Maryvale Solar Farm Bushfire Risk Assessment Battery Energy Storage System

Prepared for
Maryvale Solar Farm Pty Limited c/- WIRSOL Energy

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Glossary of Terms

Term	Description
Assets	Anything valued by people which includes houses, crops, forests and, in many cases, the environment.
Bushfire	Unplanned vegetation fire. A generic term which includes grass fires, forest fires and scrub fires both with and without a suppression objective.
Bushfire Attack Level (BAL)	A means of measuring the severity of a building's potential exposure to ember attack, radiant heat and direct flame contact, using increments of radiant heat expressed in kilowatts per metre squared, which is the basis for establishing the requirements for construction to improve protection of building elements from attack by bushfire.
Contained	The status of a bushfire suppression action signifying that a control line has been completed around the fire, and any associated spot fires, which can reasonably be expected to stop the fire's spread.
Fire management	All activities associated with the management of fire prone land, including the use of fire to meet land management goals and objectives.
Fuel hazard	Fine fuels in bushland that burn in the continuous flaming zone at the fire's edge. These fuels contribute the most to the fire's rate of spread, flame height and intensity. Typically, they are dead plant material, such as leaves, grass, bark and twigs thinner than 6 mm thick, and live plant material thinner than 3 mm thick.
Head fire	The part of the fire where the rate of spread, flame height and intensity are greatest, usually when burning downwind or upslope.
Intensity	The rate of energy release per unit length of fire front usually expressed in kilowatts per metre (kW/m).
Residence time	The time required for the flaming zone of a fire to pass a stationary point; the width of the flaming zone divided by the rate of spread of the fire.
Spotting	Behaviour of a fire producing sparks or embers that are carried by the wind and start new fires beyond the zone of direct ignition by the main fire.

Most terms are taken from the Bushfire Glossary prepared by the Australasian Fire and Emergency Service Authorities Council Limited (AFAC).

Abbreviations

Abbreviation	Description
APZ	Asset Protection Zone
BAL	Bushfire Attack Level
BESS	Battery Energy Storage System
CCT	Closed Circuit Television
ERP	Emergency Response Plan
FDR	Fire Danger Rating
GFDI	Grassland Fire Danger Index
PV	Photovoltaic
SCADA	Supervisory Control and Data Acquisition

1 Introduction

1.1 Background and Description of the Proposal

Maryvale Solar Farm Pty Limited c/- WIRSOL Energy currently has approval for the construction of a 185-megawatt (MW) solar farm using photovoltaic (PV) technology at a 1,200-hectare site (the "Subject Land") in Maryvale, NSW. The solar farm occupies 375 hectares (the "Site") out of the 1,200 hectares (equivalent to approximately 30% of the Site). An estimated 400,000 PV panels are to be installed on a single axis tracker system across the Site.

Maryvale Solar Farm Pty Limited c/- WIRSOL Energy is currently proposing to add a Battery Energy Storage System (BESS) to the approved Solar Farm project, which will have a peak capacity of ~120MW and storage capacity of ~360MW. The BESS is a lithium-ion (Li-on) based battery configuration, which is designed to enable short term energy storage for later discharge and grid network support.

Two BESS storage formats are being evaluated under this project being the Centralised (Format 1) and the Distributed (Format 2). Both of these formats are shown in Figure 1 and Figure 2 and described further in Section 1.2.

The BESS proposal also includes the following infrastructure:

- Connection of the BESS facility to a 22 kV electrical switchyard
- Inverters
- Control room (remotely located monitored by SCADA)
- Battery Management System (BMS)
- Ventilation enclosures and air conditioning units
- Medium volage transformers (up to 22 kV)
- Cabling and collector units
- Connection to an existing 22 kV electrical switchyard including minor works to connect the BESS to the Transgrid Maryvale Substation
- Transmission connection infrastructure
- Temporary construction area
- Temporary carparking and office facilities
- Asset Protection Zone (APZ)
- Security fencing and lighting
- Road access
- Drainage and stormwater management
- Other ancillary infrastructure including remote SCADA and CCTV.

This bushfire risk assessment has been prepared for WIRSOL Energy to assist with application for planning approval under Section 4.55 (1A) of the Environmental Planning & Assessment Act 1979.

Map 1 (Appendix A) indicates the location of the site which is approximately 7 km north of the town of Wellington. A detailed description of the site and the proposal was prepared by Pitt and Sherry (2018). The descriptions provided here relate specifically to the bushfire environment and risks.

This bushfire risk assessment should also be read in conjunction with the Preliminary Hazard Assessment (PHA) prepared for the BESS formats by Planager Pty Ltd (2021).

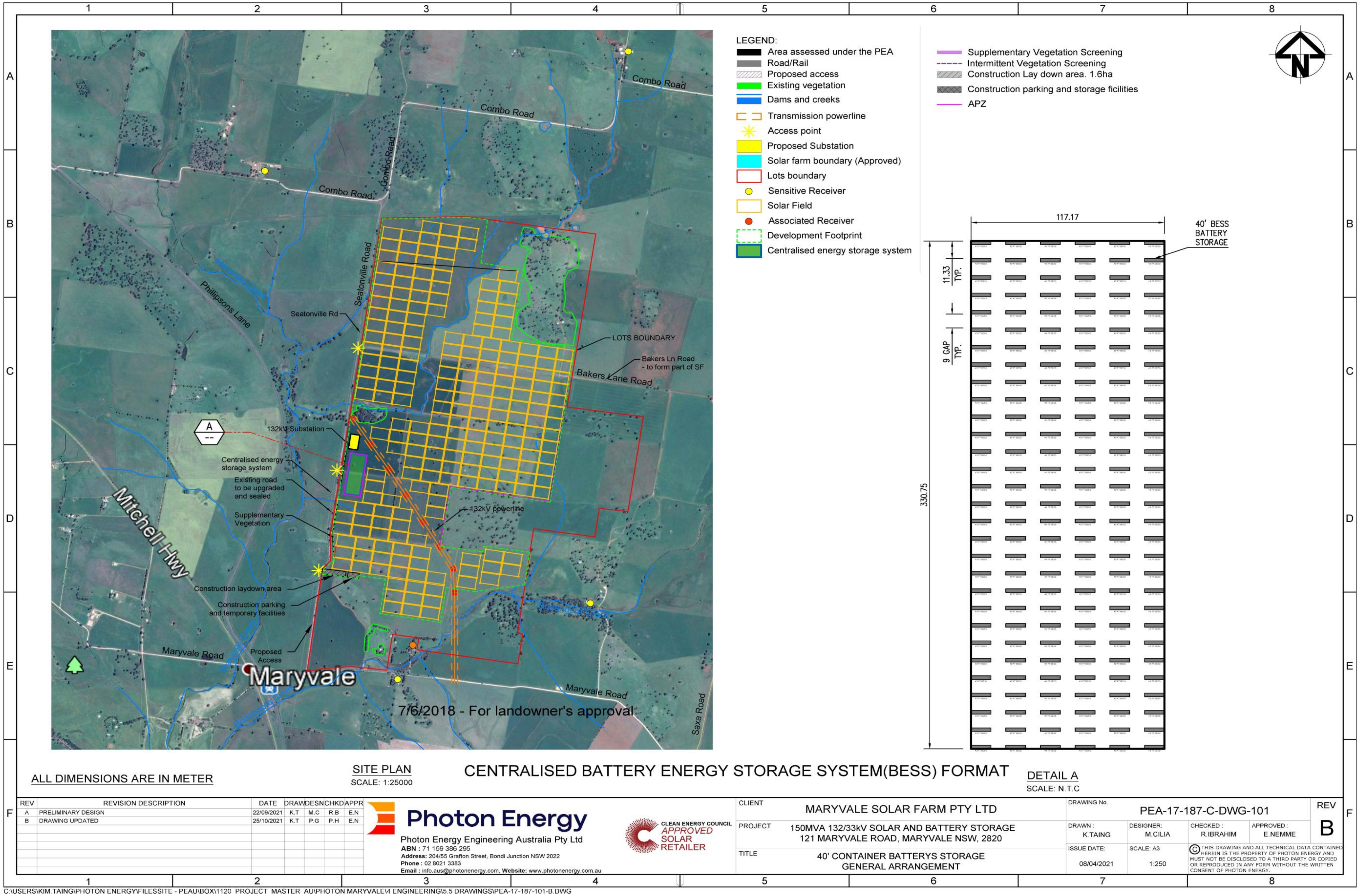

Figure 1: Centralised Battery Energy Storage System AC Coupled (Format 1)

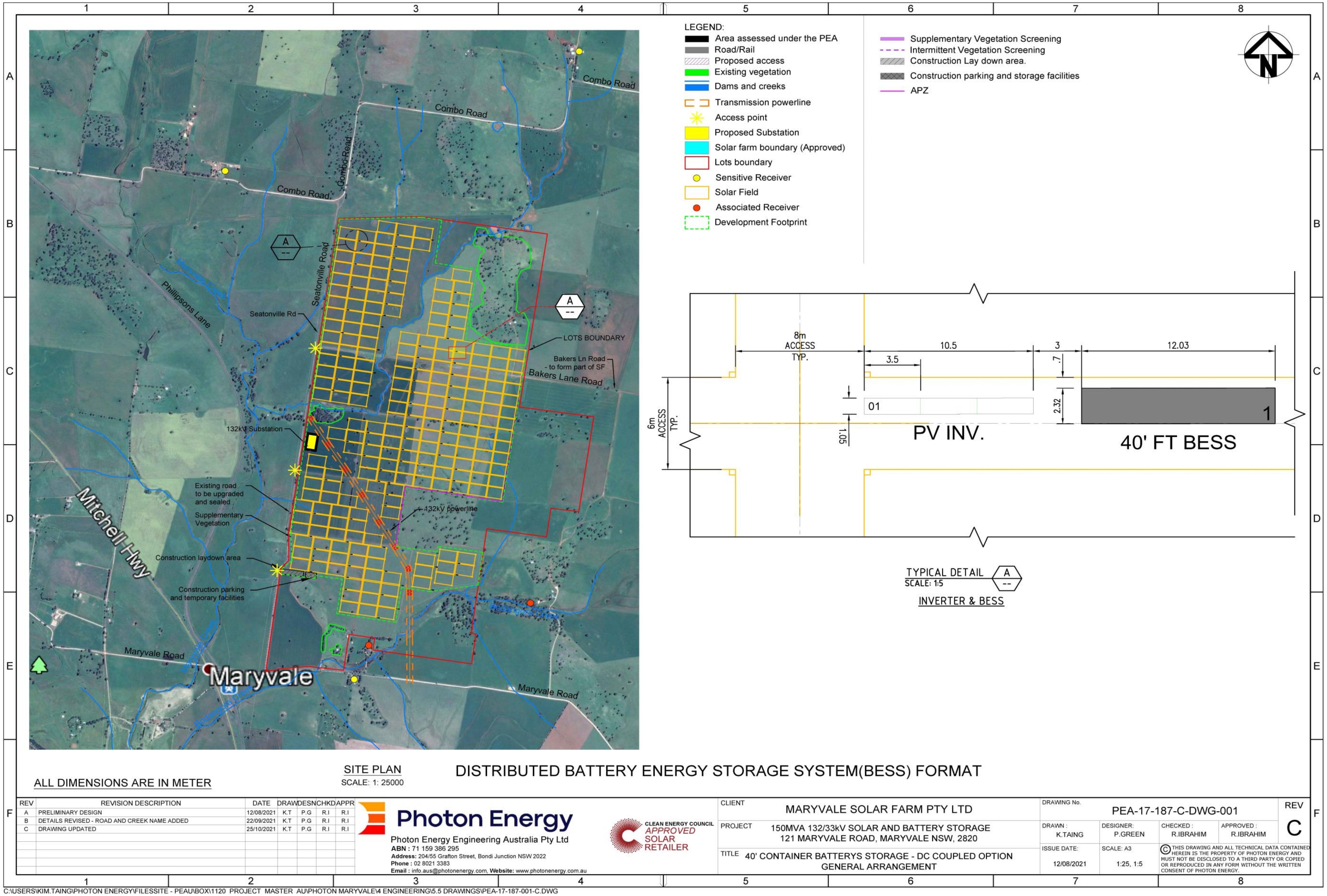

Figure 2: Distributed Battery Energy Storage System DC Coupled (Format 2)

1.2 BESS Storage Layouts

As shown in Figure 1 and Figure 2 two alternative battery storage design concept layouts are being considered for the Maryvale Solar Farm project.

The first format is a 'Centralised BESS option' which comprises of a large central battery positioned between the central inverter and grid, adjacent to the substation with the project area site. This BESS layout would cover an area of approximately 4ha and with up to 180 shipping container style enclosures grouped to house both the batteries and other ancillary equipment, which would allow the battery units to be connected to the solar farm substation and the electricity grid.

The second battery format design being considered is the 'Distributed BESS option' and is similar to the 'Centralised BESS option' of up to 180 shipping container style enclosures but these are distributed across the project area site and configured with each of the solar farm inverter stations and adjacent to the PV arrays. It is understood that the batteries are typically placed on a footing or foundation and a minimum 2m gravel apron around each of the distributed battery units is provided. Further, that sheep grazing across the site throughout the life of the project is planned, thus limiting the vegetative fuel.

A sample of an individual battery unit enclosure with approximate dimensions is shown in Figure 3.

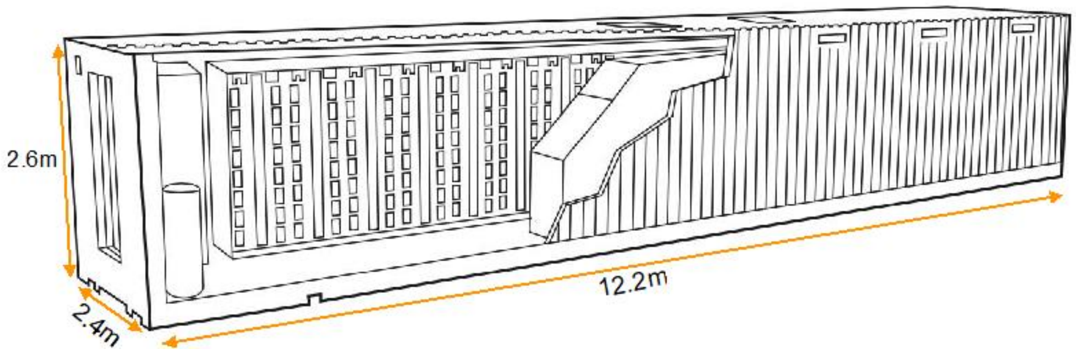

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Figure 3: Layout of an individual battery unit enclosure (Planager Pty Ltd 2021)

1.3 Aims and objectives

This bushfire risk assessment has the following aims:

- Address the requirements identified in the Secretary's Environmental Assessment Requirements (SEARs) (Table 1); and
- Recommend mitigation actions to:
  - Protect fire-fighters in the event of a fire within the site.
  - Reduce the likelihood of a bushfire impacting the site or spreading from the site.

Table 1: Where the SEARs requirements are addressed in this document

SEAR	Section of this document
10 m trafficable defendable space (fire break)	3.2
An assessment of potential hazards and risks associated with bushfires	2.1 to 2.7

2 Bushfire Risk Assessment

2.1 Fire climate

Fire climate strongly influences the likelihood of ignitions and how often, here expressed as the average number of days per year, when fires will be uncontrollable without mitigation measures. Data from the Bureau of Meteorology weather station at Wellington (site 065034 D&J Rural- approximately 10 km from the solar farm site) indicates High Fire Danger Rating (FDR) conditions or worse for grass fires occur in the months of December, January, February and March and rarely, if at all, in the other months (Table 2).

Table 2: Number of days in each month of daily Fire Danger Rating and Grassland Fire Danger Index (GFDI) categories at 3 pm at Wellington (D&J Rural)

	Incomplete	Low-Moderate (0-11)	High (12-24)	Very High (25-49)	Severe (50-99)	Extreme (100-149)	Catastrophic (150+)
January	284	821	65	17	0	0	0
February	194	843	31	5	1	0	0
March	257	872	38	9	1	1	0
April	200	940	0	0	0	0	0
May	174	1004	0	0	0	0	0
June	144	996	0	0	0	0	0
July	121	1057	0	0	0	0	0
August	266	912	0	0	0	0	0
September	194	946	0	0	0	0	0
October	239	939	0	0	0	0	0
November	202	938	0	0	0	0	0
December	277	855	37	9	0	0	0
Totals	**2552**	**11123**	**171**	**40**	**2**	**1**	**0**

Daily records at 3 pm from 1980 to 2017.

The wind directions associated with Very High or worse grassland fire danger are predominantly west, but significant fire weather from all other wind directions can occur (Table 3). Days of significant grassland fire danger with a north-west wind direction that would carry a fire from the site towards the town of Wellington are very rare (approximately 1.3 per decade).

Table 3: Number of days in eight wind direction categories with significant grass fire weather at 3 pm at Wellington (D&J Rural)

Wind Direction	Total	Total No. of days GFDI >=25	Avg. No. days per year GFDI > =25	Total No. of days GFDI >=50	Avg. No. days per year GFDI > =50
N	3420	5	0.13	0	0.00
NE	771	1	0.03	0	0.00
E	785	2	0.05	0	0.00
SE	649	1	0.03	0	0.00
S	912	2	0.05	0	0.00
SW	2502	5	0.13	0	0.00
W	1683	19	0.49	3	0.08
NW	1377	8	0.18	0	0.00
Incomplete	1790				
Totals	13889	43	1.08	3	0.077

Daily records at 3 pm from 1980 to 2017.

2.2 Fuel hazard

Although the surrounding vegetation is not mapped as bushfire prone land, there is still a bushfire risk. The area surrounding the site is mostly modified agricultural land utilised primarily for cropping and grazing with very little native vegetation. Scattered trees are located throughout the solar farm footprint but the intention is to remove all of these. There is some remnant woodland and scattered trees on adjoining land and also within parts of the site that will not be disturbed. All trees within 100 m of the solar farm could increase the potential for bushfire embers to ignite spot fires within the PV array and associated BESS, in a scenario where a fire is approaching the solar farm from a neighbouring property under severe fire weather conditions.

Any significant bushfire around the site would occur in crops, stubble or pasture. The main crops in the area are wheat and lucerne.

The PV panels will be made of glass with aluminium frames. WIRSOL Energy provided the following information regarding the fire risk for the PV panels:

> '*All electrical components are required to be manufactured in material that does not allow self-combustion and ignition and should self-extinguish. In addition, the electrical equipment is fitted with over current protection devices and isolation switches along with earth leakage protection devices.* WIRSOL Energy *has installed large scale solar farms across Europe and has no issues with fires.*'

The proponent also advised that the solar panels to be used meet the IEC 61730 (Class C) and UL1703 (Type 1) fire resistance test standards under fire conditions.

The BESS will be comprised of an array of Lithium-ion batteries placed inside battery enclosures, which are shipping container structures. The BESS components namely consist of containerised or stacked Lithium-ion batteries installed within battery modules and arranged within the enclosures with the Battery Management System (BMS), ventilation and air conditioning units (Planager Pty Ltd 2021).

The BMS has integrated safety functions that include emergency shutdown, fire detection and suppression system and gas detection.

The BESS is expected to be operational on a 24 hour, 7 days a week basis and monitored from an office facility remote to the site via SCADA and CCT. The BESS are designed to charge and discharge on one cycle per day equating to an average of 255 cycles annually. The BESS will be designed to meet the safety and installation requirements of AS 5139-2019 as well as the US National Fire Protection Association Code NFPA 855 (being the minimum requirements for mitigating the hazards of Li-ion BESS of 20kWh or above). Further, it is understood that a Fire Safety Study will be prepared for the project to inform detailed design and construction, which should address fire safety risks with the infrastructure, including the PV Panels and BESS battery units, and how to appropriately mitigate any fire risks.

It is intended that the vegetation fuel under and between the PV panels and around BESS battery units will be maintained in a low fuel state by sheep grazing and other land management activities such as mowing and application of herbicides. A fire could still spread in this fuel under severe fire weather conditions (see Section 2.3) however the likelihood of this occurring is lessened.

The likelihood of a fire spreading within the area of the proposed PV panels and BESS battery units, by propagating from panel to panel or from battery unit to battery unit in a solar farm installation, is difficult to assess at this stage, because a case history (i.e. previous fire records from fire agencies and solar farm sites) and or experiments are required for similar environments, climate and solar farm components, ideally from within Australia. No data was found from within Australia, however, the risk of a fire spreading widely from panel to panel or battery unit to battery unit is likely to be very low because of the panel and BESS battery construction materials (i.e. fire resistance rating) and the time of flame exposure to ignite these materials. Although the proponent is to finalise the BESS design, the outer material used in it's construction should be non-combustible and prohibit the entry of embers through screens and seals.

2.3 Fire behaviour potential

Crops and pasture surround the site are the main fuel for bushfires. There will be periods when the site and surrounds will be non-flammable because they are either fallow, too green to burn or are recently planted. There will also be periods when some crops are cured and highly flammable. However, given the variability in time and space of crops as a potential fuel, the grassland fire spread model for 'cut/grazed pastures' (Cheney et al 1998) has been chosen for predicting bushfire behaviour potential (Cruz et al 2015).

The fire behaviour potential for this site in surrounding crops and pasture is summarised in Table 4 applying the following parameters:

- Grassland fire spread model for 'cut/grazed pastures';
- The range of weather conditions that could occur at the site during the bushfire season (Section 2.1); and
- Upslope fire run (2 degrees) because the site rises gently from west to east (Map 2 and Map 3).

The rate of spread and fire intensity values in Table 4 indicate that fires in cured pasture and crops at this site can be very fast moving and intense; and direct attack on such a grass fire will usually fail at GFDI >49 (Cheney and Sullivan 2008). An ignition point takes some time to build to a quasi-steady state rate of spread, however, under extreme weather conditions a grass fire can be expected to reach maximum rate of spread within 30 minutes or even less (Cheney and Sullivan 2008), by which time the fire is probably uncontrollable.

Table 4 shows the fire break width required for a 99% probability of holding a head fire in grass, applying and extrapolating from the model developed by Wilson (1988). Fire breaks can be effective at stopping grass fires, however, at wind speeds greater than 25 km/h even very wide fire breaks can fail (Cheney and Sullivan 2008). Under the worst weather conditions that could be expected at this site (Section 2.1), a fire break of even 40 m width may fail to stop a grass head fire (Cheney and Sullivan 2008). The trees within 100 m of a fire break could increase the spotting potential (Map 2 and Map 3). Therefore, the fire break widths indicated in Table 4 may only be reliable up to a FDR of Very High and in the absence of trees.

Table 4: Fire behaviour predicted for grassland fires for ‘cut/grazed’ fuel (Cheney et al 1998)

Grassland FDR and GFDI[1]	Wind speed (km/h)[2]	Temperature (°C)	Relative Humidity (%)	Fuel Moisture Content (%)	Rate of Spread (km/h) [3]	Head Fire Fireline Intensity (kW/m)[4]	Fire break Width (m)[5]
Extreme (100-149)	60	40	17	3.7	17.0	23,376	13.9
Severe (50-99)	45	40	17	3.7	13.2	18,140	12.2
Very High (25-49)	35	34	17	5.0	9.2	12,679	10.3
High (12-24)	30	28	28	7.7	6.0	8,187	8.8
Low-Moderate (0-11)	20	23	38	10.1	3.1	4,307	7.5

1. GFDI value within the range for the given fire danger rating, based on wind speed, temperature and relative humidity typical for Wellington (Section 2.1).
2. 10 m height measurement for wind speed.
3. Upslope fire spread 2 degrees.
4. Heat yield for fuel kJ/kg = 16,500; fuel load = 3 t/ha.
5. Fire break width required for 99% probability of holding a head fire, relative to fire intensity (after Wilson 1988, extrapolated for Severe and Extreme).

It should be assumed that, under the most extreme weather, a fire would spread between and under solar panels and around BESS units even in heavily grazed grass and embers may breach any fire break. To calculate potential fire behaviour between and under solar panels and around BESS units, the grassland ‘eaten out pastures’ model was applied for upslope fire spread on the steepest slopes.

Table 5 indicates the rate of spread and fire intensity values for ‘eaten out pastures’ and while the rates of spread are considerably lower compared to ‘cut/grazed pastures’, significant fires can still develop. The residence time for flames in heavily grazed pasture are likely to be very short, probably less than five seconds (Cheney and Sullivan 2008), so the solar farm components will have a similarly short time of exposure to flame contact and high radiant heat.

Table 5: Fire behaviour predicted for grassland fires for 'eaten out' fuel (Cheney et al 1998)

Grassland FDR and GFDI[1]	Wind speed (km/h)[2]	Temperature (°C)	Relative Humidity (%)	Fuel Moisture Content (%)	Rate of Spread (km/h)[3]	Head Fire Fireline Intensity (kW/m)[4]	Fire break Width (m)[5]
Extreme (100-149)	60	40	17	3.7	9.7	6,700	8.3
Severe (50-99)	45	40	17	3.7	7.6	5,199	7.8
Very High (25-49)	35	34	17	5.0	5.3	3,634	7.2
High (12-24)	30	28	28	7.7	3.4	2,347	6.8
Low-Moderate (0-11)	20	23	38	10.1	1.8	1,234	6.4

1. GFDI value within the range for the given fire danger rating, based on wind speed, temperature and relative humidity typical for Wellington (Section 2.1).
2. 10 m height measurement for wind speed.
3. Upslope fire spread 4 degrees.
4. Heat yield for fuel kJ/kg = 16,500; fuel load = 1.5 t/ha.
5. Firebreak width required for 99% probability of holding a head fire, relative to fire intensity (after Wilson 1988).

The preceding discussion identifies the potential consequence (in fire behaviour terms) of a fire burning under different weather and an assumed site condition. The likelihood of a fire ignition at a point where the pattern of existing crops can carry a fire to or from the site under the wind and weather conditions investigated has not been calculated. However, it is expected to be a low probability and the ignition risk and fire history discussed below seem to support this assumption.

2.4 Fire ignitions

Bushfires occur in most years in this district, typically started by accidents such as escaped burns, machinery and hot works (e.g. welding). Lightning fires are uncommon. The area is regarded as low risk for bushfires; fires are usually small and controlled by direct attack (Peter Fothergill RFS, pers. comm.).

Rural Fire Service (RFS) mapping records indicate that 12 bushfires occurred within 20 km of the site from 2006 to 2016, all less than 66 ha and mostly in crops or pasture. These records, however, do not provide much statistical insight into the likelihood of ignitions near the site except to say that ignitions do occur occasionally.

Earth moving equipment, power tools (e.g. welders, grinders), mowers and slashers are well known for starting bushfires under conditions of high temperature, low humidity and high wind. Therefore, construction and ongoing maintenance of the solar farm will be a potential source of ignitions from December to March.

The solar panels are non-reflective and present no risk of ignitions from concentrated solar energy. Ignitions from other PV equipment is theoretically possible from electrical faults such as arc faults, short circuits, ground faults and reverse currents (Allianz Risk Consulting 2012). The proponent advised that arcing issues are normally created from the following:

- Incorrect connecting of the inter module connectors;
- Corroded inter module connectors caused from incorrect storage of modules on site;

- Electrical connections on isolators / DC combiners; and
- Mismatch of inter module connectors causing insufficient electrical connections.

The proponent also advises that: ‘All the above issues are caused during the installation process but are standard issues that will be picked up during the DC testing phases of the install before commissioning’. It is conceivable that arcs or melted components resulting from a fault could ignite grass fuels under or surrounding installations and start a bushfire. However, the level of risk from faults cannot be assessed at this stage because there is no case history available and it is not possible to compare the ignition risk from farm operations (e.g. crop harvesting) relative to solar farm operation (see also Section 2.2).

The proponent has also indicated the potential for a fire event associated with the BESS may occur through thermal runaway and / or where an internal electrical fault occurs in the battery. However there is a SCADA control system which mitigates this risk. Further, given the housing of the battery system in shipping containers with surrounding fuel management, the likelihood of a battery fire propagating is expected to be low, but a matter for consideration in the planned Fire Safety Study.

Alternatively, a fire event may occur from a nearby fire source and spread and pose an impact risk on the battery unit. In this instance the battery units are to be designed in such a means that it will not propagate a battery fire across to other battery enclosures (self-isolating) as well as ensuring sufficient separation distances are established between the solar farm infrastructure and the surrounding land (bushfire hazard source) through establishment and maintenance of the APZ (see Section 3.2).

2.5 Assets at risk

The following assets are located on site or within 2 km of the proposed solar farm:

- Various agricultural crops;
- Stock (sheep and cattle);
- Fences;
- Residences; and
- Radio receivers.

All of these assets, including the PV panels, Battery Energy Storage System (BESS) and other components of the solar farm, are at risk from a bushfire that may propagate within the solar farm, or from an external fire threat. Refer also to Section 1.1 for the proposed infrastructure on the solar farm that is potentially at risk from bushfire attack.

2.6 Fire-fighter and public safety

The usage of the general area surrounding the site is mostly limited to landowners, who are farmers, and the operators of the solar farm site.

The fire-fighters likely to respond to a bushfire in this area would be volunteers from the RFS and or individual property owners. If the solar farm is designated by Fire & Rescue NSW as major infrastructure, then brigades from Wellington town could also respond.

The risks to fire-fighter safety associated with a fire burning the solar panels, and associated equipment include:

- Electrocution – solar panels would be energised under any natural or artificial light conditions – isolation of DC current can only occur external to any solar array because there is no single point of disconnect internally (Backstrom and Dinni 2011).

- Safe use of water spray or foam application is only possible from the perimeter of the solar panelled portion of the farm and could not reach the 250 to 500 m required to reach the furthest internal distance; and
- Inhalation of potentially toxic fumes and smoke from any plastic components such as cables (although the main structure of the panels will be glass and aluminium) or other decomposed products of the panels (Allianz Risk Consulting 2012).

Other potential risks to fire fighter safety associated with the supporting BESS infrastructure (Worksafe 2019) include:

- Electrocution – BESS have the potential to deliver a severe electrical shock when interconnected as battery banks, reaching hazardous voltage levels;
- Arc Flash/Fire & Explosion – this occurs where the battery short circuits or a fault occurs which can result in temperatures reaching 12,000 degrees Celsius with the capacity to melt metal and cause fires and explosions. The higher the battery energy capacity the higher to risk of arc flash. They can also produce flammable gases if there is a fault. Fire and explosions can result from excessive temperatures, component failure, short circuit or loose connections; and
- Hazardous Chemicals – this occurs where battery casings rupture as a result of extreme temperatures occurring from chemical reactions, such as from over-changing. Where ruptured the electrolyte contained internally within the battery can leak externally releasing toxic fumes, and posing risk of burns or explosions.

The materials for individual components within the solar farm infrastructure have not yet been finalised, therefore, the flammability and toxicity of burning components cannot be determined in detail at this time. The proponent, however, advises that the burning of some materials may produce hazardous gasses and therefore may require breathing apparatus.

Thus, the level of risk from burning solar panel components and BESS infrastructure is difficult to quantify, exacerbated by the limited experience in Australia with bushfires in similar installations. Any fire-fighters from the RFS or neighbouring farms attending bushfires in this area should be equipped with breathing apparatus and trained to undertake structural and electrical fire-fighting.

2.7 Bushfire scenarios

Two worst case bushfire scenarios have been considered for the purpose of understanding risk based on the fire climate, fuels, fire behaviour potential and fire history; they assume no risk mitigation strategies:

1. A large, landscape scale bushfire occurs on a day with GFDI of 49 or similar, west wind direction and at a time when crops adjacent to the solar farm are cured. The fire started well to the west and the entire solar farm boundary on the approach side is impacted by head fire. The likelihood of such a fire occurrence is low, given the fire history of the area, but it is still possible given the fire climate and fire behaviour potential. A substantial or complete fire encroachment on PV equipment and the BESS could be expected. The impact of this relatively short (but potentially intense) fire exposure on the PV equipment and BESS is not known.

2. An electrical fault ignites grass under a PV panel or BESS unit on a day with GFDI of 49 or similar, west wind direction and at a time when crops adjacent to the solar farm are cured. The fire spreads to the east for several kilometres destroying many crops, stock and fences. Liability for losses and potentially suppression costs are potentially sought from those responsible for the ignition cause e.g. as occurs with electricity distribution companies. As for the first scenario, the likelihood of such a fire is low.

A risk of a major fire spreading from the solar farm in the direction of the township of Wellington is low, based on the wind direction associated with significant fire weather, modified and disconnected vegetative fuels and fire history indicating very low likelihood, but is still technically possible (Table 3).

3 Mitigation Strategies

3.1 Overview

Mitigation strategies are guided by knowledge of the factors that contribute to bushfire risk:

- Fuels, weather, topography, predicted fire behaviour;
- Spatial patterns and frequency of unplanned ignitions;
- Suppression capability: resources (air and ground), access (roads, tracks) and water; and
- Values and assets: people, buildings, commerce, industry, services and the natural environment.

Mitigation strategies are also guided by evidence of efficacy of available treatment options. Mitigation must be a combination of complementary strategies, all of which are required to provide the best possible protection outcome for the solar farm and the community.

During the preparation of this plan, discussions were held with officers of the RFS at Gunnedah and Dubbo. Advice from these officers was provided on the following:

- Fire history and causes: this is a low risk site;
- Local fire-fighting resources: primarily RFS volunteers;
- Mitigation measures: recommended fire breaks, water storage and emergency response plan; and
- Fire suppression: fire-fighters unlikely to operate amongst solar panels and BESS units.

3.2 Asset Protection Zone

An Asset Protection Zone (APZ) is typically designed to separate a vulnerable asset from the bushfire hazard (vegetation/fuel). An APZ is either a lower fuel hazard such as mown or heavily grazed grass or a fire break of ploughed or fallow ground. APZs do not eliminate the fire risk, but may lower it to an extent where fire control is more feasible or damage to the asset is reduced or eliminated.

Understanding the value and limitations of APZ is important, as is the understanding that bushfires attack built assets by either flame contact, radiant heat or burning debris. An APZ can be used to lower or eliminate the bushfire attack from flame contact and radiant heat around the perimeter of the solar farm, but under winds of >25 kph burning debris can result in a fire breaching a perimeter APZ to ignite grassy fuel within the solar farm itself. A fire emanating from the PV panels and / or BESS may also jump a perimeter APZ by burning debris under similar conditions.

Despite the limitations of any APZ, it is recommended that a perimeter APZ/fire break be established around the solar farm. An APZ/fire break will significantly reduce the likelihood of a bushfire spreading into the solar farm or from the solar farm into surrounding farmland.

The specifications recommended for the perimeter APZ/fire break are as follows:

- 15 m width for the entire perimeter of the solar farm footprint, with 20 m wide abutting remnant or planted treed areas;
- Preferably mineral earth (i.e. dirt or gravel) or alternatively vegetation managed to a low level in accordance with the APZ specifications detailed in PBP (RFS 2019);
- No trees and shrubs planted on the internal side of the fire break;
- APZ preferably located external to any security fence; and

- Access track located on the internal edge of the APZ, that is trafficable by Category 1 fire appliances.

These specifications will ensure the risk of a fire propagating across the APZ is minimised and that burning embers will not spot across the APZ, except under very high winds.

Trees and shrubs abutting the APZ on the side of an approaching fire increase the risk of burning embers carrying across the fire break and therefore the fire continuing to spread on the other side (Cheney and Sullivan 2008). Therefore, the planting of trees and shrubs for visual screening on the external side of the APZ will increase the risk of burning embers from an external fire entering the solar farm but not vice versa. Any of the following measures will mitigate the risk of planted or remnant trees carrying embers into the solar farm:

- Use species suitable for the environment that have low fire spotting characteristics (e.g. smooth bark);
- Increase the width of the APZ (hence the 20 m stated above); and
- Increase the distance between the trees and the APZ.

The objective for the setback of the APZ from the solar farm is to reduce the radiant heat to less than 10 kW/m^2 which is the level at which plastics and rubber components are expected to melt/burn. This is based on a fire intensity of 23,376 kW/m. The placement of the access track on the inside of the APZ is to ensure safety to fire-fighters by reducing radiant heat exposure to fire-fighters.

In addition, DELWP (2019) indicates that a solar farm facility should include maintenance of site vegetation through adequate management regimes that include maintaining grass height below 100mm during the declared bushfire danger period, together with establishing fire breaks around the perimeter of the site.

3.2.1 The Substation

The substation should have a 20 m asset protection zone around all potentially critical components e.g. anything rubber or plastic or with a lower ignition point. Preferably there would be no combustible vegetation within the substation APZ e.g. a mineral earth or gravel surface.

3.2.2 Battery Energy Storage System (BESS)

A 10 m asset protection zone should be maintained around the BESS containers/infrastructure. This complies with the APZ requirements specified by Section 8.3.5 of *Planning for Bushfire Protection* (RFS 2019) and will allow for a bushfire exposure of BAL-29 or less in most cases (i.e. outside the area of potential flame contact). Preferably there would be no combustible vegetation within the compound of the centralised BESS e.g. a mineral earth or gravel surface. Combustible vegetation (if present in the APZ) is to be kept low (i.e. less than 100mm). Solar farm infrastructure can be located within the BESS APZ, provided it does not comprise a general fire safety risk.

It is also recommended that the BESS enclosures are screened and sealed to prevent the potential for the entry of embers. This should be provided by enclosing or covering vents and weepholes with a corrosion-resistant steel, bronze or aluminium mesh with a maximum aperture of 2mm. Weather strips, draught excluders or draught seals should be installed on external doors or any other openings.

The APZ for the BESS, in combination with the APZ around the perimeter of the Solar Farm, the robust construction of the BESS containers (i.e. non-combustible shipping container type structures) and the recommended ember protection, will provide a very high level of bushfire risk mitigation.

3.3 Solar farm construction

Should construction of the solar farm take place between 1 December and 31 March (see Table 2 for data on seasonal occurrence of fire weather), the following measures are recommended to control the risk of grass fire ignitions:

- The APZ/fire break is constructed as the first stage of development;
- All plant, vehicles and earth moving machinery are cleaned of any accumulated flammable material (e.g. soil and vegetation);
- A suitable fire appliance is present on site with at least two personnel trained in bushfire fighting;
- On days when Very High FDR or worse is forecast for Wellington, the "fires near me' app is to be checked hourly for the occurrence of any fires likely to threaten the site; and
- All operations involving earth moving equipment, vehicles, slashers and hot works (e.g. grinders, welders) cease while the GFDI is or forecast to be 35 or greater (RFS 2018).

3.4 Solar farm ongoing operations

Fuel management within solar farm

It is assumed that a grass fire may start and spread within the footprint of the solar farm (see Sections 2.3 and 2.4); ignitions could include lightning fires, human error or electrical faults. For this reason, it is recommended that vegetation fuels internal to the APZ and throughout the solar farm are maintained in a minimal condition by grazing, slashing or mowing. This will minimise the radiant heat exposure to solar farm components and reduce the risk of a fire spreading beyond the solar farm. If grazing or slashing is not possible under the panels or BESS units other lower risk ground cover should be considered e.g. gravel or a non-curing ground cover and/or a very low above ground biomass.

Days of Very High or worse fire danger

To minimise the risk of grass fire ignitions, all operations on the site involving earth moving equipment, vehicles, slashers and hot works (e.g. grinders, welders) should cease while the GFDI is or forecast to be 35 or greater. This will require establishing an operational procedure for onsite recording of temperature, relative humidity and wind speed, as well as associated training.

Fire-fighter safety

The safety hazards for fire-fighters from PV panels and BESS units (Section 2.6) and local fire-fighting capability are such that fire suppression within the footprint of the solar farm cannot be expected or relied upon. The only exception to this would be aerial water bombing that is compliant with air operations safety procedures; however, these resources may not be available at short notice for a fire that could spread several kilometres within an hour (Section 2.3). Fire suppression is most likely only to be feasible from the APZ or beyond and no internal access for fire-fighting is proposed.

Given the possible toxicity of smoke from burning solar farm components, fire-fighters, farm workers and neighbours should avoid working down wind of any fire burning within the solar farm.

Given these safety concerns for fire-fighters, it is not recommended that fire-fighting equipment for fire-fighters be located permanently on site because such equipment could not be utilised safely and effectively.

Emergency Response

An Emergency Response Plan (ERP) should be prepared for the solar farm that provides the following:

- Addresses foreseeable on-site and off-site fire events;
- Clearly states work health safety risks and procedures to be followed by fire-fighters, including
    - personal protective clothing;
    - minimum level of respiratory protection;
    - minimum evacuation zone distances;
    - a safe method of shutting down and isolating the PV system / BESS units (or noting if this is not possible for safe internal access);
    - any other risk control measures required to be followed by fire-fighters;
- Evacuation triggers and protocols; and
- Suppression response strategies and tactics, including aerial suppression options/management.

Two copies of the ERP should be permanently stored in a prominent ‘Emergency Information Cabinet’ to be located at the main entrance point to the solar farm, external to any security fence or locked gate, and a copy provided to local emergency responders (Map 2 and Map 3).

Once constructed and prior to operation, contact should be made by the site operator with the Local Emergency Management Committee to establish emergency management procedures with relevant authorities for the safety hazards presented by the site. The operator of the solar farm should brief the local volunteer fire brigades and neighbouring farmers at appropriate intervals, for example, at annual pre-season fire meetings, on safety issues and procedures.

3.5 Fire protection of PV system/ BESS

All electrical equipment will comply with relevant construction standards and design; installation of electrical equipment such as junction boxes, inverters, transformer and electrical cabling is to be in accordance with AS 3000:2007 Wiring Rules. Further, it is understood that a Fire Safety Study will be prepared for the project to inform detailed design and construction, which should address fire safety risks with the infrastructure, including the PV Panels and BESS battery units, and how to appropriately mitigate any fire risks.

Other fire protection systems would include SCADA monitoring, reclosure, fault rectification and modification of operational settings on days of elevated FDR.

It is recommended that research be undertaken into the ignition, flammability and toxicity risks of the solar farm components once the design has been finalised. This information will be required to improve or streamline bushfire mitigation measures for the solar farm including PV panels and BESS units.

3.6 Water storage

Whilst the likelihood of a damaging fire impacting the solar farm is considered low, the consequence could be significant e.g. large number of panels and/or related electrical systems damaged (including BESS units). The risk of a fire starting from the solar farm and spreading to surrounding areas is also considered low.

Consideration however should be given by the proponent to increase the available water on site for fire protection of the solar farm facility.

CFA (2021) recommends that for every 150ha of a solar farm site, that this should be supplemented with 45,000L of static water supply. On this basis the total static water supply capacity of the farm would be 112,500L for fire fighting. Static water storage tank(s) should be installed in accordance with AS2419.1-2005 and clearly identifiable and unobstructed to ensure adequate access by fire fighting personnel. Water supply should be designed to provide filling points for fire tanker units near the solar farm entrance.

3.7 Summary of recommended mitigation strategies

Table 6 summarises the bushfire mitigation strategies and recommendations made in this document.

Table 6: Summary of recommended mitigation strategies and actions

Mitigation Strategy	Section of Plan	Action
Asset Protection Zone (APZ)	3.2	APZ of 15 to 20 m wide around the perimeter of the solar farm.
Substation	3.2.1	20 m APZ around the substation.
Battery Energy Storage System (BESS)	3.2.2	10m APZ provided around the BESS. Ember protection provided by screening ventilation points and sealing openings.
Solar farm construction	3.3	If construction occurs from December to March: APZ constructed first, fire appliance on site and machinery/hot works suspended when GFDI >=35.
Solar farm ongoing operations	3.4	Maintain minimal fuel load by grazing, slashing or mowing. Under panel fuels minimised. No vegetation within the Substation. Suspend site maintenance operations when GFDI >=35.
Fire-fighter safety	3.4	Avoid fire-fighting within footprint of solar farm. Avoid operating downwind of smoke from burning solar farm components. Emergency Response Plan prepared and stored at 'Emergency Information Cabinet' at main entrance to solar farm and provided to local emergency responders. Include aerial suppression options/management.
Mitigate fire risks from solar farm components	3.5	Complete a Fire Safety Study to inform detailed design and construction.
Water storage	3.6	Consideration to be given by the proponent to increase the available water on site for the fire protection of the solar farm facility.

4 Cumulative Impacts

The cumulative impacts related to bushfire mitigation and other major developments in the area are as follows:

- *Volunteer fire-fighter workload* – Response call outs should not increase because the ignition risk will be very low and possibly lower than the risk from surrounding agricultural activities. There will, however, be an ongoing requirement for briefing on the Emergency Response Plan.
- *Construction stage transport and road use* – The bushfire mitigation infrastructure (i.e. fire breaks, and water storage) will add a small percentage to the total construction traffic and road use.
- *Ongoing operations* – there would not be any cumulative operational impacts.

References

Allianz Risk Consulting 2012. *Understanding the Fire Hazards of Photovoltaic Systems*. Allianz Global Corporate & Specialty.

AS/NZ Standard. 2019. *Electrical installations-Safety of battery systems for use with power conversion equipment.*

Backstrom R. and Dinni D.A. 2011. *Firefighter Safety and Photovoltaic Installations Research Project.* Underwriters Laboratories Inc., Northbrook, USA.

Country Fire Authority (CFA). 2021. *Guidelines for Renewable Energy Installations*.

Cheney N.P., Gould J.S. Catchpole W.R. 1998. *Prediction of Fire Spread in Grasslands*. International Journal of Wildland Fire 8, 1-13.

Cheney N.P., Sullivan, A.L. 2008. *Grassfires: Fuel weather and fire behaviour*. CSIRO Publishing 2nd Edition, Collingwood, Vic.

Cruz, M.G., Gould, J.S., Alexander, M.E., Sullivan, A.L., McCaw, W.L. and Matthews, S. 2015. *A Guide to Rate of Fire Spread Models for Australian Vegetation*. CSIRO Land and Water, Canberra ACT and AFAC, Melbourne, Vic, 125 pp.

National Fire Protection Association (NFPA). 2020. *NPFA 855-Standard for the Installation of Stationary Energy Storage Systems.*

Pitt and Sherry 2018. *Project Description – Maryvale Solar Farm.* Version 1.0 unpublished report.

Planager Pty Ltd. 2021. *Preliminary Hazard Analysis for Maryvale Battery Energy Storage System, NSW.*

Rural Fire Service (2018). *Harvest fires.* https://www.rfs.nsw.gov.au/plan-and-prepare/farm-fire-safety/grain-harvesting-guide accessed 9/02/2018.

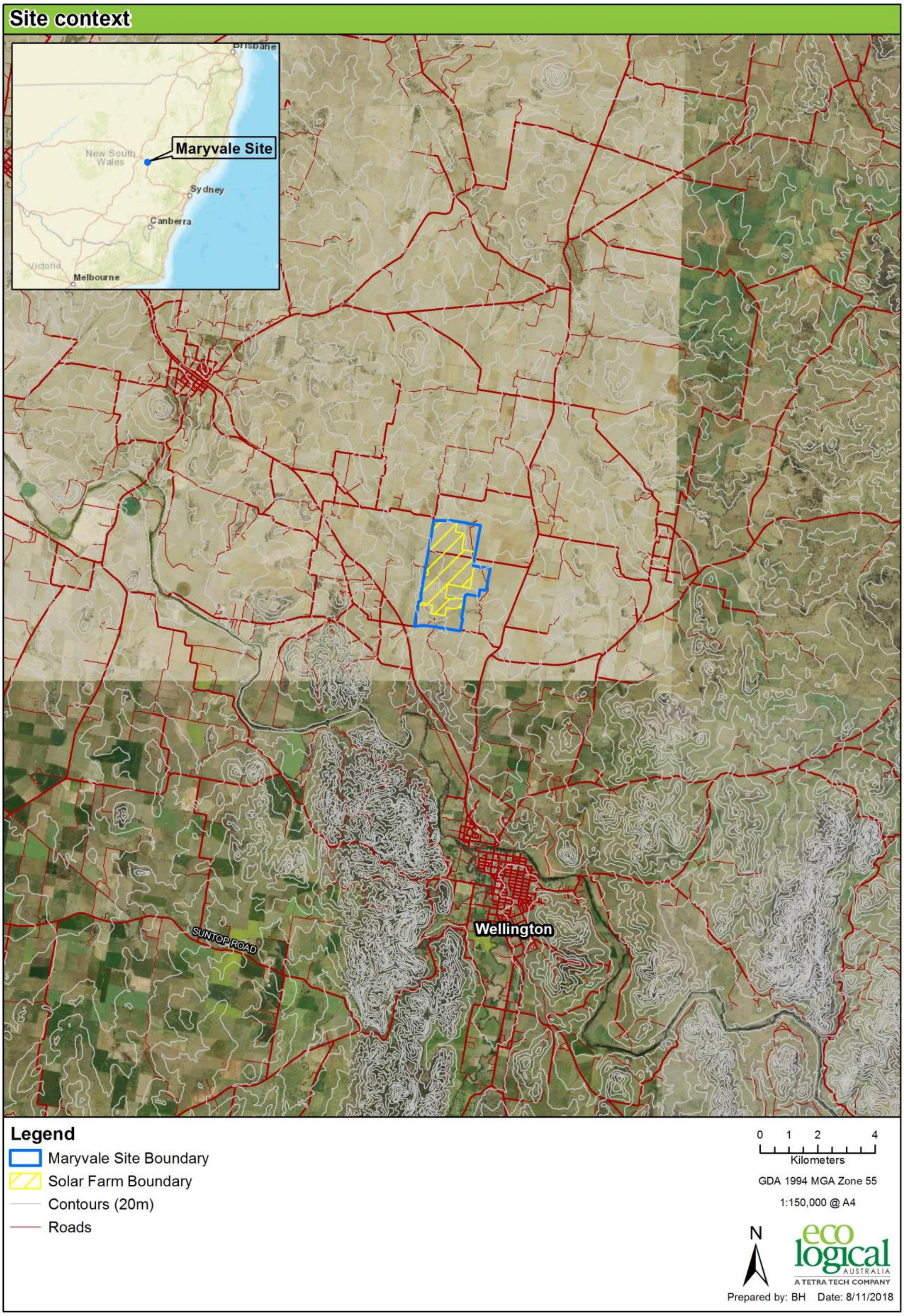
Standards Australia (SA). 2005. *AS 2419.1-2005: Fire hydrant installations-System design, installation and commissioning.*

Victoria State Government. Department Environment, Land, Water, and Planning (DELWP). 2019. Solar Energy Facilities Design and Development Guideline August 2019.

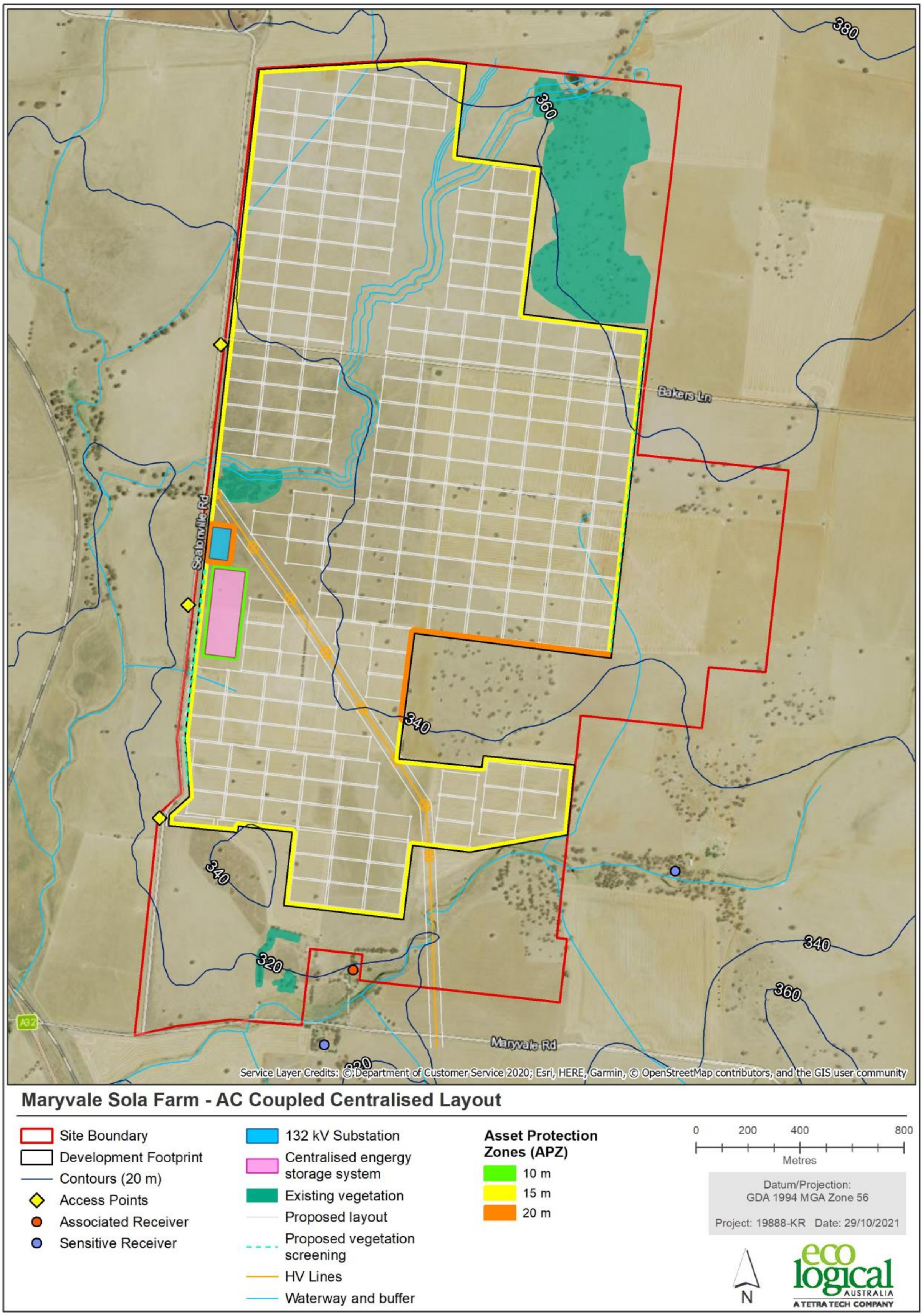
Wilson, A.A.G. 1988. *Width of firebreak that is necessary to stop grassfires: some field experiments.* Canadian Journal of Forest Research 18, 682–687.

WorkSafe. 2019. *Battery energy storage systems (BESS). Website: https://www.worksafe.qld.gov.au/safety-and-prevention/hazards/electricity/hazardous-electrical-environments/battery-energy-storage-systems*

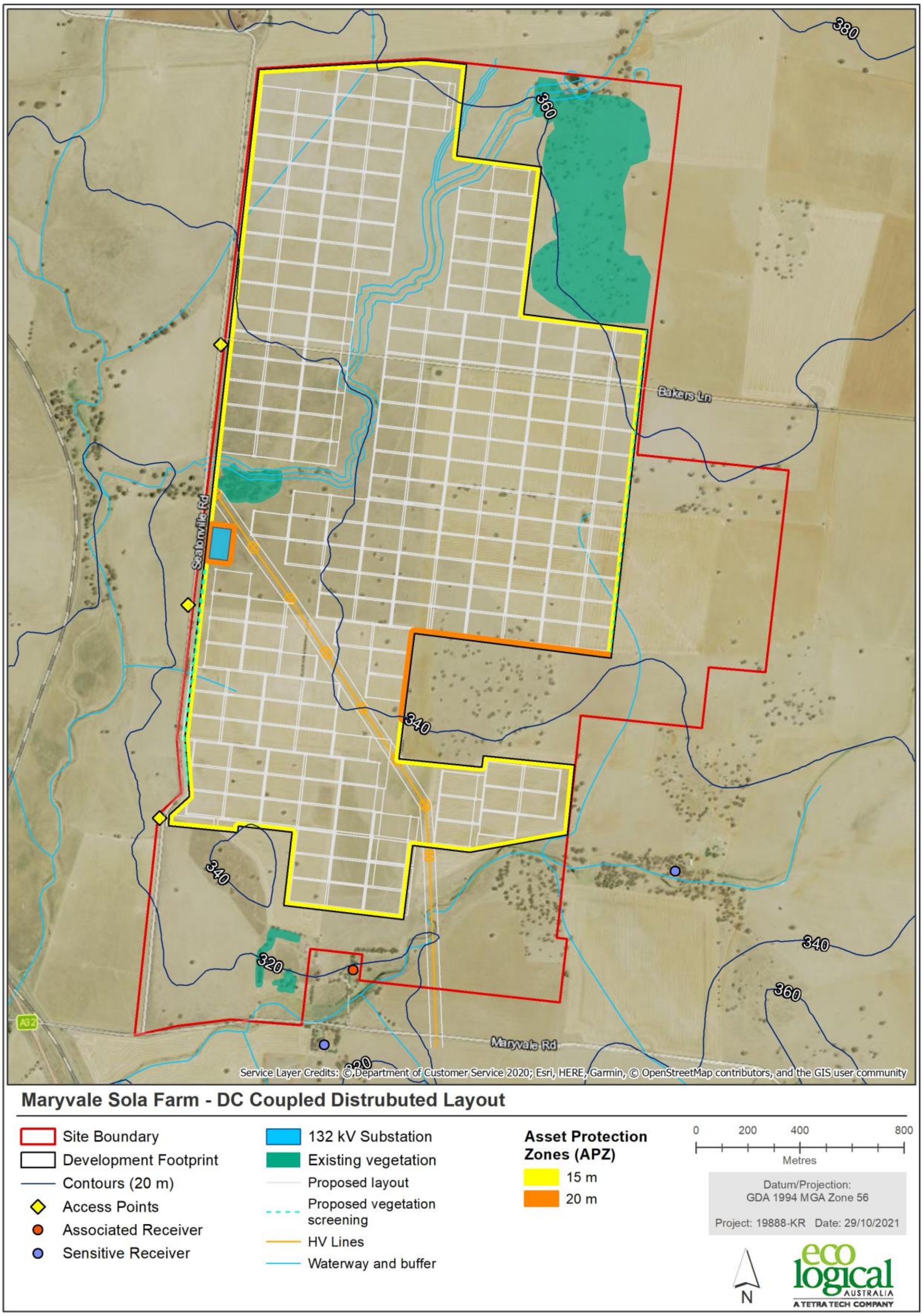
Appendix A - Maps



Map 1: Site Context



Map 2: Mitigation recommendations-BESS Centralised Format



Map 3: Mitigation recommendations-BESS Distributed Format

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