, power conversion system, monitoring, information exchange, and control (MIC) system. Furthermore, the standard also fills the need for guidance key to operating and maintaining a battery energy storage system in its application, including functional performance, optimization especially for batteries, and countermeasures for different emergencies.

6.10 EI Battery Storage Guidance Note 1: Battery Storage Planning

This publication [50] provides guidance covering various aspects of planning a battery storage facility. It provides an overview of battery storage types, planning regulations in the UK, and information on safety issues that should be considered during planning and risk assessments.

The UK planning regulations are not relevant here. The safety issues that should be considered for planning provides useful guidance.

6.11 EI Battery Storage Guidance Note 2: Battery Energy Storage System Fire Planning and Response

This publication [51] provides guidance on how to respond to BESS fires. It represents the 'current state' of knowledge (in 2019), but also identifies gaps in knowledge. The guidance covers primarily non-domestic battery installations, although the guidance may also generally be applicable to smaller, domestic-scale incidents. It provides an overview of the fire risk of common battery chemistries, briefly describes how battery fires behave, and provides guidance on personnel response, managing combustion products, risks to firefighters, pre-fire planning, and fire-aftermath.

Although much of this guidance is generally applicable to other battery chemistry types, this guidance is of particular relevance to fires involving Lithium-ion (Li-ion) chemistries, except where otherwise noted.

This publication provides useful guidance that would be input to an emergency response plan.

6.12 EI Battery Storage Guidance Note 3: Design, Construction and Maintenance

This publication [52] aims to capture learning and experience from battery storage construction projects, with special emphasis on ensuring the safety of such projects to people and environment. Based on industry interviews and available literature, this publication covers a large range of issues that have caused, or can potentially cause, issues during battery storage projects during design, construction, commissioning, or maintenance, including site selection, using containerised solutions, construction, maintenance, and decommissioning. Its purpose is not to provide a 'how to' document on constructing a battery storage system, but rather to share experience and help others to avoid some of the pitfalls that have affected previous projects, helping to avoid safety issues and project delays.

6.13 Summary

All the publications offer useful information on the safety requirements for battery energy storage systems. For the purposes of land use planning safety, NFPA 855 and FM Global DS 5-33 are most applicable.

As an example, an assessment of the Hills of Gold Wind Farm BESS against NFPA 855 has been conducted and the results shown in Appendix A.

7 RISK ASSESSMENT

7.1 Risk Criteria Comparison

The following table details a comparison of the risk analysis with the NSW DPIE Hazardous Industry Planning Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning' [3].

Table 19 Risk Criteria Comparison

Criterion Description	Criterion Value	Risk Assessment	Comment
Individual Fatality Risk Criteria			
Hospitals, schools, child-care facilities, old age housing.	0.5×10^{-6} / year	Complies	Potentially hazardous consequences, and/or fatality risks greater than the corresponding risk criterion value, are not reached at these land uses for hazards associated with the wind turbines (refer to Section 5.1), BESS (refer to Section 5.2) and electrical systems (refer to Section 5.3). Note: Bush fire risks due to a turbine fire are addressed separately in the *Bushfire Risk Assessment* (Appendix J of the EIS [30]).
Residential, hotels, motels, tourist resorts.	1×10^{-6} / year	Complies	
Commercial developments including retail centres, offices, and entertainment centres.	5×10^{-6} / year	Complies	
Sporting complexes and active open space.	10×10^{-6} / year	Complies	
Industrial.	50×10^{-6} / year	Complies	
Injury Risk			
Incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m^2.	50×10^{-6} / year	Complies	Potentially hazardous consequences (viz. >4.7 kW/m^2 or >7 kPa) are not reached at these land uses for fire / explosion hazards associated with the wind turbines (refer to Section 5.1), BESS (refer to Section 5.2) and electrical systems (refer to Section 5.3). Note: Bush fire risks due to a turbine fire are addressed separately in the *Bushfire Risk Assessment* (Appendix J of the EIS [30]).
Incident explosion overpressure at residential and sensitive use areas should not exceed 7 kPa.	50×10^{-6} / year	Complies	

Criterion Description	Criterion Value	Risk Assessment	Comment
Toxic concentrations in residential and sensitive use areas should not exceed a level which would be seriously injurious to sensitive members of the community following a relatively short period of exposure.	10 x 10^{-6} / year	Complies	Potentially hazardous consequences are not reached at these land uses for fire hazards associated with the wind turbines (refer to Section 5.1), BESS (refer to Section 5.2) and electrical systems (refer to Section 5.3). Note: Bush fire risks due to a turbine fire are addressed separately in the *Bushfire Risk Assessment* (Appendix J of the EIS [30]).
Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community.	50 x 10^{-6} / year	Complies	
Risk of Property Damage and Accident Propagation			
Incident heat flux radiation at neighbouring potentially hazardous installations or at land zoned to accommodate such installations should not exceed the 23 kW/m^2 heat flux level.	50 x 10^{-6} / year	Complies	Potentially hazardous consequences (viz. >23 kW/m^2 or >14 kPa) are not reached at these land uses for fire / explosion hazards associated with the wind turbines (refer to Section 5.1), BESS (refer to Section 5.2) and electrical systems (refer to Section 5.3). Note: Bush fire risks due to a turbine fire are addressed separately in the *Bushfire Risk Assessment* (Appendix J of the EIS [30]).
Incident explosion overpressure at neighbouring potentially hazardous installations, at land zoned to accommodate such installations or at nearest public buildings should not exceed the 14 kPa explosion overpressure level.	50 x 10^{-6} / year	Complies	
Societal Fatality Risk	Refer to HIPAP No. 4, Figure 3: 'Indicative Societal Risk Criteria'	Complies	The maximum cumulative risk of impact due to blade throw, tower collapse or nacelle collapse for WTG No. 60, 61, 62, 64, 65 and 66 is approximately 0.06 pmpy at the closest residence (AD_5) (refer to Section 5.1.1.3). This low frequency, combined with the low population density, ensures compliance with the 'Indicative Societal Risk Criteria'.

8 FINDINGS AND RECOMMENDATIONS

8.1 Findings

The key findings of the assessment include:

- The maximum cumulative risk of impact due to blade throw, tower collapse or nacelle collapse for WTG No. 20, 21, 22, 25, 26 and 34 is approximately 71.6 pmpy at the centre of the O&M building and approximately 52.2 pmpy at the centre of the BESS.

  The risk of impact was also estimated at three alternative potential locations for the O&M building. The risk at two of these locations was determined to be higher than 71.6 pmpy; however, the risk of impact at the centre of the compound located between turbines 55 and 56 (viz. 34 pmpy) is lower than at the O&M building location near the BESS (viz. 71.6 pmpy). If the centre of the O&M building were to be located equidistant between turbines 55 and 56 (i.e. c. 250 m from each), then the risk of impact would be further reduced to c. 15 pmpy.

- The potential for ice formation on the wind turbines appears to be credible based on the available meteorological data for the Project Area (refer to Section 2.5.2); however, this is based on an approach that is very conservative and may lead to an over-estimation of the icing duration.

  If sufficient icing were to occur, then ice throw may pose a hazard for personnel at the O&M building (refer to Section 5.1.3). It may also pose a potential hazard when driving along roads or accessing the wind turbines, BESS and substation during icing conditions. Measures to mitigate ice formation on the wind turbines (e.g. anti-icing or de-icing technologies) and/or control access (e.g. ice risk management plan) should be considered to reduce the risk of ice impact 'so far as reasonable practicable'.

  The three proposed alternative locations for the O&M building (refer to Section 5.1.1.3) are closer (viz. c. 140 m for turbine 37, c. 110 m for turbine 45 and c. 177 m for turbine 56) than the distance from turbine 26 to the centre of the O&M building near the BESS (viz. 192 m). However, if the centre of the O&M building were to be located to the eastern end of the compound between turbines 55 and 56 (or better still equidistant c. 250 m from each turbine), then the risk of impact from ice throw would be lower than for the centre of the O&M building near the BESS.

- The maximum cumulative risk of impact due to blade throw, tower collapse or nacelle collapse for WTG No. 60, 61, 62, 64, 65 and 66 is approximately 0.06 pmpy at the closest residence (AD_5). This is lower than the DPIE risk criterion of 1 pmpy, which applies for residential uses and was based on a conservative blade throw analysis (i.e. ignoring drag effects that would reduce the maximum projectile range).

- The thermal radiation, explosion and toxic gas effects of BESS fires would be confined within the site and there would be no potentially injurious offsite effects. The separation distance between containers should enable approach of the fire by firefighting personnel; however, if entry into a container is required for firefighting this will require self-contained breathing apparatus due to the potentially toxic fumes.

- With the separation distances shown on the example BESS block diagram (refer to Figure 17); the total area of the 8 blocks will easily fit within the area identified for the BESS (viz. 8 x blocks = c. 16,600 m^2 , which is significantly less than the area of the BESS, excluding the 20 m setback for the bushfire APZ = c. 40,900 m^2).

- Toxic gas concentrations that produce injury or irritation level are confined entirely within the site boundary, and do not reach ground level.
- If a high level gas alarm is raised, then personnel entry into a BESS container is not advisable due to the potential for an explosion.
- The explosion overpressure may reach up to 14 kPa in areas surrounding a container. At this overpressure, escalation is unlikely, some damage to utilities and cabling may occur. An explosion overpressure of 21 kPa or higher is not reached.
- The thermal radiation impacts from transformer fires are confined within the site boundary with no potentially injurious offsite effects.
- The proposed development complies with the relevant DPIE criteria for land use safety planning (refer to Section 7.1).
- The DPIE risk criteria for land use safety planning in HIPAP No. 4 do not apply to the O&M building, BESS and substation since these facilities are within the boundary of the proposed development. To comply with Section 2.4.2.1 of HIPAP No. 4, "Individual fatality risk levels for industrial sites at levels of 50 in a million per year (50 x 10^{-6} per year) should, as a target, be contained within the boundaries of the site where applicable".

8.2 Recommendations

Recommendations based on the key findings of the assessment include:

1. Relocation of the O&M building should be considered to reduce the potential risk of impact from blade throw, tower collapse or nacelle collapse.

   Note: For the three alternative identified potential locations (refer to Section 5.1.1.3), only the eastern end of the compound located between turbines 55 and 56 (or a location equidistant between turbines 55 and 56) would result in a lower risk than locating the O&M Building near the BESS. The risk due to ice throw would also be lower at this location (refer to Section 5.1.3).

2. Measures to mitigate ice formation on the turbines (e.g. anti-icing or de-icing technologies) and/or control access (e.g. ice risk management plan) should be considered to reduce the risk of ice impact 'so far as reasonable practicable'.
3. A separation distance between BESS containers of 3.05m (10 ft) is recommended, based on the requirements of NFPA 855 [20], as additional separation distances are not warranted by the explosion analysis.
4. Forced ventilation should be installed in the BESS containers (minimum 32 air changes per hour is recommended to prevent flammable mixture formation in the container).
5. An alarm should be installed to indicate loss of ventilation flow through the containers.
6. Installing a CO detector on the ventilation exhaust duct (CO is present whether the gas is ignited or not) should be considered, with shutdown of the BESS charging/ discharging if CO is detected. The HVAC should be kept on, and alarm if HVAC flow stops.
7. Firefighting in a BESS container will require breathing apparatus protection to prevent exposure to potentially lethal toxic fumes.

8. The Emergency Response Plan for the proposed development should address the specific hazards identified in the PHA (e.g. blade throw, nacelle collapse, tower collapse, ice throw, turbine fires, etc.) and ensure emergency response personnel take appropriate precautions to protect themselves and the general public from the immediate hazards and escalating events such as blade throw caused by a turbine fire.

Additional recommendations based on a gap analysis against the recommendations of NFPA 855 are also included in Appendix A.

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APPENDICES

Appendix A Comparison with NFPA 855

An assessment of the Hills of Gold Wind Farm BESS against the relevant sections of NFPA 855 [20] and has been conducted and the results are shown below. This highlights any gaps against this standard, and where further information is required. Only the specific and relevant sections of NFPA 855 [20] are included.

Note that the date of publishing of NFPA 855 was August 25, 2019, and that is labelled the 2020 Edition. The pace of developments in battery energy storage systems and the development of their standards has been proceeding in parallel. Thus, some of the parts of NFPA 855 would not have been known during the development of the Hills of Gold Wind Farm Project.

It is also acknowledged that items such as UL listing of components or systems can take time to complete.

NFPA 855 Paragraph	Potential Gap/s	Comment
4.1.1 ESS Gas Release ESS shall not release toxic or highly toxic gas creating conditions in excess of the permissible exposure limit (PEL) in the room or space in which they are located during normal charging, discharging, and use.	No Gap Identified	BESS containers are air conditioned for operational reasons. Recommendation B1: Confirm HVAC monitoring, alarming and thermal or other trip systems for individual BESS containers. See also NFPA 855 4.2.9.2.
4.1.2 Construction Documents	Not currently applicable	Project is not at construction phase. This section does provide a useful check of the requirements.
4.1.3 Emergency Planning and Training	Not currently applicable	Project is not at construction phase. This section does provide a useful check of the requirements.
4.1.4 Hazard Mitigation Analysis	No Gap Identified	This PHA study meets this requirement.
4.1.5.1 Where required elsewhere in this standard, large scale fire testing in accordance with 4.1.5 shall be conducted on a representative ESS in accordance with UL 9450A or equivalent test standard.	Unknown	The BESS batteries used will be compliant with UL 9450A.
4.2.1 Listings ESS shall be listed in accordance with UL 9450, unless specifically exempted in other sections of this standard.	Unknown	Recommendation B2: Confirm Engie BESS listed with UL 9450.

NFPA 855 Paragraph	Potential Gap/s	Comment
4.2.2 Repairs	Not currently applicable	Project is not at construction phase. This section does provide a useful check of the requirements.
4.2.3 Retrofits	Not currently applicable	Project is not at construction phase. This section does provide a useful check of the requirements.
4.2.4 Replacements	Not applicable	Project is not at construction phase. Any replacements should be evaluated as new ESS's as per this section.
4.2.5 Increase in Power Rating or Maximum Stored Energy	Not currently applicable	It is envisaged that the planning approval would set a maximum stored energy value for the BESS. Any increase would thereby be subject of an amendment or new planning approval.
4.2.6 Environment The temperature, humidity, and other environmental conditions in which an ESS is located shall be maintained in accordance with the listing and the manufacturer's specifications.	Unknown	See recommendations B1 & B2.
4.2.7 Charge Controllers	Unknown	Recommendation B3: Confirm Engie BESS charge controllers are UL 1741 listed or are provided as part of a listed ESS.
4.2.8 Inverters and Converters	Unknown	Recommendation B4: Confirm Engie BESS inverters and converters are UL 1741 listed.
4.2.9 Energy Storage Management System (ESMS)	Unknown	Recommendation B5: Confirm Engie "Energy House" safety, automation systems and Eps energy management meet the requirements of this section.
4.2.10 Reused and repurposed equipment	Unknown	Recommendation B6: Any use reused or repurposed storage batteries at the proposed facility should be subject to additional assessment and approval (As per Section 4.2.10 of NFPA 855).

NFPA 855 Paragraph	Potential Gap/s	Comment
4.3 Installation	Not currently applicable	Detailed engineering for the project has not commenced. Installation to relevant standards is assumed in the EIS [1]. It is noted that no comment about seismic risk is made in the EIS apart from compliance with relevant standards. Commentary about seismic risk is included in this PHA Report.
4.4.3.1 Classification	Gap Identified	Classification is set as *Locations near exposures* as access to the substation, O&M facility and battery storage area is via Morrisons Gap Road which is a public road. This triggers Section 4.8 which limits the ESS size to 600kWh (Table 4.8). The individual BESS units are 4.643 MWh. Recommendation B7: Confirm that the final layout of the substation, O&M facility, battery storage area and the upgrade to Morrisons Gap Road meets the separation distance requirements, especially the 30.5 m separation from public ways. This will ensure the Classification is *Remote locations*, rather than *Locations near exposures.*
4.4.3.2 Maximum Size 4.4.3.2.1 Outdoor walk-in containers or enclosures housing ESS shall not exceed 53 ft x 8.5 ft x 9.5 ft (16.2 m x 2.6 m x 2.9 m), not including HVAC and other equipment.	No Gap Identified	BESS containers are 12.192 m x 2.438 m [18].
4.4.3.3 ESS located outdoors shall be separated by a minimum of 10 ft (3048 mm) from the following exposures:		
(1) Lot lines	No Gap Identified	5 m separation around each BESS block [18].
(2) Public ways	Unknown	Current plans show Morissons Gap Road runs through the battery storage area. The EIS refers to upgrades of Morrisons Gap Road [1]. See Recommendation B7.

NFPA 855 Paragraph	Potential Gap/s	Comment
(3) Buildings	Gap Identified	BESS container separation distances are 3000 mm. The requirement is 3048 mm, unless large scale fire testing in accordance with 4.1.5 demonstrates that a fire in the ESS enclosure will not generate radiant heat flux sufficient to ignite stored materials or otherwise threaten the exposure (as per 4.4.3.3.4), or if the enclosure of the ESS has a 2-hour fire resistance rating (as per 4.4.3.3.5). Recommendation B8: As there appears to be adequate space in the battery storage area, increase the BESS container separation distance to a minimum of 3048 mm.
(4) Stored combustible materials	No Gap Identified	Identified as mitigation in the EIS [1].
(5) Hazardous materials	No Gap Identified	Identified as mitigation in the EIS [1].
(6) High-piled stock	No Gap Identified	Identified as mitigation in the EIS [1].
(7) Other exposure hazards not associated with electrical grid infrastructure	Unknown	Subject to the results of Blade Throw and Ice Throw studies. Recommendation B9: Review relative locations of the wind turbines and the battery storage based on the results of the Blade Throw and Ice Throw studies.
4.4.3.3.6 Exhaust outlets from an ESS that exhaust other than ventilation air shall be located at least 15 ft (4.572 m) from the heating, ventilating and air conditioning (HVAC) air intakes, windows, doors, loading docks, ignition sources, and other openings into buildings and facilities.	Unknown	Unclear whether Engie Energy House has or needs fire/explosion venting. See 4.12 Explosion Control.
4.4.3.4 Means of Egress Separation	Gap Identified	See Recommendation B8.
4.4.3.5 Walk-in Units	No Gap Identified	BESS containers are not occupied work centres [18].
4.4.3.6 Vegetation Control	No Gap Identified	Asset Protection Zones as identified as bushfire mitigation measures in the EIS [1] meet this requirement.
4.4.3.7 Enclosures	No Gap Identified	Compliance with AS3000 is a mitigation measure identified in the EIS [1].

NFPA 855 Paragraph	Potential Gap/s	Comment
4.4.3.8 Access Roads	No Gap Identified	Road access and required improvements to road access is identified in the EIS [1]. See also Recommendation B7.
4.4.3.9 Hazardous Atmospheres The ESS shall not be located in a classified area as defined in *NFPA 70* or IEEE C2 unless listed and approved for the specific installation	Unknown	Unclear that Hazardous Area Zoning study has occurred. Recommendation B9: Complete a Hazardous Area Zoning Study for the substation, O&M facility, battery storage area plot.
4.6.4 The AHJ shall be permitted to approve groups with larger energy capacities or smaller group spacing based on large-scale fire testing complying with 4.1.5.	Unknown	See Recommendation B2.
4.7 Occupied Work Centers ESS in occupied work centers shall comply with this section	No Gap Identified	BESS containers are not occupied work centres [18].
4.8 Maximum Stored Energy	Gap Identified	See Recommendations B7 and B8.
4.9 Exhaust Ventilation	Not applicable	Compliance to this section not required for Lithium-Ion batteries as per Table 9.2
4.10 Smoke and Fire Detection	Unknown	Whist the EIS [1] refers to such systems, detailed engineering for the project has not commenced. Recommendation B10: Confirm Engie "Energy House" has smoke and fire detection as recommended in NFPA 855 Section 4.10 (or equivalent).
4.11 Fire Control and Suppression	Unknown	Whist the EIS [1] refers to such systems, detailed engineering for the project has not commenced. Recommendation B11: Confirm Engie "Energy House" has fire control and suppression as recommended in NFPA 855 Section 4.11 (or equivalent).

NFPA 855 Paragraph	Potential Gap/s	Comment
4.12 Explosion Control	Unknown	There is no reference to any explosion control for the Engie "Energy House". Recommendation B12: Confirm Engie "Energy House" has explosion control as recommended in NFPA 855 Section 4.12 (or equivalent).
4.13 Water Supply	Unknown	Whist the EIS [1] refers to such systems, detailed engineering for the project has not commenced. Recommendation B13: Confirm water supply meets the fire control & suppression demands from NFPA 855 Section 4.11 (or equivalent) and Australian Standards.
4.14 Spill Control	Not applicable	Compliance to this section not required for Lithium-Ion batteries as per Table 9.2.
4.15 Neutralization	Not applicable	Compliance to this section not required for Lithium-Ion batteries as per Table 9.2.
4.16 Remediation Measures	Not currently applicable	Project is not at construction phase. These requirements can be included in 4.1.3 Emergency Planning and Training.
5 System Interconnection	No Gap Identified	Compliance with Australian Standards and Regulatory Frameworks is a mitigation measure identified in the EIS [1].
6 Commissioning	Not currently applicable	Project is not at construction phase, and the battery supplier for the BESS has not been selected [18]. There will be some iterative detailed design [1]. This section does provide a useful check of the requirements.
7 Operation and Maintenance	Not currently applicable	Project is not at construction phase, and the battery supplier for the BESS has not been selected [18]. There will be some iterative detailed design [1]. This section does provide a useful check of the requirements.
8 Decommissioning	No Gap Identified	Requirement for a decommissioning plan is identified in the EIS [1].

NFPA 855 Paragraph	Potential Gap/s	Comment
9.3 Thermal Runaway Protection	Unknown	Whist the EIS [1] refers to such systems, detailed engineering for the project has not commenced. Recommendation B14: Confirm thermal runaway protection meets the recommendations of NFPA 855 Section 9.3 (or equivalent).
14 Storage of Used or Off-Specification Batteries	Unknown	In the EIS [1] there is reference to "the fast-changing economics of battery storage", and allowance that the BESS can be added at a future point in time. In addition, there is no specific mention of storage of Used or Off-Specification Batteries in the EIS, apart for a very general mention of "Electronics and electrical infrastructure" in the Waste Management Section. Recommendation B15: Confirm allowed storage of Used or Off-Specification Batteries at the substation, O&M facility and battery storage area plot. Confirm the storage meets the recommendations of NFPA 855 Section 14 (or equivalent).

Appendix B DPIE Requirements for PHA

NSW Department of Planning, Industry and Environment Hazards queries e-mail items A1 to A4 and B1 to B5

A. Blade throw risk

In reviewing the layout map in EIS [1] Figure F3-1, it is noted that several wind turbines are in vicinity of an area designated for a battery energy storage system (BESS), substation with transmission line and operations & maintenance (O&M).

EIS Appendix K – Blade throw risk assessment; Section 3.1 [2] estimates a blade throw distance of 150 m. We assume the frequency of this incident is 8.4×10^{-4} per turbine per year, given inconsistent units of measure in Table 3.1. This frequency must be multiplied by the number of wind turbines within 150 m of the designated area to determine the cumulative risk of blade throw to the designated area.

Section 3.2 estimates a blade fragment throw of 800 m. We recommend a frequency of 2.6×10^{-4} per turbine per year in view of Table 3-1. Similarly, this frequency must be multiplied by the number of wind turbines within 800 m of the designated area to determine the cumulative risk of blade fragment throw to the designated area.

In view of Table 3-1 indicating that the frequency of an entire tower collapse is within the same order of magnitude of blade throw and blade fragment throw, the risk of an entire tower collapse should be assessed in a similar manner.

Please:

1. clarify the units of measure for “Recommended Value” in Table 3-1. Are numerical values for “Loss of entire blade” and “Loss of a blade tip” in terms of a single blade or blade tip in a turbine, or in terms of the entire turbine?
2. verify the number of turbines within 150 m, 800 m and greatest wind tower height (230 m) from the designated area.
3. use item 2 above to estimate the cumulative risk of blade throw, blade fragment throw and entire tower collapse to the designated area, respectively.
4. consider options to reduce the cumulative risks to the designated area, such as relocating the designated area or wind turbines.

B. BESS-related risks

As the BESS exceeds 30 MW capacity, a PHA is required.

Having reviewed EIS Appendix L [4] and noting that the SSD is located significantly away from populated area, the report is broadly acceptable as a PHA starting point for this SSD. However, please append a PHA (EIS Appendix L [4]) with the following considerations, ensuring that the PHA will be consistent with the Department’s Hazardous Industry Planning Advisory Paper No. 6, ‘Hazard Analysis’ [54]:

1. Include the findings from EIS Appendix K [2] and items A1 to A4 above in all relevant sections in the PHA, including and not limited to Table 3-2.
2. Analyse the consequences of blade throw, blade fragment throw and entire tower collapse to the designated area (fire/explosion?).

3. Assess if locating the O&M area within the areas of blade throw, blade fragment throw and entire tower collapse (where appropriate) could impact on-site emergency response capabilities.
4. Consider recent developments into research and standards for BESS. Of particular note (not exhaustive) are:

- NFPA 855 [20]
- AS 5139 [43]
- IEC 62897 [55]
- UL 9540 [45]
- UL 9540A [46]
- FM Global DS 5-33 [47]; and
- FM Global's Development of Sprinkler Protection Guidance for Lithium Ion Based Energy Storage Systems [48].

Where certain aspects of the scope or requirements from the above publications may not align exactly, reasonable best practice should be considered in the design of the BESS while taking into account the principles from these publications. Of particular importance are separation distances between:

- BESS sub-units, ensuring that a fire from a sub-unit do not propagate to neighbouring sub-units; and
- the overall BESS and other on-site and off-site receptors, ensuring fire safety.

  In noting that the final design of the BESS may not have been decided by the Applicant at this stage, the PHA above should verify if the proposed BESS capacity would be able to fit within the designated area for BESS, taking into account the spatial requirements for the separation distances above.

5. In view of items 1 to 4 above, assess if the SSD can comply with the Department's Hazardous Industry Planning Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning' [3].